



Identification and characterization of plastic debris in the gastrointestinal tract of Guiana dolphins (*Sotalia guianensis*) from Espírito Santo coast, Brazil

Leticia Versiani Gomes da Silva^{a,*}, Isis de Oliveira Carvalho Demarque^a, Eloá Corrêa Lessa Tostes^b, Marcos André de Souza Araújo^b, Carlos Eduardo Veiga de Carvalho^d, Maria Cristina Canela^b, Lupércio Araújo Barbosa^c, Leonardo Serafim da Silveira^a

^a Universidade Estadual do Norte Fluminense Darcy Ribeiro, Laboratório de Morfologia e Patologia Animal, Av. Alberto Lamego, N° 2000, Campos dos Goytacazes, Rio de Janeiro, Brazil

^b Universidade Estadual do Norte Fluminense Darcy Ribeiro, Laboratório de Ciências Químicas, Av. Alberto Lamego, N° 2000, Campos dos Goytacazes, Rio de Janeiro, Brazil

^c Instituto Organização Consciência Ambiental (Instituto ORCA), Guarapari, Espírito Santo, Brazil

^d Universidade Estadual do Norte Fluminense Darcy Ribeiro, Laboratório de Ciências Ambientais, Av. Alberto Lamego, N° 2000, Campos dos Goytacazes, Rio de Janeiro, Brazil

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ABSTRACT

The Guiana dolphin (*Sotalia guianensis*) is categorized as vulnerable in the Brazilian list of endangered animals, and its populations suffer from several anthropological threats. In this study, we analyzed the presence of macro, meso, and microplastics (MPs) in Guiana dolphins ($n = 12$) in Brazil Southeastern coast by analysing their gastrointestinal tract. The MP extractions were carried out with H₂O₂ (35 %) to remove organic matter. Four specimens ingested meso and macroplastics, including an item of polypropylene of 19.22 cm that was produced about 943 km from the place in which the animal was found stranded. All the specimens analyzed had fragment-type microplastics in their intestines. Blue was the prevailing color, followed by black, green, and red. We highlight the contamination by microplastics in the species, still little investigated, especially the need to understand the contamination by microplastics along trophic levels.

1. Introduction

Plastic is essential to society, be it in the market, industry, medical use, and cities' application (Wright et al., 2013), since it is a versatile material that can take several forms (Andrady and Neal, 2009). The per capita production of solid debris in Brazil is about 1 kg per day. The Southeastern region is the one that produces more urban solid debris, and 25.7 % of it is inadequately discarded (ABRELPE, 2022), being a source that contaminates the soil, the aquatic ecosystems, and the atmosphere (De Campos et al., 2021). According to Sodré et al. (2023), Brazil produces about 14 million tons of plastic debris annually, and most of it is mismanaged and not monitored regarding its destination in the environment. Brazil is one of the 16 main countries responsible for discarding plastic debris in the oceans (Alencar et al., 2023). Concerning the level of plastic debris on the Brazilian coast, another issue is the high

index of tourism on the beaches and the effluent that coastal cities directly discard on the oceans (Machado et al., 2016). Thus, this waste is already part of the marine environments in different forms, sizes, and kinds, going from macro to microplastic, which directly and indirectly impacts the survival of marine species whose habitats, feeding, and digestion are different.

Microplastics are particles smaller than 5 mm wide (Arthur et al., 2009; Thompson et al., 2004) and can be classified into primary and secondary according to their size and origin (GESAMP, 2015; Germanov et al., 2018). Microplastics are present in the entire marine environment and can enter and remain in trophic levels (Setälä et al., 2014). In addition, these particles can be vectors for toxic composts such as trace elements from plastic additives (Andrady and Neal, 2009), as well as persistent organic pollutants adsorbed on their surface (Worm et al., 2017). Microplastics and their potential effects on biota have been

* Corresponding author.

E-mail address: versianileticia@gmail.com (L.V.G. da Silva).

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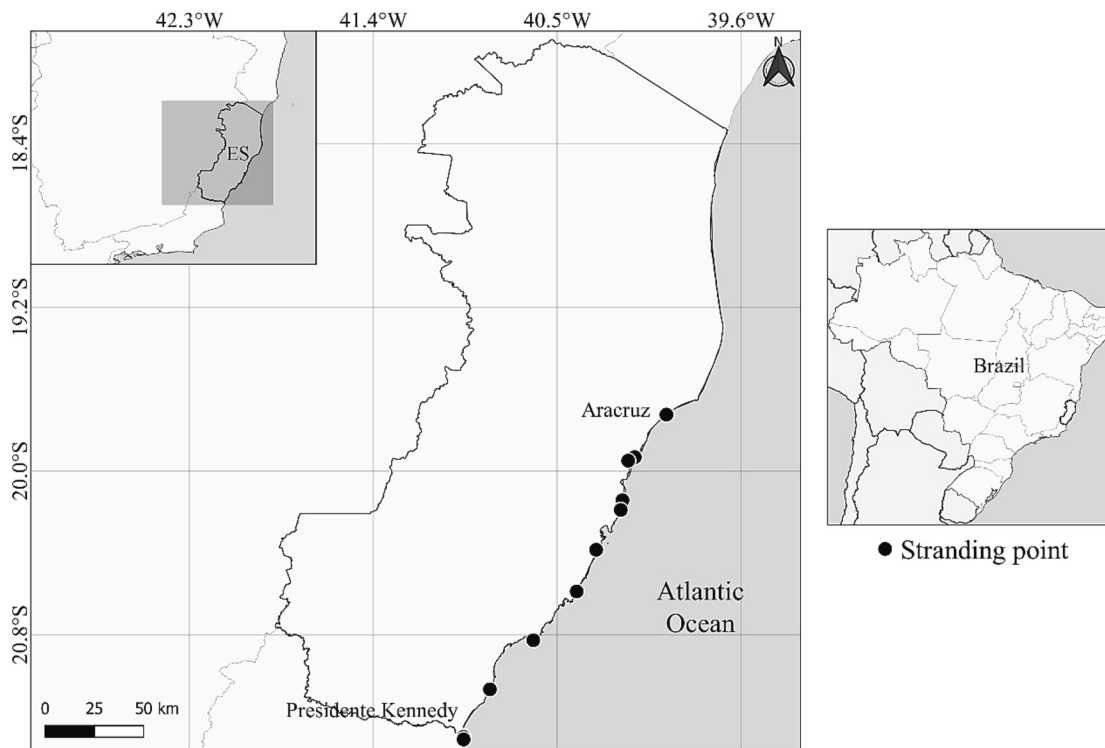


