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Plastics buried in the inter-tidal plain of a tropical estuarine ecosystem.

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ABSTRACT

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Plastics have become the most important marine contaminant of the XXI Century. Benthic fauna is not frequently a concern, but can ingest plastics which suffered fragmentation and chemical contamination accumulated in the sediments. This work approaches the amounts and types of plastic buried in the sediments of an intertidal plain on the Northeast coast of Brazil. During one seasonal cycle, 450 samples of sediment were taken. Sediments were sieved (1mm mesh). Thirty-eight plastic fragments of different sizes and types occurred distributed in space and time. Plastics size varied from 1mm to 160cm^2. All plastics were heavily weatherized. Soft plastics, nylon and hard plastics items were found. The most likely sources of these plastics are the river basin, the communities that inhabit the margins of the estuary, fishery activities and the mangrove forest. A significant difference between the rainy and dry seasons was detected for the amount and type of plastic found (plastic or nylon) among three sampling areas. Nearer to the mangrove forest there was a larger accumulation of plastic items. This estuary is undergoing an intense process of aggradation and there is a possibility of dredging of the main channel and harbor areas. This, plus the disposal of spoils will further spread the plastics once buried. The dredged areas will become a secondary source of plastics as their pollution burden will be, once more, exposed to tidal currents and main channel flow.

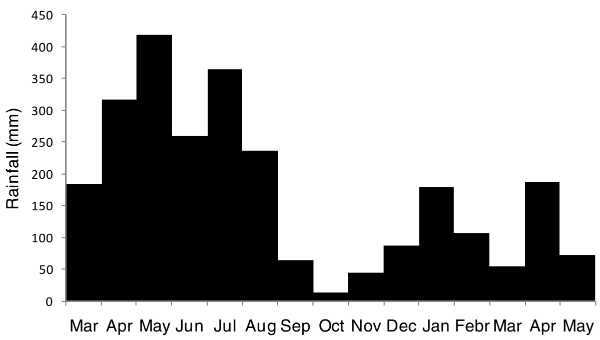
ADDITIONAL INDEX WORDS: *marine debris, estuarine conservation, plastic fragments*

INTRODUCTION

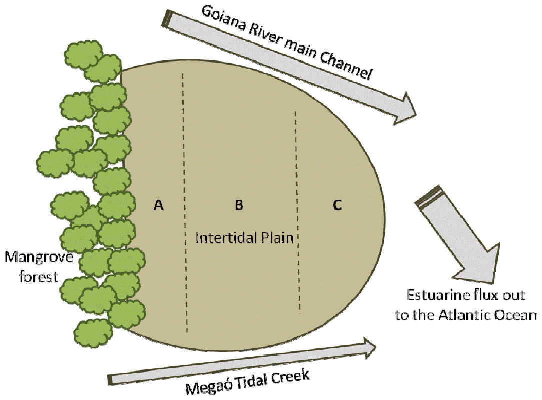
Plastics have become the most important marine contaminant of the XXI Century (Ivar do Sul and Costa, 2007; Gregory, 2009). Its prevalence at all coastal and marine environments is recognized by the scientific community, government agencies, the third sector and the general public. Plastics pollution at marine and coastal environments is an issue that speaks dearly to us all. We can frequent and easily recognize plastic items lost at sea, or deposited on beaches, and relate to them as a potential source of that pollution (Coe and Rogers, 2000). The accumulation of plastic on beaches and other aquatic and surrounding environments (mangrove forests, dunes, lagoons, river beds and banks) is conspicuous and well documented around the world (Ivar do Sul and Costa, 2007; Moore, 2008; Gregory, 2009). Plastics deposition and permanence at the bottom of the sea is another known phenomena (Spengler and Costa, 2008; Bauer et al., 2008). A point of concern and public mobilization around large plastic items at sea are the consequences to the biota, specially the charismatic marine fauna (sea turtles, birds, dolphins, manatees, and whales) that suffers from entanglement and/or ingestion (Moore, 2008; Gregory, 2009; Guebert-Bartholo et al., 2011). On the other hand, microplastics (fragmented plastics and virgin plastic pellets) are also widely spread on the surface of world oceans (Moore et al., 2001; Thompson et al., 2004; Barnes et al., 2009; Costa et al., 2009; Law et al., 2010; Ivar do Sul et al., 2010).

