

Small microplastics on beaches of Fernando de Noronha Island, Tropical Atlantic Ocean

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ABSTRACT

Oceanic islands are important areas of environmental, social, economic, and scientific interest. Therefore, it is essential to identify pollutants in these environments, including large (1 mm to ≤ 5 mm) and small microplastics (SMP) (1 μ m to ≤ 1 mm). Here, SMP were identified and characterized in the windward (WW) and leeward (LW) beaches of Fernando de Noronha Island. Samples were collected from 900 cm² quadrants on the strandline of 15 sandy beaches and were sieved through stainless steel sieves with 1 mm mesh. The SMP were characterized according to their shape, colour, and size. Synthetic fibres and fragments were identified, and synthetic fibres were predominant. Statistical differences were not found between the WW and LW beaches (160.0 ± 137.5 particles m⁻² and 128.0 ± 84.3 particles m⁻², respectively; Mann-Whitney *U* test: $U=198.5$; $p=0.81$) in relation to the total amount of SMP deposited on the beaches. Also, both types/shapes were present in the two groups of beaches (Friedman's test, $\chi^2 r=6.09$; $p=0.91$). The environmental forcings controlling the transport and potential deposition of synthetic fibres may have been different from those acting on fragments that more resembled the grains of sand in the beaches. Although it is difficult to prevent allochthonous sources of SMP at the small scale, management actions on the island are mandatory to prevent autochthonous sources.

Descriptors: Plastic pollution, Oceanic islands, Marine conservation, Atlantic Ocean, Brazil.

INTRODUCTION

Scientists, civil society, and governments have recently (< 10 y) increasing concerns about the impacts of microplastic pollution on marine ecosystems (Hu et al., 2019; Van Wijnen et al., 2019). Microplastics are plastic particles with a size of 1 μ m to 5 mm; because they have diverse behaviours within marine habitats (i.e. transport mechanisms and potential impacts), they can be classified as large (1 mm to ≤ 5 mm) or small (1 μ m to ≤ 1 mm) microplastics (SMP) (Van Cauwenberghe et

al., 2015; Gigault et al., 2018). However, SMP and large microplastics have the same sources (Boucher and Friot, 2017). Primary SMP are already at the microscopic scale when they reach the sea, such as microbeads used in cosmetics; they can enter marine environments from sewage discharge on land (Browne et al., 2011; Boucher and Friot, 2017). On the other hand, secondary SMP originate from the degradation and fragmentation of relatively larger plastics in the environment (Frias and Nash, 2019).

Generally, the smaller the size of the microplastics, the greater the number of marine animals susceptible to interaction (e.g. ingestion) with these particles; they then have the potential to be introduced into marine trophic webs (Gusmão et al., 2016; Wang et al., 2019). Also, the harmful effects of SMP are potentially worse when organic or inorganic pollutants are adsorbed onto

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SMP, as they can be released into the digestive tract of organisms, thereby even compromising human food security (Barboza et al., 2018).

Within the range of marine habitats that are already shown to be contaminated by microplastics are remote oceanic islands, where allochthonous sources (e.g. marine currents and ships) can be significant sources of plastics with a relatively larger size range (Edo et al., 2019; Lavers et al., 2019; Ryan et al., 2019). Plastic particles are commonly found in higher amounts on windward (WW) beaches of these islands owing to the direct action of physical forcing (e.g. Ivar do Sul et al., 2009; Monteiro et al., 2018). On the other hand, autochthonous sources are significant on touristic islands where there is permanent human occupation (Debrot et al., 2013; Schmuck et al., 2017). Independent of the predominant source of plastic, oceanic islands can be sources but also temporary reservoirs or final sinks of plastics in the oceans.

In the Atlantic Ocean, the UNESCO Natural Heritage of Humanity island of Fernando de Noronha covers approximately 20 km²; approximately 3,000 inhabitants

live on the island (IBGE, 2010), but the number of tourists reaches > 50,000 in the high season (austral summer season). The island is part of the Environmental Protection Area of Fernando de Noronha - Rocas - Saint Pedro and Saint Peter Archipelago and the National Marine Park of Fernando de Noronha (PARNAMAR). It has a crucial role in the preservation of threatened species such as marine turtles (*Caretta caretta*, *Chelonia mydas*, and *Eretmochelys imbricata*), fish (Lemon Shark - *Negaprion brevirostris*), seabirds (Shearwater - *Puffinus lherminieri*), and echinoderms (Starfish - *Echinaster (Othilia) guyanensis*). In addition, the Golfinhos Bay hosts a permanent population of rotator dolphins (*Stenella longirostris*) (Bellini and Sanches, 1996; Serafini et al., 2010). All endemic and migratory species are at imminent risk of plastic pollution on the island.

This study is part of a broader project on microplastic pollution in Brazilian oceanic islands. Sediment samples were fractionated with a 1 mm sieve, and large microplastics and SMP were preferentially retained in two different fractions. Large microplastic data were previously published (Ivar do Sul et al.,

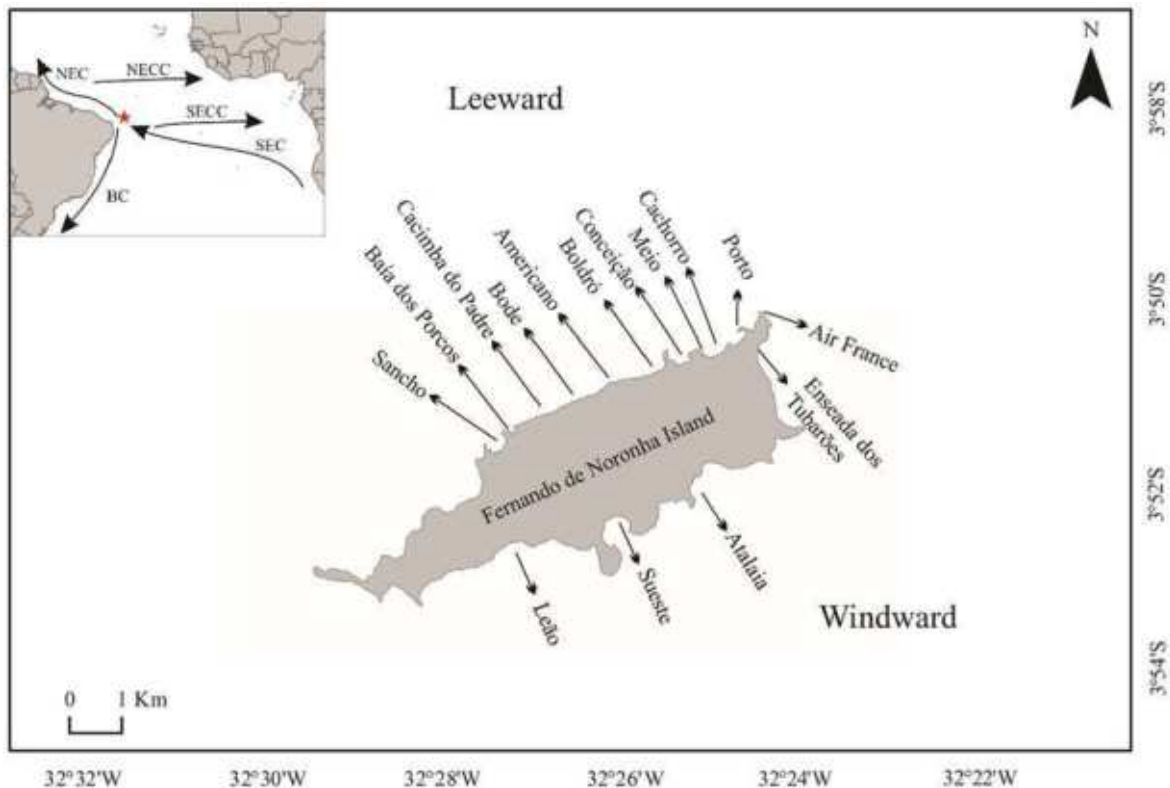


Figure 1. (A) Location of the Fernando de Noronha Island in the west of the Equatorial Atlantic Ocean and the main surface currents (SEC = Equatorial South Current; NBC = Northern Brazil Current; BC = Brazilian Current, SECC = South Equatorial Counter Current; NECC = North Equatorial Counter Current). (B) Location of beaches analyzed on the main island of Fernando de Noronha, divided into leeward and windward.

2017). Thus, the present study aimed to identify and characterize SMP in sandy beaches of Fernando de Noronha Island. Here we focused on SMP with a small spatial distribution and tested two hypotheses, as follows: (1) WW beaches are more contaminated by SMP than LW beaches and (2) are recurrent among the WW and LW beaches on the island.

MATERIAL AND METHODS

STUDY AREA

Fernando de Noronha is a volcanic archipelago located in the Tropical Atlantic Ocean (Figure 1). Its geological nature is formed by submarine volcanic mountains emerging from the fracture zone of Fernando de Noronha (Calliari et al., 2016), and it forms 21 small islands and cliffs. The weather is tropical with an average annual air temperature of $28\pm4^{\circ}\text{C}$ (Mohr et al., 2009). It has two defined seasons, namely the rainy season from February to July and the dry season from August to January (Mohr et al., 2009). The island is influenced by the southeast trade winds, which are more intense in June–August and create higher swells on the WW side of the archipelago (Calliari et al., 2016). The samples used in this study were collected in the austral summer season (March) before the higher swells reached the island. The islands are also under the influence of the South Equatorial Current (SEC) (Cirano et al., 2006), which flows from east to west and has a low concentration of suspended matter (Eston et al., 1986; Stramma and England, 1999). The local hydrodynamics and island topography generate vertical turbulence that allows the rise of deeper waters rich in nutrients (upwelling), thereby increasing the plankton biomass, which is a phenomenon called the island mass effect (Lira et al., 2014; Tchamabi et al., 2017).

The main island of the Fernando de Noronha Archipelago, which is also called Fernando de Noronha, has 37 km of coastline, of which 28.5 km (77%) are rocky shores and 8.4 km (23%) forms 32 beaches with 15 sandy beaches (Calliari et al., 2016). These sandy beaches are composed of carbonate sand, which is derived from coral reefs and volcanic rocks, with grain sizes varying from 0.1 mm to 0.5 mm (Barcellos et al., 2011; Manso et al., 2011). For this study, beaches were grouped by WW beaches, which are directly influenced by wind, marine currents, and waves; and LW beaches,

which are relatively protected from the action of wind and currents.

SAMPLING AND SAMPLE TREATMENT

Sediment samples were collected on the strandline of five WW and ten LW beaches by scraping the sand from 30×30 cm (900 cm^2) quadrants (Ivar do Sul et al., 2009). Three quadrants were sampled on each beach with one at the centre and two at each end of the beach arc. However, only one quadrant (in the centre) was sampled on Porcos and Cachorro beaches and two quadrants (at the ends of the beach arc) were sampled on Porto beach owing to the beach lengths (total of 40 samples). All samples were kept in sealed plastic bags until analysis. Particles resembling these bags were not identified in the samples; thus, they were not considered a potential contamination source of microplastics here.

In the laboratory, sediment samples were oven-dried and sieved through a stainless steel mesh of 1 mm. The fraction smaller than 1 mm (SMP + sediment) was then submitted to density separation following well-established methods (e.g. Martins and Sobral, 2011) previously detailed by Pinheiro et al. (2019). Negative blanks were performed to control possible contamination from the commercial table salt and distilled water used for density separation. Particles (including fibres) resembling those presented in this study were not identified in the blank samples and were not considered potential sources of SMP here. Filters were oven-dried in Petri dishes at 40°C and analysed under Carl Zeiss Stemi 2000-C stereomicroscope ($1\times$). During the laboratory procedures, samples were kept closed with a glass lid or Al foil to avoid external contamination (i.e. airborne fibres). SMP particles were identified according to their type/shape (e.g. fragments or synthetic fibres), colour, and size (length and total area). Fibres were recognized using visual criteria available in the literature, including the uniform diameter of fibres or the presence of bends, or by their brightness and diverse colours (i.e. blue and red), which did not resemble marine animal or plant tissue (Browne et al., 2011). Images were obtained using AxioVs40 V 4.8.2.0 software from Carl Zeiss Vision.

DATA ANALYSES

The total density (amounts) of SMP was expressed as the number of particles per square metre. The size of the SMP was expressed in millimetres and the area was

expressed in square metres. The Gaussian distribution of the data was tested, and the data showed a nonparametric distribution. The nonparametric Mann-Whitney U test ($\alpha=0.05$) was then used to check the significant differences in the amount of SMP between WW and LW beaches (Hypothesis 1). To compare the SMP types within beach groups (WW or LW), a two-way analysis with Friedman's test ($\alpha=0.05$) was used for multiple comparisons (Hypothesis 2). Data were also compared with those of a previous work (Ivar do Sul et al., 2017) to check the co-occurrence of SMP and relatively larger microplastics in beaches on the island.

RESULTS

SMP were reported in all sediment samples from Fernando de Noronha Island (Figure 2). A total of 504 SMP particles were identified. Synthetic fibres corresponded to 90% ($n=459$) (Figure 3) and fragments accounted for approximately 10% ($n=45$) of the particles. Synthetic fibres were predominant in all beaches and quadrats, except for one quadrat from Meio Beach (Table 1). Other types of SMP (e.g. microbeads) were not detected at this time.

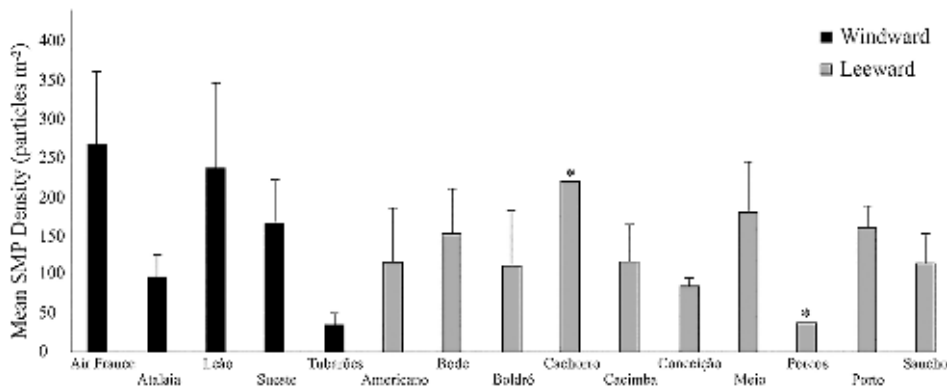


Figure 2. Mean SMP density (particles m⁻²) on the windward and leeward beaches of Fernando de Noronha Island, Tropical Atlantic Ocean. *Total values of Porcos and Cachorro beaches. Error bars represent the standard error.



Figure 3. Photographic examples of synthetic fibres found on beaches of Fernando de Noronha Island.

Table 1. Density, size e area of fragments and synthetic fibres found on windward and leeward beaches of Fernando de Noronha Island, Tropical Atlantic Ocean. E – East; M – Middle; W – West. *Underestimated.

	Beach	Position	Density (particles m ⁻²)			Total area (m ²)		Total size (mm)
			Fragment	Fiber	Total	Fragment	Fiber	Fragment
WINDWARD	<i>Leão</i>	E	-	155.6	155.6	-	2.4x10 ⁻⁵	-
		M	-	100	100	-	1.4x10 ⁻⁵	-
		W	-	455.6	455.6	-	6.4x10 ⁻⁵	-
	<i>Sueste</i>	E	-	55.6	55.6	-	5.9x10 ⁻⁶	-
		M	11.1	211.1*	222.2	9.7x10 ⁻⁶	7.4x10 ⁻⁵	4.9
		W	11.1	211.1	222.2	8.9.10 ⁻⁶	3.5x10 ⁻⁵	9.4
	<i>Atalaia</i>	E	-	44.4	44.4	-	8.5x10 ⁻⁷	-
		M	44.4	55.6	100	3.7x10 ⁻⁵	1.1x10 ⁻⁵	24.6
		W	55.6	88.9	144.4	2.4x10 ⁻⁷	2.0x10 ⁻⁶	1.6
	<i>Enseada dos Tubarões</i>	E	22.2	44.4	66.7	1.6x10 ⁻⁵	6.8x10 ⁻⁶	8.8
		M	11.1	-	11.1	1.4x10 ⁻⁵	-	5.0
		W	22.2	-	22.2	1.8x10 ⁻⁵	-	8.0
	<i>Air France</i>	E	-	455.6	455.6	-	3.7x10 ⁻⁶	-
		M	-	188.9	188.9	-	4.5x10 ⁻⁶	-
		W	-	155.6	155.6	-	1.5x10 ⁻⁶	-
	<i>Porto</i>	E	55.6	133.3	188.9	5.7x10 ⁻⁷	3.6x10 ⁻⁶	2.5
		W	33.3	100	133.3	1.7x10 ⁻⁷	2.9x10 ⁻⁶	1.0
	<i>Cachorro</i>	M	-	222.2	222.2	-	2.2x10 ⁻⁶	-
	<i>Meio</i>	E	-	188.9*	188.9	-	4.8x10 ⁻⁶	-
		M	-	66.7	66.7	-	2.5x10 ⁻⁶	-
		W	188.9	100	288.9	1.9x10 ⁻⁷	1.3x10 ⁻⁶	2.4
LEEWARD	<i>Conceição</i>	E	-	66.7	66.7	-	2.8x10 ⁻⁶	-
		M	-	88.9	88.9	-	4.8x10 ⁻⁶	-
		W	-	100	100	-	2.2x10 ⁻⁶	-
	<i>Boldró</i>	E	11.1	244.4	255.6	8.3x10 ⁻⁸	6.7x10 ⁻⁶	0.1
		M	-	44.4	44.4	-	1.2x10 ⁻⁶	-
		W	-	33.3	33.3	-	4.2x10 ⁻⁷	-
	<i>Americano</i>	E	-	255.6	255.6	-	7.5x10 ⁻⁶	-
		M	-	55.6	55.6	-	2.0x10 ⁻⁶	-
		W	11.1	22.2	33.3	3.3x10 ⁻⁸	2.4x10 ⁻⁷	2
	<i>Bode</i>	E	-	122.2	122.2	-	2.3x10 ⁻⁶	-
		M	11.1	255.6	266.7	5.7x10 ⁻⁸	1.0x10 ⁻⁷	0.1
		W	-	66.7	66.7	-	1.7x10 ⁻⁶	-
	<i>Cacimba do Padre</i>	E	-	44.4	44.4	-	1.6x10 ⁻⁷	-
		M	-	88.9	88.9	-	2.9x10 ⁻⁶	-
		W	-	211.1	211.1	-	1.9x10 ⁻⁶	-
	<i>Baía dos Porcos</i>	M	-	33.3	33.3	-	4.1x10 ⁻⁷	-
	<i>Sancho</i>	E	11.1	66.7	77.8	1.8x10 ⁻⁸	9.2x10 ⁻⁷	0.2
		M	-	77.8	77.8	-	3.8x10 ⁻⁶	-
		W	-	188.9	188.9	-	1.2x10 ⁻⁵	-

The mean size of the particles (MSP) was 1.8 ± 4.5 mm ($MSP_{WW} = 4.2 \pm 6.7$ mm; $MSP_{LW} = 0.3 \pm 0.8$ mm) (Table 1). The mean size was larger than 1 mm because longer fibres were not consistently retained by the 1 mm sieve when the sample was sieved. If all the particles were sorted on a Petri dish, then fragments would occupy an area of $1.06 \times 10^{-4} \text{ m}^2$ (Total area_{WW} = $1.05 \times 10^{-4} \text{ m}^2$; Total Area_{LW} = $1.10 \times 10^{-6} \text{ m}^2$) while synthetic fibres would occupy a relatively larger area of $3.20 \times 10^{-4} \text{ m}^2$ (Total area_{WW} = $2.50 \times 10^{-4} \text{ m}^2$; Total area_{LW} = $7.30 \times 10^{-5} \text{ m}^2$) (Table 1).

Regarding colours, blue, black, and colourless synthetic fibres represented nearly 100% of the plastic particles, except for a few pink/reddish coloured fibres. Among the fragments, blue fragments were predominant among SMP (80.0%; 36 particles), followed by green fragments (11.1%; 5 particles). Other colours such as white, yellow, gray, and red each represented 2.2% (Figure 4).