Fig. 1. Stranding locations of the *Sotalia guianensis* specimens that were analyzed.

studied in various marine invertebrates and vertebrates across different trophic levels, such as fish, turtles, birds, and mammals (Ajith et al., 2020; Ghaffar et al., 2022).

Sotalia guianensis is popularly known as the Guiana dolphin, and it inhabits estuaries, bays, and shallow areas on the Western coast of the South Atlantic Ocean (Rossi-Santos et al., 2007). The species is considered as “near threatened” worldwide (IUCN, 2018). In Brazil, it is categorized as “vulnerable” on the endangered species list of the ICMBio - Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio, 2022). Accidental captures in fishing nets, longlines, and trawl nets are clear threats (Flores et al., 2018), as is the decrease in prey availability, habitat destruction, vessel traffic, and the bioaccumulation of pollutants such as plastic debris (Flores et al., 2018; Legat and Lailson-Brito, 2010).

The presence and impact of microplastics in cetaceans is still little studied compared to other marine mammals, although the number of studies has increased in recent years (Zantis et al., 2021). Microplastic particles have already been found in the gastrointestinal tract of *Ziphius cavirostris* (Cuvier's beaked whale), *Delphinus delphis* (Common dolphin), *Phocoena phocoena* (Harbour porpoise), *Orcinus orca* (Orca whale), *Tursiops truncatus* (Common bottlenose dolphin), *Stenella coeruleoalba* (Striped dolphin), *Mesoplodon mirus* (True's beaked whale), *Neophocoena asiaorientalis sunameri* (Yangtze finless porpoise), *Sousa chinensis* (Indo-Pacific humpback dolphin), *Delphinapterus leucas* (Beluga whale), *Lagenorhynchus acutus* (Atlantic white-sided dolphin), *L. albirostris* (White-beaked dolphin), *Kogia breviceps* (Pygmy sperm whale), *Grampus griseus* (Risso's dolphin), and *Sotalia guianensis* (Guiana dolphin) (Lusher et al., 2018; Lusher et al., 2015; Xiong, 2018; Zhu et al., 2019; Nelms et al., 2019; Moore et al., 2020; Pereira et al., 2023). However, the frequency of the occurrence in marine mammals is low (Kühn and van Franeker, 2020), mainly in cetaceans (Do Nascimento et al., 2023). Zantis et al. (2021) reinforce the need for more precise and standardized investigations about the ingestion of microplastics by cetaceans to understand their presence, composition, origin, and the impacts they cause.

This study aimed to identify and characterize through physical and chemical analysis plastic debris, including microplastics present in the

gastrointestinal tract of *Sotalia guianensis* found stranded on Espírito Santo, Brazil, in the South Atlantic Ocean.

2. Materials and methods

2.1. Study area and sample collection

The State of Espírito Santo has an area of 46,074,447 km² and an estimated population of 4,064,052 inhabitants (IBGE, 2020), with about 521 km of coastline (Freitas Netto and Di Benedetto, 2008). The study area is located in the Southeast region of Brazil. The oil and natural gas extraction industries and metallic minerals can be highlighted from the State's main economic activities (Carvalho and Galeano, 2018). Numerous environmental accidents have occurred on the coast of Espírito Santo, and one of the most serious occurred in November 2015, with the collapse of an iron ore tailings dam (Mayorga et al., 2020). Another important activity is tourism, which grew 17% in 2022, with an accumulated growth of 25.5%, mainly in the summer, due to the attraction of tourists to the beaches (Setur, 2022).

The specimens of *S. guianensis* were collected by the Environmental Consciousness Organization Institute (ORCA Institute), which operates in the State, receiving carcasses from strandings and accidental capture in fishing nets, carrying out necropsies and making samples available to partner researchers under a national SISBIO license (identification number: 64724-8).