The benthic fauna is not frequently a concern regarding plastics pollution, coral reefs being a rare exception. However, benthic organisms ingest plastic fragments and, possibly, are contaminated by the persistent organic pollutants associated to them (Thompson et al., 2004; Browne et al., 2008; Graham and Thompson, 2009). Buried plastics undergo physical and chemical degradation which leads to fragmentation, a process that facilitates subsequent chemical contamination. If fragmented to small enough sizes, plastics can be ingested by benthic crustacea (Iribarne et al., 2000), mussels (Browne et al., 2008), polychaeta (Thompson et al., 2004) and sea cucumbers (Graham and Thompson, 2009). Buried plastics have the potential for developing unwanted environmental consequences increased in many orders of magnitude in relation to large plastic items. Buried plastics are temporarily immobilized by sediments, and then exposed to an inhospitable physico-chemical environment that will contribute to their degradation, fragmentation and, finally, facilitate ingestion. Sediments naturally concentrate organic and inorganic pollutants, which can contaminate buried plastic fragments.

In estuaries, the processes governing plastics fragmentation, deposition and behavior are still poorly understood (Reddy et al., 2006; Browne et al., 2010). Demersal fish of the Goiana Estuary (Possatto et al., in press) ingest plastics. The Goiana Estuary and its adjacent coastal waters have received in 2007 the status of marine conservation unit, which increases the need of studies on human impacts to the area and how to mitigate them. The present work quantified and described the types of plastic that occurred buried in the sediments of an intertidal plain of this estuary according to seasons (dry and rainy) and habitat (near the mangrove forest, intermediate or near the main channel) (Figure 1).



(a)



(b)

Figure 1. (a) Rainfall during the sampling period; (b) position of sampling areas A, B and C in relation to the forest and channel.

MATERIAL AND METHODS

Study site

The tidal Goiana Estuary (7^o 32' - 7^o 33'S; 34^o 49' - 34^o 53'W), on the Northeast coast of Brazil is subject to two main seasons: rainy at the middle of the year (March – August) and dry at the end/beginning of the year (September – February) (Barletta and Costa, 2009) (Figure 1a). Tides in the region are semi-diurnal (0.0-2.5m). Fishery of fish, mollusks and crustaceans is intense all along the estuary and year (Barletta and Costa, 2009). During low tide, exposed intertidal plains are intensely exploited by mussel pickers.

Sampling

Every month, from March 2009 to May 2010, at the new moon lowest tide, 30 cores were evenly distributed randomly according to three areas delimited on top of the tidal plain (Figure 1b). Area A was nearer to the mangrove forest and always exposed during low tide; Area B was on the top of the tidal plain and mostly exposed during low tide and; Area C at the fringe of the tidal plain, and was only occasionally exposed at low tide. The cylindrical corer used had 20cm in diameter and 20cm height (h). The volume (cm^3) of the cylindrical corer is defined as:

$$V = \pi r^2 * h \ (cm^3) \qquad (1)$$

The density of plastic items within the sediment sample was calculated using:

$$D = (N°.\ of\ items) / V \qquad (2)$$

Laboratory procedures

The whole volume of sediments (6 294 cm^3) in each core was sieved through a 1mm mesh. Plastic items were separated, dried and, their size (area in cm^2) and weight (0.01g) measured. The material was registered as either nylon or plastic. Characteristics as hard / soft plastic, plastic degradation, most probable source (land-based, fishery, sea) and fouling were also noted.

Statistical analysis

Analysis of variance (Two-Way ANOVA) was used to test the effect of the factors time (season) and space (area) on the distribution and density of the plastic items buried in the sediment. Cluster analysis (group average), based on the Euclidean distance, was used to determine the distribution patterns of the buried plastic along the space and time in the intertidal sand bank of lower portion of the estuary.

RESULTS AND DISCUSSION

After 15 months, 450 samples of sediments were taken at the intertidal plain. Typically, there was one item per core, but some were contaminated with up to three plastic items. A total of 59 plastic items.m^{-3} were found in the 450 samples (Table 1). From these, 67.6% is composed by plastic and 32.4% by nylon filaments. During the dry season was observed the highest frequency of plastic items in the sediment (Table 1). However, area A showed the highest concentration of plastic items (Table 2, Figure 2), independent of time of the year. The cluster analysis showed two main groups (Figures 3 and 4). The group I is formed by sub-group A, which is represented only by the plastic items found in area C during the rainy season, and sub-group B, which is characterized by the plastic items found in area B independent from season and area C during the dry season. The second group is composed by the plastic items found in area A (Figures 3 and 4).

