A scale to classify plastic marine debris into physical degradation stages

Marine debris are a widespread problem that affects every river basin, costal and marine environment ever studied for this pollutant. Its full characterization is paramount in the efforts to identify and abate sources, as well as in the raising filed of risk studies. In addition to variables as material, size, colour and shape, state of degradation is also an important feature to be observed, registered and included in numerical analysis that aim at describing marine debris spatio-temporal patterns of distribution. A scale that attributes three degrees, or states, of degradation (1 recent; 2 intermediate; 3 old) to individual marine debris items was created. It is described here together with the criteria adopted to classify among its categories. The scale allows for the inclusion of a relatively difficult to determine factor into statistical analysis as a categorical variable through recognizable levels of physical abrasion. Although degradation is a continuous process, when surveying plastic marine debris the large amount of items does not allow for detailed individual assessment (through chemical and mechanical tests, for instance), and therefore a quick direct observation method adds value to the work without overloading personnel, being time-consuming or resulting in excessive financial costs. We suggest that, until further studies are conduced, the scale is used to compare marine plastic debris items, mainly within surveys.

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“A scale to classify plastic marine debris into physical degradation stages”

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INTRODUCTION

Marine debris is a problem that originates either on the continent or at sea. It affects the oceans from coastal habitats to deep sea trenches. Since the 1970s, plastics – the most significant fraction of marine debris – have been detected and reported in increasing amounts in the world oceans. The prevalence of plastics is due to its production, use and discard patterns. Also, they are easily transported and last for prolonged lengths of time in the oceans (Bergmann, Gutow, & Klages, 2015). The sources of marine debris, especially plastics, can be diverse and range from social/human activities on land to every maritime operation (Ivar do Sul & Costa, 2007). Although many countries have adequate public policies for the management of solid wastes on land (Brasil, 2010), from the point of view of marine debris generation, with rare examples, their efficacy cannot yet be perceived. Scientific works that approach marine debris, especially the developing consequences of its plastic fraction, greatly contribute to the raising of general awareness about the problem.

Usually marine debris surveys on beaches and other coastal and marine environments consider variables as size, density (items m^2), materials etc. However, some value is lost, since not all the possible information available in each plastic item is recorder during field or lab work. The degradation state of debris is one example that could be further exploited from the field to more detailed laboratory examinations. Physical and chemical degradation are possible to be determined through standard tests, but become virtually impossible to be applied to every item found during beach litter surveys, or by unassisted personnel. Some sort of alternative direct/visual analysis can be made to remedy this situation. However, standardization of criteria to class debris would be needed, in order to help observers in their task. Scales that class a variable into categorical degrees have been developed for other theme in marine sciences, e.g. stranded carcasses (Pugliares et al., 2007). Such method allows for the relatively rapid introduction of a difficult to precise variable into field worksheets, matrixes and statistical analysis. In the case of plastic marine debris, the main difficulty would be to consider the wide variety of polymers that can appear in the samples. However, to the naked eye, carcasses also vary widely in decomposition characteristics due to the different species and cause of death.

By noting the decomposition of plastics, it is possible to proceed with (at least) within surveys comparisons and to establish which items have been available in the environment for longer. This should be important in the estimation of its probability of interaction with the biota. Therefore, it would be possible to further advance predictions on the field of risks to the different animal groups. The longer a plastic marine debris stays in the environment, the greater the risk of interaction with living resources and all the fauna. In addition, studies on plastics fragmentation could benefit from the existence of a degradation scale since, once in the environment, plastic items tend to be broken into smaller pieces, threatening different animal groups (Ivar do Sul & Costa, 2014).

The objective of the present work is to propose a scale for the classification of plastic marine debris degradation state based on samples collected at the bottom of the main channel of an estuary. After classification, the items were deposited in a marine debris scientific collection for keeping and reference (Alves, Pontes, Ivar do Sul, & Costa, 2010).

METHODS

The marine debris used for the creation of the proposed degradation scale was sampled in different coastal habitats of the Brazilin Northeast. The site with the largest contribution to this work was the Goiana estuary (Barletta & Costa, 2009), along the bottom of the main channel (Costa, Barletta, & Dantas, 2011). Sampling was made with an otter trawl net (Dantas et al., 2010). Other sampling sites were Boa Viagem beach at Recife, where marine debris were being surveyed along the strandline (Silva-Cavalcanti, Araújo, & Costa, 2013; Silva-Cavalcanti, de Araújo, & da Costa, 2009; Silva, Barbosa, & Costa, 2008). Mangrove forests surrounding the Goiana estuary (Ramos et al., 2011; Ivar do Sul et al., 2014), Carne de Vaca beach and the University campus also contributed with items that helped to set the criteria and levels of the scale.

Each plastic item was entered in a worksheet were variables necessary for this analysis were registered (origin, material, type of use, colour, fouling, physical properties - friability, flexibility, and elasticity). A new, non-conventional, variable registered was the decomposition state. Items were classed in a scale ranging from 1 to 3, being 1 attributed to the less degraded items and 3 to the most degraded items.