The carcasses received by the ORCA Institute were weighed and evaluated externally, observing the code referring to their decomposition condition (IBAMA, 2005). Biometric measurements were taken with a commercial tape measure, including total length (TL), which corresponds to the upper tip of the rostrum to the median notch of the tail fluke (Norris, 1961). The animals were categorized into mature (TL > 185 cm) and immature (TL < 185 cm) (Ramos et al., 2000), determining the age range and sex identified through body morphology.

During necropsy, the gut was dissected and stored for later analysis. An incision was made in the stomach to investigate plastic items larger than 5 mm. ORCA Institute made available data such as location and



Fig. 2. Plastic items ingested by *Sotalia guianensis*, stranded in Espírito Santo's coast between 2019 and 2022. A: SOT 389, white and multicolored films of polyethylene (PE, score - 991) and polyethylene (PP, score - 994), respectively; B: SOT 389, blue filament of PE (score - 993); C: SOT 462, part of multicolored film of PP (score - 874). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

date of stranding, biometrics, necropsic report, and photos. Fig. 1 shows the stranding locations of *Sotalia guianensis* specimens ($n = 12$) that occurred between August 2019 and August 2022.

2.2. Laboratory procedure

The gut samples were opened and washed with deionized filtered water, and the presence of larger debris was checked. The gut contents were placed in glass bottles with metal lids, and the particles were extracted. Each sample was separated into beakers and hydrogen peroxide was added (H_2O_2 - Neon, Suzano -Brazil, 35 %, 3:1, 60 °C, for about 96 h). The recovery rate was tested by contaminating the sample with pieces of microplastics from five different commercial polymers: PP (polypropylene), HDPE (hard-density polyethylene), PET (polyethylene terephthalate), PVC (polyvinyl chloride), LDPE (low-density polyethylene), and PS (polystyrene). The contaminated sample received the same treatment as the analyzed specimens samples, and the recovery rate was 157.5 %, probably due to the fragmentation of particles that resulted from the organic matter's oxidation.

After digestion, the samples were filtered by using a quantitative filter paper (Quantity®, pores: 8 μm) in a vacuum filtration kit. The filters were identified and stored in Petri dishes and in a refrigerator until they were analyzed with a Leica S6D stereomicroscope to characterize the particles. Photomicrographs of the particles present in each filter were taken to be measured in the Image J editor program. The microplastics were counted and characterized according to color and type (fragment, film, or sphere) (Lusher et al., 2018).

The meso (size ranging from 5 mm to 2.5 cm) and macroplastic (size larger than 2.5 cm) (Lippiat et al., 2013) items found in the forestomach were washed with filtered deionized water, photographed and measured with the same software used to measure microplastics. The Fourier transform infrared technique with ATR (attenuated total reflection) coupling (Shimadzu, IRTracer-100) was used for the chemical characterization of plastic debris. The spectral resolution was 4 cm^{-1} , in the 4000–400 cm^{-1} range with Happ-Genzel apodization. The analysis was performed through of 50 scans, and a filter was used for atmospheric correction. The presented results were demonstrated in Absorbance and compared with the library (ATR-Polymer 2) present in the equipment (Shimadzu IRTracer-100). The scores (hit quality index or HQI), which indicates how closely it matches the target spectrum, were reported (0–1000 - where the closer the value is to 1000, the higher the correlation between the two spectra).

2.3. Contamination control

All the analysis processes of the gut content and the microplastic extraction were carried out in a room without ventilation, under laminar flow and cotton clothes were worn by the researchers to prevent the samples from getting contaminated. For every phase of the chemistry extraction, we made an analytical blank. All reagents were filtered twice through 0.2 μm cellulose acetate membranes. All the materials used were of glass or aluminium materials and they were washed with Extran P.A. (5 %) (Merck - Rio de Janeiro, Brazil), Milli-Q® ultrapure water, and acetone P.A. (Synth - Diadema, Brazil) before and after procedures.