Plastics of different sizes (>1mm) and types occurred in eleven out of fifteen sampling months. The month during sampling when most plastic items were found buried in the tidal plain was October 2009, with 11 items. On the other hand, on July 2009, February, April and May 2010, no plastic items were found in the cores. Plastics fragments sizes varied from 1mm (mesh) to 10cm x 6cm soft plastic fragments. All items were fragments of larger plastic objects. The average area of the plastic debris was 10.5cm^2 (range 1.1 to 160cm^2), and the average weight was 0.15g (range 0.01 to 3.0g).

Most plastics were heavily weatherized (32 items in 38) (Figure 5). This is in accordance with the expected for this habitat of high temperatures, high salinity and low oxygen. Only six items were new plastic, with little degradation signals. Nylon (polyamide), hard plastics (probably PP) and soft packaging (cellophane) were present. The plastic and cellophane fragments were the most common items found (28 in 38 items). Hard plastics accounted for 12 of the 38 items found. The other fragments were soft plastics. Nylon threads, frequently found in the gut contents of benthic fish in the area (Possatto et al., in press), were the second most common type of item (10 items in 38). No fouling was observed on these items.

The higher contamination of area A can be attributed to two main factors. First, being closer to the mangrove forest, it will be subject to contamination by plastic items and fragments from

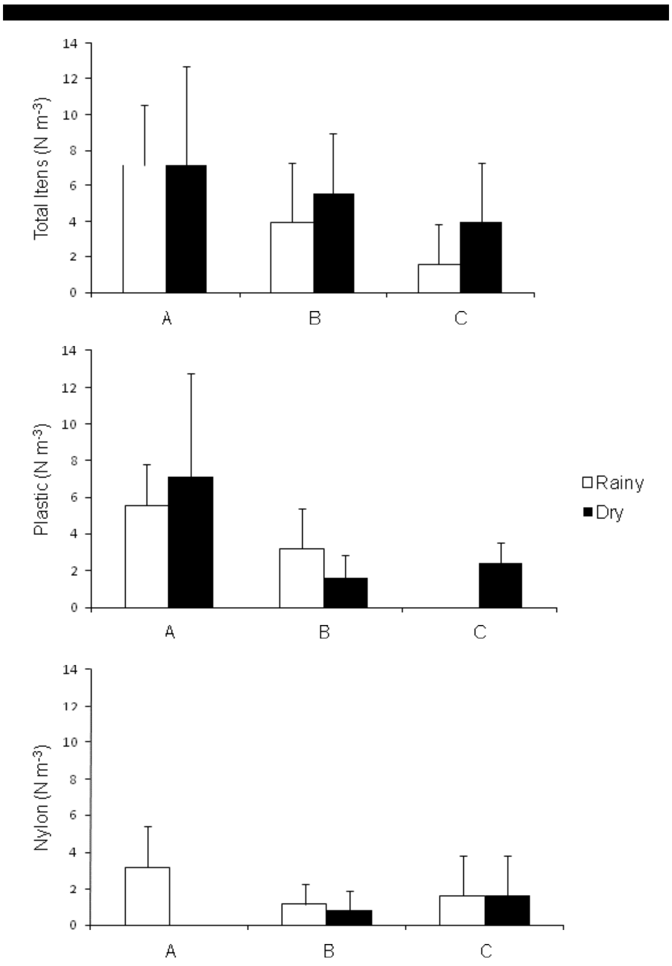


Figure 2. Distribution of average number of plastic items, plastics and nylon per m^3 of sediments according to the area of the intertidal plain (A, B, C) and season (rainy and dry) at the Goiana Estuary.

plastics accumulated in the forest (Ramos et al., 2011) or hanging from tree branches. Secondly, it is mainly located at the prograding front of the forest, and is a naturally fast growing sedimentary environment of the lower estuary, which facilitates burial of plastic items.

The source of these plastic fragments are, probably, the river basin, the communities that inhabit the margins of the estuary and mussel pickers (boat gear, tools, snacks packaging, fishery gear). Thirteen of the items had their attributed origin to some fishery activity. By digging the sediments for mussels, fishers can also be an element of exhumation of previously buried plastic items. The intertidal plain is littered with plastic items that may become buried due to the sediment revolving done by the mussel pickers. Another possible burying process is animal bioturbation, in which larger animals, as crabs, could bury the plastic debris, a process also observed in the adjacent mangrove forests within the estuary and elsewhere (Iribarne et al., 2000). A marine origin is also possible, although probably less frequent.

