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Marine Debris in the Island of Santa Catarina, South Brazil: Spatial Patterns, Composition, and Biological Aspects

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ABSTRACT

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The prevalence of marine debris is a worldwide issue, especially in coastal areas. Half of the Brazilian population live within 200 km of the coast and generate large amounts of garbage, which is not always sent to an appropriate destination. This study aims to assess patterns of spatial variability and composition of marine debris in the beaches of Florianópolis, an important tourist destination in Brazil. Biological aspects were also assessed. Five beaches were sampled twice, and abundances of litter ranging from 12.8 to 498 items/100 m^2 were found, depending on location and time of sampling. Plastic items accounted for almost 90% of the material collected. Only 5% of the items collected showed biological encrustations, suggesting that most items had a local origin. A weak negative correlation was found between the number of items and the number of ghost crab (*Ocypode quadrata*) open burrows. These results can be used for management purposes and to make comparisons with other coastal cities.

ADDITIONAL INDEX WORDS: *Coastal management, Florianópolis, ghost crab, marine litter, marine pollution,* Ocypode*, tourist beaches.*

INTRODUCTION

Marine debris is a term used to describe "any manufactured or processed solid waste material (typically inert) that enters the marine environment from any source" (Coe and Rogers, 1997). A visible indication of the influence of human activities on world oceans, the problem of marine debris is far reaching. Marine debris has been found in remote parts of world oceans, such as subantarctic islands (Walker *et al.*, 1997), and has been found submerged on oceanic floors (Galil, Golik, and Turkay, 1995) and estuaries (Widmer, 2003). It is therefore a worldwide issue that is particularly serious near populated, coastal areas (Willoughby, Sangkoyo, and Lakaseru, 1997).

Marine debris is an aesthetic nuisance (Williams and Nelson, 1997) and an issue of public health (Dixon and Dixon, 1981). It also represents a threat to marine vertebrates such as mammals, turtles, fish, and birds (Laist, 1987; UNEP, 2009). Fouling invertebrates may use marine debris as a vector of transportation (Gregory, 1991), with unclear ecological consequences. Economically, marine debris can obstruct cooling systems of nautical engines and are a direct threat to coastal cities based on tourism (Corbin and Singh, 1993).

According to Moraes (1999), half of the Brazilian population live within 200 km of the ocean. Urbanization is a major feature of most Brazilian coastal areas. The majority of Brazilian metropolitan regions are located by the sea. According to Santos and Câmara (2002), 90% of all solid waste collected in Brazil is taken to unregulated, open-air landfills, half of which are next to lagoons, rivers, the sea, or legally protected areas.

Information is scarce on the ecological and economic consequences of the presence of debris in the marine environment in Brazil (but see Ivar do Sul and Costa, 2007; Santos, Friedrich, and Ivar do Sul, 2009). Therefore, the aim of this study is to increase the understanding of marine debris by testing the following hypotheses:

A. Oceanographic patterns (*e.g.*, currents and winds) are considered to be a factor that can affect the amount of marine debris present on beaches (Debrot, Tiel, and Bradshaw, 1999). If this model is also valid for Florianópolis, one would expect to find similar quantities of marine debris on beaches experiencing similar oceanographic conditions.
B. Plastic items are reported to be a major component of marine debris worldwide (Ivar do Sul and Costa, 2007; UNEP, 2009). The model proposed is that this is a general pattern, also valid for Florianópolis. Therefore, plastic is expected to be more prevalent than other types of marine debris.
C. An increasing rate (from poles to tropics) of biological colonization of marine debris has been anticipated (Barnes, 2002; Winston, Gregory, and Stevens, 1997).

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According to this model, the percentage of debris items colonized for the latitude 27° S is approximately 10%. Therefore, a similar percentage is expected in Florianópolis.

D. The abundance of ghost crabs (genus *Ocypode*) has been cited in the literature as a good indicator of human pressure on the environmental quality of beaches (Barros, 2001; Blankensteyn, 2006). The model proposed is that the presence of marine debris is one human effect that negatively impacts these crabs. Therefore, one would expect a negative correlation between the number of ghost crab open burrows and the number of litter items found on the beaches of Santa Catarina Island.

STUDY AREA

In the Brazilian state of Santa Catarina, 30% to 40% of the population live on the coast (Moraes, 1999). Florianópolis is the capital city of Santa Catarina state. The municipality occupies the totality of Santa Catarina Island and a small portion of the mainland (Figure 1). The city is a regional tourist center for the southern Brazilian region, receiving tourists from Argentina, Uruguay, and Paraguay. State and municipal public policies are clearly designed to increase the tourist influx to the island (Lisboa *et al.*, 1996). During the summer season of 2002/2003 (from December to March), the city received 370,627 tourists (SANTUR, 2003), a number greater than its estimated permanent population of 342,315 (IBGE, 2003). This tourist activity represented an income of more than US$80,000,000 to the local economy (SANTUR, 2003). It also represented an average increase of 100 tn/d of solid waste collected by the municipality (City of Florianópolis, 2003). An estimated 776,374 tourists visited the island in the austral summer season of 2007/2008 (SANTUR, 2008), which represents a vast increase in the number of visitors in the previous 5 years.