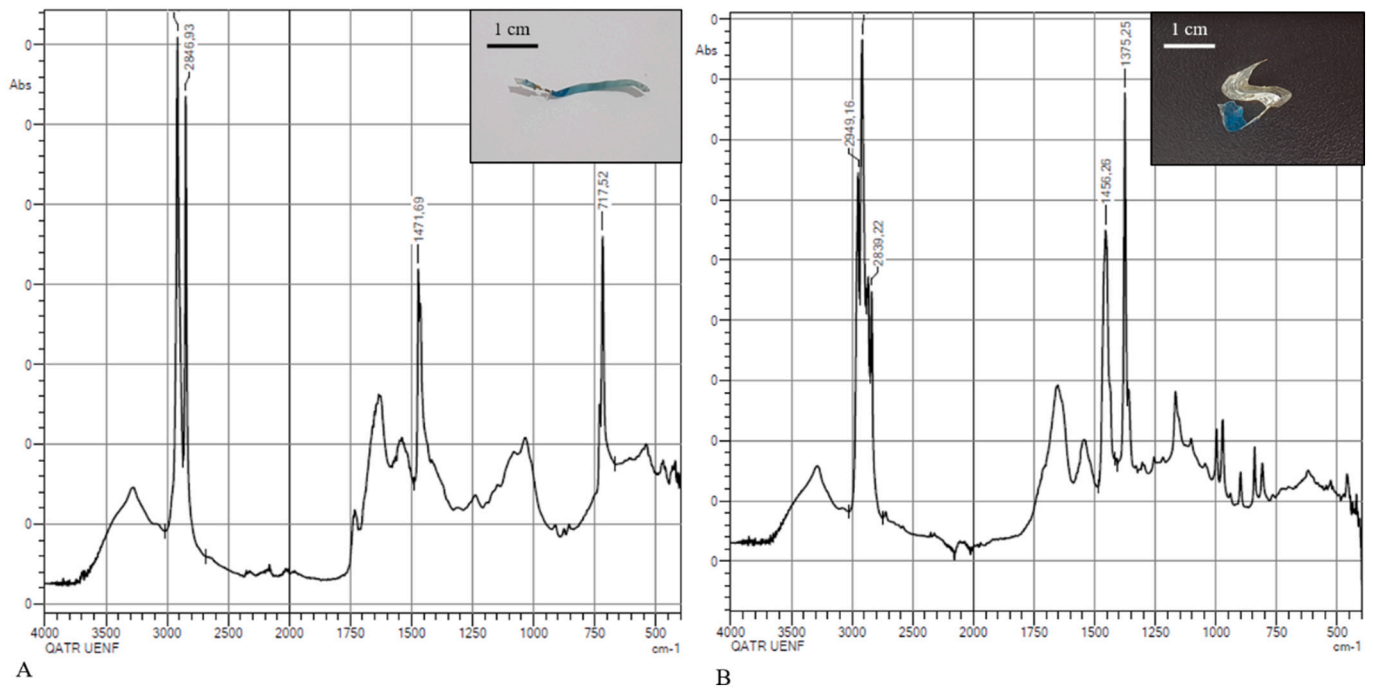


Fig. 3. Spectra of plastic items ingested by *Sotalia guianensis* stranded on the coast of Espírito Santo between 2019 and 2022. A: polyethylene (PE, score - 994); B: polypropylene (PP, score - 994).

Table 1

Plastic debris (>5 mm) identified in the forestomach of *Sotalia guianensis* stranded on Espírito Santo's coast between 2019 and 2022.

Individual	Format	Color	Polymer (score)	Size (cm)
SOT 361	Filament	Blue	PE (994)	2.37
	Filament	Transparent	PE (994)	2.39
	Film	White	PE (991)	1.26
SOT 389	Filament	Blue	PE (993)	6.01
	Film	Multicolored	PP (994)	1.56
SOT 403	Fragment	Black	PE (985)	1.21
SOT 462	Film	Multicolored	PP (874)	19.22

2.4. Data analysis

Descriptive analyzes of the analyzed parameters in the specimens and the plastic and microplastic items found were carried out. The abundance and frequency of occurrence of microplastics (percentage of analyzed animals that had more than one particle of MPs in their gut content) (Pereira et al., 2023) were calculated. Spearman's correlations ($p < 0.05$) was tested between the specimen TL and microplastic variables. The data analysis was carried out in RStudio (R Core Team, 2022).

3. Results

From the 12 animals (nine males and three females) whose gastrointestinal tracts (GIT) were analyzed for the presence of plastic debris, five (41.66 %) did not have the cause of death determined due to the carcass' advanced decomposition condition, and the others seven (58.34 %) died due to accidental entanglement in a fishing net, according to necropsic examination. An adult female stands out that had the posterior region of her body amputated by sharp material and also had mesh marks on her body. We also reported that the death of a female was similarly associated to entanglement and presented two macroplastic in her stomach. The female was pregnant, and the fetus, which was also a female, presented a total length size of 80 cm.

Four specimens presented debris that is considered meso ($n = 5$) and macroplastic ($n = 2$) in the forestomach (Fig. 2). The items' size varied

from 1.21 cm to 19.22 cm ($\bar{X}=4.86$ cm, ± 1.76). The biggest plastic item that was found was produced in São Paulo State about 943 km in straight line from the place where the animal was found stranded, in Espírito Santo, according to the postal code impressed in the packaging. Two items (28.57 %) were of polypropylene (PP) and probably were from a food packaging. The other five plastic items found were made of polyethylene (PE) (Fig. 3) and in different formats, such as fishing equipment filament and packaging film. Table 1 presents data from the chemical characterization of plastic items found in *Sotalia guianensis*.

We found 426 possible microplastic particles in the studied specimens of *S. guianensis* ($n = 10$), with a frequency of occurrence (FO) of 100 %. An adult female, with 179 cm of total length, was the one that presented the highest number of microplastic ($n = 75$), whereas an adult male (188 cm) was the one that presented the lowest number of microplastic ($n = 13$). From the particles that were found, 374 (87.79 %) were fragments, 45 (10.56 %) were of film format, and seven (1.64 %) were spheres (Fig. 4). Due to the difficulty of counting with precision, the fibers were not computed in the analyses. From the 11 different colors that were found, the most prevailing ones were blue (61.73 %), black (22.06 %), green (6.8 %), and red (6.1 %) (Fig. 5). The size varied from 6.39 μm to 1701.72 μm ($\bar{X}=155.34$ μm , ± 183.12) for all the formats of microplastic. Separately, the fragments had $\bar{X}=129.90$ μm (± 140.69), films $\bar{X}=370.82$ μm (± 315.21), and spheres $\bar{X}=89.93$ μm (± 62.57). Table 2 presents all the results related to the sizes and morphological characteristics of the microplastics. The animal dimension (TL – total length) did not correlate with the abundance ($p = 0.241$) and size ($p = 1$) of found microplastics.