The amount of SMP in the WW and LW beaches ranged from 33.3 ± 16.9 particles m^{-2} to 266.6 ± 94.9 particles m^{-2} and from 85.1 ± 9.7 particles m^{-2} to 181.4 ± 64.2 particles m^{-2} , respectively. There was no statistical difference between these groups of beaches (WW beaches = 160.0 ± 137.5 particles m^{-2} ; LW beaches = 128.0 ± 84.3 particles m^{-2} ; Mann-Whitney *U* test: $U = 198.5$; $p = 0.81$) when considering the total amount of SMP, so Hypothesis 1 was not corroborated.

However, the amounts of SMP were more variable among WW beaches than among LW beaches (Figure 2). In general, Air France and Leão beaches presented the highest amounts of SMP as they were both located on the WW side of the island. Considering the types of SMP, synthetic fibres and fragments were present in both WW and LW beaches (Friedman's test, $\chi^2 r = 6.09$; $p = 0.913$), thereby corroborating Hypothesis 2.

While large microplastics were previously reported on 8 of 13 beaches (Ivar do Sul et al., 2017), SMP were present on 9 of 15 beaches (Figure 5). However, both microplastic size categories co-occurred on five beaches, with three on the WW side of the island (i.e. Enseada dos Tubarões, Atalaia, and Sueste) and two on the leeward side (i.e. Bode and Porto).

DISCUSSION

Fernando de Noronha was a key island to test the hypotheses presented in this study because it is relatively isolated from the continent and directly influenced by the SEC (Figure 1), but is also inhabited and receives thousands of tourists each year (Cristiano et al., 2020). Thus, plastics were expected to originate from both allochthonous and autochthonous sources, including microplastics (Ivar do Sul et al., 2009). Although the occurrence of microplastics in relatively larger size ranges was already reported in beaches and

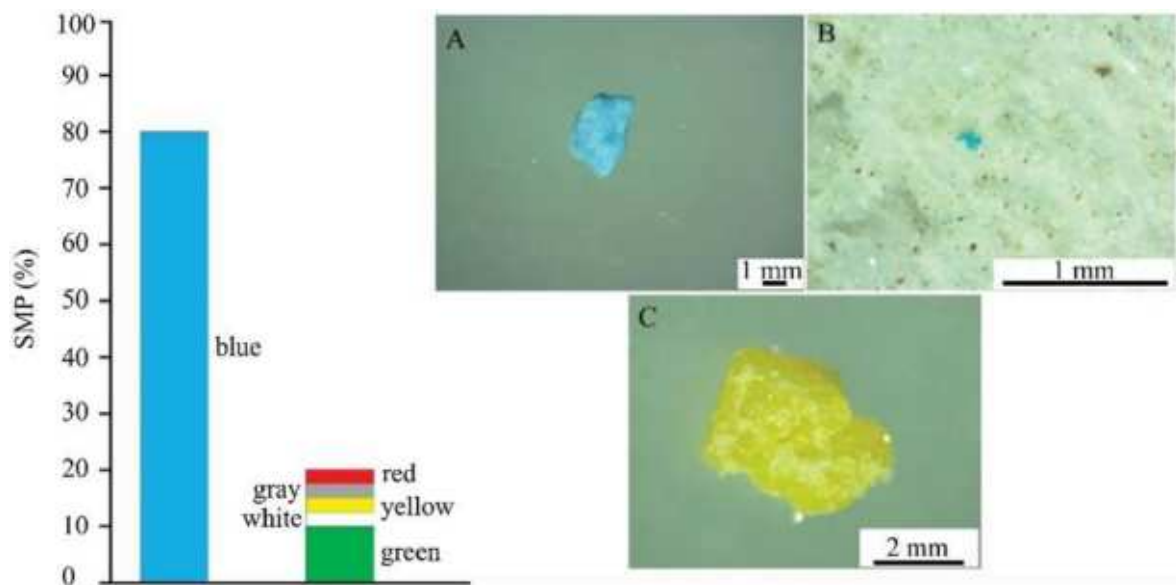


Figure 4. Colours of the plastic fragments identified on the windward and leeward beaches in Fernando de Noronha Island, Tropical Atlantic Ocean, N=45 plastic particles. A) Blue plastic fragment collected at Tubarão beach; B) Plastic fragment collected at Meio beach; C) Fragment plastics collected on the beach.

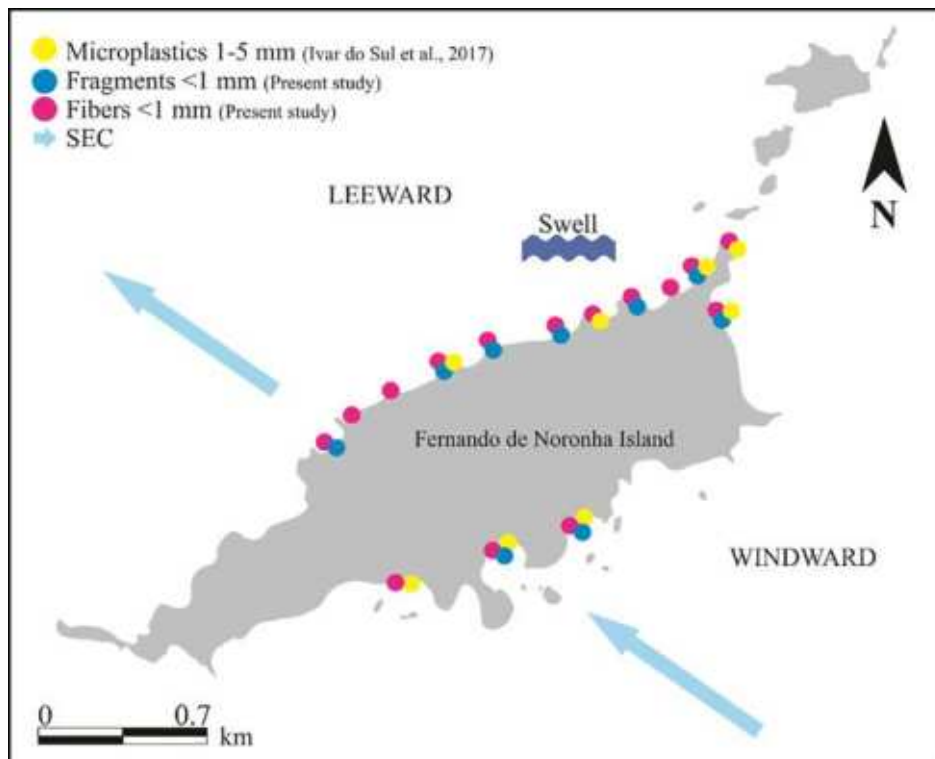


Figure 5. Larger microplastics fraction between 1-5 mm (Ivar do Sul et al., 2017)¹, a fraction less than 1 mm (this study)² found on the beaches in the windward and leeward of the Island of Fernando de Noronha, Tropical Atlantic Ocean. SEC: South Equatorial Current; ¹Total of 13 beaches sampled, Porcos and Cachorro beaches have not sampled in this work; ²Total of 15 beaches sampled, including Porcos and Cachorro beaches.

in the surface waters around the island (Ivar do Sul et al., 2013; 2017), this study reported microplastics < 1 mm for the first time.

Sources of microplastics in the small size range are more difficult to identify compared with those of larger plastics. Based on the sampling strategy used in this study, no statistical difference was reported between the WW and LW beaches in relation to the amount of SMP. This indicated that independent of physical forcing and potential transport of allochthonous plastic particles, microplastics in this size range accumulated in the island beaches. On the other hand, the predominance of relatively larger microplastics (mostly fragments) in the WW beaches (Ivar do Sul et al., 2009; 2017) indicated a clearer influence of surface ocean currents on their transport and deposition on beaches. This was expected because the microplastic fragments were similar in size and shape to the grains on sandy beaches; therefore, their dynamics within the beach environment were expected to resemble sediment movement/deposition. Thus, the results presented here were influenced by the predominance of synthetic fibres (which were absent in

the previous study), which had multiple and distinguished sources compared with the fragments. In addition, the deposition/removal of fibres was likely controlled by different environmental forcings; for example, local sources (i.e. wastewater discharge) and winds may have had more influence on their potential accumulation.

The results showed that WW beaches presented higher variability among beaches in relation to the amount of SMP (Figure 2). This may have been due to different small-scale current patterns, the dominant grain size in the beaches, wave action, and/or relative wind exposure. The influence of the island mass effect (Tchamabi et al., 2017) on microplastics distribution must still be investigated. It may have played a special role mainly in the transport of fibres within the insular platform and finally on their deposition on the island beaches.

The predominance of fibres was reported in previous studies, including studies on sea ice in the Arctic Ocean and in the air around an urban city (Dris et al., 2016; Bergmann et al., 2019). In the marine environment, sources are commonly associated with wastewater, but

it has been shown that fishing equipment and other items can also release fibres into the sea (Mishra et al., 2019). For example, in the Saint Pedro and Saint Paulo Archipelago, which is approximately 500 km from Fernando de Noronha, industrial fishing is considered a potential source of pelagic synthetic fibres (Ivar do Sul et al., 2013). Therefore, local fishing was a possible source of fibres in this study. Large fishing equipment (including nets and fishing lines) was previously reported to be submerged in the PARNAMAR area of the island (Link et al., 2019), and some of these items have been recognized as sources of fibres in the sea.

The potential impacts of SMP, including fibres, include their potential ingestion by organisms from the benthos community. For example, small arthropods of the order Collembola (Hexapoda: Entognatha) inhabit interstitial sediments and soils on the island (Lima and Zeppelini, 2015; Palacios-Vargas et al., 2013). They can carry organic and inorganic particles in the same size range as SMP particles within sediment layers, so there is the potential for them to also transport those SMP that would then be available to other organisms in the sediment (Maaß et al., 2017). If ingested, SMP may decrease the feeding and locomotion capacity of organisms through physical or chemical (persistent organic pollutants and heavy metals) effects (Besseling et al., 2013). Also, as organisms in the benthos support organisms in higher trophic levels, the availability of SMP may introduce these particles in the trophic web and have unknown consequences on the insular ecosystem.

Although the ingestion of fibres has been reported for organisms in different levels within marine food webs, there are very few insights related to the preferential colour that is ingested. Fibres samples in this study were mainly blue and/or black, which fit with most of the fibres that were previously reported to be ingested by polychaetes in the Atlantic and Mediterranean seas and were also in the same size range (i.e. 2–4 mm) (Gusmão et al., 2016). Moreover, blue and black fibres (77%) were also reported to be prevalent over other microplastic particles ingested by the Atlantic ghost crab (Costa et al., 2019). Based on the results presented here, there is a real potential of ingestion of fibres deposited on sandy beaches. Endemic, resident, and migratory species on the island are at imminent risk of microplastic ingestion.

CONCLUSION

The presence of SMP pollution on Fernando de Noronha Island, which is a hotspot of marine biodiversity, was confirmed for the first time. Future studies about

(micro)plastic pollution should consider meteorological and oceanographic forcing, seasonality, beach morphodynamics, and anthropogenic influences to allow the understanding of the accumulation and removal processes of SMP in the beaches of Fernando de Noronha Island. Finally, island managers should determine ways to prevent and remediate the plastic pollution on the island to ensure a healthy marine ecosystem for future generations, such as the District Decree N° 002 approved in December 12th, 2018 that provides for the prohibition of single-use plastics in the island.

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GLOVE: The Global Plastic Ingestion Initiative for a cleaner world

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ABSTRACT

Plastics are one of the most used materials in the world. Their indiscriminate use and inappropriate disposal have led to inevitable impacts, for instance ingestion, on the environment arousing the attention of the global community. In addition, plastic ingestion studies are often written in scientific jargon or hidden behind paywalls, which makes these studies inaccessible. GLOVE is an online and open-access dashboard database available at gloveinitiative.shinyapps.io/Glove/ to support scientists, decision-makers, and society with information collected from plastic ingestion studies. The platform was created in the R environment, with a web interface developed through Shiny. It already comprises 530 studies, including all biological groups, with 245,366 individual records of 1458 species found in marine, freshwater, and terrestrial environments. The main goal of the GLOVE dashboard database is to improve data accessibility by being a scientifically useful grounded tool for designing effective and innovative actions in the current scenario of upcoming global and local agreements and actions on plastic pollution.

1. Introduction

Currently, plastic pollution is recognized as a global crisis, and we are moving forward to a global agreement to combat this issue. The UNEP resolution named “End Plastic Pollution: Towards an internationally legally binding instrument” in the Fifth Session of the United Nations Environment Assembly (UNEA-5) reinforced the creation a plastic pollution international agreement by the end of 2024. The resolution addresses whole lifecycle of plastics, including their production, design, and final disposal (UNEP, 2022). The transition to a global agreement needs science-based information accessibility to support the

efforts and involvement of all sectors, including scientists, governments, industries, third sector entities, and society.

In this context, an open-access platform is a powerful tool to aid the identification of knowledge gaps and provide guidance for ongoing and future measures. Also, this is relevant to obtain accurate conclusions reducing the number of redundant studies and rising and inspiring new research-based solutions. The availability of web-based platform data has a crucial role in the application of science-based management actions and public policies (e.g., Global Partnership on Marine Litter – www.gpmlitter.org, Global Biodiversity Information Facility (GBIF) – www.gbif.org, Freshwater Information Platform (FIP) – www.fip.org

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freshwaterplatform.eu, The IUCN Red List of Threatened Species – www.iucnredlist.org) since the number of publications and information have been increasing rapidly leading to a data overload. They ensure the most up-to-date grounded information to the universities, research centers, decision-makers, and other stakeholders who can develop the most suited environmental strategies. However, we do not have a global platform for ingested plastic debris involving whole Earth great ecosystems (marine, freshwater and terrestrial) to support future international agreements and local actions on animal and environmental health (Walker et al., 2021).

The magnitude of plastic pollution has created a scenario in which its effects are considered irreversible (MacLeod et al., 2021). One of the most deleterious effects is related to ingestion by wild animals that can cause harmful problems such as chronic and acute health problems (Bucci et al., 2020; Marn et al., 2020; Puskic et al., 2020; Santos et al., 2021). Up to now, >1400 species have ingested plastic ranging from small invertebrates (e.g., zooplankton) to large mammals (e.g., elephants). In addition to affecting individuals, plastic spreading through different food webs harms the biota at community levels (Santos et al., 2021) since the formation of heteroaggregates in the gut of prey can increase trophic transfer to predators. Thus, this could affect the energy and nutrients transfer to higher trophic levels (Egbeocha et al., 2018). Also, plastic ingestion is a route for entrance and biomagnification of toxic substances (e.g., phthalates, pesticides, heavy metals), which can cause a reduction in feeding activity, depletion of energy on offspring and mortality of exposed individuals (Carbery et al., 2018).

Lists of species that have ingested plastics have been widely published in different articles and reports over the last years (e.g., Gall and Thompson, 2015; Kühn and van Franeker, 2020; Santos et al., 2021). However, they are not updated as new lists are published, so these lists often become outdated due to the rapid pace of publication (Santos et al., 2021). In addition, they are frequently hidden behind paywalls, expensive journal subscriptions, and written into scientific jargon making the information inaccessible to decision-makers, scientists, local communities, and non-governmental organizations (NGOs), especially to organizations and people from low- and middle-income countries.

Therefore, we present GLOVE (the *Global Plastic Ingestion Initiative*), the first web-based and open-access dashboard database aimed to share science-based data to support participatory, collaborative, and transformative processes. Our goal is to provide information for scientists, general public, conservation managers, policymakers, and local communities who cannot easily access to plastic ingestion data. This information is needed to better decision-making on marine, freshwater, and terrestrial management which may contribute to determine the level or concentrations of plastic debris in their territories; identify and alert risk factors to local/endangered species as well as potential sources of plastic.

GLOVE dashboard database improves data availability, accessibility, and comparability that changes the way how we use data on plastic pollution. The platform wants to provide information and enable knowledge to support local and global actions for the environment and society. It permits monitoring plastic ingestion data by biological group or species according to a wide range of descriptors, such as polymeric composition, color, and shape of plastic debris. All the data can be downloaded free of charge in CSV format.

The GLOVE dashboard database mission includes:

- [1] Reducing the complexity of the studies published by providing rapid responses for plastic ingestion about the biological groups and technical features of plastics;
- [2] Providing an overview of methodologies and main results published on plastic ingestion studies;
- [3] Monitoring past and present plastic ingestion studies seeking to identify changes, trends, and gaps;

- [4] Promoting and supporting a communication that allows scientists, researchers, and other stakeholders to discuss protocols for plastic ingestion analysis.

This initiative supports our commitment to the 2021–2030 United Nations Decade of Ocean Science for Sustainable Development goals (IOC, 2020), which propose disseminating information on ocean-related issues to guarantee a clean, transparent, and accessible ocean for future generations. Also, the Decade on Ecosystem Restoration aims to prevent, halt, and reverse the degradation of ecosystems on every continent and in every ocean (ONU, 2019). To achieve these purposes, it is required a solid information base fed by long-term observations.

2. Methods

2.1. Data sources

The GLOVE platform aggregates a set of research studies on plastic ingestion available on Google Scholar (GS). To build the dataset, we searched the literature of GS using the following keywords terms: “debris ingestion” and “plastic ingestion” with the Boolean operator “or”. Then, we filtered records of plastic ingestion involving marine (i.e., estuarine, coastal, and oceanic), freshwater, and terrestrial species published in peer-reviewed journals and books in English. When articles from other languages (e.g., Portuguese, Dutch, and Spanish) were retrieved in the search, they were included.

The scientific names were reviewed to eliminate possible synonyms and the scientific nomenclature (family, genus, and species) was aligned with the current specific taxonomic databases, FishBase – www.fishbase.org/search.php, AviBase – www.avibase.bsc-eoc.org/avibase.jsp, ASM Mammal Diversity Database – www.mammaldiversity.org/, The Reptile Database – www.reptile-database.org/, and the World Register of Marine Species: WoRMS – www.marinespecies.org/.

2.2. GLOVE and the Shiny app

The GLOVE platform is digitized in R as an object of the class data frame. R is one of the most widespread statistical, collaborative, and open-access software (www.r-project.org/). A web-based dashboard application was devised to permit: (1) the presentation of GLOVE and the participation of additional users and contributors; (2) spatial and temporal visualization of the information available in the GLOVE platform, and (3) the selection of user-defined subsets of data and related scientific publications.

The GLOVE web-based application was developed using Shiny (Chang, 2015), an R package designed to build interactive web apps directly from the R platform. Shiny allows the development of user-friendly interfaces linked directly to statistical functions and routines in the R environment, so that non-expert R users can easily obtain complex plots or tables without the need for coding. The principal goals of the Shiny application for GLOVE are to promote data sharing and support the user in the quantification of species' plastic ingestion.

2.3. Data descriptors

To be included in this platform, only papers, books, or chapters were required, and they should have satisfied the following prerequisites:

- Reporting specifically on plastic ingestion by wild animals;
- Published or posted online prior to December 2020;
- All languages were considered;

Papers were not included when:

- Presented data on external interactions, i.e., with the fish gills or skin;

- They are review and preprint papers, abstracts, and other types of gray literature;
- Reported on experimental trials on plastic ingestion.

As the GLOVE dashboard database is a recent tool, the studies included on the platform were published or posted online until December 2020 to start the structuring of the platform, data extraction, and data curation, as well the interpretation of data and writing of this manuscript throughout the years 2021 and 2022. Nevertheless, our trained research team will be working to update the platform continuously.

To include and organize the studies on GLOVE platform, two different researchers carried out the search on GS. Then, a dataset was available to a trained team of four researchers who so far are the only ones responsible for feeding the platform. They did a systematic review of this dataset that was debugged, and duplicates were eliminated before including on the platform. To determine the use of an article or a book, descriptions like wild or farm organisms, or experimental studies in the title, abstract, or methods were used as an exclusion criterion. So, each study was read individually to extract the information manually from methods and results. This information was organized in an excel sheet to submit to the GLOVE dashboard database.

The following categories were retrieved from each publication (Table 1). In addition, a full table with all descriptors used in the study can be found in the Supplementary material (Table S1).

Overall, these descriptors were grouped as described below and in the Fig. 1.

