

pp'-DDT observed in the Antarctic sector of the South Atlantic air implies a decrease from the 1990s. No significant temporal trend was observed in atmospheric PCB data over the period from 1987 to 1995 in the Antarctic Peninsula.

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References

- Aires, C.B., Kirchhoff, V.W.J.H., 2001. Transporte de monóxido de carbono gerado em queimadas para regiões onde não se queima. *Rev. Brasil. Geof.* 19 (1), 61–74.
- Alvalá, P.C., Boian, C., Kirchhoff, V.W.J.H., 2004. Measurements of CH₄ and CO during cruises in the South Atlantic. *Atmos. Environ.* 38 (27), 4583–4588.
- Bidleman, T.F., Walla, M.D., Roura, R., Carr, E., Schmidt, S., 1993. Organochlorine pesticides in the atmosphere of the southern ocean and Antarctica, January–March, 1990. *Mar. Pollut. Bull.* 26 (5), 258–262.
- Iwata, H., Tanabe, S., Sakai, N., Tatsukawa, R., 1993. Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of ocean on their global transport and fate. *Environ. Sci. Technol.* 27, 1080–1098.
- Kallenborn, R., Oehme, M., Wynn-Williams, D.D., Schlabach, M., Harris, J., 1998. Ambient air levels and atmospheric long-range transport of persistent organochlorines to Signy Island, Antarctica. *Sci. Total Environ.* 220, 167–180.
- Kawano, M., Tanabe, S., Inoue, T., Tatsukawa, R., 1985. Chlordane compound found in the marine atmosphere from the Southern Hemisphere. *Trans. Tokyo Univ. Fisheries* 6, 59–66.
- Larsson, P., Jarnmark, C., Sodergren, A., 1992. PCBs and Chlorinated Pesticides in the atmosphere and aquatic organisms of Ross Island, Antarctica. *Mar. Pollut. Bull.* 25 (9–12), 281–287.
- Montone, R.C., Taniguchi, S., Weber, R.R., 2003. PCBs in the atmosphere of King George Island, Antarctica. *Sci. Total Environ.* 308, 167–173.
- NCEP, 2004. National Center for Environmental Prediction. (on line). Available from <http://wesley.wvb.noaa.gov/ncep_data/index.html>.
- Schreitmüller, J., Ballschmiter, K., 1994. Levels of polychlorinated biphenyls in the troposphere of the North- and South-Atlantic Ocean. Studies of global baseline pollution XVII. *Fresenius J. Anal. Chem.* 348, 226–239.
- Tanabe, S., Tatsukawa, R., Kawano, M., Hidaka, H., 1982. Global distribution and atmospheric transport of chlorinated hydrocarbons: HCH (BHC) isomers and DDT compounds in the Western Pacific, Eastern Indian and Antarctic Oceans. *J. Oceanogr. Soc. Japan* 38, 137–148.
- Tanabe, S., Hidaka, H., Tatsukawa, R., 1983. PCB and chlorinated hydrocarbon pesticides in the Antarctic atmosphere and hydrosphere. *Chemosphere* 12, 277–288.
- Tatsukawa, R., Yamaguchi, Y., Kawano, M., Kannan, N., Tanabe, S., 1990. Global monitoring of organochlorine insecticides: an eleven-year case study (1975–85) of HCHs and DDTs in the open ocean atmosphere and hydrosphere. In: Kurtz, D.A. (Ed.), *Long Range Transport of Pesticides*. Lewis Publishers, pp. 127–141.
- Troniskov, I., Nobre, C.A., 1998. Estimation of aerosol transport from biomass burning areas during SCAR-B experiment. *J. Geophys. Res.* 103 (D24), 32129–32137.
- Weber, R.R., Montone, R.C., 1990. Distribution of organochlorines in the atmosphere of the South Atlantic and Antarctic Oceans. In: Kurtz, D.A. (Ed.), *Long Range Transport of Pesticides*. Lewis Publishers, pp. 185–197.

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Overseas garbage pollution on beaches of northeast Brazil

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Plastic wastes have been considered global pollutants (Morrison, 1999) and many studies have described their lethal and sub-lethal effects on populations of turtles, seabirds, and mammals (Laist, 1997). Floating debris

also acts as a substrate for invertebrate dispersion over large distances (Barnes, 2002). At tourist beaches, litter incidence has been related to economic losses and risks to beach users (Ballance et al., 2000; Santos et al., 2003a).