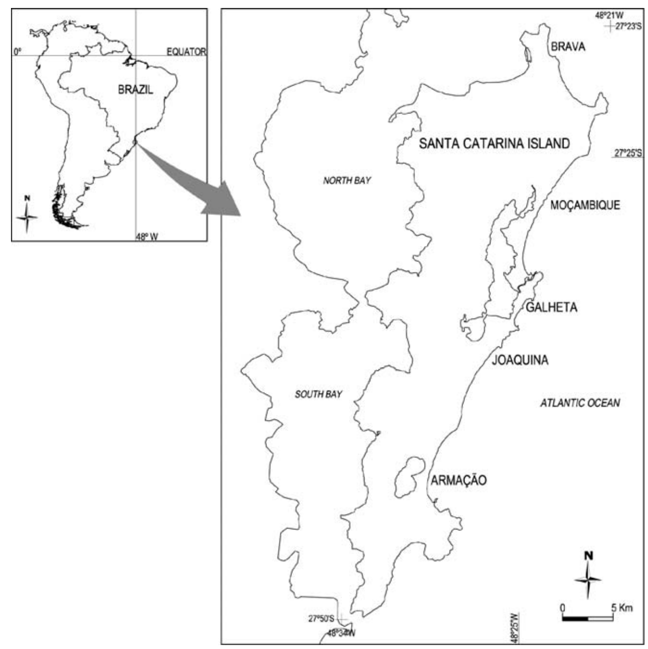

Figure 1. Study area in Santa Catarina Island, south Brazil, where the state capital city of Florianópolis is located. Names represent the five sampled beaches on the east side of the island.

METHODS

Sampling

In order to test the hypotheses, five beaches on the east coast of Santa Catarina Island were chosen, covering both north and south parts of the island (Figure 1). These beaches are exposed to intense current and wave dynamics, with a prevalence of well-sorted, quartzoic sands. According to the abundance and diversity of mollusks, these beaches were also grouped together by Ruthland and Saalfeld (1987). Being oceanic beaches facing east, they are exposed to similar conditions of wind, waves, and passage of cold fronts (Cruz, 1998). They have some differences in terms of orientation, slope, and grain size, but nevertheless they were assumed to be a good representation of beaches on the exposed side of the island.

There is documented evidence (*e.g.*, Silva-Iñiguez and Fisher, 2003; Tudor and Williams, 2001) that marine debris tends to accumulate on the supralittoral zone of beaches, near frontal dunes. It is generally assumed that there is a small amount of litter on the intertidal zone. In order to check the generality of this model, a pilot study was performed with five randomly selected transects, each covering 100 m^2 of the intertidal zone. These transects were sampled for marine debris on three of the five beaches studied. These preliminary observations indicated a very low presence of marine debris in the intertidal zone. Only 3 out of 15 transects contained marine debris, averaging 0.3 ± 0.2 (mean $\pm$ standard error [SE]) items/100 m^2. Therefore, given such a low presence of marine debris in the intertidal zone, this study focused on litter accumulated in the supralittoral region, adjacent to the sand dunes.

On each beach, two sites were haphazardly chosen. At each site, five transects measuring 50 m $\times$ 2 m (100 m^2) were randomly placed parallel to the beach on the zone adjacent to the frontal dunes. According to Velander and Mocogni (1999), this method is simple and collects large amounts of accumulated litter. In each transect, all visible litter was collected using a constant search effort (two observers searching for litter twice along the transect). Litter was sent to the laboratory, where it was sorted into eight categories of composition (plastic, metal, glass, timber, paper, textile, organic, and unknown). Items for each category were counted, and the total weight of each category was obtained using a precision scale (to the nearest 0.1 g). The presence or absence of zoological fouling was recorded for each item. Identification of organisms was done to the best possible taxonomic level. *Ocypode quadrata* open burrows were visually counted for each transect. In order to assess the generality of the results across time, sampling was done in October 2003 and repeated in March 2004. A different set of haphazardly chosen sites and transects was used in each occasion, in order to estimate intrinsic variability in each beach for each sampling time.

Table 1. *Results of ANOVA for differences among and within beaches. Part A represents the number of litter items; part B represents the weight of litter. Data were logarithmic transformed (base e) in order to remove heterogeneity of variances. For part A, Cochran's C = 0.14 (not statistically significant [ns]); for part B, Cochran's C = 0.17 (ns).*

	A				B		
Source of Variation	MS	df	F	p	MS	F	p
Time	53.01	1	52.21	<0.001	7.24	2.52	0.14 (ns)
Beach	7.36	4	7.25	0.005	7.29	2.54	0.10 (ns)
Site (Time × Beach)	1.01	10	2.05	0.038	2.87	1.54	0.14 (ns)
Time × Beach	7.32	4	7.21	0.005	7.04	2.45	0.11 (ns)
Residual	0.49	80			1.87		

MS = mean square, df = degrees of freedom.