- [1] Information on the biological group – Taxonomic details, integrated using the “taxize” package in the R environment (Chamberlain et al., 2017), and body size.
- [2] Information on the sampling procedures – Methods and geographic information (location and time). When the geographic coordinates were not available or assessed in the study, the latitude (1) and longitude (1) were estimated (Table 1), and remarks were inserted on the OBS column.
- [3] Information on the results – The characteristics and quantity of the plastic debris. When possible, plastic debris were classified according to GESAMP (2019): MiP - microplastics (<5 mm), MeP - mesoplastics (5–25 mm), or MaP - macroplastics (>25 mm–1 m) as well as shape and color categories. In addition, we calculated the total number of items identified per each study and/or the frequency of occurrence, when the number of individuals that ingested plastics and the total number of individuals analysed was provided by the authors. In these cases, remarks were inserted on the OBS column such as “Total items of plastic debris overestimated” if other types of litter were included (e.g., fisheries items). “Total items of plastic debris underestimated” was used when other categories of non-plastic litter were excluded (e.g., miscellaneous items). In addition, the frequency of occurrence (FO% PD – plastic debris) descriptor might be a little different from the original study due to data inclusion or exclusion of non-plastic litter. Then, remarks are also included in the OBS column. Finally, when any kind of data was not available or assessed in the studies, the descriptor was noted as “NA”.

3. Results and discussion

Here we outline the dashboard database visualization presenting the panels of GLOVE dashboard database and a brief introduction to the website. In addition, the main outcomes are described regarding all biological groups and features of plastics ingested.

3.1. Dashboard database visualization

GLOVE platform supports different modes of interactive use via the

Table 1

Table summarization listing all descriptors used in the GLOVE dashboard database. Here, you can check the structure and definitions used based on GESAMP (2019). The fully table are available in the Supplementary material (Table S1).

Categories	Description	Class	Units	Required
REFERENCE	Reference	Character	–	Yes
DOI/ISSN	DOI/ISSN of the publication. If not available/assessed = NA	Character	–	Yes
CODE CITATION	Code Citation of the references inserted on the base	Numeric	MPB00000	Yes
YEAR	Publication year	Numeric	–	Yes
ECOSYSTEM, HABITAT, COUNTRY	Place and/or area where samples were collected. If not available/assessed = NA	Character	–	No
BIOLOGICAL GROUP	Biological group of the organisms analysed	Character	–	Yes
MEAN SIZE	Mean size of organisms that ingested plastic or did not ingest plastic. If not available/assessed = NA	Numeric	µm, mm, cm, m	No
UIS	Individual size unit. If not available/assessed = NA	Character	µm, mm, cm, m	No
ML	Measuring length of organisms that ingested plastic or did not ingest plastic. If not available/assessed = NA. It includes beak length, body length, carapace length, carapace width, cephalothorax length, curved carapace length, discs length, fork length, Full length, larval length, lower jaw fork length, lower jaw fork length, nearest centimeter, pedal disc diameter, shell diameter, and others	Character	–	No
SIZE VARIANCE	Size variance of organisms that ingested plastic or did not ingest plastic. If not available/assessed = NA	Numeric	MAD, SD, SE	No
VARIANCE UNIT	Individual size unit. If not available/assessed = NA	Character	MAD, SD, SE	No
MAX AND MIN IND LENGTH	Minimum and maximum individual length of organisms that ingested plastic or did not ingest plastic. If not available/assessed = NA	Numeric	µm, mm, cm, m	No
	Starting and final month of sampling.	Character	–	No

(continued on next page)

Table 1 (continued)

Categories	Description	Class	Units	Required
STARTING AND FINAL MONTH	If not available/assessed = NA			
STARTING AND FINAL YEAR	Starting and final year of sampling. If not available/assessed = NA	Character	–	No
SAMPLING FREQUENCY	Sampling frequency. If not available/assessed = NA. It can present a combination of one, two or more periods. So, it includes daily, weekly, biweekly, monthly, annually, occasionally, and seasonally	Character	–	No
SAMPLING METHOD	Sampling method refers to the way the plastic debris were sampled. It can present a combination of one, two, or more ways. It includes the visualization of bolus and/or feces, lavage, necropsy, dissection, body, radiography, regurgitation, direct observation of feeding, and others	Character	–	Yes
ORGAN CONTENT	Type of organ analysed. If not available/assessed = NA. Abbreviations: GIT = gastrointestinal tract; Proventriculus = gizzard for birds; Proventriculus/Gizzard + Ventriculus = stomach for birds. Gut might be Stomach + Intestine for fish. Tissue = all body of invertebrates. Data from bolus, faces and others not included in this column.	Numeric	–	No
NUMBER OF SAMPLING UNITS	Total amount of sampling unit studied related to bolus, feces, organs, and others	Numeric	–	Yes
NUMBER OF ORGANISMS	Total amount of organisms analysed. If not available/assessed = NA	Numeric	–	No
TOTAL MiP, MeP, AND MaP	Total amount of MiP (microplastics < 5 mm), MeP (mesoplastics 5 mm–25 mm), and MaP (macroplastics > 25 mm–1 m) found in the sampling units. If not available/assessed = NA. Size	Numeric	–	No

Table 1 (continued)

Categories	Description	Class	Units	Required
TOTAL PD	classification according to GESAMP (2019) Total amount of plastic debris. If not available/assessed = NA. The TOTAL PD might be different from original data published due to inclusion or exclusion of other marine litter types (e.g., metal, wood). When it occurs, remarks like “Total items of plastic debris overestimated” or “Total items of plastic debris underestimated” is described on OBS column	Numeric	–	No
FO% PD	The FO% plastic debris (PD) can be different from original due to data inclusion or exclusion of other types of marine litter (e.g., metal, wood). This column includes FO% of all organisms analysed or organisms that ingested plastic debris according to the study. Remarks in the OBS column like “FO% plastic debris overestimated” and “FO% plastic debris underestimated”. $FO\% = Ni/N \times 100$. FO% = frequency of occurrence of plastic debris. Ni = number of sampling units that contained plastic debris. N = total number of sampling units examined. If not available/assessed = NA.	Numeric	–	No
NF% PD	NF% plastic debris. Numeric frequency $NF\% = Na / N \times 100$. NF% = numeric frequency of plastic debris. Na = number of plastic debris. N = total number of items. If not available/assessed = NA.	Numeric	–	No
FW% PD	FW% plastic debris. $FW\% = Wa / W \times 100$. FW% = frequency of weight of plastic debris. Wa = weight of plastic debris. W = total	Numeric	–	No

(continued on next page)

Table 1 (continued)

Categories	Description	Class	Units	Required
DEAD	weight of items. If not available/assessed = NA If the animal was found dead or was not survive during the rescue/research. If not available/assessed = NA	Character	–	No
TOTAL FRAGMENTS, PELLETS, AND OTHERS.	Total amount of fragments and others. Some definitions: Fragments; Fibers (including filament, strand, and thread); Pellets (including resin bead and mermaid's tears); Beads (microbeads); Foam (including EPS and PUR); Film (including sheet); and Paint chips. If not available/assessed = NA. Definitions according to GESAMP (2019)	Numeric	–	No
TOTAL OTHER SHAPES	Total amount of other shapes (e.g., straws, packing, fishing nets). If not available/assessed = NA	Numeric	–	No
SHAPE UNIT	Unit used by the authors (i.e., total number, percentage, %FO). If not available/assessed = NA	Numeric	–	No
AVERAGE SIZE PD	Average size of plastic debris. If not available/assessed = NA	Numeric	–	No
MIN AND MAX SIZE PD	Minimum and maximum size of plastic debris. If not available/assessed = NA	Numeric	μm, mm, cm, m	No
SIZE VARIANCE PD AND VARIANCE TYPE	Size variance and variance type of plastic debris. If not available/assessed = NA	Numeric	–	No
SIZE UNIT	Size unit of plastic debris (i.e., μm, cm, mm). If not available/assessed = NA	Character	–	No
AREA PD	Total area of plastic debris. If not available/assessed = NA	Numeric	μm ² , mm ² , cm ² , m ²	No
AREA UNIT	Area unit of plastic debris (i.e., μm ² , cm ² , mm ² , m ²). If not available/assessed = NA	Character	–	No
MASS PD	Total mass of plastic debris in grams. If not available/assessed = NA	Numeric	g	No
VOLUME PD	Total volume of plastic debris in ml	Numeric	ml	No
		Numeric	–	No

Table 1 (continued)

Categories	Description	Class	Units	Required
TOTAL COLOR (BLUE, WHITE AND ETC.).	Total amount of color items. If not available/assessed = NA. It includes blue, white, transparent, gray, black, yellow, brown, orange, colored, and other colors. "Colored" is multicolor items or are a classification used by the authors. "Other colors" refer to silver, tan, red-brown and other unusual colors sorted by the authors. Definitions according to GESAMP (2019)			
COLOR UNIT	Color unit of plastic debris used by the authors (i.e., total number, percentage, %FO). If not available/assessed = NA	Character	–	No
POLYMER (1) to (12)	Type of polymer identified in the samples. If not available/assessed = NA	Character	–	No
POLYMER (1) to (12) ITEMS	Total amount of polymer identified in the samples. If not available/assessed = NA	Numeric	–	No
OTHER POLYMER	Type of polymer not completely identified in the samples. If not available/assessed = NA	Character	–	No
OTHER POLYMER ITEMS	Total amount of polymer in the samples. If not available/assessed = NA	Numeric	–	No
POLYMER UNIT	Polymer unit of plastic debris used by the authors (i.e., total number, percentage, %FO). If not available/assessed = NA	Character	Percentage, number	No
QA/QC PROTOCOL	Yes/No to QA/QC (quality assurance/quality control) protocols applied during the sampling and/or analysing. If not available/assessed = NA	Character	–	No
EXTRACTION METHOD	Extraction method of plastic debris from the sampling units. It can present a combination of one, two or more ways. If not available/assessed = NA. It includes digestion, filtration, density separation, and visual selection	Character	–	No

(continued on next page)

Table 1 (continued)

Categories	Description	Class	Units	Required
POLYMERIC ANALYSIS	Method used for polymer analysis. If not available/assessed = NA. It includes ATR-FTIR, HT-SEC, Melting test, Raman spectroscopy, Micro-FTIR, Bright- and dark-field spectroscopy, density gradient, and others	Character	–	No
OBS	Observation – a remark about the columns LAT and LONG (remark - Geographic coordinate estimated when lat/long unavailable), FO% PD (remark - FO% plastic debris overestimated or FO % plastic debris underestimated when data were calculated adding/ excluding other categories of non-plastic debris), and TOTAL PD (remark - Total items of plastic debris overestimated or Total items of plastic debris underestimated when data were calculated adding/ excluding other categories of non-plastic debris). If not available/assessed = NA	Character	–	No
SPECIES, KINGDOM, PHYLUM, CLASS, SUBCLASS, ORDER, FAMILY, SUBGAMILY, GENUS	Taxonomy rank of the organisms studied. If not available/assessed = NA. To species category if not identified, it was added sp. Or spp. According to the authors	Character	–	No
LAT AND LONG	Latitude and longitude of sampling point. The geographic coordinate was estimated based on the location of the study area when not available. Remarks in the OBS column (Geographic coordinate estimated)	Numeric	Decimal degrees	Yes
ENGLISH COMMON NAME	English common name of the organisms studied. If not available/assessed = NA	Character	–	No
TOTAL P	Total amount of plastics debris identified	Numeric	–	No

website through maps, plots, and tables on the main interface (Fig. 2). For instance, to search a species on this platform:

- Open <https://gloveinitiative.shinyapps.io/Glove/> in a web browser

Then, the web interface is presented and organized in two subpanels as you can see in Fig. 2a. The left subpanel represents the main component of the interface and hosts a dynamic bar showing the principal statistics of the dashboard database and its subsets defined according to the user's inputs through the selection menu (in the right subpanel). The left subpanel also hosts a series of windows displaying: I. **Overview**: a short looped video that presents the GLOVE geo database (Fig. 2a); II. **Map**: a dynamic, fully zoom-capable map showing the distribution of all the items of plastic debris ingested by the species or sample(s) corresponding to the user query (Fig. 2b); III. **Summary plot**: three plots summarizing the colors and percentage composition of the polymers and shapes of plastic ingested in the subsets selected by the user (Fig. 2c); IV. **References**: the list of references (scientific studies) corresponding to the user's selection. A direct link to each paper is provided in the final column of this table (Fig. 2d); V. **About**: used for mentioning the people who lead the project and helped in the creation of the GLOVE; VI. **Helps and Feedback**: email contact for additional help or to submit feedback or bug reports; VII. **License & Terms of use**: a statement that Glove is free software, and everyone can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation.

The interactive menu on the right side allows the user to select different subsets of the GLOVE platform records (Fig. 2a) based on four features: I. **Period** – the time range in years of the desired publications and related data can be defined using a slider bar; II. **Biology** – four picker input boxes allow the user to select the **Biological Group**, **Class**, **Species name**, and **Common name**; III. **Geography** – two picker input boxes allow the user to select the **Habitat/Ecosystem** and **Country**, and IV. **Plastics** – three picker input boxes allow the user to select the **Shape**, **Color**, and **Polymer** of the ingested plastics. Every time the user interacts with one of the widgets in this menu, the Shiny application automatically queries the GLOVE dashboard database and updates all the maps, plots, and tables in the main interface. Finally, the user can also download the complete table of the GLOVE database for the selected query through the **Download** button located in the bottom right of the menu.

4. Overview of the GLOVE data

GLOVE platform resulted from peer-reviewed papers and books published or made available online from the 1980s to the end of 2020. Almost 90 % (467) of the studies inserted in the platform were published in the past ten years, indicating an increasing number of studies during this period (Fig. 3). The data encompasses all five oceans and seven continents (Fig. 4). We examined 530 studies covering all biological groups, including 245,366 individuals representing 1458 species from marine (M) (88.6 %), freshwater (F) (7.9 %), and terrestrial (T) (2.5 %) environments or a combination (C) of them (1 %). Most of the species were fish - 62.8 % (from M – 82.7 %, F – 16.4 %, and C – 0.9 %) and birds - 23.7 % (from M – 89.6 %, F – 1.7 %, T – 0.9 %, and C – 1.7 %), followed by invertebrates, 9.3 % (from M – 89.7 %, F – 9 %, and C – 1.3 %), mammals, 3.7 % (from M – 92.7 %, F – 1.8 %, and F – 5.5 %), and reptiles - 0.5 % (from M – 100 %).

The studies (total number of records) identified were conducted primarily in Europe (23.3 %), and Asia (19 %), followed by South America (14.2 %), North America (13.3 %), Oceania (13.5 %), Africa (2.7 %), Antarctica (0.3 %), and Central America (0.3 %) (Fig. 4). A number of studies were predominantly in wealthier countries, where more scientific infrastructure is available to support research activities on plastic pollution. In this context, low- and middle-income countries are more vulnerable as a result of limited infrastructure which threatens

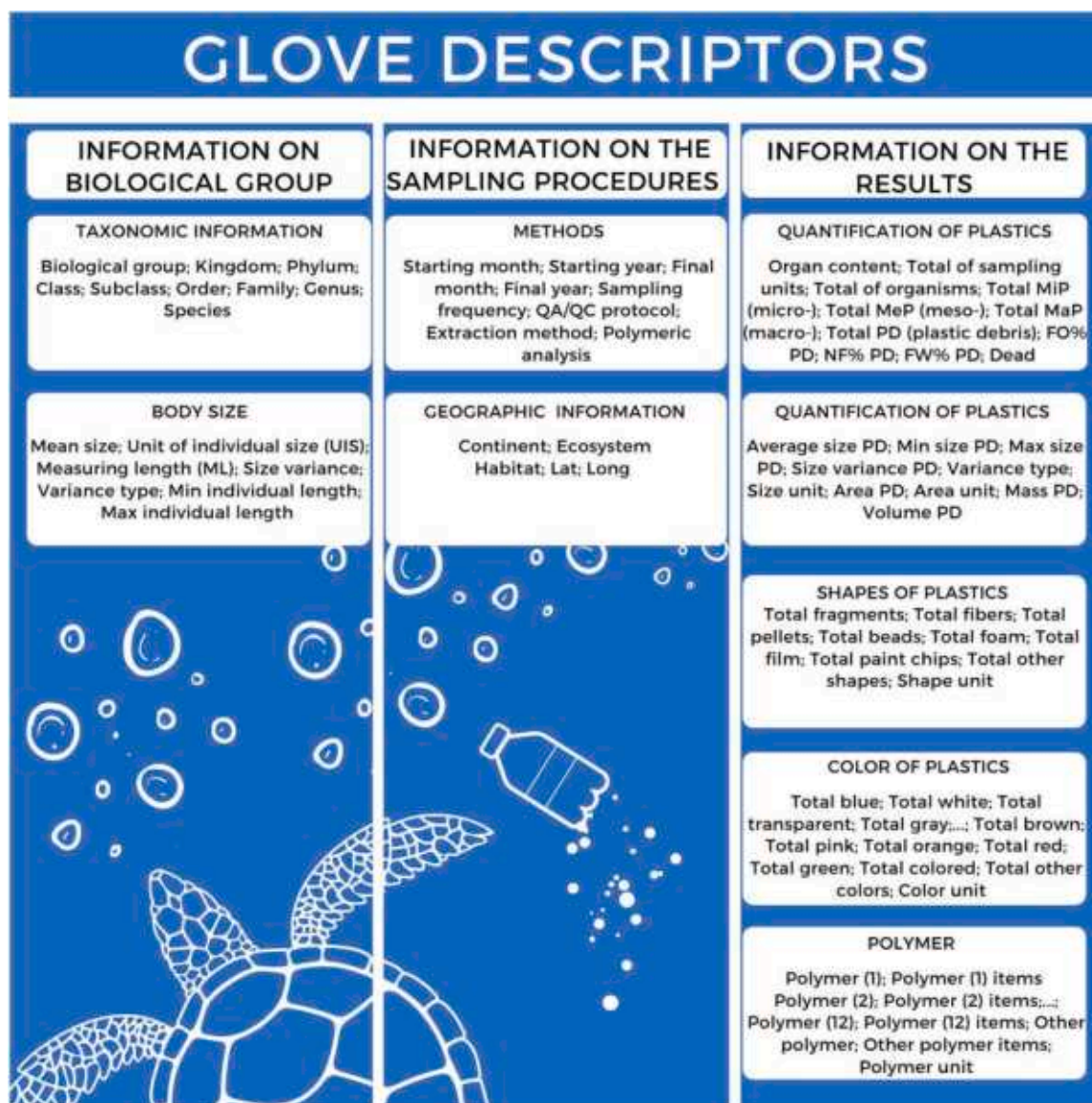


Fig. 1. Diagram showing how the descriptors are divided into three categories in the GLOVE dashboard database. The information on biological group provides taxonomic information, and body size. The information on sampling procedures describes the methods used and provides geographic data where the samples were collected. The information on the results provides quantitative data on plastic ingestion, including the total number of items of MiP (microplastics), MeP (meso-plastics), MaP (macroplastics); the Frequency of Occurrence of the Plastic Debris (FO% PD); the Numeric Frequency of the Plastic Debris (NF% PD), and the Frequency of the Weight of the Plastic Debris (FW% PD); the characteristics of the plastic debris; the shapes of plastic, colors, and the polymer identified in the samples.

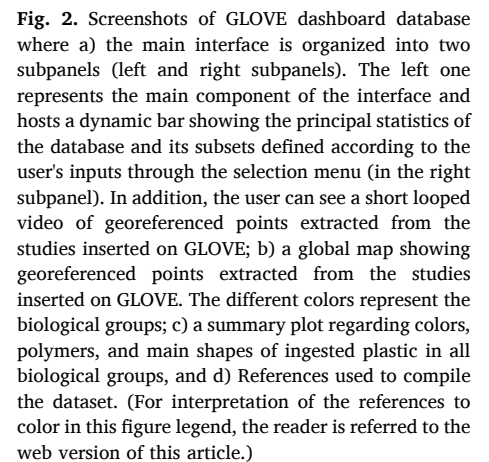
the health of both the environment and their human population, especially in regions where fishery resources, for example, are an indispensable food resource for local communities (e.g., populations in the Amazon region, Brazil – Giarrizzo et al., 2019). Human consumption of animals that have ingested plastic offers the potential to co-transfer hazardous substances (Cox et al., 2019).

The platform includes the report of 164,866 items of plastic debris ingested by varied species. The frequency of occurrence (FO%) of plastic ingestion in all biological groups indicated that fibers were most frequently observed (71 %), followed by fragments (58.2 %), and film and sheet (26.5 %). Other shapes represented <20 % (Fig. 5). Regarding biological groups, fibers are the main shape found in all groups, except for Birds (Fragments – 63 %), and commonly reported to invertebrates (95 %) (Fig. 5). Other shapes like plastic pellets were reported in Birds (39.4 %) and Reptiles (26.7 %) in great proportions, while paint chips (3.3 %) were just reported in Reptiles (Fig. 5).