Despite having more than 8500 km of coastline, studies concerning marine debris on Brazilian beaches are still very scarce and have been mainly conducted in southern Brazil (Figueiredo et al., 2001; Santos et al.,

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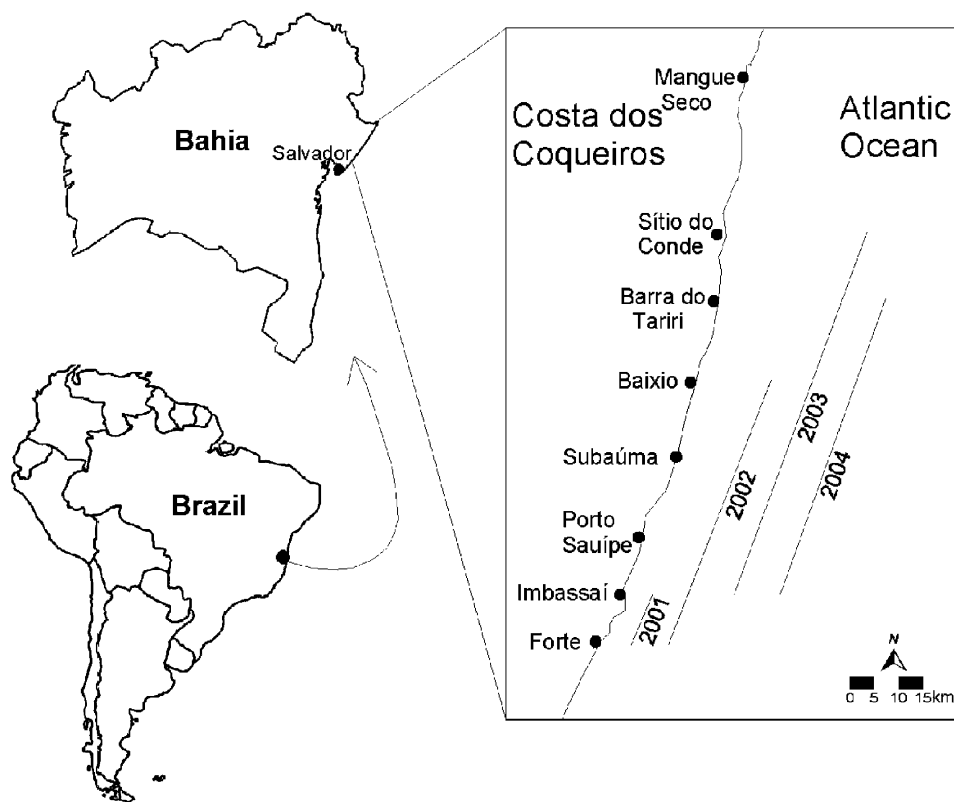


Fig. 1. Map of the study area and beach sectors sampled between 2001 and 2004.

2003a,b; Wetzel et al., 2004). The only previous study in NE Brazil investigated tourism-related litter in Pernambuco State (Araújo and Costa, 2003). In this paper, the first semi-quantitative data are reported for overseas litter found in non-urbanized beaches in Bahia State, at a region called “Costa dos Coqueiros” (Fig. 1). This region is situated approximately 60 km north of Salvador City, which is the third most populated Brazilian city and the location of the most important port in N/NE Brazil.

In general, the northeastern Brazilian coastline is characterized by low population densities and by the relatively pristine nature of its beaches. In Costa dos Coqueiros, there are several small towns (Fig. 1) that have been attempting to increase tourism. This area is also a site of marine turtle reproduction, and thus beach litter conflicts with both tourist activities and turtle conservation. The beaches involved are sandy, straight, and continuous, with intermediate or dissipative morphodynamic characteristics.

The incidence of overseas garbage in Costa dos Coqueiros was first observed in February 2001, when 81 pieces were recorded between the Forte and the Imbassaí beaches. After that, surveys were conducted in 2002 (February), 2003 (November) and 2004 (April), when all kinds of overseas litter found on the beach were collected and catalogued, regarding their type, manufac-

turer, country of manufacture, bar code, and manufacturing date and validity. Bar codes were used for identifying the origin of the garbage, as the first three bar code digits indicate the manufacturing country. Only overseas garbage, which could be identified by one of the characteristics listed above, was collected. Studied beach sectors from Costa dos Coqueiros and their respective years of survey are presented in Fig. 1.

