Marine Pollution Bulletin xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

How marine debris ingestion differs among megafauna species in a tropical coastal area

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ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Marine debris
Megafauna
Fish
Turtle
Dolphins
Brazilian coastal area

ABSTRACT

The marine debris ingested by megafauna species (*Trichiurus lepturus*, *Chelonia mydas*, *Pontoporia blainvillei*, and *Sotalia guianensis*) was recorded in a coastal area of southeastern Brazil (21–23°S). Marine debris was recorded in all species, mainly consisting of plastic material (flexible and hard plastics – clear, white, and colored- and nylon filaments). The 'pelagic predators' *T. lepturus* and *S. guianesis* showed the lowest percent frequencies of debris ingestion (0.7% and 1.3%, respectively), followed by the 'benthic predator' *P. blainvillei* (15.7%) and the 'benthic herbivorous *C. mydas* (59.2%). The debris found in *C. mydas* stomachs was opportunistically ingested during feeding activities on local macroalgal banks. In the study area, the benthic environment accumulates more anthropogenic debris than the pelagic environment, and benthic/demersal feeders are more susceptible to encounters and ingestion. The sub-lethal effects observed in *C. mydas*, such as intestinal obstruction due to hardened fecal material, should be considered a local conservation concern.

1. Introduction

Marine debris is defined as any solid waste material of anthropogenic origin that enters the oceanic environment from either land- or marine-based sources (Scheavly and Register, 2007; Murray, 2009). In this context, land-based sources account for up to 80% of the world's marine pollution (GESAMP, 1991). Marine debris is a global issue that negatively impacts humans, wildlife, and habitats, preferentially accumulating in estuaries, along coastlines, and on the seabed, in addition to floating in the water column (Stefatos et al., 1999; Derraik, 2002; Splenger and Costa, 2008; Sutherland et al., 2010).

Plastic debris (*e.g.*, plastic beverage bottles, various packing materials, tarps, and synthetic fishing lines) is one of the world's most pervasive types of pollution affecting marine areas (Derraik, 2002; Scheavly and Register, 2007). Plastic debris directly threatens marine organisms through ingestion, entanglement, smothering, and general debilitation (Laist, 1987, 1997). Species may also be indirectly affected by plastic ingestion due to the transference and accumulation of pollutants (Rios et al., 2007; Scheavly and Register, 2007).

Debris ingestion by marine megafauna is mainly recorded among turtles and seabirds (Ryan, 2008; Schuyler et al., 2013), but mammals and large fishes are also affected (van Franeker et al., 2011; Choy and Drazen, 2013; Baulch and Perry, 2014). Debris can damage the gastrointestinal tract of megafauna due to ulcerations, perforations, or obstructions (Jacobsen et al., 2010; Brandão et al., 2011; Awabdi et al., 2013a) and can reduce feeding stimulations (Macedo et al., 2011); however, an absence of physical damage has also been noted (Denuncio et al., 2011; Di Beneditto and Ramos, 2014).

In the present study, the marine debris ingested by megafauna species that co-occur in a tropical coastal area of southeastern Brazil is described and compared to elucidate specific differences. The origin of the debris ingested by these species is also discussed.

2. Materials and methods

This study was conducted in a marine tropical coastal area of southeastern Brazil, between 21–23°S. The study area comprised waters from <1 to 56 km from the coastline, with depths varying from <10 to 50 m. The analyzed megafauna species were adult female specimens of *Trichiurus lepturus* L. 1758, which is a fish target of commercial gillnet fisheries (Bittar et al., 2008; Bittar et al., 2012); juvenile specimens of *Chelonia mydas* L. 1758, a turtle species that predominates among the total turtle carcasses collected from strandings and incidental captures in fisheries (Reis et al., 2009); and juvenile and adult specimens of *Pontoporia blainvillei* Gervais and D'Orbigny, 1844 and *Sotalia guianensis* Van Bénedèn, 1864, which are dolphins that are incidentally captured

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http://dx.doi.org/10.1016/j.marpolbul.2014.09.020
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in commercial gillnet fisheries (Di Beneditto et al., 1998; Di Beneditto, 2003).

The species were classified according to their preferred feeding habit (carnivorous or herbivorous) and preferred feeding area (pelagic or benthic). *T. lepturus* is a benthopelagic carnivorous fish, which was classified here as a 'pelagic predator', as adult specimens (>100 cm length) usually feed near the sea surface during daytime and migrate to the bottom at night (Froese and Pauly, 2014). In the study area, juveniles of *C. mydas* are herbivorous that feed on benthic macroalgae (Awabdi et al., 2013b), and this species was classified as a 'benthic herbivorous'. The dolphins *P. blainvillei* and *S. guianensis* are carnivorous, but with differences in their main feeding habits. For *P. blainvillei*, demersal prey are better represented in the diet than pelagic prey, while for *S. guianensis* an opposite pattern is observed (Di Beneditto et al., 2011). Considering these differences, the first species was classified as a 'benthic predator' and the second as a 'pelagic predator'.

The solid waste of anthropogenic origin (referred to as debris) found in the specimens' stomachs during dietary analyses was classified by its type and percent frequency (Table 1). Visual inspection of the whole digestive tracts of the specimens was performed to verify the presence of ulcerations, perforations, or obstructions possibly caused by debris. Differences between the percent frequencies of debris ingestion by megafauna species were tested via normal approximation of the Chi-square test. *P* values were interpreted as the strength of evidence for the null hypotheses, rather than on a dichotomic scale of significance testing (Hurlbert and Lombardi, 2009).