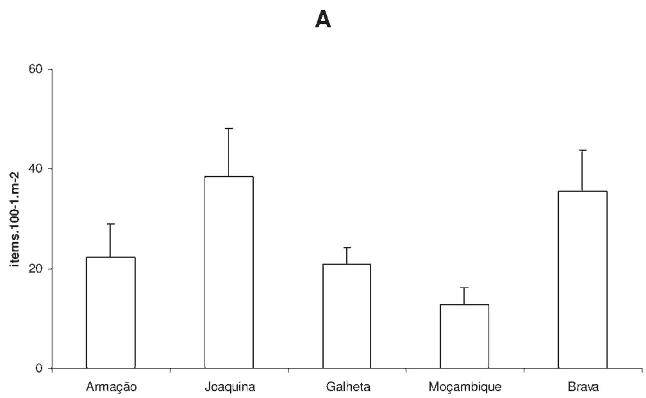

Figure 2. Mean amount of marine litter on five beaches sampled in (A) October 2003 and (B) March 2004. Note that different scales on the y-axis are used. Error bars represent standard errors of the means.

Statistical Tests

Hypothesis A was tested using analysis of variance (ANOVA), where the first fixed factor was *Time*, with two levels. The second fixed factor was *Beach*, with five levels. The third random factor was *Site*, nested in *Time* and *Beach*. There were five independent replicates ($n = 5$) for each combination of these three factors. Hypothesis B was tested using ANOVA with a single factor *Material* (fixed), with eight levels. There were 100 replicates ($n = 100$) for each level. For hypothesis C, the mean percentage of colonized debris items was tested against the value of 10% using the Student's t test. Pearson's correlation index was calculated to test hypothesis D.

Prior to ANOVA calculations, homogeneity of variances was tested using the Cochran's test. If necessary, appropriate transformations of data were used to remove heterogeneity of variances. Hypotheses A and B were tested using data consisting of the number of debris items and weight of debris. When ANOVA indicated significant results, differences among levels were tested by Student-Newman-Keouls (SNK) procedure of paired comparisons.

RESULTS

A total of 10,226 items were collected from 10,000 m^2 of beach area. This resulted in an average of 102 items/100 m^2. Typical items included packing material such as plastic containers, fishing equipment such as fragments of nylon gill nets, and other unidentifiable plastic fragments. In addition, a large number of plastic pellets were found at Galheta Beach on the second sampling occasion. The influence of location on the abundance of beach debris was dependent on the time of sampling (Table 1A). Mean amounts of debris were not significantly different across beaches in October 2003 (Figure 2A). However, this pattern changed in March 2004, when mean amounts of debris in Joaquina, Armação, and Galheta beaches were significantly greater than those observed in Moçambique and Brava beaches, according to SNK pairwise tests (Figure 2B). Similarly, the effect of time of sampling on the mean amount of debris was dependent on the beach considered. The difference between the mean amounts of debris in the two periods of sampling was not significant for Brava Beach. For the other four beaches studied, however, mean amounts of debris were statistically greater in March 2004 compared to October 2003. A significant difference between sites within a beach was observed in one beach during one sampling. In the other nine combinations of beach *vs.* time, differences between mean amounts of debris from sites within beaches were not statistically significant. Across beaches, there were 26.04 ± 3.1 items/100 m^2 of litter in the first sampling, whereas in the second sampling this estimate increased substantially, averaging 178.4 ± 36.9 items/100 m^2 (mean ± SE). When the weight of debris was considered, no significant differences were found (Table 1B). All items collected weighed 21.5 kg, averaging 215 ± 41 g/100 m^2.

Plastics were clearly the most abundant type of debris, one order of magnitude more abundant than other types of litter found on beaches during both samplings (Figure 3A, Table 2A). The number of plastic items was significantly greater than other types of litter (SNK pairwise tests). On a weight basis, however, timber debris was significantly heavier than other types of debris (Figure 3B and Table 2B; SNK pairwise tests).

A total of 461 items showed evidence of biological encrustation. The percentage of encrusted items was 4.7% ± 0.6% (mean ± SE). This was significantly lower than the expected