Table 1: Summary of the results for plastic items and its two main fractions (plastics and nylon), according to season and area of the intertidal plain. Frequency of occurrence of plastic items in sediment samples for each situation.

		Items.(m^{-3})			
	Season	Total	Plastic	Nylon	Freq.(%)
Area A	Rainy	15.89	11.12	6.36	6.7
	Dry	14.30	14.30		11.7
Area B	Rainy	6.36	6.36	1.59	8.3
	Dry	11.12	3.18	1.59	10
Area C	Rainy	4.77	1.59	3.18	1.7
	Dry	6.36	4.77	3.18	8.3
Total (items.m^{-3})		58.79	41.31	15.89	

Table 2. Summary of ANOVA results. NS: non significant; *:$p<0.05$; (—): similar groups. Post hoc test: LSD.

	Source of Variance		
Variable	Area (1)	Season (2)	Interaction
Total Itens	ns	ns	ns
Plastic	*	ns	ns
	A BC		
Nylon	ns	ns	ns

There is a strong possibility that the plastic fragments detected during the present work are only the precursors of even smaller plastic fragments (<1mm) that will also concentrate in the sediments of the estuary (Reddy et al., 2006; Browne et al., 2010).

Sedimentation and settling of the plastics, together with suspended particulate matter, is another explanation for their presence buried in the sediments. This estuary is undergoing an intense process of aggradation due to unsustainable land use along the river basin (Barletta and Costa, 2009). Ferry operators and other boat users are now considering the possibility of dredging this estuary for deepening of the main channel and harbor areas.

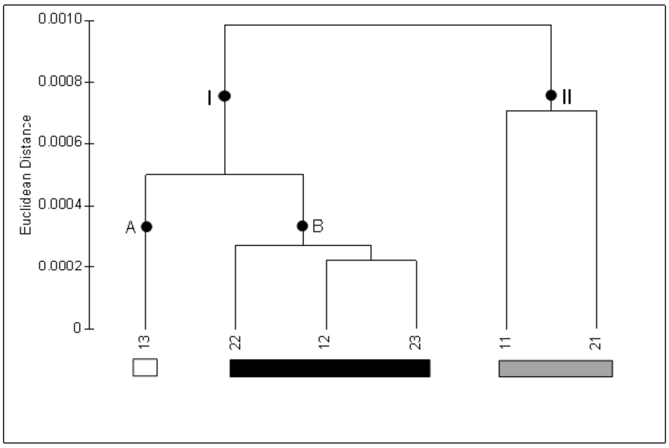


Figure 3. Plastic items volume (items.m^{-3}) found in the studied areas of the intertidal sand bank of the lower portion of Goiana Estuary. Samples were clustered by group average of Euclidean Distance.

CONCLUSIONS

Plastic fragments of varied sizes and types are buried in estuarine sediments where they will not necessarily remain unchanged. Fragmentation, contamination and exhumation are all possible processes these plastic items can go through. The disposal of the resulting dredged spoils will certainly help further spread the plastics once buried. Also, the surface of the dredged areas will become a secondary source of plastics as their pollution burden will be once more exposed to the incoming and outgoing currents of the main channel. This paper is a contribution for the evaluation of the potential hazard of dredging operations within estuaries and should be taken into consideration if the works are to go forward at the Goiana Estuary, or at another estuary with, or without, a marine conservation unity status.