Overseas garbage was found in all the beaches studied. High litter amounts often occurred in short beach sectors, indicating recent deposition and accumulation, probably due to regional oceanographic characteristics. The beach sector between Subaúma and Baixio had the highest litter densities, with an overall average of 14.6 items km^{-1} , a value approximately two times above other beach sectors (Fig. 2). A message in a bottle posted by a navigator at the coordinates 16°45' S and 05°48' W, 4000 km away from its collection site, demonstrates that floating garbage arrives at Costa dos Coqueiros beaches after traveling long distances. However, even though global ocean circulation patterns and trade winds in the South Atlantic promote the transportation of floating litter towards NE Brazilian beaches, it seems more probable that most containers were discarded near the coast, because encrusting organisms were uncommon and most residues found were well preserved.

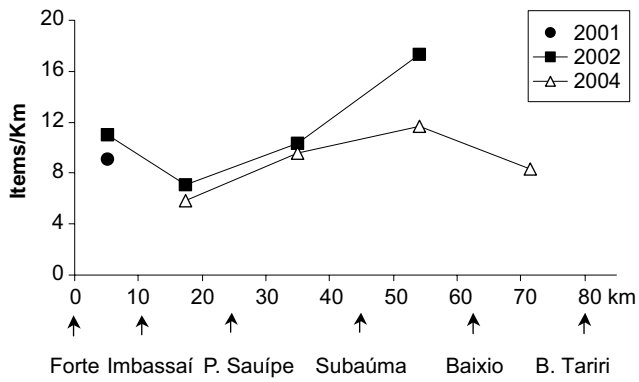


Fig. 2. Distribution of overseas containers in studied beach sectors. Distribution for 2003 is not available.

Table 1
Percentage of types of overseas garbage and total number of items per km on Costa dos Coqueiros beaches

Material	2001	2002	2003	2004	Total
Plastic	48.9	72.1	66.5	73.1	69.8
Metal	27.7	13.6	16.7	10.4	14.0
Paper	18.1	11.4	13.2	13.2	12.8
Glass	3.2	2.5	3.1	2.5	2.7
Wood	2.1	0.1	0.2	0.3	0.3
Styrofoam	0.0	0.4	0.0	0.5	0.3
Foam	0.0	0.0	0.4	0.0	0.1
Total	100	100	100	100	100
Number of items km	94	730	522	628	1974
Items km ⁻¹	10.3	62.7	82.1	69.3	224.4
	9.1	11.6	6.4	9.1	8.8

Plastic was the main type of material found in litter, followed by metal (Table 1). This is a common feature of litter stranded on beaches and has been found by many authors around the world (Derraik, 2002). This may be explained by characteristics such as floatation, high use by modern society, persistence in the environment, and increasing flows with time (Goldberg, 1995; Thiel et al., 2003). The most prevalent plastic garbage was water bottles, which comprised nearly 35% of all residues (Table 2).

In Table 3, the total numbers of residues and their countries of origin are presented. The United States, followed by Italy and South Africa are the main manufacturers of litter found on Costa dos Coqueiros beaches. Besides the 10 countries shown in Table 3, residues from 59 other nations from all over the world were also found. Although the investigated area has lower shipping traffic and human habitation than other regions, such as the North Atlantic and the Mediterranean, this appears to be the most diverse record of overseas litter found worldwide (Dixon and Cooke, 1977; Dixon and Dixon, 1981; Galil et al., 1995; Garrity and

Table 2
Percentage of original content of containers found on Costa dos Coqueiros beaches

Product	2001	2002	2003	2004	Total
Mineral water	22.3	37.9	30.5	38.2	35.3
Milk/juice	21.3	11.2	13.8	11.3	12.4
Cosmetics/toiletries	13.8	10.5	8.6	8.1	9.4
Household cleaners	16.0	10.7	14.2	9.9	11.6
Food	11.7	12.2	11.5	14.6	12.8
Insecticides	8.5	1.6	4.4	1.8	2.7
Soft drinks	3.2	4.9	6.9	6.7	5.9
Alcoholic drinks	0.0	1.2	2.9	1.3	1.6
Drugs	0.0	1.0	1.0	1.9	1.2
Lubricating oil	1.1	0.0	3.4	2.9	1.9
Others/not identified	2.1	8.6	2.7	3.3	5.1
Total	100	100	100	100	100

Levings, 1993; Golik and Gertner, 1992; Merrel, 1980; Ribic et al., 1997; Ryan, 1987; Slip and Burton, 1991).