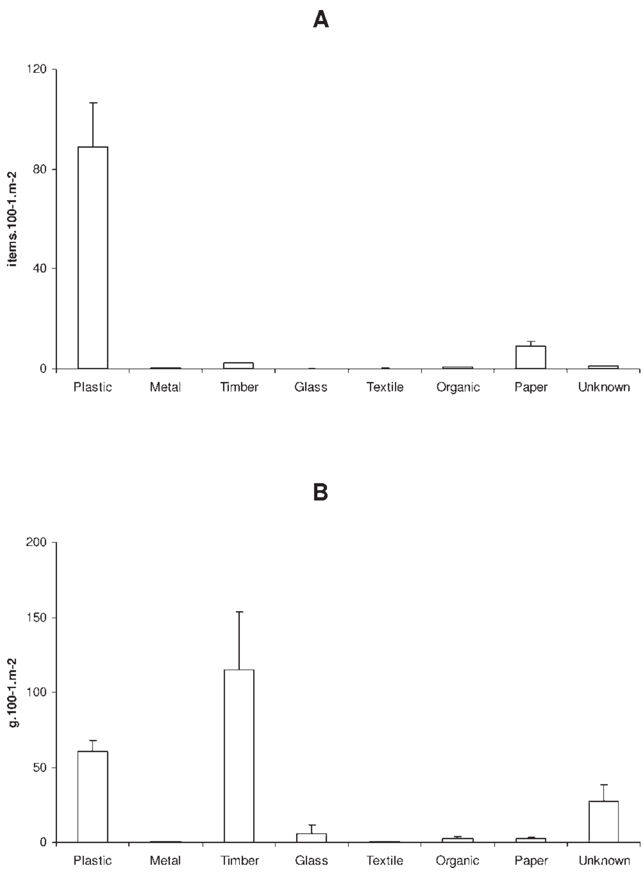

Figure 3. Abundance of eight categories of litter items: (A) mean number of items, (B) mean weight of items. Error bars represent standard errors of the means.

value of 10% (Student's t test: t = −8; 99 df; $p < 0.001$). The percentage of encrusted items varied across beaches on both sampling occasions. There was also a greater percentage of encrusted items in March 2004 compared to October 2003.

The great majority of encrusted items were plastic (98%), followed by timber (1%) and metallic items (0.5%). Out of the identified taxa, encrusting bryozoans were the most common fouling organisms, followed by balanomorph barnacles and serpulid polychaetes (Figure 4).

There was a weak negative correlation between the total number of debris items and the number of ghost crab burrows

Table 2. *Results of ANOVA for different materials of marine debris. Part A represents the number of litter items; Cochran's C = 0.9 (*p < 0.01*). Part B represents the weight of litter; Cochran's C = 0.8 (*p < 0.01*). Both tests were done with untransformed data, since no transformation was able to remove heterogeneity of variances. Analysis of variance is a robust test for such condition, particularly for large, balanced data sets such as this one (Underwood, 1997).*

Source of Variation	A				B		
	MS	df	*F*	*p*	MS	*F*	*p*
Material	95,086	7	23.09	<0.001	169,716	7.9	<0.001
Residual	4117	792			21,233		

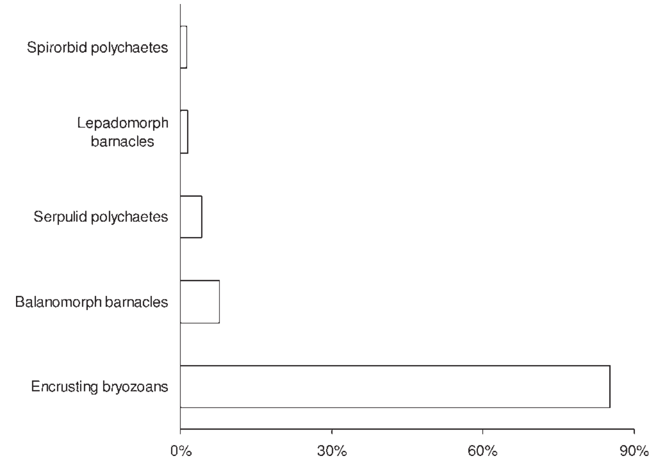

Figure 4. Percentage of fouling taxa on beach debris found with some biological fouling.

in October 2003, when the burrows were not counted in five transects (r = −0.246; 43 df; $p = 0.05$; see Figure 5). In March 2004, when the burrows were not counted in two transects, this correlation was not significant (r = 0.129; 46 df; $p > 0.05$).

DISCUSSION

Spatial and Temporal Differences

This study found that the quantity of beach debris (*i.e.*, number of items) on the east side of Santa Catarina Island is dependent on an interaction of location and time of sampling. In the first period of sampling, no significant difference across beaches was observed, whereas in the second period of sampling, the amount of debris present on three beaches was significantly higher than the amount found on two other beaches. When the weight of debris was considered, no significant difference was found. This result suggests that oceanographic patterns can only partially explain the amount of marine litter on beaches. It is important to note that there

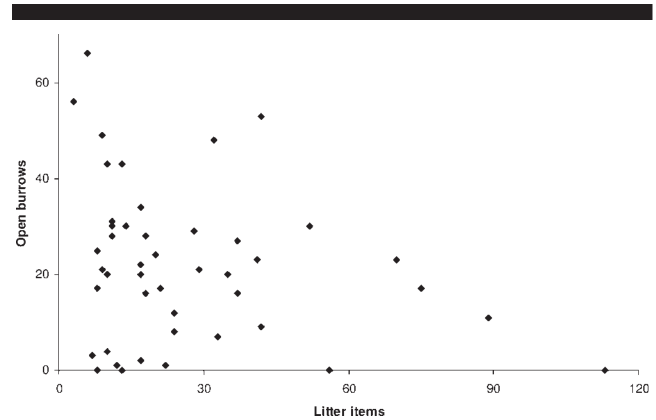

Figure 5. Plots of the number of *O. quadrata* open burrows (y-axis) and the number of beach litter items (x-axis) in October 2003.

was a threefold difference in the amount of marine debris found on Joaquina and Moçambique beaches in the first sampling. Galheta Beach had 14 times more litter than Brava Beach in the second sampling, mainly due to small plastic fragments and plastic pellets. Typically, plastic pellets are sampled in small areas, by sieving known volumes of sand or with the aid of a plankton net mounted on an appropriate harness. In this study, the majority of the 100-m^2 transects did not present an extensive amount of small plastic items (smaller than 1 cm). This would make sampling such a large area unfeasible. After a detailed, constant search effort across transects, plastic pellets were found only on four transects in the second sampling. They were included in the analysis because they fit the sampling criterion (being visible) and because their presence illustrates the idea that marine sources such as shipping cannot be entirely ruled out as significant contributors to the mix of litter present at beaches, even at those where human presence due to tourism is intense.