Finally, plastic marine debris items were photographed, and deposited in a scientific collection (Alves et al., 2010; Costa et al., 2011a). Scientific collections about marine debris are important in the keeping of examples of plastics, including different degradation stages, and help in the establishment of the criteria that divides one category from the other. Items, once fully identified, will serve for display and communication of the problem of plastics fragmentation at sea (Alves et al., 2010; (Andreoli, Silveira, & Widmer, 2016).

RESULTS & DISCUSSION

Over 250 items were used to form the criteria and the scale (Table 1). The plastic marine debris items used during this study were fairly large items, and fell in the size categories created by (Madzena & Lasiak, 1997) that considers micro (<1cm²), small (1-10cm²), medium (11-100cm²), large (101-1000cm²) and macro (>1000cm²). Size allowed for easier observation of the decomposition state.

In the case of Goiana estuary, older items (degree 3 in the present scale) were prevalent. All three habitats sampled (upper, middle and lower) presented a similar pattern (Figure 1). This was probably due to the complex architecture of the bottom of the main channel, where branches, stones, roots and other obstacles contribute to the trapping of plastic and other items. Therefore, items tend to stay at the bottom until some event (ex. sampling, dredging, river flush) removes them. During the relatively long time they stay at the bottom, items are exposed to physical and chemical stresses that may contribute to degradation. At the main channel, these items suffer direct action of currents and tides, being transported preferentially near the bottom. The length of the main channel (~25km) probably takes time to be overcome by these items, making possible their degradation to quite advanced states at each reach of the ecosystem. Therefore, the prevalence of older items might be a characteristic of this habitat, although the precise determination of their residence time was still not possible (Costa, Barletta, et al., 2011).

The items from the mangrove forest were also classed as old due to the extended retention time in the forest soil and difficulty to be removed from the deepest parts of the tidal creeks by flooding waters (Ivar do Sul et al., 2014; Ramos et al., 2011).

The items found on beaches were mainly recent, since the main source is beach users (Silva-Cavalcanti et al., 2013, 2009). Some intermediate items occur due to tide and currents action that takes litter from the sand and after their trapping in near-shore circulation cells, deposit plastics and other marine debris on the strandline. The University campus is heavily littered, and it is not difficult to find plastic items from food packaging and other urban uses. The prevalence is of more recent items as cleaning action does take place on a fairly regular basis. In both environments, urban beaches and the campus, cleaning services are not enough to guarantee that litter is adequately treated and, therefore, it is frequently lost to the environment.

It is practically impossible for a plastic marine debris item to remain intact once feral in the environment. Wave action, turbulence, oxidizing conditions, and solar radiation are factors that contribute to plastic polymers degradation (Ivar do Sul & Costa, 2010). Also, these factors are synergic and serve as precursor of biodegradation. Such process is facilitated by the weaker polymer structure, that is more susceptible to the action of microorganism (Lucas et al., 2008; Shah et al., 2008). So, one of the possible applications of this practical scale is in the development of better estimating models for biodegradation processes.

Our results question the common belief that plastics last for extremely long times at sea, and calls attention to the fact that, depending on prevailing environmental conditions, it will fragment and deteriorate into smaller and more pervasive size fractions. Some polymers are more resistant than others, or its shape may contribute to a longer residence time, but ultimately all will interact with biotic and abiotic agents that will degrade them into different items that will offer new risks to the marine environment (Bergmann et al., 2015). In addition to impairing their removal, degradation and fragmentation increases the interaction possibilities between plastics and marine organism, affecting even the smallest of groups in all habitats.

CONCLUSIONS

A degradation scale for plastic marine debris is a way to use an information that is available in samples but is seldom approached due to the difficulty of determining it during surveys. The analysis of the trends of this variable during a survey can suggest if the environment under investigation has long-term accumulation characteristics (sink) or not (source). In this way we hope to have raised this variable from a mere perception level, in which comments on degradation state were generalized and little informative, to a status of measurable and statistically workable variable. The measurement of a new variable can help enrich surveys results through the use of consolidate and reproducible criteria of classification. Through the observation of these criteria selected during the present work (colour, biting, fouling etc.), it was possible to conclude that plastics do deteriorate in the environment rather rapidly. The proposed classification brings an easy and simple to apply alternative for field and/or lab surveys and should improve future studies on marine plastic debris on every coastal and ocean environment.

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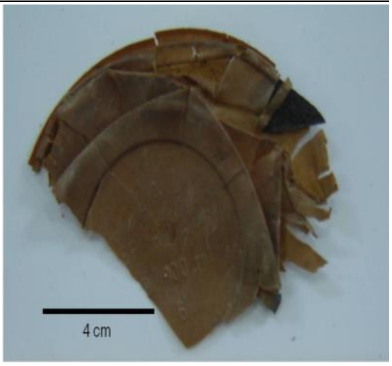
Table 1: Plastic marine debris decomposition scale and criteria for inclusion of items in each of the three categories. Photos: Sara Siqueira. (a) University campus; (b, c, d, e, f, h, i, j, l, o, q, r) main channel of the Goiana estuary; (g, k, p) Boa Viagem beach-Recife; (n) mangrove forest; (m) Carne de Vaca beach (Northeast Brazilian coast).