The four main sources of marine and coastal litter are recreational and tourism-related litter, fishing debris, sewage-related debris and shipping waste (Somerville et al., 2003). Even though we do not have information about the relative importance of such sources, the evidence that ships are an important source of garbage to beaches of Costa dos Coqueiros is very strong. Firstly, no indication of Brazilian importers on the product labels proves the litter did not come from local sources, including tourism. Secondly, the types of beach debris (Table 2) offer additional evidence that marine vessels are the primary garbage source. Finally, the absence of important local sources, such as tourism and large rivers draining populated areas, diminishes the relative importance of land-based sources. The influence of Salvador city also appears to be small because the longshore current in Bahia State is predominantly southward (Bittencourt et al., 2000, 2002).

Table 3
Percentage of country of origin of containers found on Costa dos Coqueiros beaches

Country	2001	2002	2003	2004	Total
USA	10.6	13.7	14.8	8.6	12.2
Italy	3.2	9.6	3.8	9.2	7.6
South Africa	9.6	6.2	5.2	7.2	6.4
Argentina	5.3	4.2	5.2	8.9	6.0
Germany	8.5	5.9	5.7	4.6	5.6
United Kingdom	6.4	4.4	5.9	3.5	4.6
Taiwan	4.3	7.3	2.1	2.9	4.4
Singapore	0.0	1.4	5.7	5.1	3.6
Spain	4.3	4.0	3.6	3.0	3.6
Malaysia	3.2	2.9	1.9	4.5	3.1
Others	38.3	33.7	38.9	33.3	35.2
Unidentified	6.4	6.8	7.1	9.2	7.6
Total	100	100	100	100	100

Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL) prohibits any overboard disposal of plastics and limits other waste discharges based on the ship's location and distance from the shore. Some studies have shown that the accumulation and impacts of debris have not diminished since the implementation of Annex V (Henderson, 2001; Page et al., 2004; Ribic et al., 1997) and our results show that ships continue to dump litter into the oceans. As a result, Brazilian economic activities in the coastal zone (i.e., tourism, fishing, and navigation) and marine biota are endangered by shipping wastes. These impacts have not been fully assessed in Brazil, but recently two sea turtles were found with plastic debris in their stomachs near our study area, which probably caused their deaths (Mascarenhas et al., 2004).

In Brazil, and in most developing countries, the absence of garbage reception facilities in most ports, associated with a lack of inspection and fines for faulty ships, are believed to explain the observed scenario. International management actions are fundamental in diminishing this problem. Financial compensation for biological and scenic degradation and the use of port fees for environmental issues are examples of such actions, although they are very difficult to implement. The acknowledgement of marine debris as a problem in Brazil and the involvement of different stakeholders in the coastal zone is fundamental to solve this problem. Taking into account the absence of earlier studies, our results should place the Brazilian authorities on the alert, and provide background information for future assessments after the implementation of local management strategies for decreasing shipping-related debris.