Generally, fibers are the predominant shapes identified in several organic and inorganic samples. They are becoming a global aquatic

pollutant being found in the atmosphere, bottom sediments, and invertebrates (Mishra et al., 2020). The ingestion of fibers and other shapes of plastic debris can be affected by the color and odor of plastics since they may determine the detectability of an item or the preference of a given species (Santos et al., 2021; Xiong et al., 2019) or due to plastic availability resulting in expected increases in ingestion. On the GLOVE platform, we detected a trend regarding colors in which the predominant ones were blue (61 %), black (58.1 %), and light colors (transparent – 44.3 % and white – 40.3 %) in all biological groups (Fig. 6). A color preference, in this case, is a relevant and accessible drive that may provide interesting insights into plastic ingestion. So, future research should provide more systematic insights into possible patterns of plastic ingestion related to the taxon or geographic area (based on local availability), which may better clarify the role of plastic color in the detection and ingestion of items by organisms with distinct foraging strategies and water column position.

The understanding of the potential drivers of plastic ingestion is crucial to evaluating the risks faced by species (Santos et al., 2021). The



More importantly, to understandably study plastic pollution, it is necessary to standardize procedural methods for future studies on plastic ingestion. This poses a major gap in plastic pollution research in

In the studies added to the platform, several methods were used and applied in accordance with the animal's size. Visual methods (i.e., naked eye or microscope) were commonly used in larger animals (e.g., birds and mammals) while chemical-based extraction or other detail-oriented methods were used in smaller animals, such as small invertebrates and fish. These distinct methods imply plastic debris identification differences regarding their size. It means that visual methods, for instance, are not suitable to identify small particles, especially items smaller than 1 mm (Hidalgo-Ruz et al., 2012), and therefore, the total loads of plastic identified in larger animals might be underestimated since smaller items might have been lost. This could result in biased trends in and amongst all biological groups. Thus, the combination of different methods, i.e., chemical digestion, flotation, and polymer techniques may improve the

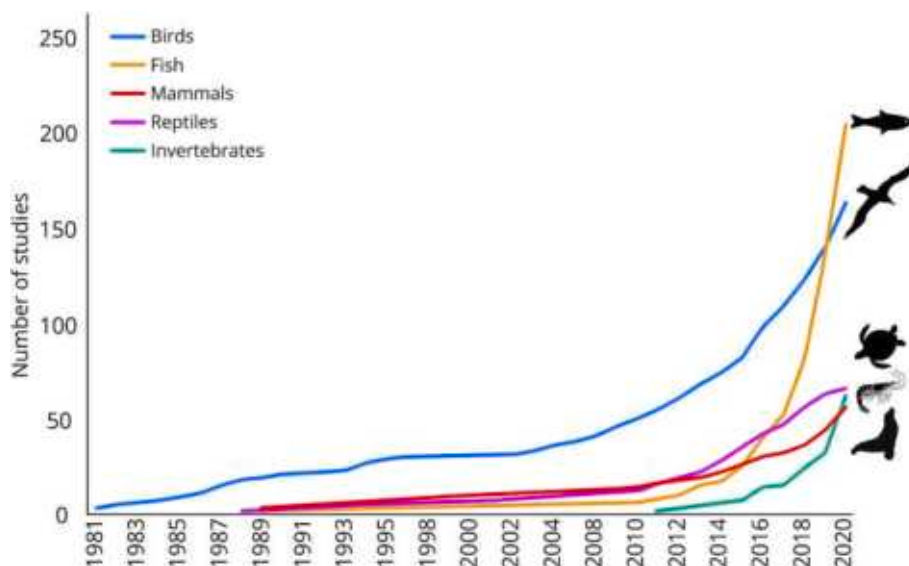


Fig. 3. Timeline of the publication of the reports of the ingestion of plastic debris by the species of the different biological groups. These include all the known records of plastic ingestion in marine, freshwater, and terrestrial wildlife. Data showed for birds, fish, mammals, reptiles, and invertebrates.

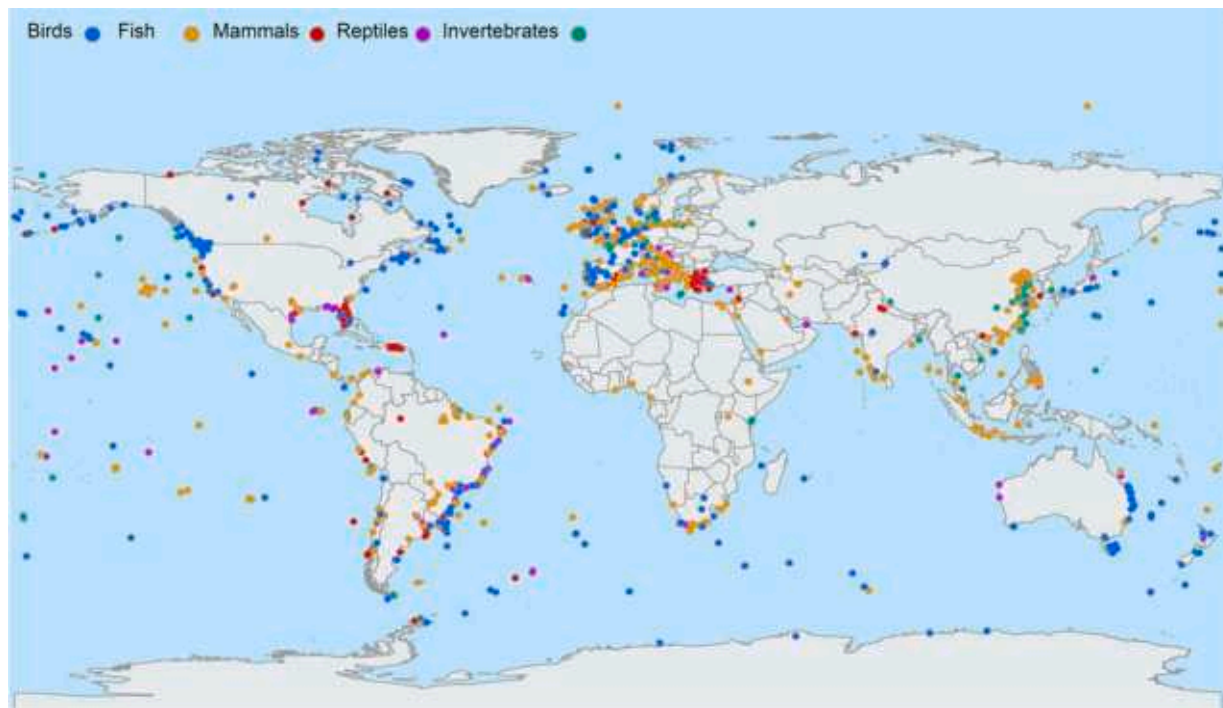


Fig. 4. Global distribution of the plastic ingestion records ($n = 6155$) by marine, freshwater, and terrestrial wildlife. Data are showed for birds, fish, mammals, reptiles, and invertebrates.

extraction and identification of small-sized items.

Considering the polymer composition, it was similar in and amongst biological groups, especially to Polyethylene (PE), Polyamide (PA), and Polypropylene (PP) (Fig. 7). Overall, these polymers are the most produced on a large scale as follow: 118 million tonnes of high- and low-density PE, 68 million tonnes of PP, and 59 million tonnes of PA, including other polymer fibers (Geyer et al., 2017). To identify these and other polymers, spectroscopic methods (28.1 % - $N = 530$) (i.e., ATR-FTIR, Micro-Raman, and NIR-FTIR) were used more frequently than gas chromatography-mass spectroscopy (0.2 %) or fluorescent microscopy (0.2 %) in the identification of ingested polymers. This might be pertinent and applicable to determine potential toxic substances

intrinsically contained in plastic polymers during their production e. g. plasticizers, flame retardants, pigments, and antimicrobial agent as triclosan, many of them well-known endocrine disrupters, and carcinogenic (Lithner et al., 2011). Despite this, only around a third of the studies added to the GLOVE platform applied some method of polymeric analysis (Fig. 7).

5. The future

Many improvements are planned for the GLOVE dashboard and its database in the near future. We hope the platform could be connected to other databases (e.g., FishBase - <https://www.fishbase.se>, SeaLifeBase -

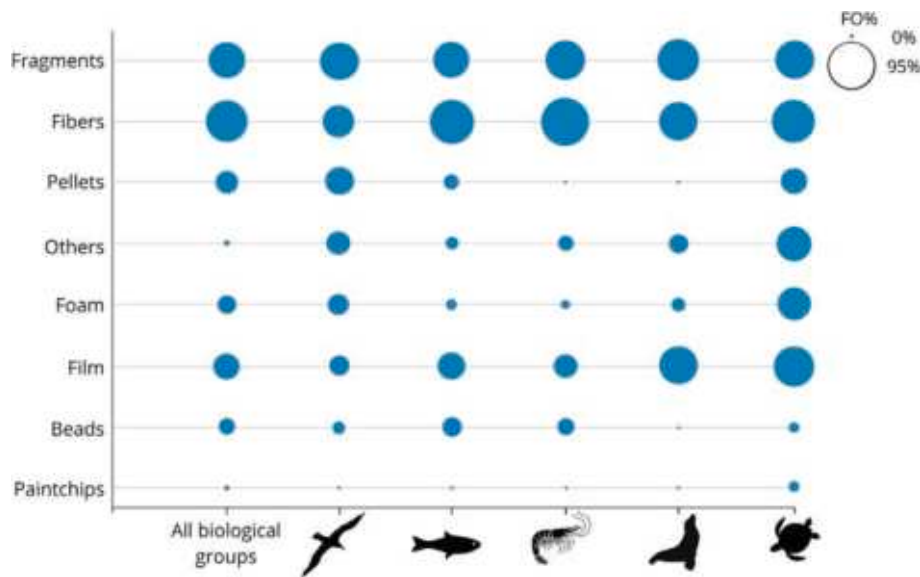


Fig. 5. Prevalence of plastic shapes ingested by wildlife. The frequency occurrence (FO%) was calculated from all known records of plastic ingestion in marine, freshwater, and terrestrial wildlife retrieved from the revised publications. Data are showed for all biological groups, birds, fish, invertebrates, mammals, and reptiles.

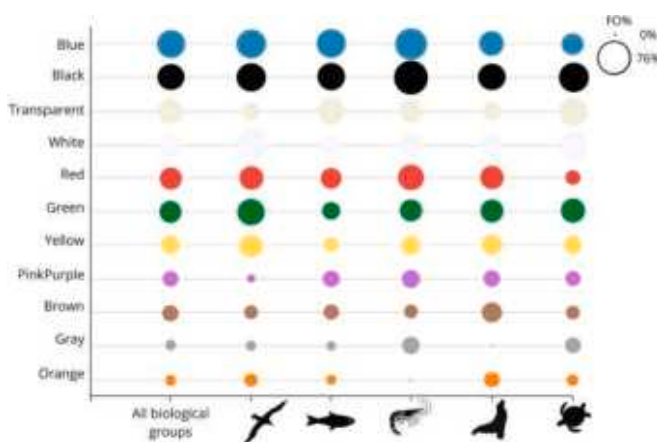


Fig. 6. Prevalence of plastic shapes ingested by wildlife. The frequency occurrence (FO%) was calculated from all known records of plastic ingestion by marine, freshwater, and terrestrial wildlife retrieved from revised publications. Data are showed for all biological groups, birds, fish, invertebrates, mammals, and reptiles. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

<https://www.sealifebase.ca/>, and the NCEI Marine Microplastics - <https://www.ncei.noaa.gov/products/microplastics>) to improve the quality and integration of data, as well as being a communication channel to facilitate an inclusive network around the standardization of methods.

Currently, the platform is fed just by our trained team, but we are planning to develop new ways to submit studies where researchers can send their results to be included and consequently feed the GLOVE dashboard database. This solution can also speed up new data entry and simultaneously support more collaborations and integration amongst the scientific community. For now, it is intended that the database be updated monthly to keep the platform up to date.

6. Conclusions

The lack of access to plastic ingestion data is problematic for many scientists, conservation managers, decision-makers, the general public,

and local communities since they need good information to aid in the development of strategies, decisions, or processes to protect their habitats, ecosystem, and species. Nowadays, data from articles or reports are ordinarily not available and are written in technical terms becoming a barrier for those who need information as a basis for conservation. In addition, the exponential number of publications can generate a loss of information due to the lack of a reference source to find these studies. Thus, the GLOVE dashboard database facilitates efficient workflow by providing open-access information on plastic ingestion and sharing information from published data on articles and books about plastic ingestion by a range of diverse species from several environments of the world. Also, it provides an ample range of possibilities of using and applications to be a support tool for science, industry, conservation, education, management, culture, and environmental assessment as follows: to identify geographic, species, and thematic gaps; to synthesize information in species or biological groups; and to develop best practices and methods in plastic ingestion. To decision-makers – to identify species and gaps locally; and to find technical guidance to support initiatives through published studies.

The benefits of GLOVE platform are directed to environmental and social issues since, for instance, monitoring programs could be created to analyse species used for human consumption and/or those species of economic relevance and conservations programs for endemic species and animals listed on the IUCN Red List of Threatened Species. Thus, environmental projects on preventing and mitigating plastic pollution incidence and effects on biota could be better design, mainly those for specific taxa or geographic region. Regarding third-sector entities, they can produce strategic awareness campaigns and alliances in the conduction of social and environmental projects.

Our product is freely accessible allowing users to select data according to biology (e.g., biological group and species, environments), spatial (e.g., country), and plastics (e.g., polymer and shape) information. The user can make comparatives analysis amongst biological groups, species, geographic location, and plastic features. After being selected, the user can download the data free of charge in CSV format without registration thus facilitating the access to information. GLOVE dashboard database must be cited whenever any data is downloaded and used in studies, reports, and any media, as well as the references used on the platform.

Overall, this initiative aims to strengthen approaches to tackle and

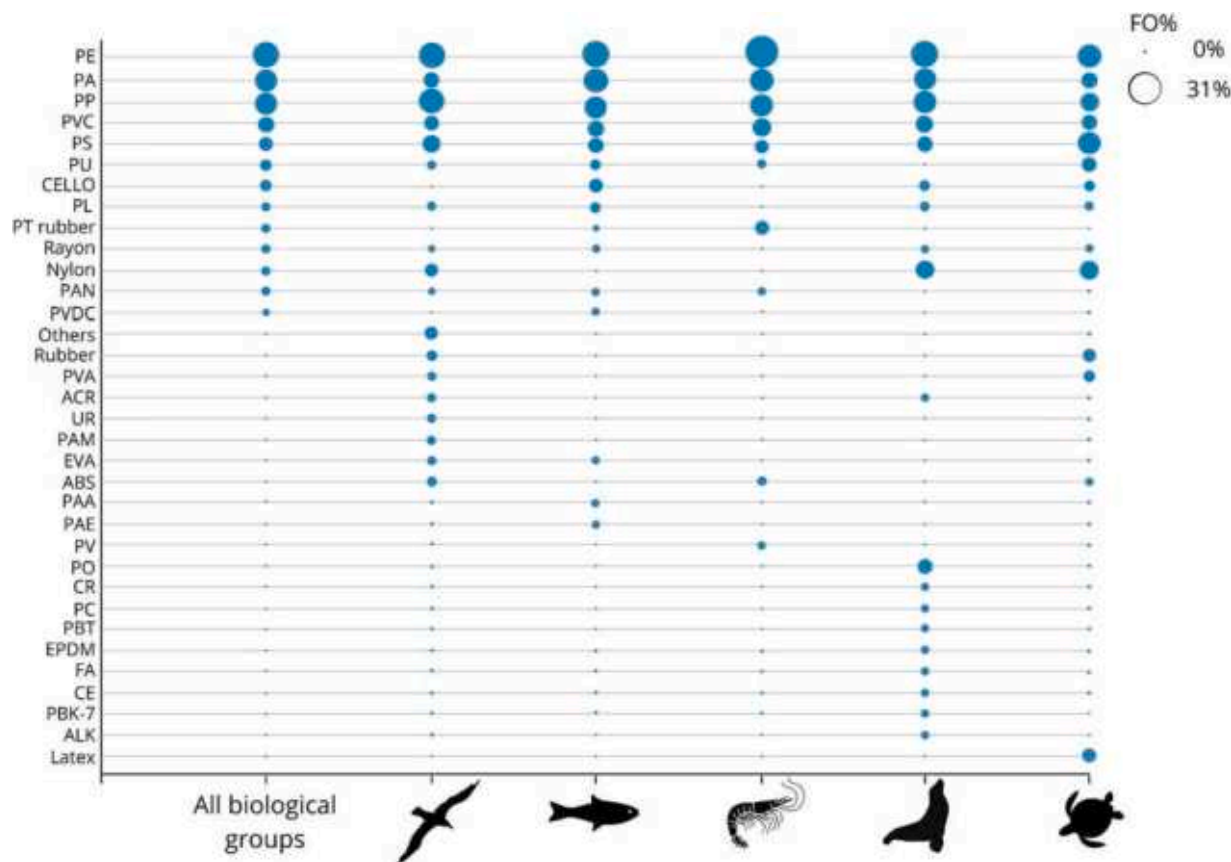


Fig. 7. Prevalence of plastic of different polymers. The frequency occurrence (FO%) was calculated from all the known records of plastic ingestion in marine, freshwater, and terrestrial wildlife retrieved from the publications identified in the literature search. Polymer abbreviation: Polyethylene – PE, Polyamide – PA, Polypropylene – PP, Polyvinyl chloride – PVC, Polystyrene – PS, Polyurethane – PU, Cellophane – CELLO, Polyester – PL, Polyterpene rubber – PT rubber, Polyacrylonitrile – PAN, Polyvinylidene chloride – PVDC, Polyvinyl acetate – PVA, Acrylic – ACR, Urethane – UR, Polyacrylamide – PAM, Ethylene vinyl acetate – EVA, Acrylonitrile butadiene styrene – ABS, Polyarylamide – PAA, Poly(aryl ether) – PAE, Polyvinyl – PV, Polyolefin – PO, Polychloroprene – CR, Polycarbonate – PC, Polybutylene terephthalate – PBT, Poly(ethylene propylene diene) – EPDM, Formaldehyde – FA, Cellulose – CE, Carbon black – PBK-7, Alkyd resin – ALK. Data are showed for all biological groups, birds, fish, invertebrates, mammals, and reptiles.

prevent plastic pollution, in line with Sustainable Development Goal (SDG) 14 *Life below water* as per its target 14.1 *Reduce Marine Pollution*: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. Moreover, SDGs 6 *Clean Water and Sanitation*, 11 *Sustainable Cities and Communities*, and 12 *Responsible Consumption and Production* are relevant to marine litter prevention. They are connected to the Ocean Decade (IOC, 2020) and the Decade on Ecosystem Restoration (ONU, 2019). Both Decades are focused to promote the transformation of thinking, attitudes, and policies for the implementation of all SDGs. Amongst their outcomes, they purpose to restore degraded areas, including the ocean, to improve habitat for wildlife (Claudet et al., 2020).

Moreover, the latest resolution approved by UNEP to create a global plastic pollution agreement by 2024 certifies the urgency of dealing with this problem at a global level (UNEP, 2022). We need global agreements to combat plastic pollution that give possibilities to governments and society, mainly from developing countries, to work under their conditions (e.g., lack of data on waste generation or few resources for waste management). We emphasize the urgency of these blue new deals (Armstrong, 2022) and science diplomacy to prevent and protect our societies and biodiversity from collapsing over the next few years (Polejack, 2021). The GLOVE dashboard database and its team are committed to enhancing the visibility and understanding of the data on plastic ingestion by wildlife to the benefit of all the sectors interested in solving the plastic pollution crisis.

Finally, we expect that this platform could influence the current research directions motivating new ways of plastic pollution research because, as we can see, the challenges are global on the Earth. Then, we need to face them through global networks using innovative tools and supporting data transparency and accessibility.

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.marpolbul.2022.114244>.

CRediT authorship contribution statement

TG conceived the principal and led all stages of the research project. RM, TP, LM and M compiled the data. TR and AS checked the data quality. TR and EN constructed the Shiny App. RM and RA led the writing of the manuscript, and all the other authors contributed to the writing and approved the final version.