3. Results

Marine debris ingestion was recorded in all megafauna species, with important differences being observed among them. For *T. lepturus*, only one stomach (0.7%) contained debris among the 149 stomachs examined. In *S. guianensis* as well, only one stomach (1.3%) exhibited debris among the 77 analyzed stomachs. In *P. blainvillei*, debris was recorded in 14 (15.7%) of the 89 stomachs assess. In contrast *C. mydas*, a high occurrence of debris was observed (59.2%, 29/49 stomach contents).

The 'pelagic predators' were similar in terms of their marine debris ingestion ($p = 0.652$). Differences ($p < 0.01$) between the percent frequencies of debris ingestion were recorded for 'pelagic predators' *vs*. both 'benthic predators' and 'benthic herbivorous', and for 'benthic predators' *vs*. 'benthic herbivorous'. The differences were greater ($p < 0.0001$) in all comparisons with 'benthic herbivorous'.

The marine debris recovered from the examined stomach contents was composed mainly of plastic material, such as flexible and hard plastics (clear, white, and colored) and nylon filaments. However, diverse types of debris were recorded, including items such as a flasher lamp (Table 1). The largest variety of debris was recorded in the stomachs of *C. mydas*, in which more than one type of debris was found in 22 specimens (Fig. 1).

No ulcerations, perforations, or obstructions were visually recorded in the digestive tracts of *T. lepturus* (present study), *P. blainvillei* and *S. guianensis* (see Di Beneditto and Ramos, 2014). However, partial obstruction of the intestine caused by plastics and hardened fecal material was visually detected in five specimens of *C. mydas* (17%), all of which exhibited debris in the stomach (see Awabdi et al., 2013a).

4. Discussion

In the study area, the frequency of ingestion of marine debris among coastal megafauna showed the following order: benthic herbivorous>>>>benthic predators>>pelagic predators. Most of the ingested debris was plastic material (*e.g.*, flexible and hard plastics, both clear and colored, and nylon filaments), which is not surprising. Plastic is the primary type of debris found in oceanic and coastal environments, preferentially accumulating in estuaries, along coastlines, and on the seabed (Derraik, 2002; Ivar do Sul and Costa, 2007; Splenger and Costa, 2008), but if can also find floating in the five accumulation zones (oceanic gyres) in subtropical areas of the major ocean basins (Lebreton et al., 2012). This type of debris reaches marine ecosystems through river discharge (land-based sources) or via direct disposal (beach visitors, ships and boats, harbor and offshore activities), and it is the most common form of debris ingested by hundreds marine species, including both vertebrates as invertebrates (Laist, 1987, 1997; Murray and Cowie, 2011; Carson, 2013; Hong et al., 2013; Schuyler et al., 2013; Baulch and Perry, 2014).

There are a number of possible explanations for why marine species ingest plastic and other debris: (i) they are opportunistic feeders, ingesting debris in proportion to what they encounter in the environment (Tourinho et al., 2010; Jantz et al., 2013); (ii) they ingest debris because it resembles their prey (Mrosovsky et al., 2009; Schuyler et al., 2014); (iii) they ingest debris secondary to the ingestion of prey with debris in gastrointestinal tract; and/or, (iv) they ingest debris accidentally during predation events, or when the debris is an item of curiosity or object of play, as reported in some marine mammal species (Laist, 1987; Di Beneditto and Ramos, 2014).

T. lepturus is a predator fish occupying a high trophic level, and the preferred feeding sites of adult females of this species are in pelagic areas (Bittar et al., 2008; Di Beneditto et al., 2012). The direct ingestion of debris, as recorded in this study, may arise from an opportunistic situation, although the possibility of secondary ingestion cannot be disregarded. Studies on marine debris ingestion in pelagic predatory fish are still scarce, and more comprehensive studies have only been developed recently in the central North Pacific (Choy and Drazen, 2013; Jantz et al., 2013). These authors investigated fish species showing similarities in their pelagic predatory habits and observed an average percentage of debris ingestion of approximately 20%, which is 28 times higher than in the present study. Pelagic accumulation zones of marine debris are situated in subtropical oceanic areas, dominating in the northern hemisphere (Lebreton et al., 2012). This study was conducted in a tropical coastal area of the southern hemisphere, which might explain the lower quantity of debris available to 'pelagic predators' (*T. lepturus* and *S. guianensis*).

Moreover, only adult females of *T. lepturus* were considered here, and differences between the sexes regarding movement patterns may influence debris ingestion. Adult females of *T. lepturus* are mainly associated with the inner continental shelf, while adult males travel to oceanic areas, beyond shelf limits (Martins et al., 2005; Chiou et al., 2006). Thus, females would be less susceptible than males to encountering and ingesting debris floating at feeding sites, as debris in coastal areas is mainly associated with the seabed (Splenger and Costa, 2008). Further studies including adult male specimens may allow sexual differences in debris ingestion to be evaluated, confirming this assumption.

In *S. guianensis*, only one nylon filament was recorded in one specimen, and its origin was not clear. This nylon filament could have been ingested opportunistically, accidentally, or even in a secondary manner. This dolphin is a coastal pelagic predator that feeds mainly on fish whose sizes vary from <10 to 100 cm (Di Beneditto and Ramos, 2004), and some of its prey could ingest debris directly. Simmonds (2012) reviewed interactions between cetaceans and marine debris worldwide, suggesting that species inhabiting surface waters, such as *S. guianensis*, are less likely to ingest debris than those showing a greater association with the bottom.