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Baseline

Plastic debris retention and exportation by a mangrove forest patch

Juliana A. Ivar do Sul *, Monica F. Costa, Jacqueline S. Silva-Cavalcanti [1], Maria Christina B. Araújo [2]

Laboratory of Ecology and Management of Estuarine and Coastal Ecosystems, Departamento de Oceanografia, Universidade Federal de Pernambuco, Av. Arquitetura, Recife, PE CEP 50740-550, Brazil

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ABSTRACT

An experiment observed the behavior of selected tagged plastic items deliberately released in different habitats of a tropical mangrove forest in NE Brazil in late rainy (September) and late dry (March) seasons. Significant differences were not reported among seasons. However, marine debris retention varied among habitats, according to characteristics such as hydrodynamic (i.e., flow rates and volume transported) and relative vegetation (*Rhizophora mangle*) height and density. The highest grounds retained significantly more items when compared to the borders of the river and the tidal creek. Among the used tagged items, PET bottles were more observed and margarine tubs were less observed, being easily transported to adjacent habitats. Plastic bags were the items most retained near the releasing site. The balance between items retained and items lost was positive, demonstrating that mangrove forests tend to retain plastic marine debris for long periods (months-years).

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The historical occupation of estuarine and mangrove areas put them at great risk of pollution, including contamination with plastic debris. Considering the social, economic and ecological importance of mangroves, relatively few works on plastic pollution have been conducted in these habitats worldwide, and Brazil is no exception (e.g., Cordeiro and Costa, 2010; Costa et al., 2011). However, such baseline studies are an essential first step in the conservation of estuarine areas and mangrove forests worldwide, guaranteeing the integrity of the river-estuary-ocean gradient.

Plastics are widely spread all over the marine environment (Moore, 2008), and once in the sea they are easily dispersed to adjacent areas by surface currents, winds and tides (Wilber, 1987; Kubota et al., 2005; Ivar do Sul et al., 2009), where it accumulates. Plastic cargoes accidentally spilled in the ocean have been used to the benefit of the ocean sciences such as opportunistic experiments like other Lagrangian floaters (drift bottles, cards and more recently ALPS), to help provide insight into paths of contaminants and sea current patterns in the North Pacific Ocean. In coastal areas, the deliberate experimental release of marine debris to trace their trajectory has been used in previous studies focused on tagged items as tracers of plastic movements on beaches and estuarine environments (Williams and Simmons, 1996; Wilson and Randall, 2005).

In this context, we released and tracked tagged items in a mangrove forest patch at the Goiana Estuary, an estuary in the Northeast coast of Brazil (Fig. 1a). The estuary (4700 ha) is an important source of natural resources and services to traditional communities of a Marine Conservation Unit (Barletta and Costa, 2009; Silva-Cavalcanti and Costa, 2009). The occurrence of plastic debris was reported on downstream estuarine beaches throughout the year (Ivar do Sul and Costa, 2013).

The site chosen for our release and track experiment was an island with the river (Goiana river) at one side and a tidal creek on the other side (Fig. 1b). Both sides are subject to tide and river flow (Table 1). The higher ground is a relatively high and flat area, flooded only during extreme tidal events. The habitats considered in the experiment (river, higher ground and tidal creek) (Fig. 1c) have different hydrodynamic characteristics and mud/sand sediment ratio, resulting in different plastic debris retention potential. The forest (*Rizhophora mangle*) density and height were also expected to influence plastic debris trapping at each habitat (Table 1 and Fig. 1c).

On each habitat, three identical tagged items (Table 2 and Fig. 1d, e) were put in areas of 20 m^2 delimited by zebra-tape for reference during work. The experimental areas were cleared from all plastic debris before starting the experiment. Three items of each type were painted yellow (March – early rainy season) and pink (September – early dry season) (Barletta and Costa, 2009)

* Corresponding author. Tel./fax: +55 (021 81) 2126 7223.
E-mail address: julianasul@gmail.com (J.A. Ivar do Sul).

[1] Present address: Universidade Federal Rural de Pernambuco, Unidade Acadêmica de Serra Talhada, Fazenda Saco, Serra Talhada, PE CEP 56900-000, Brazil.

[2] Present address: Universidade Federal do Rio Grande do Norte, Departamento de Oceanografia e Limnologia, Via Costeira, Natal, RN CEP 59014-100, Brazil.