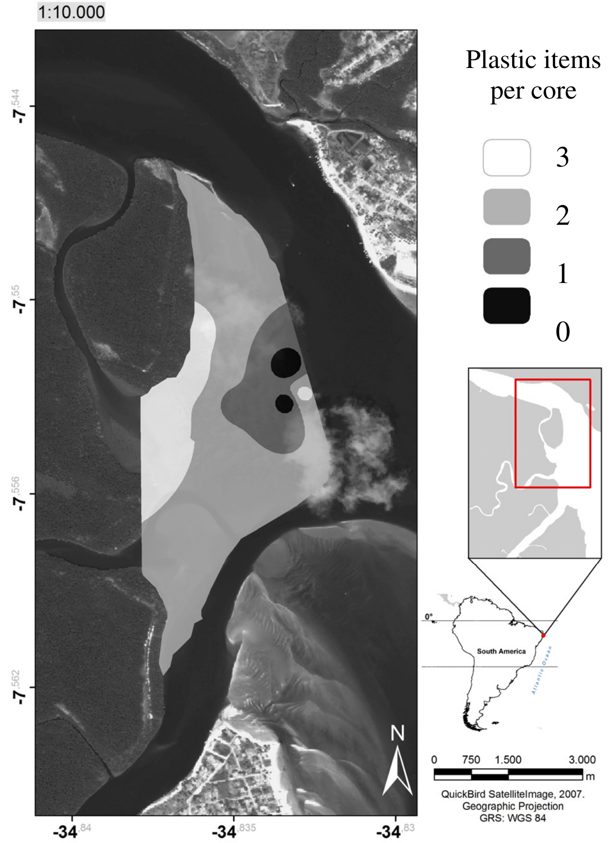


Figure 4. Spatial distribution of plastic items on the ~1ha intertidal plain of the Goiana Estuary studied here and where most of the exploitation of infaunal clams (*Anomalocardia brasiliana*) is made. N=450 cores along 15 months. .

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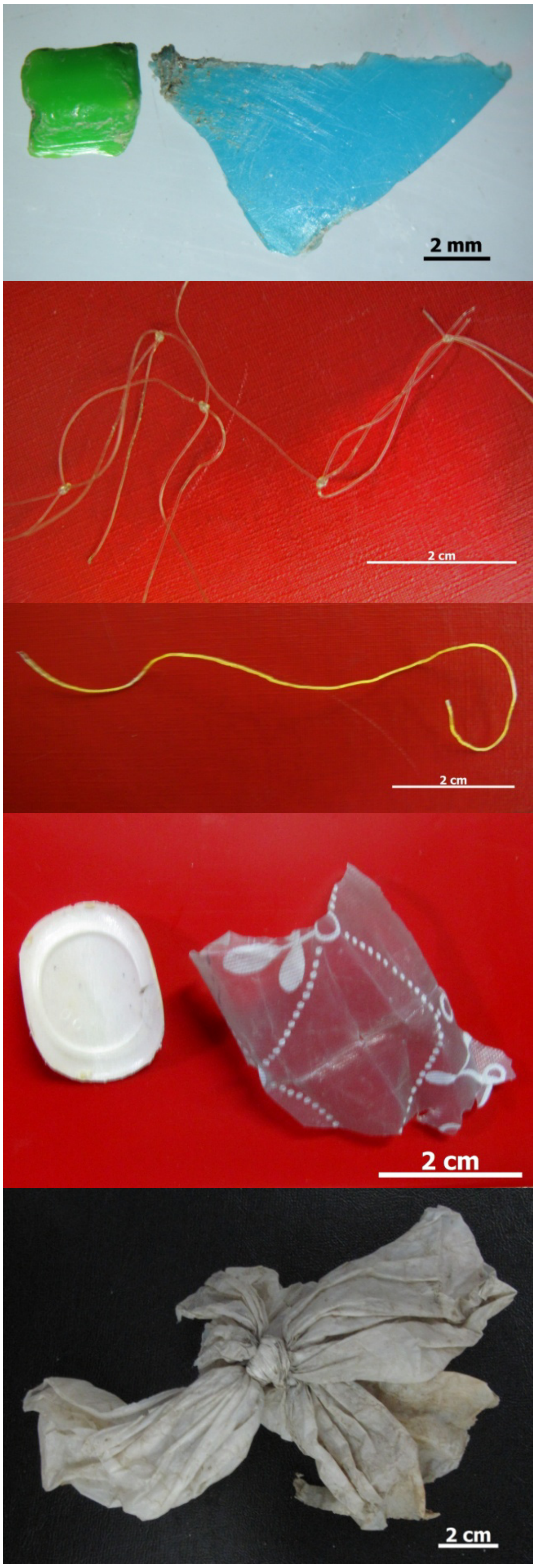

Figure 5. Examples of plastic items found buried in the tidal plain (Goiana Estuary). (a) hard plastic, (b) fishing net, (c) nylon thread, (d) soft plastics, (e) knotted plastic bag. Photos by André Lima & Jonas Ramos using Canon PS G10 and Stemi 200 (Zeiss).

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