Recent	Intermediate	Old
Items that only recently entered the environment Information on labels is clear Bar code visible and readable Original colours present in plastic and labelling Not yet fragmenting	Plastic starting to weather Alterations of colour Still possible to detect what use Polymer starts to fragment Loss of mechanical characteristics Possible interactions with the biota (fouling, biting)	Weathering advanced not possible to determine source dry, friable biological fouling, especially of slow growth (small invertebrates) unidentifiable fragments

Plastic cups

(a)


(b)



I

Supermarket/shopping bags

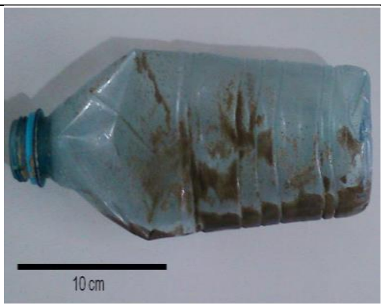
(d)

I

(f)

PET bottles

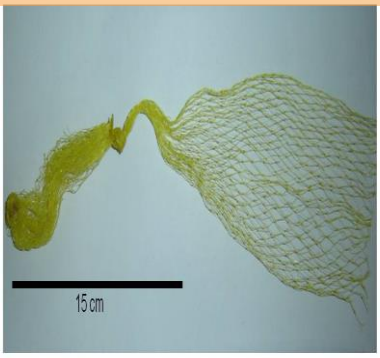
(g)



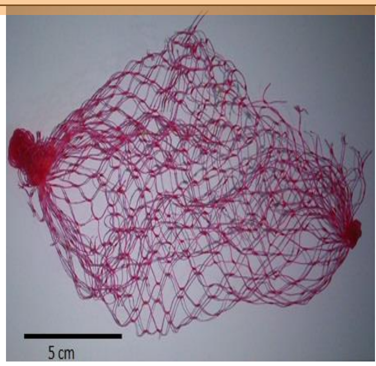
(h)

(i)

Nylon nets (bags)



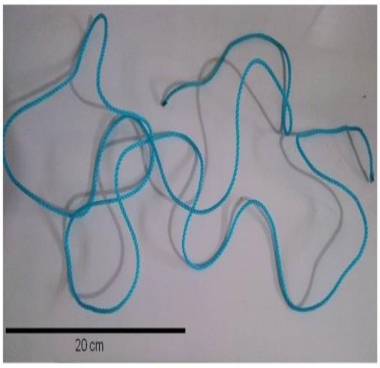
(j)



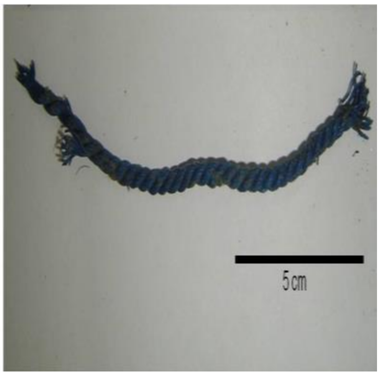
(k)

(l)

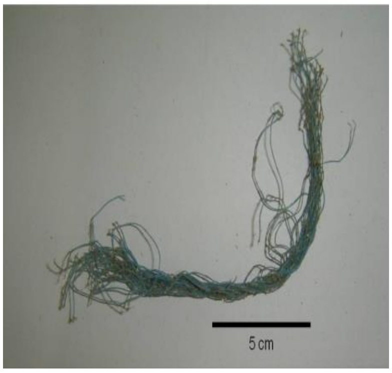
Nylon cables (fisheries)



(m)



(n)



(o)

napies

(p)

(q)

(r)

216

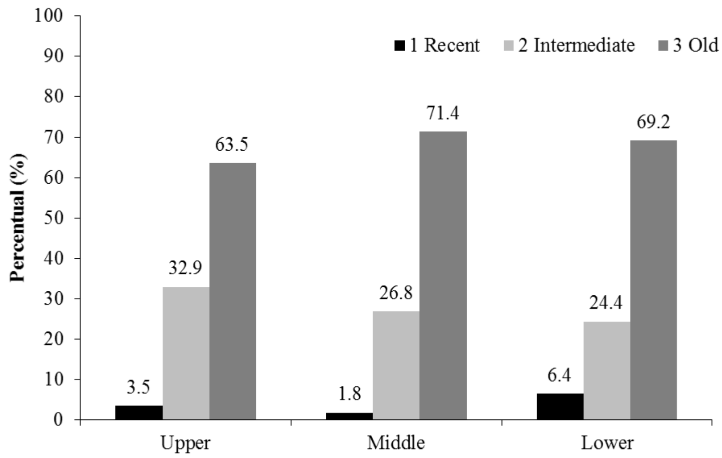


Figure 1: Percentage of each degradation degree in the samples form Goiana estuary (N=250) along the three reaches of the main channel.

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