Declaration of competing interest

The authors 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

The data used in this study are available at <https://gloveinitiative.shinyapps.io/Glove/>

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Baseline



Plastic nests: The first record of the Yellow-rumped Cacique (*Cacicus cela*) and the Great Kiskadee (*Pitangus sulphuratus*) building nests with discarded fishing material on the Amazon Coast

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ABSTRACT

The Amazonian coastal ecosystems face a significant threat from plastic contamination, posing a major risk to their biodiversity. Here, we provide the first evidence of using plastics in nest building by Yellow-cacique Cacique (*Cacicus cela*) and Greater Kiskadee (*Pitangus sulphuratus*). During 2023 and 2024, 15 nests built with ropes and fishing lines were recorded in the Brazilian Amazon Coast, a colony of 12 nests in the State of Amapá and one nest in Pará for *C. cela*, and one nest for *P. sulphuratus* was observed in Maranhão during the fieldwork, covering all Brazilian Amazon Coast. These nests were observed on the edge of mangroves, built with solid waste from fishing activities, pointing out how environmental pollution can be incorporated into wildlife this issue. Our records emphasize the effect of plastic pollution on two passerine species associated with mangrove forests and the need for conservation measures and further research.

The Amazonian marine, coastal, and estuarine habitats are very productive and diverse, supporting the hotspots for biodiversity, such as mangroves (Miloslavich et al., 2011). Anthropogenic pressures like overfishing, ocean acidification, altered land use, and pollution—including plastic waste—are negatively impacting these hotspots (Häder et al., 2020) and the traditional communities along the Amazon coast who depend on these environments for food, their subsistence, and income generation (Watson et al., 2018). Plastics and microplastics are being identified in different sample arrays from several reservoirs, including biota in the Amazon (Morais et al., 2024). However, plastic pollution studies in the area are still scarce, although it is essential to preserve the biological diversity of the area and its people (Giarrizzo et al., 2019; Morais et al., 2024).

Papers on the relationship between plastics and biota date back to the 1960s (Thompson et al., 2009). The main focus of these studies is plastic ingestion, entanglement (Thompson et al., 2009), and, more recently, about using plastic in nests (Blettler and Mitchell, 2021;

Miloslavich et al., 2011). Hundreds of interactions between plastic and coastal and marine biota have been observed (Flemming et al., 2022; Kühn et al., 2015; Kühn and van Franeker, 2020; Monteiro et al., 2022). Plastic ingestion has been documented extensively globally and is known to cause negative effects on the digestive system. Plastics may lead to issues like blockages and ulcers or induce a deceptive sense of fullness (Kühn and van Franeker, 2020). Other interactions include the use of plastic as nesting material for birds (Battisti et al., 2019; Blettler and Mitchell, 2021), including studies in Brazil (Azevedo-Santos et al., 2022). This use can be harmful to species at the individual or ecosystem level since “decorated” nests (i.e., the presence of plastic in nests) could be more susceptible to predation when compared to undecorated nests (Mansfield et al., 2024). Also, studies have shown that adults and chicks are entangled in plastics used to build nests (Antczak et al., 2010; Blettler and Mitchell, 2021; Bond et al., 2012).

Birds, especially seabirds, are the most biological group studied regarding interactions with macro- and microplastic, such as ingestion

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and entanglement (Kühn and van Franeker, 2020; Monteiro et al., 2022). Therefore, few studies have been focused on plastics and birds in freshwater and terrestrial habitats (Blettler and Mitchell, 2021). In the Amazonian region, records of interactions between plastic and biota are focused on the ingestion of plastic particles by fish and invertebrates (Andrade et al., 2019; Morais et al., 2024, 2020; Pegado et al., 2018) which, up to 2023, were the only groups that have observed interactions with plastic (Morais et al., 2024). Recently, plastic incorporation into bird nests was observed by (Lopes et al., 2024). We do not know which, how many, where, and how the Amazonian species interact with plastic, including macro and microplastics, from different reservoirs. The Amazon region is a hotspot for biodiversity, and plastic pollution is increasing worldwide and probably affecting biodiversity, including the Amazonian species. Here, we present, for the first time in the world, plastic nests observed for the Yellow-rumped Cacique (*Cacicus cela*) and the Great Kiskadee (*Pitangus sulphuratus*), which were observed in three Amazonian states covering all of the Amazon Coast of Brazil (Fig. 1).

The Yellow-rumped Cacique (called *japiim* or *xexéu* in Brazil) and the Great Kiskadee (called *bem-te-vi* in Brazil) are birds of the families Icteridae and Tyrannidae, respectively, order Passeriformes (Bernardon and Nassar, 2012). As omnivorous birds, their primary food sources are fruits and seeds (Latino and Beltzer, 1999; Robinson, 1986). The Yellow-rumped Cacique reproduces in colonies, and the females build pendulous bag-shaped nests made of grass, twigs, and leaves in 19.8 ± 8.3 days (Mobley, 2008). Nests may have an average length of ~ 40 cm and are

~ 3.5 m or more above the ground (Silva and Campos, 2011). Colony nests are formed, usually in low trees near bodies of water (Robinson, 1986; Silva and Campos, 2011), and they may be composed of 2 to 250 nests in the Peruvian Amazon (Robinson, 1985) and of 8 to 687 nests in the Brazilian Amazon (Silva and Campos, 2011), as observed in previous studies. Conversely, both sexes of the Great Kiskadee build a sizable nest with a side entrance and a dome (Llambías and Ferretti, 2003). Nests comprise grasses, leaves, and feathers and have an average size of ~ 19 cm (Nascimento et al., 2007). In addition to using organic material in nest-building, we also observed plastic material in nests built by these two species during expeditions on the Amazon Coast, in protected and unprotected areas, and in plastic pollution projects. All the 15 nests observed in both species' nests were visually composed of plastic lines, grass, leaves, fishing lines, and ropes in different quantities, which could be observed in the three states from the Brazilian Amazon Coast (Amapá, Pará, and Maranhão) (Fig. 1).

The first plastic nest was observed on May 9, 2023, at the Maracá-Jipioca (ESEC Maracá-Jipioca), a protected area in Amapá State ($2^{\circ}00'00''$ N $50^{\circ}25'00''$ W). We observed a Yellow-rumped Cacique nest made of natural plant fibers that some fishing ropes were incorporated into the nest (Fig. 2A). Outside the Maracá-Jipioca, the subsequent year, on April 11, 2024, a colony composed of 12 nests of the same species was observed on Goiabal beach in Calçoene ($2^{\circ}35'58''$ N $50^{\circ}50'47''$ W), Amapá State (Fig. 2B and C). Two empty and abandoned nests from this identified colony were transported to the lab in Amapá State, where they

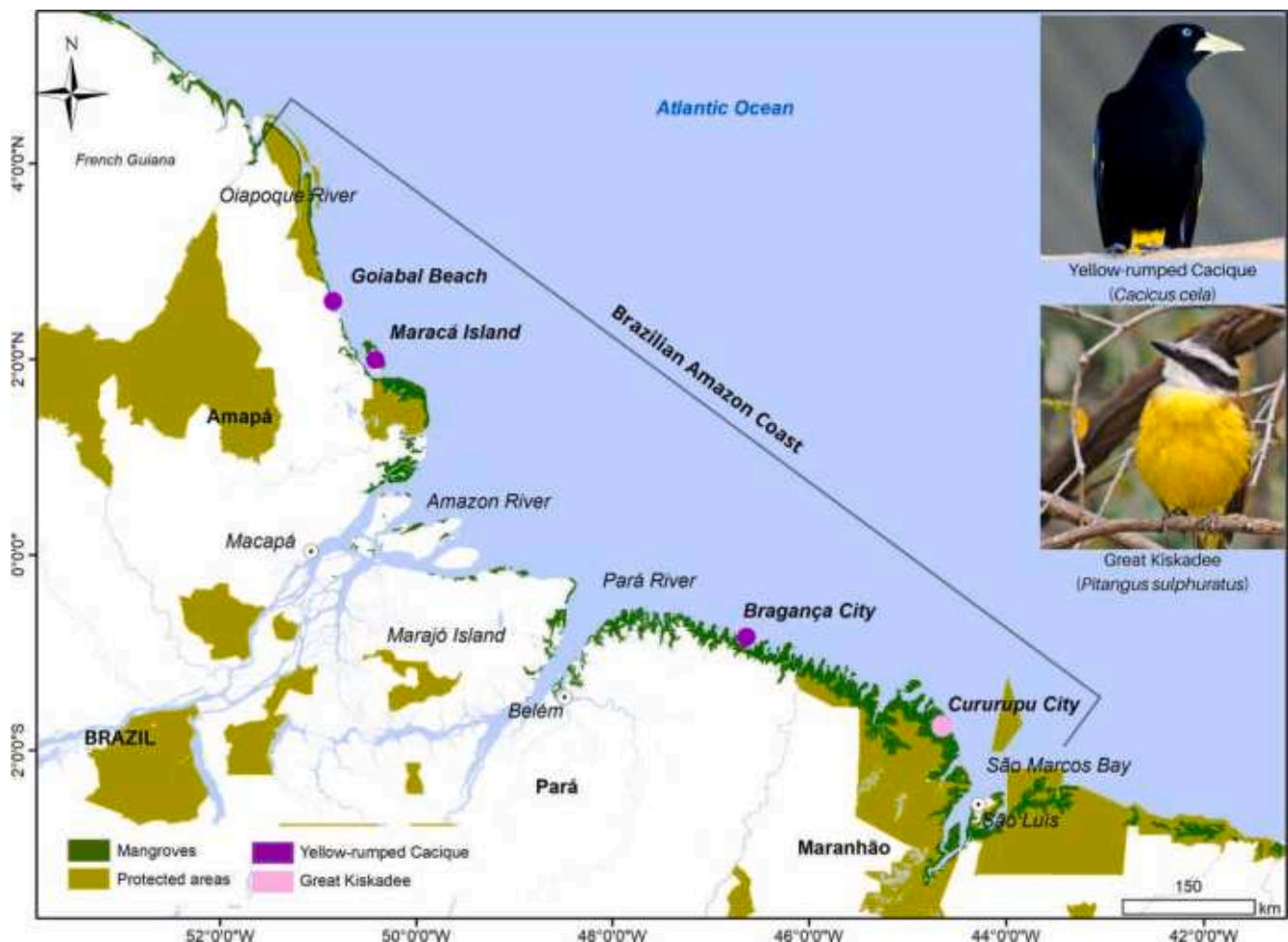


Fig. 1. Location of plastic nests ($N = 15$) found on the Brazilian Amazon Coast in protected (3) and unprotected (1) areas. Nests of Yellow-rumped Cacique *Cacicus cela* were observed in Goiabal Beach - Calçoene City (Colony of 12 nests), Maracá Island - ESEC Maracá-Jipioca, Amapá City (1 nest), and Furo do Chato - Bragança City (1 nest) state inside the Caeté-Taperaçu Marine Extractive Reserve. A nest of Great Kiskadee *Pitangus sulphuratus* was found in Cururupu Extractive Reserve, Cururupu City (1 nest).



Fig. 2. Nests of Yellow-rumped Cacique *Cacicus cela* (A, B, C, and D) and Great Kiskadee *Pitangus sulphuratus* (E and F) in the Brazilian Amazon Coast. A) Nest in the Maracá-Jipioca Ecological Station (ESEC Maracá-Jipioca), Amapá state; B) nest colony, 12 nests, on the Goiabal beach, Amapá state; C) abandoned nest made of fishing lines on the Goiabal beach, Amapá state; D) nest observed near a tidal channel in the Furo do Chato, Bragança city, Pará state; E) frontal view of a nest found in the Cururupu Extractive Reserve, Maranhão State; and F) enlarged side view with details of the material used to build the nest where you can see grass, white plastic threads and blue nylon threads. Image credits: A - Emarielle Pardal; B - Raqueline Monteiro, C - José Pantoja “Chicão”; D - Renata Padovan, and E/F - Marcelo Andrade.

were reserved until their liberation by the Brazilian Environmental Council (Fig. 2C). In Pará and Maranhão States, nests of Yellow-rumped Cacique and Great Kiskadee were observed in protected areas. In Pará State, on 20 June 2023, another abandoned nest of the Yellow-rumped Cacique was observed at Furo do Café (0°50'20" S 46°38'34" W) in Bragança city, Pará state inside the Caeté-Taperaçu Marine Extractive Reserve (Fig. 2D). The Great Kiskadee nest was recorded in the Cururupu Extractive Reserve (1°43'16" S 44°39'20" W), Maranhão State (Fig. 2E and F). The nests found in the three states mainly comprised grass, white plastic threads, fishing lines, and blue nylon rope strands commonly used in fishing activities.

Different potential sources of plastic may be cited in these areas, including tourism and fishing in coastal areas, except for protected areas, since these anthropogenic activities are generally prohibited in protected areas in Brazil (Brasil, 2000). Other potential sources may be related to the transport of plastic and microplastics by oceanographic

conditions, mainly the winds, waves, and tides (Lorenzi et al., 2020). Plastics from fisheries at sea are occasionally lost, abandoned, or discarded by fishing boats on the coast and continental shelf, and they become available to organisms on mangrove edges and beaches. For instance, during our fieldwork on Goiabal Beach, many fishing items were available on the beach on the strandline, i.e., plant debris from nearby forests and other aquatic plants carried by the tides were deposited on the strandline (Fig. S1a and b). These differences in plastic sources and their high or low availability may influence the use of plastics to construct birds' nests in terrestrial and freshwater environments, as observed by Mansfield et al. (2024). Additionally, these fishing items can cause injuries to biota still at sea or when they arrive at the coastline, resulting in the phenomena known as “ghost fishing” (Matsuoka et al., 2005).

In Brazil, records of plastic incorporation in nests are recorded in continental and marine environments. However, these interactions are

poorly understood and studied (Azevedo-Santos et al., 2022; Daudt et al., 2023). Brazil has approximately 20 % of global avifauna (Gill et al., 2021; Pacheco et al., 2021) occupying all Brazilian biomes (Daudt et al., 2023), including 8500 km of coastline from the Northern Hemisphere 4° to 34° in South Latitude, covering different natural ecosystems such as mangroves, coral reefs, and salt marshes (Fernandez et al., 2019). Regarding geographical location, in Brazil, plastic interaction studies on estuarine or mangrove habitats represent only 10 % (of 87 documents) of scientific articles or gray literature published up to December 2021 (Daudt et al., 2023). Pará State (part of the Amazon Coast) has only one record of birds (Lopes et al., 2024).

Future studies should examine whether the Yellow-rumped Cacique or the Great Kiskadee uses the most synthetic or natural resources available in the ecosystem or whether they prefer plastic materials. This will help to fully understand how the presence of plastic may impact these species' reproductive and ecology. These studies ought to consider any potential sources of plastic in the vicinity of the nesting colonies. Nonetheless, given that the composition, distribution patterns, and dangers to the avifauna are still known, it is imperative to conduct surveys and investigations over the entire Amazon Coast (Rodrigues, 2007), considering all species along the region. For instance, to identify how it might affect different species with different types of nests from various ecosystems, such as beaches, estuaries, and mangrove areas. In addition, more studies are needed to know how often entanglement occurs, resulting in the injury or death of individuals, including adults and chicks.

Even though the Amazon is valued for its social, cultural, economic, and environmental significance worldwide, basic sanitation and waste management remain major challenges. The dearth of research and diagnosis on plastic pollution in its wide variety of ecosystems and fauna, along with the lack of incentives for successful public policy in this area, leaves a knowledge gap concerning this new issue, particularly among traditional populations. This makes the Amazon Coastal Zone stand out as a particularly vulnerable region to plastic pollution, necessitating further in-depth research. Also, it is essential to have plans to manage plastic waste, especially in protected areas like the ones mentioned in this note. In this context, the goal is pursued by the OLAMAR project along the Amazon Coast evaluating the effects of anthropogenic waste on the biota and the traditional human communities, encompassing the Brazilian states of Amapá, Pará, and Maranhão.

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CRediT authorship contribution statement

Raqueline Monteiro: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Emarielle Coelho Pardo:** Writing – review & editing, Visualization, Methodology, Funding acquisition, Data curation, Conceptualization. **Marcelo Andrade:** Writing – review & editing, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Dayene Santiago Mendes:** Writing – review & editing. **Carine Gomes Moraes:** Writing – review & editing, Data curation. **José Raimundo Salustiano Da Silva:** Writing – review & editing. **Marcus Emanuel Barroncas Fernandes:** Writing – review & editing, Visualization, Resources, Project administration, Methodology, Funding

acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors 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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Baseline

Microplastics and microfibers in the Guajará Bay, Amazon delta: Potential sources and variability

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ABSTRACT

The role of Amazon on the transport and as a source of microplastics (MPs) to the ocean is uncertain. This study is an assessment on the distribution of MPs and microfibers (MFs) in a portion of the Amazon delta. Guajará bay is a potential source for surrounding waters, since a metropolis is located at the right margin. Surface water samples were collected during the dry and rainy season of 2014/2015 at six stations. MP and MF abundance ranged from 218 to 5529.98 (1565.01 ± 196.94) particles·m⁻³. Transparent, white and blue particles were frequent. Higher values were detected on the right, urbanized margin of the bay ($p = 0.0124$). Most of the particles were anthropogenic cellulose fibers (68.8 %). Polyethylene terephthalate (52.9 %) and polyamide (34.4 %) were the dominant polymers. Our results indicate higher MP and MF abundances near to the potential source, the urban nucleus, and related to local hydrodynamic characteristics.

Plastics are omnipresent in our daily products, but since these materials are not properly disposed of or recycled, they reach the aquatic ecosystems. The plastics accumulated in the environment, coupled with their slow fragmentation, resulted in a widespread distribution of micro-sized plastic particles, even in relatively preserved (Morais et al., 2020) and remote areas (Bergmann et al., 2017). In addition, tropical environments are expected to be polluted by microplastics (MPs) since they have a higher rate of plastic degradation and consequent MP formation due to high temperatures, exposure to ultraviolet light and weathering rate (Arias-Villamizar and Vázquez-Morillas, 2018).

The continent is the main source of plastics, transported primarily by watersheds (Meijer et al., 2021) to the ocean. Amazon, the largest world's river basin, is the natural source of huge loads of sediments, associated to its massive freshwater discharge ($>5 \times 10^{12}$ m³/y, Callède et al., 2010) and the largest contributor to solute release to the Atlantic (Nitttrouer et al., 2021). Therefore, it is expected that the Amazon basin

becomes a significant source of plastics due to the intense discharge and recent urbanization (Giarrizzo et al., 2019). In addition, Brazil is the 4th country in the world in terms of plastic waste production and is one of the least effective plastic recyclers (approximately 1.3 %), well below the global average (Kaza et al., 2018).

Guajará bay, located at the southern region of the Amazon delta, may be a potential source of MPs, since the second and fourth largest cities in the Amazon are located at the right margin (IBGE, 2021). Sewage collection and treatment are neglected at the Brazilian Amazon, being nearly or totally absent in most cities (Mansur et al., 2016). In addition, the Brazilian Amazon contributes around 6 million tonnes/year and 328 kg/capita/year of solid wastes, which lacks a significant recycling chain (ABRELPE, 2021).

Rivers are the main MP transport route to the ocean, and these particles can present long-term retention, putting at risk the freshwater biota (Yuan et al., 2022). The Amazon biome presents the greatest

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biodiversity hotspot of freshwater fishes on the planet (Tonella et al., 2023), which has been impacted by plastics already (Andrade et al., 2019), potentially leading to impacts on biodiversity. Despite the negative scenario, knowledge on MPs in the Amazon is still limited to a few published studies, most of them related to ingestion by animals (e.g. Dos Anjos Guimarães et al., 2023).

The investigation of MPs in continental and estuarine waters is necessary to understand the levels of pollution, and to define a baseline for future environmental mitigation measures. Here, we quantified MPs and MFs from surface waters of the Guajará bay, located in the complex Pará river estuarine system, Amazon delta, since the region is a possible source of MPs to adjacent areas.

Sampling took place at Guajará Bay and adjacent areas (Fig. 1), which is part of the Pará River estuarine system, on the southern portion of the Amazon delta (da Silva Gregório and Mendes, 2009), and downstream the Tocantins-Araguaia, Guamá and Capim rivers. While the right margin of the Guajará bay is heavily urbanized and represented by the urban nucleus of Belém metropolitan region, the left margin is composed of a vegetated island and several channels and supports a traditional community (Neu et al., 2018).