Such large differences suggest that other factors, such as human use of beaches, may also be an important element that affects the amount of debris in the study area. The significant increase in the amount of debris from October 2003 to March 2004 in four out of the five beaches sampled also suggests that summer beach visitors, many of whom are tourists, may be an important source of litter. The composition of the debris found on the beaches provides further support for this idea. In the first sampling on Brava Beach, there were several corks from sparkling wine, typically consumed on celebrations of New Year's Eve. On Moçambique Beach, on the other hand, the large quantity of fragments of gill nets is in accordance with the proximity of this beach to Barra da Lagoa, a traditional fishing district. It seems that a differential pattern of human use and managerial effort may be responsible for differences of litter abundance among beaches during the second sampling. The low percentage of fouled items provides further support for the idea of beach litter originating from local sources. The presence of fragments of gill nets and pieces of fishing ropes suggests that traditional fishing should not be excluded as a contributing source of beach litter.

Sampled beaches in this study seem to be at an intermediate level of litter contamination when compared to other Brazilian studies. Oigman-Pszczol and Creed (2007) found lower litter densities (13.7 items/100 m^2) in touristic beaches of Armação dos Búzios (Rio de Janeiro State), whereas some beaches in the NE region of Brazil present higher densities of litter, as reported by Santos, Friedrich, and Ivar do Sul (2009) and other studies cited therein.

Types of Debris

As hypothesized, plastic items were the most common type of litter. Several studies found similar results elsewhere (Goldberg, 1997; Ivar do Sul and Costa, 2007; Moore, 2008; Santos, Friedrich, and Ivar do Sul, 2009). Therefore, this survey validated for Florianópolis the general concept that oceans are being increasingly contaminated with plastic on a worldwide basis. This result has important implications for Brazilian packing and plastics industries, since their products represent a significant fraction of beach litter, originating most likely from beachgoers and stormwater drainage. In some production sectors, such as the battery industry, companies have undertaken the responsibility of collecting used batteries and providing an appropriate destination for them. Similarly, one can speculate that the packing and plastics industries (*e.g.*, those producing polyethylene terephthalate bottles) also have an environmental duty of care and should therefore take an active role in preventing beaches from becoming the final resting place of their products' life cycle.

Processed timber material represented the majority of beach litter in terms of wet weight. Using the wet weight of beach litter poses certain problems. Even so, this method was used here because it provides a more realistic figure for the planning of collection and transportation of beach debris. Silva-Iñiguez and Fisher (2003) found that wood material was a major component of beach debris on a Baja California (Mexico) beach. However, their findings are not entirely comparable to the present study, because their results are in terms of number of items. Nevertheless, it shows that despite firm evidence that plastic items constitute the majority of beach litter worldwide, there will be particular cases where a different pattern may occur. Oigman-Pszczol and Creed (2007), for example, found that paper was the most abundant type of beach litter in the touristic town of Armação dos Búzios. These results have management implications. If the goal is to reduce the aesthetic effect of litter on beaches (which is dependent on the number of visible items), plastic debris should be the prime target. Conversely, reduction of processed-timber material on beaches would help reduce municipality costs associated with beach cleanup procedures, which are partially dependent on the wet weight of the material being collected and transported.

The small amount of glass bottles or glass fragments and the absence of aluminum cans may be a consequence of Brazilian socioeconomics. The absence of these materials as a major component of beach litter may be related to their value as recyclable materials. In a country where the unemployment rate is high, it seems that beaches (and many other areas) are being searched for glass and cans by people that collect and sell them as a source of income. This idea is supported by frequent observations of these collectors in the municipality. The majority of items collected in this study seem to either have no current economic value as a recyclable material or be of a size that is too small to be collected by beach-cleaning staff.