4. Discussion

Accidental capture in fishing nets, or entanglement, is the main cause of negative interactions between cetaceans and humans (Di Benedetto, 2004; Netto and Barbosa, 2003) and is also the main death cause of *S. guianensis* in Espírito Santo (Mayorga et al., 2020), as observed in this study, since the death of seven specimens of *S. guianensis* was associated with this cause. Fishing activity also introduces plastic debris and microplastics into the marine environment (GESAMP, 2015; Kutralam-

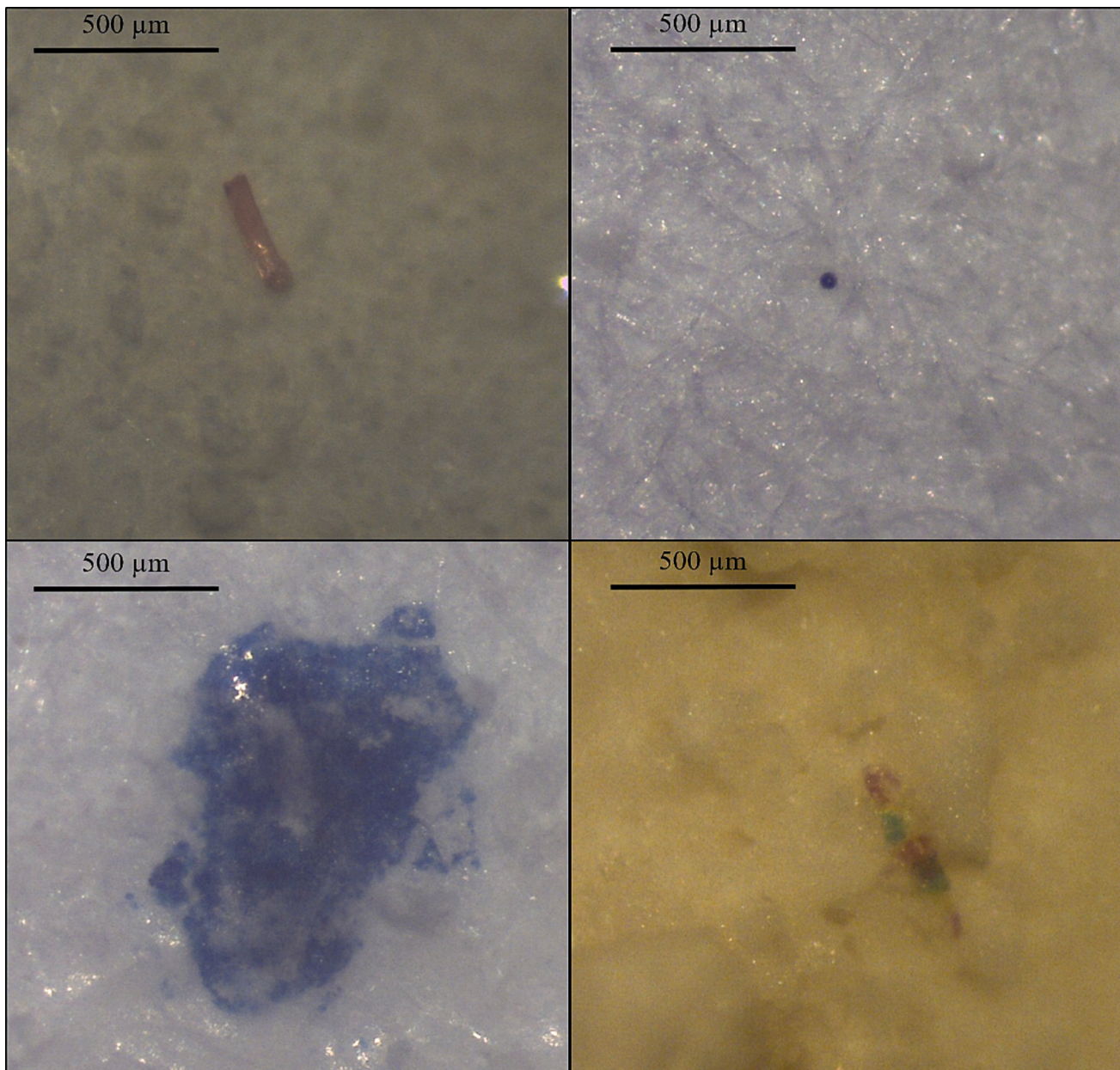


Fig. 4. Microplastics extracted from the gastrointestinal tract *Sotalia guianensis* stranded on the coast of Espírito Santo between 2019 and 2022. Blue and multi-colored films (A and B), blue sphere (C), and red fragment (D). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Muniasamy et al., 2021).