The estuarine system of the Pará River starts at das Bocas Bay and continues to the Atlantic Ocean, surrounding the south and east of the Marajó island, where it receives a fluvial contribution from the Amazon

River through the Breves and Boiuçu channels (Callède et al., 2010). The estuary is influenced by three major river basins: the Amazon, the Araguaia-Tocantins, and the North Atlantic Coast basins. The system is strongly influenced by the proximity to the ocean. Semi-diurnal tides alter river hydrodynamics, increase the water's residence time and provide an enhanced connection between the riparian zone, floodplains, and the main river channel (Gagne-Maynard et al., 2017).

The region presents a strong rainfall seasonality, with a dry period from August to December, and a rainy period, from January to July. Based on the historical series (1987–2016), the average annual temperature is 26.7 ± 0.4 °C and the average annual precipitation is 3206 ± 131 mm (INMET, 2018).

The samples were collected during three monthly sampling campaigns in two seasonal periods: the dry (August to October 2014), and the rainy season (February to April 2015). Sampling was carried out in a 17 km long transect crossing the Furo Grande, the Guajará Bay and the Guamá River that bathe the city of Belém. A total of six sampling stations were established: three on the right margin (Belém city, P1–P3) and three on left margin (Onças Island, P4–P6). Additional data like limnological variables are available as supplementary material (Table S1).

Surface water samples (100 L) were collected using a 10 L aluminum bucket. The water was immediately filtered through a 50 µm mesh



Fig. 1. Sampling stations for microplastic and microfiber assessment in surface water of Guajará bay and adjacent areas, southern portion of the Amazon Delta, Brazil. Sampling stations P1 to P3 were defined as right margin (P1 is on the right margin of Guamá river, while P2 and P3 are on the right margin of Guajará bay), and P4 to P6 as the left margin.

stainless-steel sieve. The bucket and sieve were previously cleaned at each sampling station with distilled water. The retained material was transferred to clean, externally identified glass flasks containing pre-filtered solution of 40 % ethyl alcohol for preservation and were stored in the dark until laboratory analysis. The separation and characterization of potential MPs was performed in glass petri dishes, and the particles were analyzed individually using a stereomicroscope. MFs and MPs were counted and classified by size, type and color according to GESAMP (2019). The inferior size limit considered was 100 μm since the particles were mechanically separated under the stereomicroscope.

A maximum of 30 units from each type and color, in each season, were randomly selected, measured, photographed, and analyzed by Fourier-transform infrared (FTIR) spectroscopy using the Varian FT-IR 660 spectrometer in the mid-infrared region, with Agilent software for processing the spectra at the Multiuser Spectrometry Laboratory from the Institute of Chemistry, Universidade Federal Fluminense, Brazil. Each particle was analyzed individually and identified by comparing their infrared spectra with reference spectra published in the literature for plastic and cellulose polymers (Jung et al., 2018). The diagnostic absorption bands were compared to those of the literature references, and only spectra with a match percentage ≥ 60 % were accepted. In addition, the full spectral profile of each particle was compared to the references to confirm the assignments.

At the laboratory, standard control procedures were adopted, including the use of a white cotton coat, coverage of labware and samples, and avoidance of plastics (Prata et al., 2021). Cleaning was often carried out on site, and the materials were washed with milli-q water before and after use (Queiroz et al., 2022). Filtration and sample preparation were performed inside a laminar flow hood to minimize airborne contamination. Blank controls were prepared for the ethyl alcohol and milli-q water, with three replicates for each solution. The optical equipment was covered to avoid external contamination (Torre et al., 2016).

Abundance data (particles·m⁻³) were provided as mean followed by the standard error. A permutational multivariate analysis of variance (PERMANOVA) was used to test for differences in particle composition between the river margins (two fixed levels: right and left margin), and seasons (wet and dry season) (Anderson et al., 2008). The abundance of the different MP (chips, fragments, and films) and MF types (plastic and cellulose fibers) were considered as independent variables. Statistical significance was tested using 9999 permutations of the residuals with a reduced model (Freedman and Lane, 1983) and the Type III (partial) sums of squares (Anderson et al., 2008). The PERMANOVA was run on a Euclidean similarity matrix, calculated from the log₁₀ (x + 1) transformed abundance data. The differences between the significant treatments were visualized in a metric multidimensional scaling (MDS) ordination by the bootstrap averaging based on repeated resampling from the original dataset (Clarke and Gorley, 2015). The global relationships among spatio-temporal treatments variation in particle composition were assessed using the shade plot routine. All statistical analyses were performed in PRIMER v7 (Clarke and Gorley, 2015).

The MPs and MFs were recorded in all the 35 surface water samples (P3 from April 2015 was missing). The minimum values were observed at P2, 10/2014 (65 MPs·m⁻³ and 153 cellulose MFs·m⁻³), and the maximum for P1, 09/2014 (1719 MPs·m⁻³ and 3811 cellulose MFs·m⁻³). Significant difference was not detected between seasons (1708.1 $\pm$ 249.3 and 1429.9 $\pm$ 305.6 particles·m⁻³ for the rainy and dry season, respectively), but the right, urbanized margin of Guajará bay showed higher particle abundance than the left margin (1907.8 $\pm$ 342.5 and 1239.4 $\pm$ 183.4 particles·m⁻³, respectively).

The one-way PERMANOVA analysis demonstrated a significant difference among the sampling stations ($p = 0.0395$) and between the left and right margins ($p = 0.0124$) (Table 1). Differences were observed between P1 and all the left margin stations (P4–P6) and between P3 and stations P4 and P6 (Table S2), confirming the higher abundances of MPs and MFs in the right margin. However, the two-way PERMANOVA

resulted in the absence of significance for the interaction between seasonality and river margin ($F = 1.1729$, $p = 0.2939$).

The MDS depicted the clear formation of two groups, one for each river margin. Most of the samples (~80 %) were included in these groups according to the 95 % confidence interval (Fig. 2). The shade-plot elucidated the distribution of the types of particles between seasons and margins, with higher values for all particle types occurring at the right margin. In addition, cellulose and plastic MFs were the most abundant particles and higher abundances of cellulose MFs were observed during the rainy season (Fig. 3).

Cellulose MFs were dominant, with abundances from 153 to 3811 particles·m⁻³ (1063.3 $\pm$ 135.1 particles·m⁻³), followed by plastic MFs (64–1658; 450.6 $\pm$ 60.2 particles·m⁻³). Fragments, chips and films were present in lower abundances (Fig. S1), or even absent from samples: fragments ranged from 0 to 54 particles·m⁻³ (23.3 $\pm$ 3.3 particles·m⁻³), chips between 0 and 50 particles·m⁻³ (11.9 $\pm$ 2.6 particles·m⁻³) and films between 0 and 30 particles·m⁻³ (5.4 $\pm$ 1.1 particles·m⁻³) (Fig. S2).

Ten distinct colors were observed (Fig. 4, Fig. S1). Transparent MFs were widely common (85.61 %), in addition to blue (6.28 %), black (3.14 %), green (2.61 %), red (2.14 %), and yellow (<1 %) colors. A similar pattern occurred for the fragments, with dominance of transparent (58.95 %), followed by white (22.4 %), green (8.01 %), brown (3.5 %) and smaller proportions of other colors. The green paint chips were the most common (37.21 %), followed by white (23.25 %), equal proportions of blue and yellow (16.28 %) and multicolored chips (6.98 %). Most films were transparent (65.53 %), followed by white (20.39 %), multicolored (7.28 %), blue (4.85 %) and finally by black and orange (<1 %).

Regarding the size, microplastics represented 94.97 % of the particles, followed by a reduced contribution of mesoplastics (5.03 %) (Fig. S1). The MFs presented a minimum of 200 μm and a maximum of 4.9 mm (2.396 $\pm$ 1.12 mm), while fragments were found in a size range between 100 μm and 3.9 mm (1.488 $\pm$ 1.191 mm). The chips were described between 100 μm and 3.8 mm (1.77 $\pm$ 1.07 mm), and the films presented a variation of 200 μm to 4.6 mm (1.19 $\pm$ 0.86 mm). Some MFs and films were also classified as mesoplastics, since they reached up to 10.9 mm and 9.6 mm, respectively. Anthropogenic cellulose MFs were the dominant particle type (68.8 %), followed by plastic MFs (28.61 %), fragments (1.47 %), chips (0.77 %) and films (0.35 %) (Fig. 4, Fig. S1).

Except for the cellulose microfibers, 10 types of polymers were identified: polyethylene terephthalate (PET, 52.86 %), polyamide (PA, 34.43 %), polypropylene (PP, 4.16 %), ethylene vinyl acetate (EVA, 2.72 %), polyvinyl chloride (PVC, 1.82 %), polyethylene (PE, 1.59 %), acrylonitrile butadiene styrene (ABS, 0.24 %), methyl polymethacrylate (PMMA, 0.18 %), and mixed cellulose (ABS, PVC and PET, 1.7 %). The most common polymers, PET and PA, were widely represented by plastic fibers. The fragments were the most heterogeneous regarding polymer composition, with PVC and PE as the most frequent, followed by PE, PVC, EVA, PMMA and mixed cellulose - ABS. The films were composed mainly of cellulose, in addition to EVA and PE, while all the analyzed chips were composed of EVA.

Table 1

Results from the one-way PERMANOVA for each factor, demonstrating the significant interactions between the sampling stations and river margins. Bold and italics: significant values ($p < 0.05$).

Factors/groups	Total sum of squares	Within-group sum of squares	F	p
Sampling months	45.34	39.18	0.9124	0.5211
Sampling stations	45.34	33.94	1.948	0.0395
Dry $\times$ rainy season	45.34	44.12	0.9176	0.4017
Left $\times$ right margin	45.34	39.98	4.429	0.0124

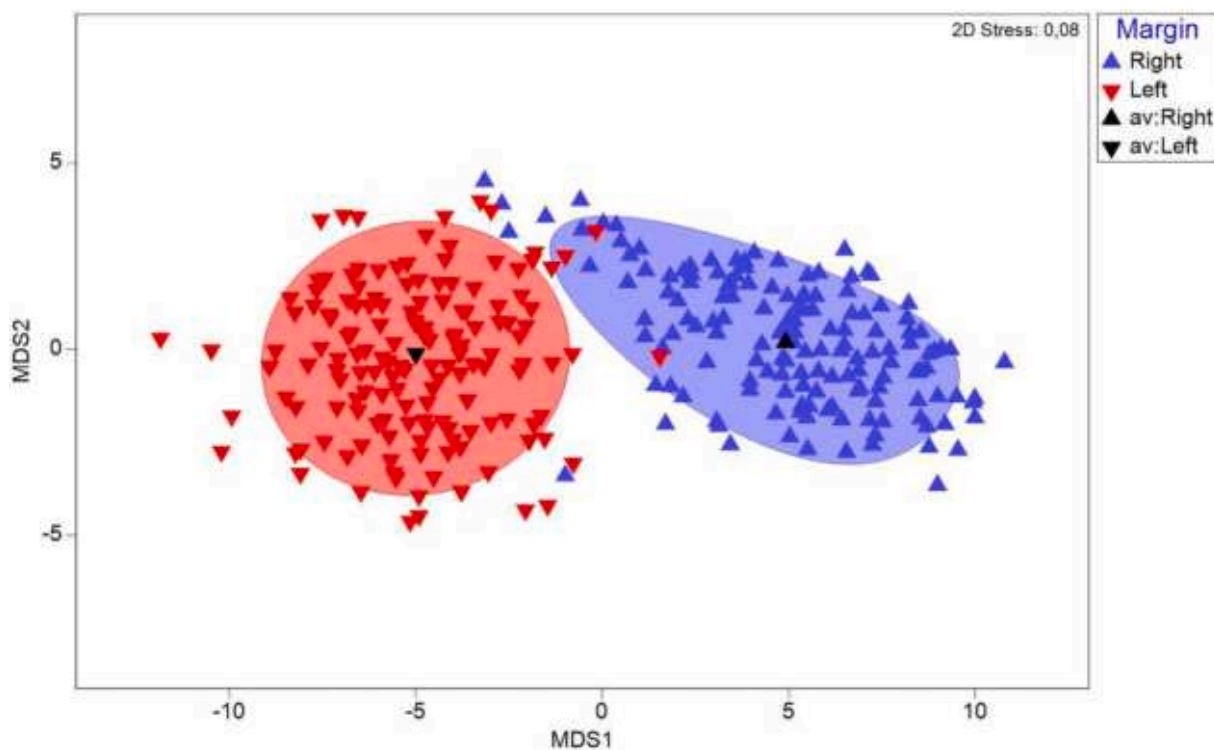


Fig. 2. Multidimensional scaling (MDS) ordination, depicting the formation of two groups of samples: the left and the right margins of Guajará bay.

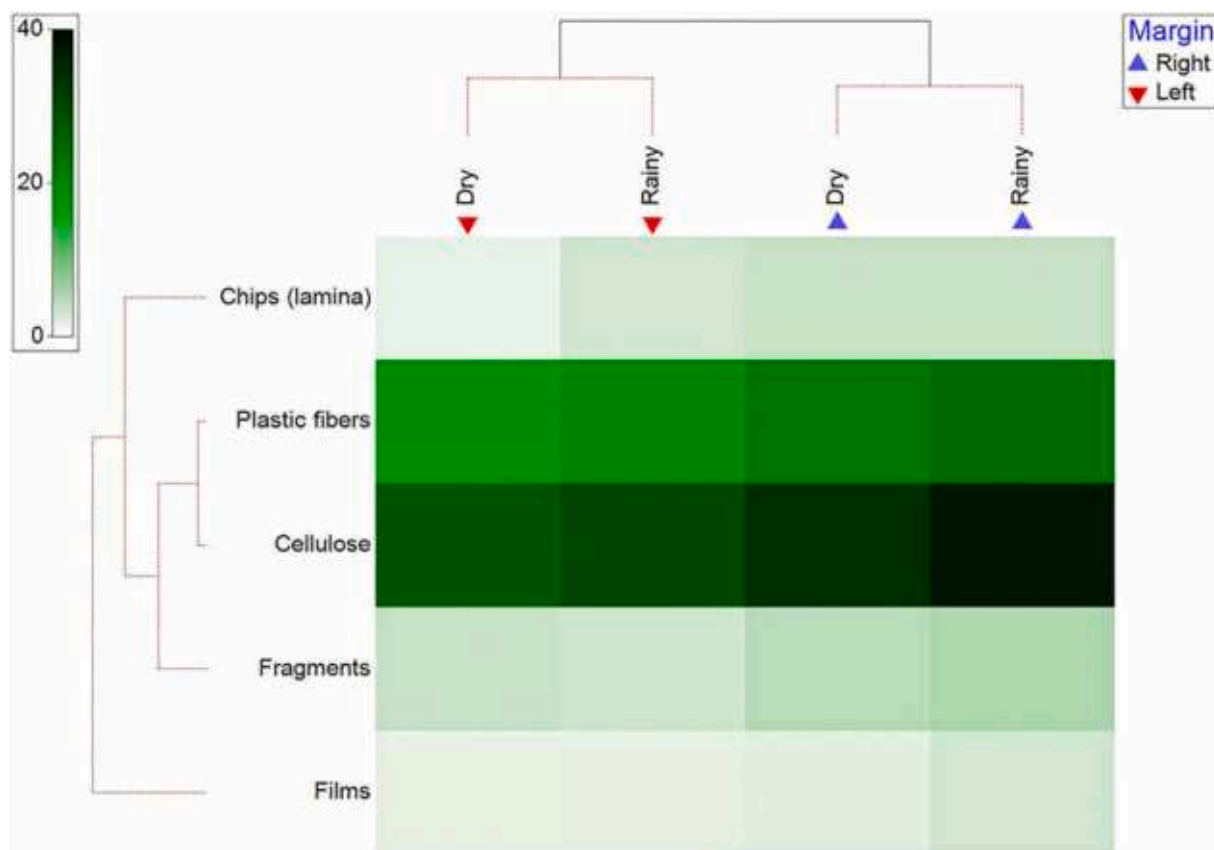


Fig. 3. Shade plot graphic illustrating the relationships among spatio-temporal treatments in particles types from surface water samples from Guajará bay. Shading intensity within the matrix indicates the relative abundance of each microplastic types (a legend is in the upper left of plot).

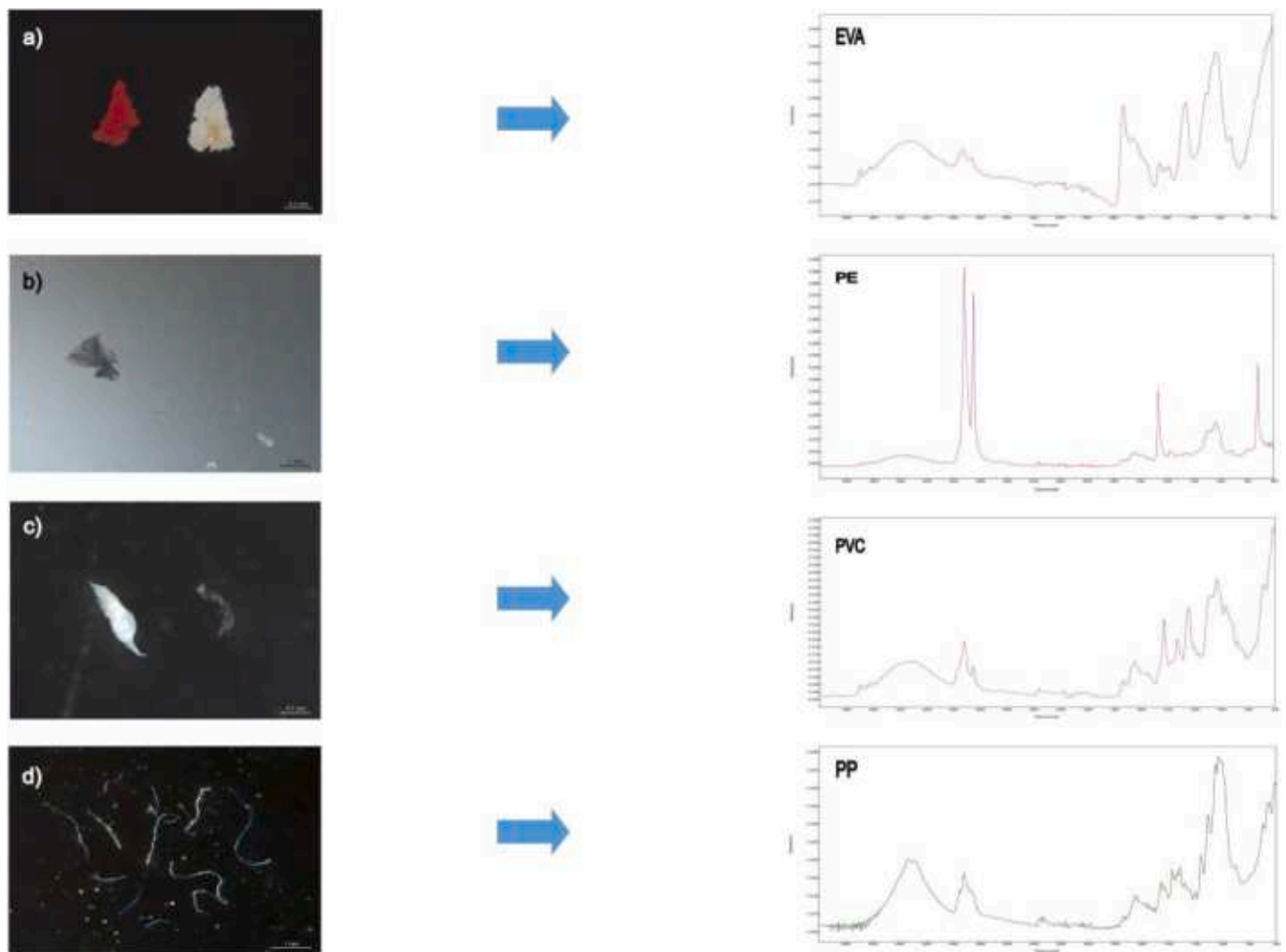


Fig. 4. Examples of microplastics and microfibers from Guajará bay, Brazilian Amazon. A) ethylene-vinyl acetate chips; B) polyethylene textile film; C) polyvinyl chloride microplastic fragments; D) textile, polypropylene fibers.

The Amazon is a continental sized area, but data on MPs are absent for most of it. Recently, the first paper on MPs in Guajará Bay analyzed six surface water samples and found abundances between 23 and 3095 particles·m⁻³ (Rico et al., 2023). If we excluded cellulose fibers from our study, the MPs abundance alone dropped to 65–1719 particles·m⁻³, similar to the findings described by Rico et al. (2023).