Biological Aspects

In the present survey, less than 5% of all items collected showed evidence of biological fouling. This was significantly smaller than the expected percentage (10%) for this latitude (27° S), according to the model of Barnes (2002). It must be emphasized, however, that Barnes's paper focused on oceanic islands, while this study was done on an island adjacent to the mainland. The present result is in accordance with a recent study made on several beaches in NE Brazil, where the presence of fouled items was negligible (Santos, Friedrich, and Ivar do Sul, 2009). Such a small percentage suggests that the majority of the items collected were not present in the marine environment for long enough to be fouled. Instead, it seems that the majority of items had a local, land-based origin, most likely from beachgoers and storm-water drainage. Among the fouled items (mainly plastics), the most frequent taxon was encrusting bryozoans. This result agrees with the proposal of Winston (1982) that the bryozoan *Electra tenella* is taking advantage of floating plastics to expand its geographic distribution. The cirriped *Lepas ansenifera* was also present as a fouling organism. This species represents an important constituent of the pleuston, defined by Barnes and Hughes (1982, 18) as "organisms that straddle on the air-water interface." Considering that biota recorded from beached debris are biased toward taxa that have resistant parts (Gregory, 2009), it is likely that a more diverse assemblage colonized these items while they were at sea, including algae and many fleshy sessile animals, as well as other motile organisms. Since much less is known about organisms that hitchhike on plastics than about marine debris itself (Barnes *et al.*, 2009), this description of fouling taxa is an initial step toward future research that increases understanding of the ecological effects of anthropogenic debris in the marine environment.

The weak negative correlation between the number of *O. quadrata* open burrows and the number of litter items in the first sampling is an indication that the presence of beach litter may affect the biology of this crab species. This study is in accordance with results from Neves and Bemvenuti (2006), who conclude that human activity on beaches is unfavorable to ghost crabs. It is not yet clear, however, whether human presence affects the real numbers of these animals or if it alters their behavior, reducing their ability to build new burrows or to maintain previously made burrows (Barros, 2001). Results of this study are in opposition to the suggestion made by Steiner and Leatherman (1981) that the abundance of ghost crabs is positively affected by human presence on the beach due to food scraps left by visiting people, considering that these animals are important consumers of organic detritus (Wolcott, 1978). Since the majority of litter was found to be plastic, it is unlikely that populations of *O. quadrata* on sampled beaches are positively affected by the presence of beach litter.

It is important to note that the negative correlation was weak, considered significant because the p value obtained was 0.05, equal to the typical critical value for type I error in inferential statistics. Furthermore, the correlation was not consistent over time, since there was no statistical significance in the second sampling. Considering that a correlation is *not* evidence of a causal relationship, mainly due to third variables (Ruxton and Colegrave, 2006), more experiments (including manipulative ones) are recommended to clarify the role of beach debris in affecting the prevalence of *O. quadrata*.

This study supports the idea that the region of frontal sand dunes is an accumulating area for marine debris. Besides the issues addressed above, such debris may cover or damage the native vegetation that occurs in this area, such as *Hydrocotyle bonariensis*, *Remirea maritima*, *Senecio crassiflorus*, *Blutaparon portulacoides*, and *Panicum racemosum*, among others. Therefore, this finding can also help managers allocate resources more efficiently on beach cleanups in order to reduce potential litter damage to sand dune vegetation, which has an important role in diminishing the magnitude of coastal erosion.

Beach Management

The information generated by this study may also be used to inform comprehensive, all-inclusive strategies for beach management (Micallef and Williams, 2002). These strategies typically address issues such as the provision of infrastructure (*e.g.*, showers), swimmers' safety (*e.g.*, drowning, jellyfish burns), beach access over sand dunes, and reduction of beach litter. If satisfactorily executed, beach management plans are likely to encourage coastal tourism. They seem suited for Florianópolis, where beaches play a pivotal role in the attraction of tourists. A federal-government initiative for waterfront management, called "Projeto Orla," and the international program for beach certification, "Blue Flag," use the amount of debris as indicators of beach quality. Therefore, the results of this study can now be used by these programs to compare the quality of beaches in Florianópolis with the quality of beaches in other coastal cities. In addition, this study also sets a reference value against which future studies can be compared, since no previous quantification of beach litter is known for the city of Florianópolis.

Araújo and Costa (2006) stated that cleaning services on some NE Brazilian beaches reduced significantly the amount of beach litter and generated aesthetic, sanitary, and environmental benefits. However, they argued that these are just palliative and inefficient solutions and suggested that solid-waste collection at municipal sources and adequate disposal of litter are important strategies for minimizing the problem. Santos *et al.* (2005) and Silva, Barbosa, and Costa (2008) found that tourism is a main generator of beach litter and that beach contamination depends on beach visitor density, which reinforces the importance of strategies for environmental education of tourists, as well as other beach users.

In an emerging economy such as Brazil, where socioeconomic problems abound, economic growth is widely proposed as an imperative for achieving desirable outcomes. Combined with unplanned urbanization and intense tourist activity, consumerism will not help to reduce the problem of marine debris. Environmental-education programs aimed at increasing public awareness of consumerism and its negative environmental effects, like intense generation of marine debris, are suggested. According to the United Nations Environment Programme (UNEP, 2009), the promotion of activities that encourage recycling and reuse of solid waste and the development of voluntary beach and waterway cleanup campaigns seem appropriate for reducing the problem of litter in Florianópolis beaches. Moore (2008) also suggests the promotion of cleanup efforts in storm drains and catchment basins, which would prevent plastic debris from reaching the ocean.

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LITERATURE CITED

Araújo, M.C.B. and Costa, M.F., 2006. Municipal services on tourist beaches: costs and benefits of solid waste collection. *Journal of Coastal Research*, 22(5), 1070–1075.