The ingestion of *meso* and macroplastic was reported in 61.1 % of odontocete species, of which 37 are delphinids, and even the presence of small amounts in the TGI can be fatal for these animals (Jacobsen et al., 2010; Kühn and van Franeker, 2020). In this study, the Guiana dolphin presented a significant frequency of occurrence (FO = 33.3 %; $n = 12$) of ingestion of plastic debris when compared to the study that Di Benedetto and Awabdi (2014) carried out in the Brazil's Southeastern region, (FO = 1.3 %; $n = 77$). In Brazil's Northeastern region, a plastic mesh with 6.5 cm was reported in a male Guiana dolphin (Guimarães et al., 2013). Pereira et al. (2023) identified six plastic items larger than 5 mm (FO = 5 %) with the same species in their study. However, they did not specify the size and characterization of the items. The only plastic debris that Di Benedetto and Ramos (2014) reported in the species was a filament considered to be 3.1 cm nylon. However, no technique was used to characterize the component polymer. In this study, the three filaments

found in two specimens were blue ($n = 2$) and transparent ($n = 1$) PE, which probably originated from fishing artifacts that fragmented in the environment (Ivar do Sul et al., 2014).

The sources of plastic debris can be terrestrial or oceanic (GESAMP, 1990). Among terrestrial sources are stormwater and river discharge, industrial activities, tourism-related activities on the coast, and improper waste disposal. Marine sources result from fishing activities, oil and gas extraction platforms, and recreational ships (Pawar et al., 2016). The origin of plastic can be local or not, as it may travel long distances before being deposited in the ocean (Sheavly and Register, 2007) or ingested by fauna. Therefore, estimating or concluding the origin of plastics from packaging ingested by the animals analyzed in this study is not possible. However, we emphasize to the fact that the plastic found in individual SOT 462, produced in a location distant from the stranding area, underscores the importance of holding packaging industries accountable for their disposal.

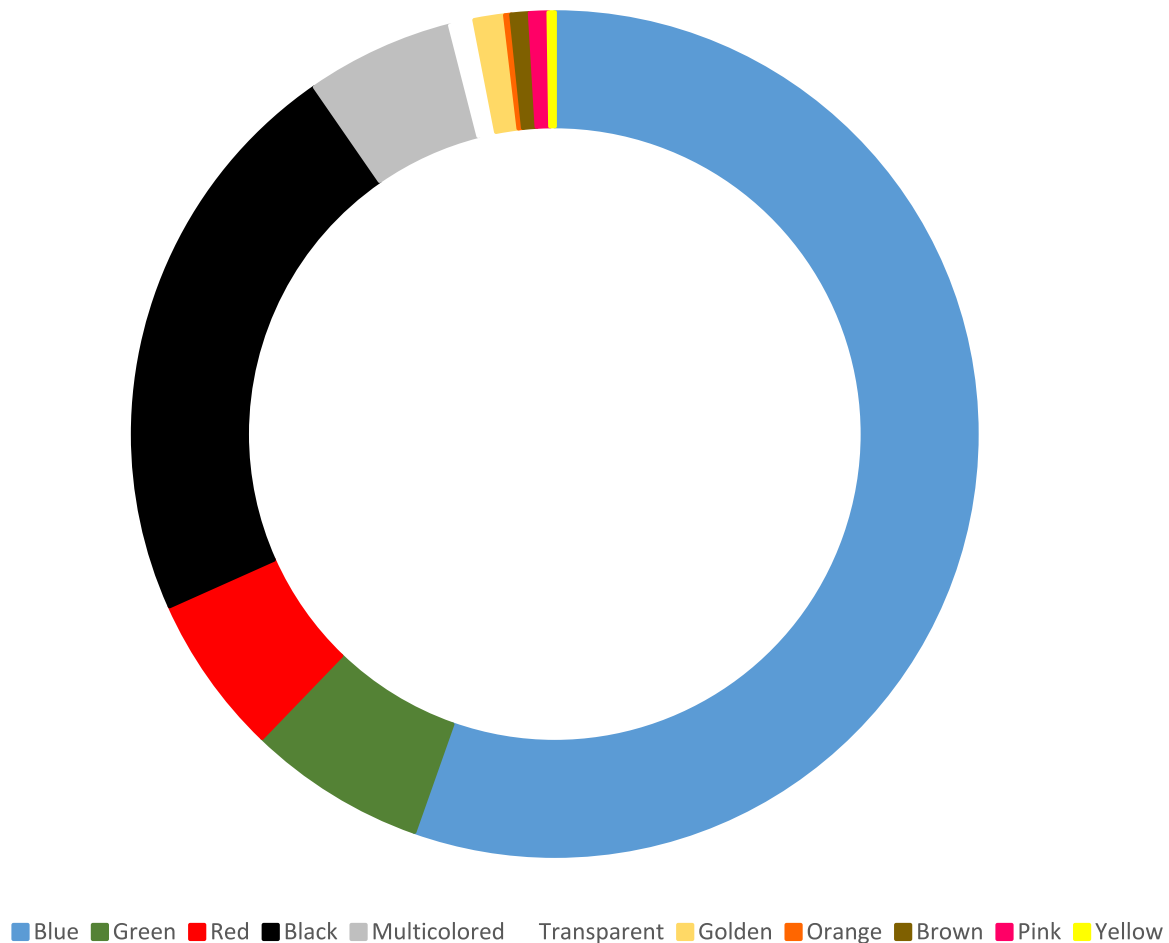


Fig. 5. Colors of microplastics particles found in the intestines of *Sotalia guianensis*, whose strandings occurred on Brazil's Southeastern coast.