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References

- Araújo, M.C.B., Costa, M., 2003. Análise quali-quantitativa do lixo deixado na Baía de Tamandaré (PE, Brasil) por excursionistas. *Gerenciamento Costeiro Integrado* 3, 58–61.
- Ballance, A., Ryan, P.G., Turpie, J.K., 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. *South African Journal of Science* 96, 210–213.
- Barnes, D.K.A., 2002. Invasions by marine life on plastic debris. *Nature* 416, 808–809.
- Bittencourt, A.C.S.P., Dominguez, J.M.L., Martin, L., Silva, I.R., 2000. Patterns of sediment dispersion coastwise the State of Bahia, Brazil. *Annals of the Brazilian Academy of Sciences* 72, 271–287.
- Bittencourt, A.C.S.P., Martin, L., Dominguez, J.M.L., Silva, I.R., Souza, D.L., 2002. A significant longshore transport divergence zone at the Northeastern Brazilian coast: implications on coastal quaternary evolution. *Annals of the Brazilian Academy of Sciences* 74, 505–518.
- Derraik, J.G.B., 2002. The pollution of the marine environment by plastic debris: A review. *Marine Pollution Bulletin* 44, 842–852.
- Dixon, T.R., Cooke, A.J., 1977. Discarded containers on a Kent beach. *Marine Pollution Bulletin* 8, 105–109.
- Dixon, T.R., Dixon, T.J., 1981. Marine litter surveillance. *Marine Pollution Bulletin* 12, 289–295.
- Figueiredo, A.G., Lyra, A.C., Mordo, M.L., Santos, R.H., 2001. Lixo flutuante na Baía de Guanabara, Rio de Janeiro, Brasil. *Gerenciamento Costeiro Integrado* 1, 13.
- Galil, B.S., Golik, A., Turkay, M., 1995. Litter at the bottom of the sea: a sea bed survey in the eastern Mediterranean. *Marine Pollution Bulletin* 30, 22–24.
- Garrity, S.D., Levings, S.C., 1993. Marine debris along the Caribbean coast of Panama. *Marine Pollution Bulletin* 26, 317–324.
- Goldberg, E.D., 1995. Emerging problems in the coastal zone for the twenty-first century. *Marine Pollution Bulletin* 31, 152–158.
- Golik, A., Gertner, Y., 1992. Litter on the Israeline coastline. *Marine Environmental Research* 33, 1–15.
- Henderson, J.R., 2001. A pre- and post-MARPOL Annex V summary of Hawaiian monk seal entanglements and marine debris accumulation in the northwestern Hawaiian Islands, 1982–1998. *Marine Pollution Bulletin* 42, 584–589.
- Laist, D.W., 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: Coe, J.M., Rogers, D.B. (Eds.), *Marine Debris: Sources, Impacts and Solutions*. Springer-Verlag, New York, pp. 99–140.
- Mascarenhas, R., Santos, R., Zeppelini, D., 2004. Plastic debris ingestion by sea turtle in Paraiba, Brazil. *Marine Pollution Bulletin* 49, 354–355.
- Merrel, T.R., 1980. Accumulation of plastic litter on beaches of Amchitka Island, Alaska. *Marine Environmental Research* 3, 171–184.
- Morrison, R.J., 1999. The regional approach to management of marine pollution in the south pacific. *Ocean and Coastal Management*, 503–521.
- Page, B., McKenzie, J., McIntosh, R., Baylis, A., Morrissey, A., Calvert, N., Haase, T., Berris, M., Dowie, D., Shaughnessy, P.D., Goldsworthy, S.D., 2004. Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. *Marine Pollution Bulletin* 49, 33–42.
- Ribic, C.A., Johnson, S.W., Cole, C.A., 1997. Distribution, type, accumulation, and source of marine debris in the United States, 1989–1993. In: Coe, J.M., Rogers, D.B. (Eds.), *Marine Debris: Sources, Impacts and Solutions*. Springer-Verlag, New York, pp. 35–48.
- Ryan, P.G., 1987. The origin and fate of artefacts stranded on islands in the African sector of southern ocean. *Environmental Conservation* 14, 341–346.
- Santos, I.R., Friedrich, A.C., Duarte, E., 2003a. Percepções sobre o lixo na praia do Cassino, RS, Brasil. *Mundo & Vida* 4, 11–17.
- Santos, I.R., Friedrich, A.C., Wallner-Kersanach, M., Fillmann, G., Shiller, R.V., Costa, R., 2003b. Geração de resíduos sólidos pelos usuários da praia do Cassino, RS, Brasil. *Gerenciamento Costeiro Integrado* 3, 12–14.

- Slip, D.J., Burton, H.R., 1991. Accumulation of fishing debris, plastic litter, and other artefacts, on Heard and Macquarie Islands in the Southern Ocean. *Environmental Conservation* 18, 249–254.
- Somerville, S.E., Miller, K.L., Mair, J.M., 2003. Assessment of the aesthetic quality of a selection of beaches in the Firth of Forth, Scotland. *Marine Pollution Bulletin* 46, 1184–1190.
- Thiel, M., Hinojosa, I., Vasquez, N., Macaya, E., 2003. Floating marine debris in coastal waters of the SE-Pacific (Chile). *Marine Pollution Bulletin* 46, 224–231.
- Wetzel, L., Fillmann, G., Niencheski, L.F.H., 2004. Litter contamination on the Brazilian southern coast: processes and management perspectives. *International Journal of Environment and Pollution* 21, 153–164.