Barnes, D.K.A., 2002. Invasions by marine life on plastic debris. *Nature*, 416, 808–809.

Barnes, D.K.A.; Galgani, F.; Thompson, R.C., and Barlaz, M., 2009. Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B*, 364, 1985–1998.

Barnes, R.S.K. and Hughes, R.N., 1982. *An Introduction to Marine Ecology*. Oxford: Blackwell, 339p.

Barros, F., 2001. Ghost crabs as a tool for rapid assessment of human impacts on exposed sandy beaches. *Biological Conservation*, 97(3), 399–404.

Blankensteyn, A., 2006. O uso do caranguejo maria-farinha *Ocypode quadrata* (Fabricius, 1787) (Crustacea: Ocypodidae) como indicador de impactos antropogênicos em praias arenosas da Ilha de Santa Catarina, SC. *Revista Brasileira de Zoologia*, 23, 870–876.

Coe, J.M. and Rogers, D.B., 1997. *Marine Debris: Sources, Impacts, and Solutions*. New York: Springer Verlag, 431p.

Corbin, C.J. and Singh, J.G., 1993. Marine debris contamination of beaches in St. Lucia and Dominica. *Marine Pollution Bulletin*, 26(6), 325–328.

Cruz, O., 1998. *A Ilha de Santa Catarina e o Continente Próximo—Um Estudo de Geomorfologia Costeira*. Florianópolis, Brasil: Editora da Universidade Federal de Santa Catarina, 280p.

Debrot, A.; Tiel, A., and Bradshaw, J., 1999. Beach debris in Curaçao. *Marine Pollution Bulletin*, 38(9), 795–801.

Dixon, T.R. and Dixon, T.J., 1981. Marine litter surveillance. *Marine Pollution Bulletin*, 12, 289–295.

City of Florianópolis, 2003. City Profile. Florianópolis Local Council. http://www.pmf.sc.gov.br/cidade/perfil_de_florianopolis/limpeza.htm (accessed May 9, 2003).

Galil, B.S.; Golik, A., and Turkay, M., 1995. Litter at the bottom of the sea: a sea bed survey in the eastern Mediterranean. *Marine Pollution Bulletin*, 30, 22–24.

Goldberg, E.D., 1997. Plasticizing the seafloor: an overview. *Environmental Technology*, 18, 195–202.

Gregory, M.R., 1991. The hazards of persistent marine pollution: drift plastics and conservation islands. *Journal of the Royal Society of New Zealand*, 21, 83–100.

Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society B*, 364, 2013–2025.

IBGE (Brazilian Institute of Geography and Statistics). Demographic Census 2000. http://www.ibge.gov.br (accessed May 9, 2003).

Ivar do Sul, J. and Costa, M., 2007. Marine debris review for Latin America and wider Caribbean Region: from the 70's until now, and where do we go from here. *Marine Pollution Bulletin*, 54(8), 1087–1104.

Laist, D.W., 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin*, 18, 319–326.

Lisboa, A.M.; Silva, J.E.; Silva, J.O.; Silva, J.R.; Dietrich, L.J., and Franzoni, T.M., 1996. *Uma Cidade numa Ilha: Relatório sobre os Problemas Sócio Ambientais da Ilha de Santa Catarina*. Florianópolis, Brasil: Insular/CECCA, 248p.

Micallef, A. and Williams, A.T., 2002. Theoretical strategy considerations for beach management. *Ocean and Coastal Management*, 45(4), 261–275.

Moraes, A.C.R., 1999. *Contribuições para a Gestão da Zona Costeira do Brasil—Elementos para uma Geografia do Litoral Brasileiro*. São Paulo: Hucitec EDUSP, 229p.

Moore, C.J., 2008. Synthetic polymers in the marine environment: a rapidly increasing, long-term threat. *Environmental Research*, 108, 131–139.

Neves, F.M. and Bemvenuti, C.E., 2006. The ghost crab *Ocypode quadrata* (Fabricius, 1787) as a potential indicator of anthropic impact along the Rio Grande do Sul coast, Brazil. *Biological Conservation*, 133, 431–435.

Oigman-Pszczol, S.S. and Creed, J.C., 2007. Quantification and classification of marine litter on beaches along Armação dos Búzios, Rio de Janeiro, Brazil. *Journal of Coastal Research*, 23(2), 421–428.

Ruthland, J. and Saalfeld, K., 1987. Ocorrência e distribuição de algumas espécies de moluscos marinhos na Ilha de Santa Catarina, SC, Brasil (Gastropoda, Bivalvia). *Iheringia*, 66, 83–94.

Ruxton, G. and Colegrave, N., 2006. *Experimental Design for the Life Sciences*. Oxford: Oxford University Press, 184p.

SANTUR (Santa Catarina State Department of Tourism), 2003. Pesquisa Mercadológica Estudo da Demanda Turística Município de Florianópolis – Abril/2003. http://www.santur.sc.gov.br/demanda2002/Floripa.htm (accessed May 5, 2003).