The abundance described here is below those reported in some estuaries and bays located in Brazil and in the world (see Table S3), but these studies used mesh apertures from three to six times higher than ours and were generally conducted in mesohaline to euryhaline waters. On the other hand, the values described in Guajará bay were similar to an estuary in China (Wu et al., 2019). Values from two times to even one order of magnitude higher than ours were also observed in other estuaries (Table S3); however, these studies used a lower limit for mesh size like ours, ranging from 40 to 75 µm. The great variability on the estimation of MP abundances relies on the lack of methodological standardization, although the values described here were inside the range observed by the few authors in the same or in adjacent areas (Queiroz et al., 2022; Rico et al., 2023).

Despite the limited information on MPs in environmental matrices in the Amazon, the dominance of MFs in riverine water is a common finding (Forrest et al., 2020; Acharya et al., 2021). The dominance of anthropogenic MFs in the Amazon was described in the sediment (Gerolin et al., 2020), and in surface waters along the Amazon River (Rico et al., 2023), where 51 % of the particles were plastic fibers

(cellulose fibers were not accounted), and on surface waters from the Amazon shelf, when 58 % of the particles were MFs during the rainy season (Queiroz et al., 2022). These MFs may result from the release from synthetic fabrics during the washing processes (Browne et al., 2011), reaching effluents and consequently the bay, since it drains a metropolitan area. Another possible source for plastic MFs is the fisheries industry, a main economic activity at the Brazilian Amazon coast (Jimenez et al., 2020). The disposal of fishing artifacts in the aquatic environment is a common practice and may be a source of nylon MFs (Martinelli Filho and Monteiro, 2019).

The most common polymers described here were also common in previous studies from the Amazon. PE, PVC, and PA were the most frequent MPs extracted from the stomach content of freshwater fishes from the Xingu River (Andrade et al., 2019). Nylon (PA) was also identified by the single publication on the ingestion of MPs by a freshwater invertebrate in the Amazon, the endemic shrimp *Macrobrachium amazonicum* (dos Anjos Guimarães et al., 2023). Both authors related the presence of PA to materials that are widely used in the fishing industry, which possibly contributes to the presence of these MPs in surface waters.

Even fewer studies determined the polymeric composition of MPs in environmental samples in the Brazilian Amazon. A recent study found PA, followed by PU, ABS, PET and EVA as the most abundant polymers in surface waters from the Amazon shelf (Queiroz et al., 2022). The assessment by Rico et al. (2023) was the first to describe polymeric

composition of the MPs in surface water samples from the Amazon River basin. The authors also observed that PET was the most common polymer, followed by PP, PS and PE. Despite some variations on the FTIR techniques employed here and in [Rico et al. \(2023\)](#), the main difference is that PA was the second most common polymer here but absent from the previous study.

PA and PET tend to shrink due to their specific gravity ([GESAMP, 2019](#)); however, they were dominant polymers in this study. Some factors such as hydrodynamics may explain this pattern, since Guajará bay presents physical forces such as strong wind currents, and a voluminous water flow ([Prestes et al., 2020](#)). In addition, the low topography, the mesotidal regime and turbulence ([da Silva Gregório and Mendes, 2009](#)) would allow the constant resuspension of MPs and MFs in the water body.

Our study area, on the east portion of the Amazon delta, is influenced by the Tocantins basin and its mouth. The Tocantins basin is the most anthropogenically impacted in the Amazon biome, with 58 % of its area occupied by agricultural activity ([Pelicice et al., 2021](#)). Intense land change use, leading to development of agriculture, cattle farming and the fast growth of cities, took place on the margins of the river tributaries ([Becker, 2016](#)). Owing to the economic activities, settlement of middle-sized cities on the river margin, and lack of proper sewage and solid waste management, the river mouth is a possible source of MPs and MFs to the Amazon delta.

Guajará bay is wrongly attributed as a bay. In fact, it is part of the lower Pará river estuary ([Barros et al., 2015](#)). The strong water flow, tidal transport and turbulence are high variable ([Prestes et al., 2020](#); [da Silva Gregório and Mendes, 2009](#)), and probably influence the distribution, dispersal, and fate of MPs and MFs. The hydrodynamic model by [Barros et al. \(2015\)](#) showed higher concentrations of contaminants associated to the right margin of the bay, due to a low velocity stream. This feature, in addition to the proximity of the potential MP/MF sources (Belém - Ananindeua metropolitan area) on the right margin, would explain our results.

Many questions remain regarding the sources and sinks of MPs, as well as their spatial and temporal variability in the Amazon delta. [Rico et al. \(2023\)](#) performed a single sampling in 2020, but even our study with six months of sampling was not sufficient to elucidate significant differences between the dry and rainy seasons. It is possible that the rainy period presents higher abundances of plastic particles due to the watershed transport, but a proper sampling design is still necessary to verify such hypothesis. Besides the Belém metropolitan area, the Tocantins basin and the Boiçu and Breves channels are important regions to determine the sources of MPs and MFs in the delta and their possible transport to the inner adjacent shelf. The enormous delta and its complexity call for a more detailed study on the potential contributions of the tributaries and the transport of MPs and MFs to the adjacent Atlantic waters.

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CRediT authorship contribution statement

Luana Francy Oliveira Santos: Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization. **Vania Neu:** Project administration, Funding acquisition, Resources, Conceptualization, Methodology, Writing – review & editing. **Raque-line Cristina Pereira Monteiro:** Data curation, Investigation, Visualization, Formal analysis. **Vinicius Tavares Küttner:** Methodology, Writing – review & editing. **Leonardo Mario Siqueira Morais:** Supervision, Writing – original draft, Writing – review & editing. **Abilio Soares-Gomes:** Methodology, Formal analysis, Writing – review & editing. **David Chelazzi:** Data curation, Methodology, Formal analysis, Writing – review & editing. **Tommaso Giarrizzo:** Conceptualization, Methodology, Formal analysis, Investigation, Supervision, Writing – original draft, Writing – review & editing. **José Eduardo Martinelli**

Filho: Project administration, Funding acquisition, Resources, Conceptualization, Methodology, Formal analysis, Writing – review & editing, Writing – original draft, Visualization, Supervision.

Declaration of competing interest

The authors 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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REC4

Maria Lindalva Oliveira Fernandes
Emarielle Coelho Pardal
José Eduardo Martinelli Filho
Raqueline Cristina Pereira Monteiro

em

OS RISCOS QUASE INVISÍVEIS

DO MICRO PLÁSTICO



FICHA TÉCNICA

Fernandes, Maria Lindalva Oliveira

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OLÁ PESSOAL!

Meu nome é Recicléia Pet Canudos – mais conhecida como Recy, sou muito especial porque fui montada a partir de materiais reutilizáveis encontrados em várias áreas da cidade de São Miguel do Guamá-PA. Minha cabeça foi formada de uma bola encontrada no igarapé Patauateua; meu corpinho de uma garrafa encontrada no lixão do município; meus braços e pernas são feitos de canudinhos encontrados na beira do rio Guamá; e o meu cabelo de sacolas plásticas encontradas em bueiros da cidade.

Bem...! Hoje vamos conversar sobre os riscos silenciosos dos microplásticos, que são partículas formadas pela fragmentação de plásticos, e depois de entender melhor vamos ver como podemos contribuir para a manutenção de um ambiente limpo e saudável para todos.



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APRESENTAÇÃO

O Livro “Recy em: Os riscos quase invisíveis do microplástico” partiu de um sonho idealizado através do projeto ‘Recicléia adote essa ideia’. Acreditamos que a educação ambiental pode despertar, através desse livro paradidático, o comprometimento das pessoas para com o meio ambiente.

Dentro desse contexto e considerando os Objetivos de Desenvolvimento Sustentável da Organização das Nações Unidas, expomos esta nova proposta, oferecendo subsídios básicos para melhor aproveitamento deste material. Queremos educar, mostrando a importância da agenda 2030 e a Década Oceânica, além de entender como podemos nos inserir neste fazer coletivizado!

Este livro almeja sugerir como trabalhar esta temática como uma ferramenta pedagógica, para a realização de atividades interdisciplinares, na certeza de enriquecer o trabalho do educador.

Agradecemos a parceria dos nossos amigos Doutores Emarielle Pardal e Eduardo Martinelli e nossa Embaixadora do Oceano Atlântico Raqueline Monteiro, grandes pesquisadores desta temática!

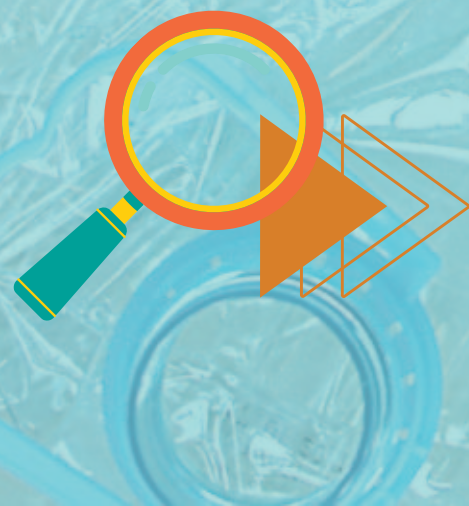
Embarque nessa leitura com a Recy...

A IMPORTÂNCIA DO PLÁSTICO



A utilização dos plásticos em substituição aos materiais tradicionais como o vidro, metal e madeira tem sido cada vez mais frequente, contribuindo para a qualidade de vida da sociedade e proporcionando diversos benefícios.

Por exemplo, na área da saúde, a substituição da seringa de vidro, entre outros materiais, por utensílios de plásticos, possibilitou a redução dos riscos de contaminação entre pacientes.



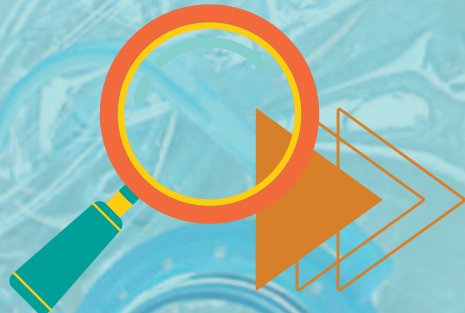
SAIBA MAIS sobre a importância do Plástico em nossas vidas:
<https://www.youtube.com/watch?v=6I57tdGXj0k>



CONSUMO DESENFREADO DO PLÁSTICO

O consumo desenfreado de plástico tem sido motivo de crescente preocupação ambiental, devido a grande quantidade de resíduos que são gerados. A produção mundial de plástico tem crescido significativamente nos últimos anos, de 1,5 milhões de toneladas em 1950 para mais de 300 milhões de toneladas em 2017.

Além disso, há a expectativa de que o aumento da produção mundial de lixo plástico acompanhe o crescimento populacional, que segundo estimativas, em 2050 pode atingir o incrível contingente de 9,2 bilhões de habitantes e uma produção de 1.124Mt/ano (um milhão cento e vinte e quatro mil toneladas de plástico por ano).



SAIBA MAIS sobre o consumo desse resíduo:
<https://revistapesquisa.fapesp.br/planeta-plastico/>

PLÁSTICOS E SUAS CLASSIFICAÇÕES

Existe uma variedade muito grande de plástico, e para melhorar o entendimento vamos organizar a classificação dos plásticos de acordo com a sua origem, ao tipo (polímero) e ao tamanho.

ORIGEM

PRIMÁRIOS É aquele já produzido em tamanho microscópico, como os pellets e microesferas.

As microesferas são utilizados em produtos cosméticos, como esfoliantes, sendo diretamente liberadas no ambiente em forma de pequenos grânulos.



SECUNDÁRIOS São oriundos da quebra mecânica de plásticos maiores, resultante da fragmentação do plástico descartado no ambiente aquático e terrestre.



SAIBA MAIS sobre Pellets:

<https://www.youtube.com/watch?v=UiX1pJT4LEg>



CLASSIFICAÇÃO QUANTO AO TIPO DE PLÁSTICO



PET

**POLIETILENO
TEREFTTALATO**

GARRAFAS DE
ÁGUA E ETC.



PEAD

**POLIETILENO
DE ALTA
DENSIDADE**

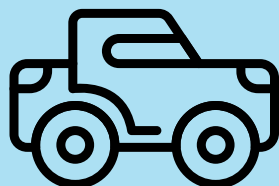
FRASCOS DE
XAMPU,
PRODUTOS DE
LIMPEZA. ETC.



PVC

**POLIETILENO
DE VINILA**

MATERIAIS
PARA
CONSTRUÇÃO,
BRINQUEDOS,
CHUVEIRO ETC.



PEBD

**POLIETILENO
DE BAIXA
DENSIDADE**

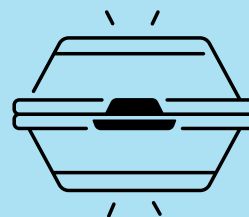
SACOLAS E
EMBALAGENS
FLEXÍVEIS



PP

POLIPROPILENO

EMBALAGENS
DE ALIMENTO,
TAMPINHA DE
GARRAFA, ETC.



PS

POLIESTIRENO

COPOS,
MARMITAS
TAMPAS
DESCARTÁVEIS E
ETC.



OUTROS

OUTROS

EMBALAGENS
MULTICAMADAS,
MAMADEIRAS,
CD, DVD ETC.



SAIBA MAIS sobre a identificação do plástico de acordo com sua numeração:

<https://www.youtube.com/watch?v=756to0vqNFE>

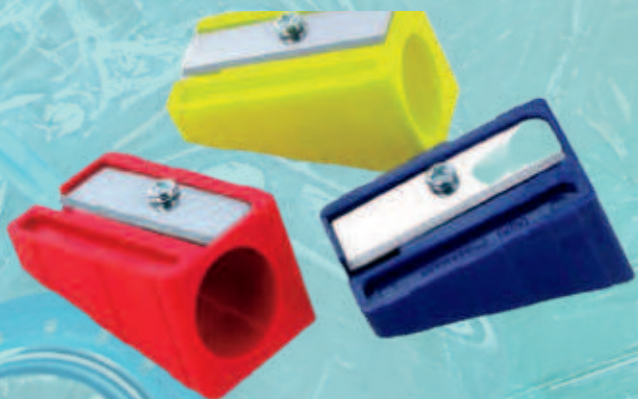
OS DIFERENTES TIPOS DE PLÁSTICOS (POLÍMEROS)

OS PLÁSTICOS MAIS COMUNS

Polietileno de baixa densidade (PEBD), um plástico de baixo custo muito usado para embalar alimentos.



Polimetilmetacrilato (PMMA) o conhecido acrílico e Poliestireno expandido (EPS), que também conhecemos como isopor.



CLASSIFICAÇÃO QUANTO AO TAMANHO

Plásticos maiores se fragmentam em pedaços menores pela ação do sol, das ondas e marés, resultando em partículas pequenas de plásticos. Quando essas partículas são menores que 5 mm (0,5 cm), elas são chamadas de microplásticos.

Os microplásticos são de grande preocupação ambiental e estão sendo identificados em amostras ambientais de água e sedimento de rios, lagos, mares e oceanos ao redor do mundo.

- Megaplásticos (> 1 m);
- Macroplástico (2,5 – 100 cm)
- Mesoplástico (0,5 – 2,5 cm)
- Microplástico (1 μ m – 0,5 cm)
- Nanoplástico (< 1 μ m)



SAIBA MAIS sobre os microplásticos e suas classificações:
<https://www.youtube.com/watch?v=MVIIjjODw10>

SAIBA COMO OS ESTUDOS COMEÇARAM

O estudo sobre a presença de microplásticos no meio ambiente iniciou-se em 1972, quando pesquisadores notaram quantidades expressivas de partículas na superfície do mar do sargaço.

Segundo a pós-doutora em Oceanografia Jacqueline Santos Silva Cavalcanti, a partir dessa data, foram encontrados microplásticos em cerca de 270 espécies de organismos marinhos.

Sendo assim, tais partículas plásticas são um fator de preocupação por poluírem cada vez mais os ambientes aquáticos.



MICROPLÁSTICO: UM INIMIGO QUASE INVISÍVEL

Com dimensões tão pequenas, algumas partículas tornam-se invisíveis ao olho humano. Além de estarem na areia, na água do oceano e nos produtos que usamos no dia-a-dia, inclusive eles também já foram detectados dentro do próprio corpo humano.

Foram encontrados microplásticos no pulmão de pessoas vivas, o que leva a crer que a inalação é o principal foco de exposição aos microplásticos.



SAIBA MAIS sobre a pesquisa:
<https://agencia.fapesp.br/identifica-da-pela-primeira-vez-a-presenca-de-microplasticos-ambientais-no-pulmao-humano/36197/>

Foram detectados microplásticos na corrente sanguínea humana. Uma pesquisadora envolvida no estudo diz que é preciso “compreender o quanto espalhados estão no corpo humano, e o quanto perigosos podem ser”.



SAIBA MAIS sobre a pesquisa:
<https://g1.globo.com/meio-ambiente/noticia/2022/03/24/cientistas-encontram-microplasticos-na-corrente-sanguinea-humana.ghtml>

MICROPLÁSTICOS EM DIFERENTES LUGARES



Concetrações de microplásticos de PET foram 10 vezes maiores nas fezes de crianças do que nas de adultos. O fato de levarem objetos plásticos à boca, como mamadeira, pode ser um dos motivos.



SAIBA MAIS sobre a pesquisa:

<https://revistagalileu.globo.com/Ciencia/Meio-Ambiente/noticia/2021/09/criancas-tem-10-vezes-mais-microplasticos-nas-fezes-do-que-adultos.html>

Há centenas de espécies de animais em que partículas de plásticos já foram detectados. Até 2021, mais de 1,5 mil espécies animais já tinham ingerido pelo menos uma partícula de plástico.



SAIBA MAIS sobre a pesquisa:

<https://www.nationalgeographicbrasil.com/animais/2021/07/ingestao-de-plastico-ja-foi-registrada-em-mais-de-15-mil-especies-animais>

MICROPLÁSTICOS EM DIFERENTES LUGARES



A presença de microplásticos nos pinguins da Antártica foi identificada, o que significa que o lixo chega mesmo aos lugares mais remotos da Terra, como os polos Norte e Sul.

SAIBA MAIS sobre a pesquisa:



<https://www.tveuropa.pt/noticias/pinguins-na-antartida-ja-sofrem-a-poluicao-por-microplasticos/>

Além dos seres vivos, os microplásticos são encontrados em areia de praia, na água do mar, rios, neve, chuva, em água engarrafada, em frutas e outros alimentos.

SAIBA MAIS sobre esse problema:



<https://www.publico.pt/2022/05/14/infografia/sao-microplasticos-perigos-703>

MICROPLÁSTICOS EM DIFERENTES LUGARES



Muitos cosméticos e produtos de higiene, como pasta e escovas de dentes, xampu, gel de banho, cremes ou detergentes, têm microesferas plásticas (microbeads). Além desses, também são usados em tintas e fertilizantes.

Como estas pequenas partículas não são filtradas pelas estações de tratamento de água, acabam indo parar no mar.

SAIBA MAIS sobre os cosméticos:

<https://www.farmalfenasjunior.com/post/os-danos-do-uso-de-micropl%C3%A1sticos-em-cosm%C3%A9ticos>

Já foram detectados microplásticos na placenta humana, o que traz grande preocupação, já que estas partículas podem prejudicar o desenvolvimento do sistema imunológico dos bebês.

SAIBA MAIS sobre essa pesquisa:

<https://exame.com/ciencia/plastico-ja-esta-ate-na-placenta-humana/>

MICROPLÁSTICOS EM DIFERENTES LUGARES



Foi descoberto que os microplásticos podem ser levados pelo vento e ficar em suspensão da atmosfera. A Pesquisadora Imogen Napper, da Universidade de Plymouth no Reino Unido, encontrou microplásticos no pico do Monte Everest, o ponto mais alto do planeta. Estas partículas foram detectadas em amostras de neve retiradas de 11 locais desta região montanhosa– e todas tinham microplásticos.



SAIBA MAIS sobre essa pesquisa: <https://revistagalileu.globo.com/Ciencia/Meio-Ambiente/noticia/2020/11/microplasticos-sao-encontrados-em-neve-proximo-ao-topo-do-everest.html>

Mergulhando no oceano, o aposentado da Marinha dos Estados Unidos, Victor Vescovo, descobriu sacolas plásticas e embalagens de doces na Fossa das Marianas, o ponto mais profundo da Terra.