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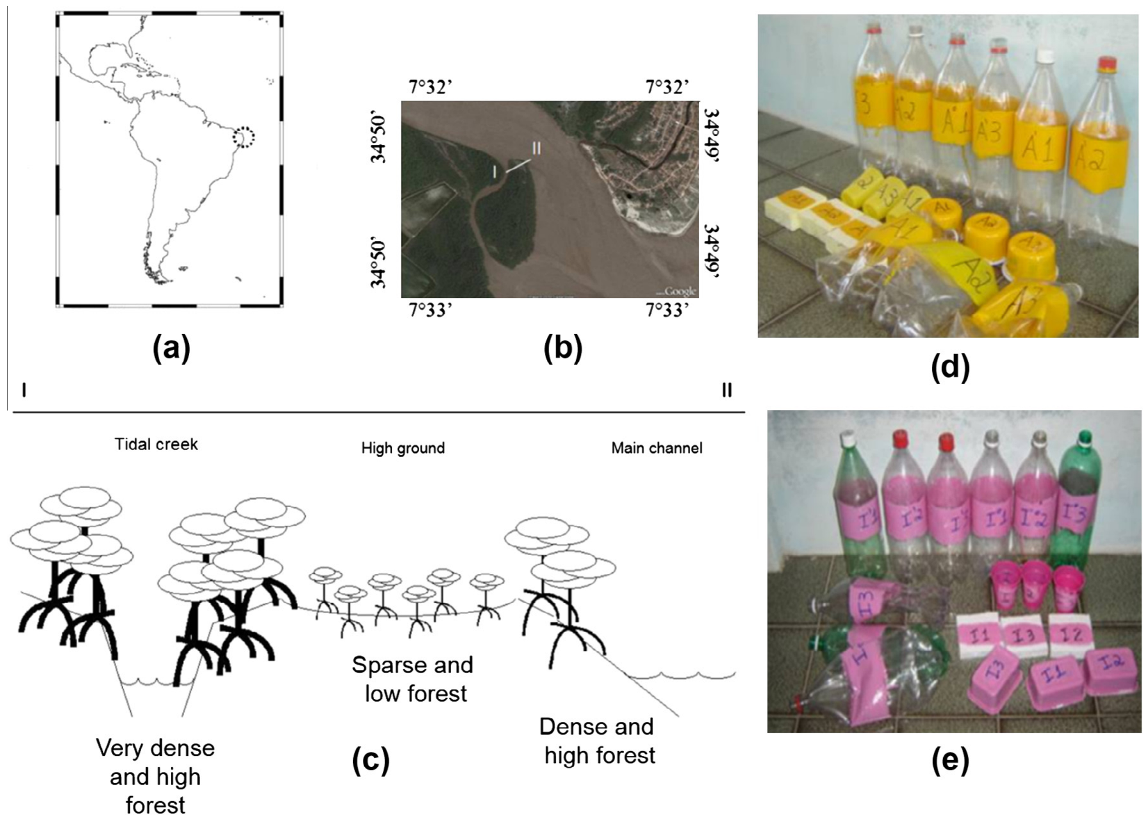

Fig. 1. (a) Location of the Goiana Estuary in the Northeast of Brazil; (b) the studied island (~300.000 m^2) and transect I-II, from the tidal creek to the river; (c) schematic representation of the monitored habitats according to the transect I-II. The tagged items were painted (d) yellow for March and (e) pink for September. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Detailed dynamic characteristics of the studied habitats.

Goiana river	
Physical characteristics	
Width	*River:* 10 m–1.7 km from the upper to the lower portions of the estuary (400 m around the studied area)
	Tidal creek: 20 m
Depth	*River:* 6–8 m
	Tidal creek: 3 m
Sediment	*River:* fine sand
	Tidal creek: mud
	Higher grounds: sandy mud
Bank slopes	*River:* 160° from the water surface
	Tidal creek: 110° from the water surface
Winds	Prevailing winds E-S-SE (130° Az); high percentages E (70–92° Az). Wind speed 0–6 m s^{-1} (higher concentration 3–4 m s^{-1})
Hydrodynamic characteristics	
Volume transported	*River:* March – 1.749,888 m^3 7 $days^{-1}$
	River: September – 12.703,824 m^3 7 $days^{-1}$
Flow rates	*River:* ~11 $m^3\ s^{-1}$ (0.5–25 $m^3\ s^{-1}$)
	Tidal creek: ~0.005 $m^3\ s^{-1}$
Waves	No waves inside the estuary; high incidence of frontal waves on the coast
Tides	0.0–2.5 m (semi-diurnal)
Mangrove forest	
(*Rhizophora mangle*)	*River:* 0.7 ind. m^{-2}
	Tidal creek: 1 ind. m^{-2}
	High grounds: 0.4 ind. m^{-2}

and identified with numbers and letters, which corresponded to each area (Fig. 1d and e). A total of 189 tagged items were released in the mangrove forest in each experiment. Both experimental periods corresponded to equinoctial tides.

In the first day of each experiment (0 h), the tagged items (n = 189) were randomly thrown into their respective areas within each habitat. During the following 6 days, the items remaining in the forest were counted every 24 h (24, 48, 72, 96, 120 e 144 h),

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