SANTUR, 2008. Pesquisa Mercadológica Estudo da Demanda Turística Município de Florianópolis – Março/2008. http://www.santur.sc.gov.br/index.php?option=com_content&task=view&id=230&Itemid=179 (accessed July 18, 2008).

Santos, T. and Câmara, J., 2002. GeoBrazil 2002—Brazil Environment Outlook. Brasília, Brazil: United Nations Environment Programme/Brazilian Ministry of the Environment, 447p.

Santos, I.R.; Friedrich, A.C.; Wallner-Kersanach, M., and Fillmann, G., 2005. Influence of socio-economic characteristics of beach users on litter generation. *Ocean and Coastal Management*, 48, 742–752.

Santos, I.; Friedrich, A.C., and Ivar do Sul, J., 2009. Marine debris contamination along undeveloped tropical beaches from Northeast Brazil. *Environmental Monitoring and Assessment*, 148(1–4), 455–462.

Silva, J.S.; Barbosa, S.C.T., and Costa, M.F., 2008. Flag items as a tool for monitoring solid wastes from users on urban beaches. *Journal of Coastal Research*, 24(4), 890–898.

Silva-Iñiguez, L. and Fisher, D.W., 2003. Quantification and classification of marine litter on the municipal beach of Ensenada, Baja California, Mexico. *Marine Pollution Bulletin*, 46(1), 132–138.

Steiner, A.J. and Leatherman, S.P., 1981. Recreational impacts on the distribution of ghost crabs *Ocypode quadrata* Fab. *Biological Conservation*, 20, 111–122.

Tudor, D.T. and Williams, A.T., 2001. Transect size and other threshold levels in beach litter measurement. *Shore & Beach*, 69(4), 13–18.

Underwood, A.J., 1997. *Experiments in Ecology: Their Logical Design and Interpretation Using Analysis of Variance*. Cambridge, England: Cambridge University Press, 522p.

UNEP (United Nations Environment Programme), 2009. Marine Litter: A Global Challenge. http://www.unep.org/regionalseas/marinelitter/publications/docs/Marine_Litter_A_Global_Challenge.pdf (accessed September 30, 2009).

Velander, K. and Mocogni, M., 1999. Beach litter sampling strategies: is there a "best" method? *Marine Pollution Bulletin*, 38(12), 1134–1140.

Walker, T.R.; Reid, K.; Arnould, J.P.Y., and Croxall, J.P., 1997. Marine debris surveys at Bird Island, South Georgia 1990–1995. *Marine Pollution Bulletin*, 34, 61–65.

Widmer, W.M., 2003. Recreational boats and submerged marine debris in Sydney Harbour, Australia. Recent Advances in Marine Science and Technology. *In:* Saxena, N. (ed.), *PACON 2002*. Tokyo: Japan International Marine Science and Technology Federation, pp. 565–575.

Williams, A.T. and Nelson, C., 1997. The public perception of beach debris. *Shore and Beach*, 65(3), 17–20.

Willoughby, N.G.; Sangkoyo, H., and Lakaseru, B.O., 1997. Beach litter: an increasing and changing problem for Indonesia. *Marine Pollution Bulletin*, 34(6), 469–478.

Winston, J.E., 1982. Drift plastic—an expanding niche for a marine invertebrate. *Marine Pollution Bulletin*, 13, 348–357.

Winston, J.E.; Gregory, M.R., and Stevens, L.M., 1997. Encrusters, epibionts, and other biota associated with pelagic plastics: a review of biogeographical, environmental, and conservation issues. *In:* Coe, J.M. and Rogers, D.B. (eds.), *Marine Debris: Sources, Impacts, and Solutions*. New York: Springer-Verlag, pp. 81–97.

Wolcott, T.G., 1978. Ecological role of ghost crabs, *Ocypode quadrata* (Fabricius) on an ocean beach: scavengers or predators? *Journal of Experimental Marine Biology and Ecology*, 31, 67–82.

□ **RESUMO** □

Os resíduos sólidos são um problema em escala mundial, especialmente em áreas costeiras. Aproximadamente metade da população brasileira vive em uma faixa de até 200 km da costa, gerando grandes quantidades de resíduos sólidos, os quais nem sempre recebem uma destinação adequada. Nesse sentido, este estudo teve por objetivo estimar padrões de composição e variabilidade espacial de resíduos sólidos praiais, bem como aspectos biológicos a eles associados. O estudo foi realizado em Florianópolis, uma importante cidade turística brasileira. Após duas campanhas de amostragem em cinco praias, encontrou-se abundâncias de resíduos sólidos variando entre 12,8 e 498 itens/100 m^2, dependendo de uma interação entre local e data de coleta. Os plásticos representaram quase 90% do material coletado. Apenas 5% dos itens coletados apresentaram incrustações biológicas, o que sugere que a maior parte dos itens foi originada localmente. Uma fraca correlação negativa foi encontrada entre o número de itens coletados e o número de buracos de caranguejos maria-farinha (*Ocypode quadrata*). Os resultados obtidos nesse estudo podem ser usados para o aprimoramento do gerenciamento das praias em Florianópolis, bem como para comparação com outras cidades costeiras.