In seven years of monitoring (from 2010 to 2017) part of Brazil's Southeastern coast, no specimen of Guiana dolphin was found ingesting solid waste (Do Nascimento et al., 2023). *Sotalia guianensis* is a predatory pelagic fish, and therefore it is not as susceptible to ingestion of macro debris when compared to other species that feed on prey that are associated with the seabed (Di Benedetto and Ramos, 2004; Simmonds, 2012; Di Benedetto and Oliveira, 2019). On the other hand, due to its low density, some plastic debris like PE and PP when not colonized by microorganisms, have a greater buoyancy capacity (Guo and Wang, 2019) and can be an item of curiosity and play for marine mammals (Laist, 1987). However, odontocetes do not ingest these items as they confuse them with prey due to their foraging strategies (Di Benedetto and Ramos, 2004; Gazda et al., 2005) and their complex echolocation system (Walker and Coe, 1989). All animals analyzed in this study that presented plastic debris larger than 5 mm were adults and thus experienced. Except for the item found in specimen SOT 462, which was larger, we suggest that the other meso- and macroplastic come from secondary or incidental ingestion, as suggested in the study of Di Benedetto and Awabdi (2014).

In Brazil, the ingestion of plastic debris has already been reported in some species of marine mammals (Castro et al., 2018). However, regarding microplastics, only *S. guianensis* from Ceará's coast were analyzed (Pereira et al., 2023). The abundance and characteristics of microplastics are different in specimens from each studied region (Castro et al., 2018), so it is important to carry out studies with the same species in different locations.

The frequency of MP occurrence was 100 % in the present study and others (Lusher et al., 2015, 2018; Xiong et al., 2018; Zhu et al., 2019; Nelms et al., 2019), except for the study carried out in *S. guianensis* from

Brazil's Northeastern region (FO, 95 %) (Pereira et al., 2023). Although coastal cetaceans are more exposed to sources of contamination from marine debris (Lusher et al., 2018), we observed that there is no pattern concerning the FO of MPs and habitat of the cetacean species that were already studied. Pollutants are transported by wind and marine currents throughout the oceans, as Moore et al. (2020) observed in *Delphinapterus leucas*.

Lusher et al. (2015) identified microplastics for the first time in a cetacean species (*Mesoplodon mirus*, Ziphiidae, $n = 1$) and found 88 MPs, of which 89 % corresponded to fibers. The fibers were also predominant in six different odontocetes species that were analyzed in Ireland (83.6 %) (Lusher et al., 2018), in two in China (Xiong et al., 2018; Zhu et al., 2019) and in eight species in England (Nelms et al., 2019). The fragments prevailed only for Brazil's Northeastern *S. guianensis* (Pereira et al., 2023) and for *Delphinapterus leucas* (Moore et al., 2020). In this study, possible microplastic fibers were not counted to avoid the over-estimation of the counting. We suggest future analyses of this type of MP in *S. guianensis* on Brazil's Southeastern coast, considering that 77 % of the microplastics that were found in the sediment from Vitória Bay (ES) corresponded to fibers related to fishing equipment (Neto et al., 2019) and that fibers were also predominant in mollusks from the same region (Da Costa et al., 2023).

In this study, 11 different colors were found, emphasizing blue, red, green, and black. Lusher et al. (2018) found microplastics of nine different colors in the species of the studied odontocetes, while for *N. a. sunameri* about 40 % of MP were blue (Xiong et al., 2018). In *S. guianensis* from Brazil's Northeast, Pereira et al. (2023) found a predominance of white and black MPs. Such results are different from those that were found in other cetacean species and in this study. Nelms et al. (2019)

Table 2

General data about *Sotalia guianensis* from Espírito Santo coast, analyzed ($n = 12$). Necroscopic diagnosis, age range, total length (TL), weight, sex (F – female; M – male), Number of microplastics (MPs), average size of microplastics (\bar{X} MP), Average size of fragments (Frag), films (Fil) and spheres (Sph), Number of plastic debris >5 mm (N PD) and Average size of plastic debris >5 mm (\bar{X} PD).

	Diagnosis	Age	TL (cm)	Weight (kg)	Sex	N MP	\bar{X} MP (μm)	Frag (μm)	Fil (μm)	Sph (μm)	N PD	\bar{X} macro (cm)
SOT 361	Entanglement	Adult	189	112	F	–	–	–	–	–	2	2.38
SOT 380	Undetermined	Adult	212	110.5	M	48	186.6	142.51 ($n = 40$)	407.05 ($n = 8$)	–	–	–
SOT 387	Entanglement	Young	118 ^a	48 ^a	F	68	109.1	103.36 ($n = 62$)	196.31 ($n = 6$)	25.075 ($n = 1$)	–	–
SOT 389	Entanglement	Adult	176	79	M	43	190.9	148.58 ($n = 39$)	603.81 ($n = 4$)	–	3	2.94
SOT 394	Entanglement	Adult	193	110	M	30	115.3	83.52 ($n = 29$)	1037.77 ($n = 1$)	–	–	–
SOT 397	Entanglement	Adult	191	90	M	32	157	109.76 ($n = 27$)	20.72 ($n = 4$)	81.2 ($n = 1$)	–	–
SOT 398	Entanglement	Adult	188	75.5	M	13	115.3	144.34 ($n = 10$)	302.54 ($n = 2$)	28.27 ($n = 1$)	–	–
SOT 399	Undetermined	Adult	179	64.5	M	37	114.6	117.94 ($n = 35$)	65.85 ($n = 1$)	46.8 ($n = 1$)	–	–
SOT 402	Entanglement	Young	164	52	M	37	210.6	139.76 ($n = 31$)	26.85 ($n = 5$)	105.5 ($n = 1$)	–	–
SOT 403	Undetermined	Adult	179	64.5	F	75	178	165.69 ($n = 64$)	267.08 ($n = 10$)	72.7 ($n = 1$)	1	1.2
SOT 405	Undetermined	Adult	181	60	M	42	131.8	129.35 ($n = 37$)	168.23 ($n = 4$)	78.45 ($n = 1$)	–	–
SOT 462	Undetermined	Adult	189	84	M	–	–	–	–	–	1	19.22
Average	–	–	185.54 (± 12.15)	–	–	42.5 (± 18.05)	155.34 (± 183.13)	129.90 (± 140.69)	370.82 (± 315.21)	89.93 (± 62.57)	–	6.43 (± 8.55)

^a TL and estimated weight because the specimen had an amputation in the body's posterior region.

also characterized multicolored microplastics (0.7 %), and we showed that the presence of multicolored microplastics must be related to packaging fragmentation.

From the analyzed individuals, 83.3 % were adults, which may influence the number and type of microplastics found. As in this study, other studies also found no correlation between total length and MP abundance (Nelms et al., 2019; Hernandez-Gonzalez et al., 2018; Pereira et al., 2023). The abundance of MP must be associated with secondary ingestion via prey. The abundance of MP may be related to the age group. *S. guianensis*'s offspring, not analyzed in this study, should ingest fewer particles during the lactation period since the main source of contamination, prey, is not yet available.

Ingestion may depend on the availability and size of the prey that is ingested and how affected they are by microplastics pollution. Microplastics were studied in some stuck species of *S. guianensis* such as the gender *Stellifer* and *Mugil*, and the species *Micropogonias furnieri* in the Atlantic Ocean (Cremer et al., 2012; Rodrigues et al., 2020; Arias et al., 2019; De Amorim et al., 2020; Nunes et al., 2021). These species are known to be prey of *S. guianensis* and they have feeding habits in different locations in the water column and make different types of microplastics available to the cetacean. We recommend investigations about the ingestion of microplastics by the prey that *Sotalia guianensis* most consumes in future studies to understand the presence of the pollutant in the food chain in which the Guiana dolphin is a top predator.

The Rio Doce region is an important hotspot for *S. guianensis* (Pineiro, 2014). However, this was not evaluated in this study, and we suggest future studies to evaluate the possible interactions between microplastics, Guiana dolphins, and contaminants that are carried due to the rupture of the Mariana dam. The Guiana dolphin is the odontocete cetacean that most often runs aground on Espírito Santo's coast, which is justified by its coastal distribution (Mayorga et al., 2020). Furthermore, the top predator species is a sentinel for the coastal waters of Brazil's Southeast (De Moura et al., 2014). Thus, it can indicate the presence of microplastics in the ecosystem it lives in and should be used in other

studies to understand microplastics contamination.

5. Conclusion

Although the community recognizes that marine animals ingest plastic debris, this is little reported by the scientific community concerning cetaceans in Brazil. The type of polymer, size, and color of ingested items are characteristics that must be studied for macro and microplastic ingested by cetaceans to help understand the impact that plastic debris causes on species populations.

The PE and PP meso and macroplastics ingested by *Sotalia guianensis* provide the species with trace elements that can affect the population's health in the long term. Monitoring the types of polymers accidentally ingested by the species via macro or microplastics is important to identify health risks and develop management and conservation plans for the Guiana dolphin, not only in the study area, but in its entire distribution area.

The results of this work reveal that in Espírito Santo, an important location for its distribution, the Guiana dolphin is vulnerable to the ingestion of plastic debris, mainly fragment-type microplastics. Impacts such as environmental accidents, tourist regions, and high population density in the coastal region, which change the turbidity and composition of water and sediment, can lead these species to accidentally feed on this debris. Ingesting these non-processable materials that carry contaminants increases the vulnerability of these species. Finally, this work draws attention to the need for greater production control and a higher recycling rate of plastic waste in the State and in Brazil's Southeastern region, since more and more studies show the presence of plastic debris in marine organisms that were not previously exposed to these materials.

CRedit authorship contribution statement

Leticia Versiani Gomes da Silva: Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation,

Formal analysis, Data curation, Conceptualization. **Isis de Oliveira Carvalho Demarque:** Writing – review & editing, Methodology, Conceptualization. **Eloá Corrêa Lessa Tostes:** Writing – review & editing, Methodology. **Marcos André de Souza Araújo:** Methodology. **Carlos Eduardo Veiga de Carvalho:** Resources, Funding acquisition. **Maria Cristina Canela:** Writing – review & editing, Resources, Methodology. **Lupércio Araújo Barbosa:** Resources. **Leonardo Serafim da Silveira:** Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: LVGS reports financial support was provided by Coordination of Higher Education Personnel Improvement. MCC reports equipment, drugs, or supplies were provided by National Institute of Advanced Analytical Sciences and Technologies. MASA reports financial support was provided by National Council for Scientific and Technological Development. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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