SAIBA MAIS sobre essa aventura: <https://oeco.org.br/salada-verde/expedicao-encontra-plasticos-no-ponto-mais-profundo-do-pacifico/>

MICROPLÁSTICOS EM AMBIENTES DE ÁGUA DOCE

Os microplásticos também estão sendo observados em ecossistemas de água doce da América do Norte, Europa e Ásia.

Considerando que os rios contribuem com o transporte de aproximadamente 80 % dos resíduos sólidos presentes no oceano, é extremamente relevante a investigação de microplásticos diretamente nesses ambientes.

Além disso, do ponto de vista da saúde humana, pode-se considerar a contaminação de água doce por microplásticos até mais preocupante, dado a dependência do consumo de água potável pela população.

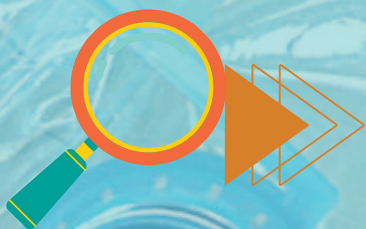
SAIBA MAIS :

<https://www.youtube.com/watch?v=1IB0zDAoySg>

ONDE ESSE PLÁSTICO VAI PARAR?

Em virtude de seu pequeno tamanho, esses plásticos atingem a base da cadeia alimentar. Podem afetar toda a fauna aquática através de interações como a predação.

Os microplásticos causam efeitos tóxicos nas células dos seres vivos que ingerem essas partículas, especialmente em pessoas que comem pescados, como peixes e camarão.



SAIBA MAIS :

<https://www.youtube.com/watch?v=jVLpl0icshA>

MICROPLÁSTICOS NOS AMBIENTES MARINHOS



Fonte: Raqueline Monteiro

Desse total , 80% são provenientes, da ação humana, realizada em terra firme, e metade dele (12,5 milhões) são produtos plásticos.

Todos os anos é despejado uma quantidade enorme de resíduos nos oceanos.

Segundo a Associação Internacional de resíduos sólidos 20 milhões de toneladas são despejadas anualmente.

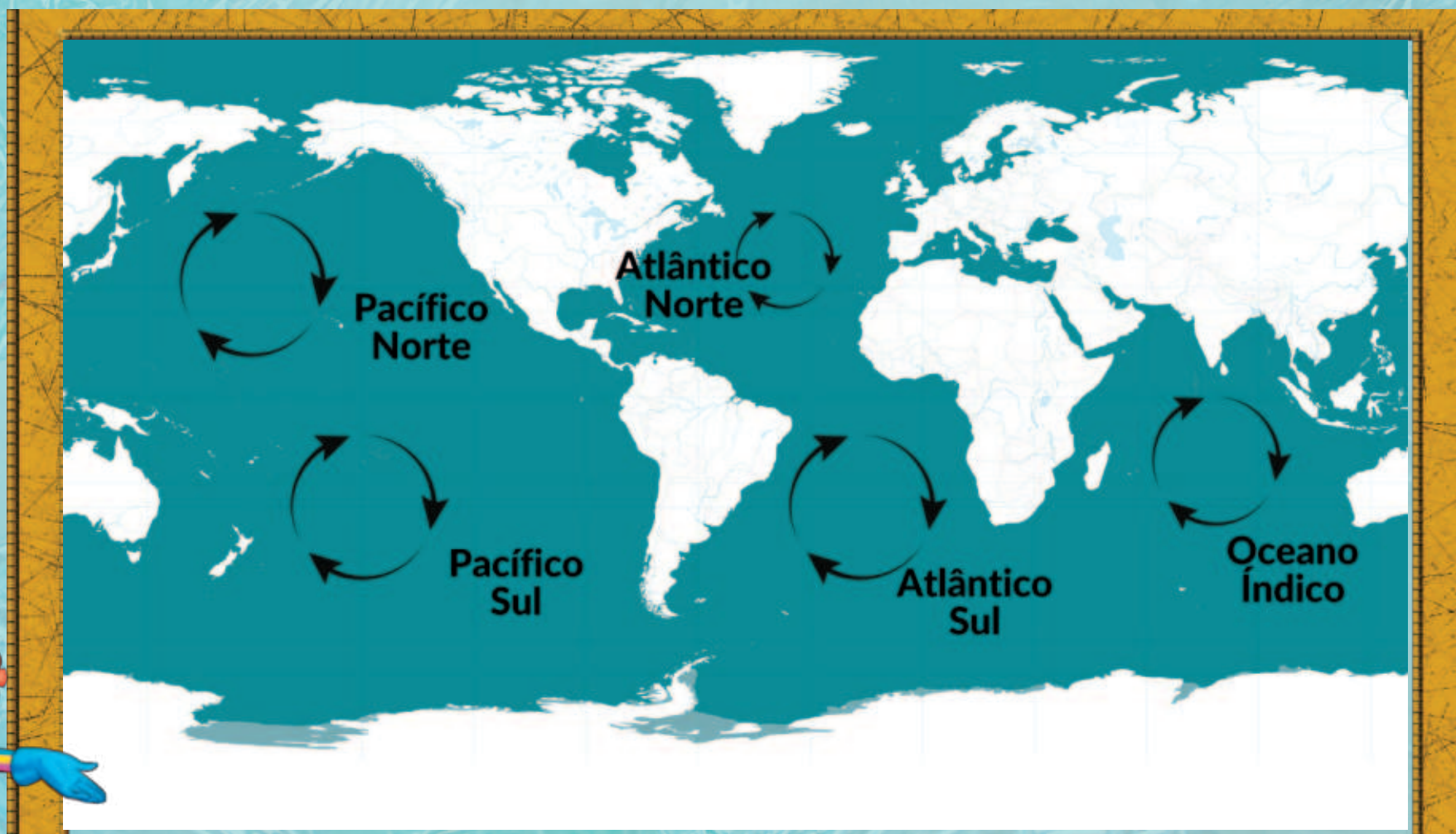


Fonte: Raqueline Monteiro

O SÉTIMO CONTINENTE: "SOPA DE PLÁSTICO" NO OCEANO

No mundo , existem 5 ilhas de plástico flutuantes que afetam todo o ecossistema marinho.

Umas das maiores é a ilha de lixo do Pacífico Norte (conhecida como sopa de plástico, sétimo continente ou Mancha gigante de plástico) que tem uma extensão de quase 3x (três vezes) o tamanho do estado do`Pará.



Fonte: Adaptado de " The Ocean Revealed

ESTAMOS COMENDO PLÁSTICO!



A ingestão de resíduos plásticos provoca, por exemplo, a perfuração ou obstrução do estômago dos animais por confundirem plástico com alimento. Isso pode causar até a morte do animal.

Os animais aquáticos são afetados pelos resíduos, a pesca sofre danos diretos, ocasionando perdas econômicas.

Os humanos também são afetados diretamente, pois ingerem microplásticos e outras substâncias nocivas através do consumo de animais marinhos, podendo desenvolver doenças e intoxicações.



MICROPLÁSTICOS NO BRASIL



Diversos trabalhos foram publicados sobre o assunto na América Latina, cerca de um terço foram realizados no Brasil.

A partir de 1990, quando o Brasil iniciou estudos dessa temática, a maioria dos trabalhos foi realizado nas regiões sudeste e nordeste, embora já existam trabalhos em todas as regiões brasileiras, atualmente.

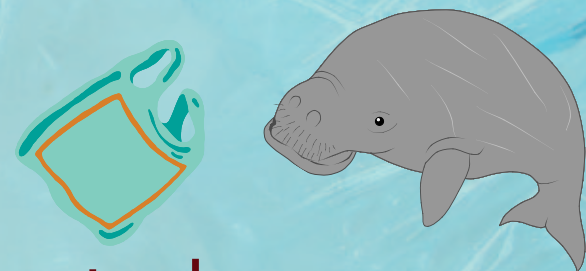


Em relação à fauna, a maioria dos estudos (cerca de 80%) pesquisou a presença, ingestão acidental e os efeitos de microplásticos em peixes, tanto marinhos, quanto os de água doce.



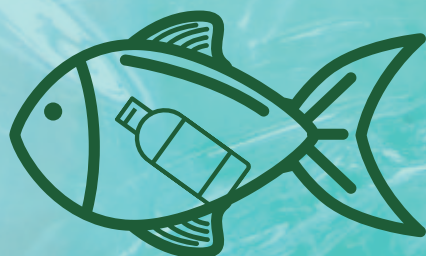
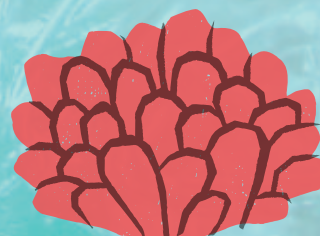
MICROPLÁSTICOS NA AMAZÔNIA

Estudos sobre microplásticos são recentes para a região Norte do Brasil, principalmente para a Amazônia. Contudo, em 2010 a pesquisadora Michelle Guterrez Pazin realizou na Amazônia, um dos trabalhos mais antigos para todo o país. Esse trabalho registrou a ingestão de plástico pelo peixe-boi.

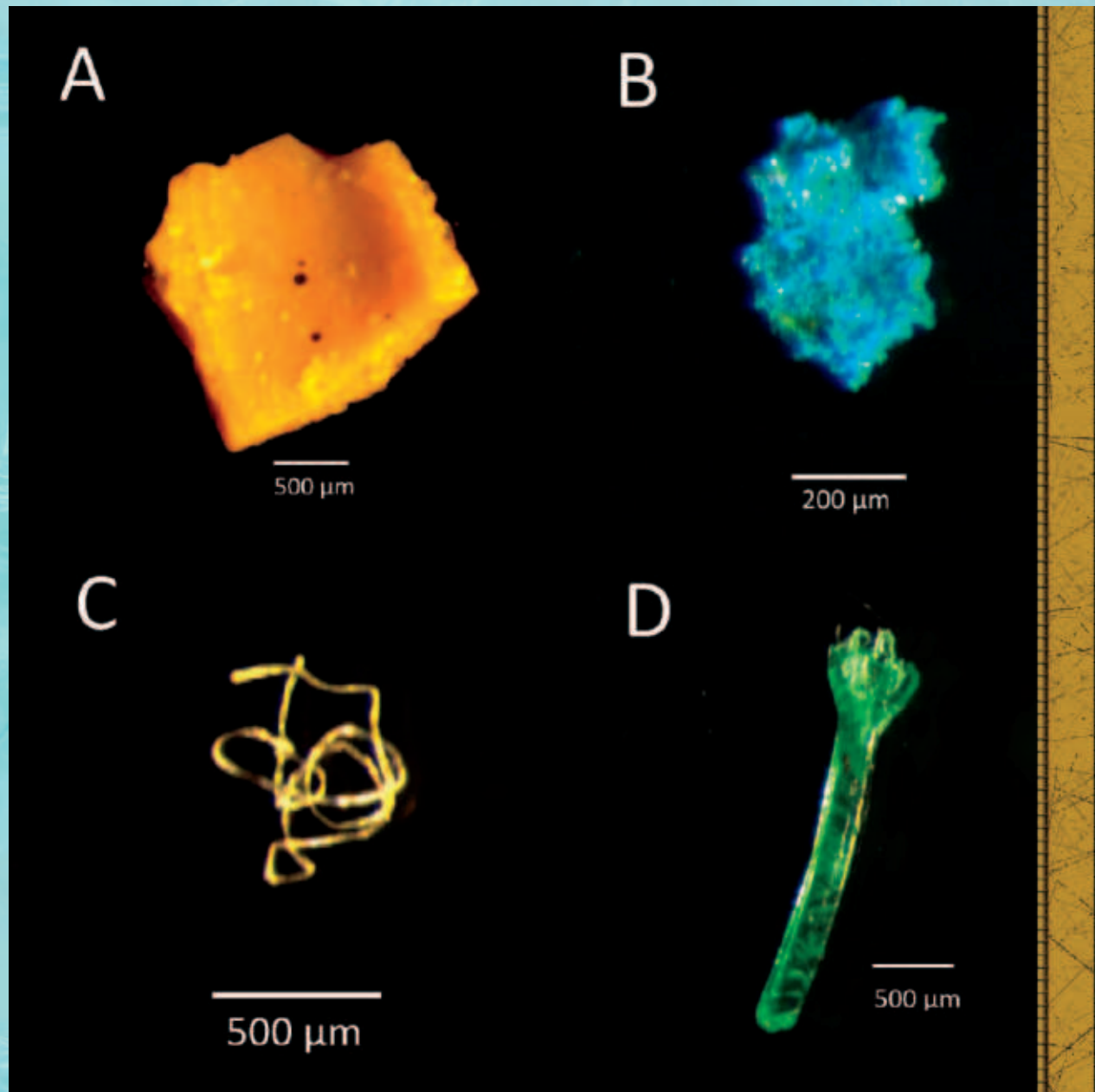


Em relação à fauna, microplásticos foram encontrados em peixes marinhos, de água doce e em arraias. Um trabalho também encontrou essas partículas em anêmonas do mar, animais comuns em praias na costa do Pará.

Recentemente, pesquisadores da Universidade Federal do Pará e do Instituto de Pesquisas Científicas e Tecnológicas do Estado do Amapá, tem realizado pesquisas e demonstrado a presença de microplásticos em diversos ambientes amazônicos: desde reservatórios, em grandes rios, passando pelo sedimento, praias e até em alto mar.



MICROPLÁSTICOS NA AMAZÔNIA



Diferentes microplásticos encontrados na Praia da Corvina, Pará.

Fonte: Martinelli Filho & Monteiro (2019)

PLÁSTICOS NA AMAZÔNIA

Em pesquisas realizadas em vários lugares da Amazônia foram feitos registros fotográficos desse tipo de poluição que chega aqui em nossa região vindos de vários lugares do planeta.



Caranguejo preso em rede de pesca descartada incorretamente.

Marajó-Pará

Foto: Adrielle Lopes e Martinelli Filho



Linha de deixa (muito plástico no meio da vegetação).

Joanes, Marajó-Pará

Foto: Martinelli Filho em 02/2022

PLÁSTICOS NA AMAZÔNIA

RESÍDUOS ENCONTRADOS EM SALINÓPOLIS, PARÁ



Desengraxante de Singapura.
Foto: Martinelli Filho



Detergente da Espanha
Foto: Martinelli Filho

PLÁSTICOS NA AMAZÔNIA

RESÍDUOS ENCONTRADOS EM ABAETETUBA, PARÁ



A raiz do açaizeiro retém pedaços de plástico (uma pequena rede em amarelo).

Praia de Beja , Abaetetuba - Pará

Foto: Martinelli Filho em 03/2022



Uma corda de nylon com mais de dois metros, liberando pequenas fibras ao se decompor. (Do megaplástico ao microplástico)

Praia de Beja , Abaetetuba - Pará

Foto: Martinelli Filho em 03/2022

COLEÇÃO AMAZÔNICA SOBRE LIXO MARINHO



Foto: Martinelli Filho

A Amazônia Lixo Marinho (ALMA) é a primeira coleção da Rede de Coleções Didáticas e Científicas de Lixo Marinho (@recolixo) na região amazônica.

Essa coleção é composta por resíduos sólidos coletados em praias e rios. Vai de coisas que, infelizmente, são fáceis de encontrar no dia a dia, como tampinhas, copos e garrafas pet à resíduos mais incomuns, como embalagens de produtos internacionais.

A coleção física logo mais poderá ser visitada pelo público.

Mais informações em:
@recolixo_amazonia.

Texto: @recolixo_amazonia

OBJETIVOS DE DESENVOLVIMENTO SUSTENTÁVEIS- ODS

Em 2012, a Conferência das Nações Unidas sobre desenvolvimento sustentável elaborou 17 Objetivos de Desenvolvimento Sustentável (ODS) no Rio de Janeiro.

Os 17 ODS são integrados e reconhecem que a ação em uma área afetará os resultados em outras áreas e que o desenvolvimento deve equilibrar a sustentabilidade social, econômica e ambiental.



Nesse sentido, o ODS 14 Vida na Água (em inglês, "Life below Water") vem trazer metas voltadas a proteger a vida marinha, carregando consigo a grande importância de mostrar para todos os setores da sociedade as diversas importâncias desse ambiente, bem como as problemáticas que precisam ser discutidas.

SAIBA MAIS sobre a ods 14:

https://www.youtube.com/watch?v=Zh_UVjH3Smk

DÉCADA DA CIÊNCIA OCEÂNICA



Até 2030, a Década da Ciência Oceânica objetiva sensibilizar a população sobre esse cenário bem complexo e desafiador, no intuito de nos unirmos para uma vida mais sustentável.

Todos os setores da sociedade (setores públicos, privados e sociedade civil organizada) devem estar engajados em ações que favoreçam a saúde e a sustentabilidade dos mares.

Neste contexto, a Amazônia e nós, amazônidas, temos muito a contribuir com o conhecimento gerado pelas universidades e pelas nossas cidades urbanas e ribeirinhas, e comunidades tradicionais e indígenas.

Para você ter ideia da nossa importância, o Rio Amazonas descarrega no Oceano Atlântico 20% de toda a água doce que chega nos oceanos globais.



QUAL A SAÍDA PARA DIMINUIR O PLÁSTICO EM NOSSO PLANETA?

De acordo com a publicação Atlas do Plástico, além do conhecimento sobre a temática, é necessário vontade política e ação urgente dos governos para enfrentar esta crise crescente.

Esse livro conclui que é necessário uma mudança para abordagens circulares, incluindo práticas de consumo e produção sustentáveis, o desenvolvimento e adoção rápida de alternativas pelas empresas, e uma maior conscientização do consumidor para encorajar escolhas mais responsáveis.

Você pode baixar ou solicitar a versão impressa gratuitamente no site da Fundação Heinrich Böll.

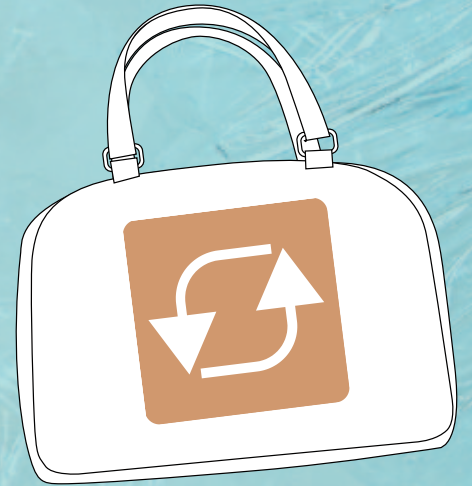
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<https://br.boell.org/pt-br/2020/11/29/atlas-do-plastico>



QUAL A SAÍDA PARA DIMINUIR O MICROPLÁSTICO EM NOSSO PLANETA?

**RECUSAR
E
REDUZIR**



- Não aceite sacola plástica;
- Use sacolas de pano que podem ser retornáveis;
- Diga não aos descartáveis;
- Viva sem canudinho, ele não te faz falta.

QUAL A SAÍDA PARA DIMINUIR O MICROPLÁSTICO EM NOSSO PLANETA?

**INCENTIVAR
E
APRIMORAR**

**REDUZA
REUSE
RECICLE**

- Coleta Seletiva e a Reciclagem
- Evitar os plásticos de uso único (descartáveis)



QUAL A SAÍDA PARA DIMINUIR O MICROPLÁSTICO EM NOSSO PLANETA?

AMENIZAR A TOXICIDADE DO PLÁSTICO NO AMBIENTE

- Simplificar sua fabricação para torná-los menos prejudiciais;
- Incentivar a produção de bioplásticos (plásticos de terceira e quarta gerações)



QUAL A SAÍDA PARA DIMINUIR O MICROPLÁSTICO EM NOSSO PLANETA?

APROVAR LEIS

- Para reduzir o uso de embalagem descartável;
- Para banir o uso de determinados tipos plástico de uso único;
- Para incentivar a Coleta Seletiva e a Reciclagem;



QUAL A SAÍDA PARA DIMINUIR O MICROPLÁSTICO EM NOSSO PLANETA?

**INVESTIR NA EDUCAÇÃO
AMBIENTAL EM TODOS OS SETORES
DA SOCIEDADE, PARA JUNTOS
CONSTRUÍRMOS UMA SOCIEDADE
MAIS SUSTENTÁVEL**

E VOCÊ? NÃO PODE FICAR PARADO!



Convidamos todos a praticar em casa, pequenas atitudes que também podem colaborar, o descarte correto dos resíduos, separar os recicláveis, é algo simples que todos podem contribuir.

Essas ações devem começar desde a infância, com atividades educacionais. No Instituto Sol Nascente/Projeto Recicléia, alunos de todas as idades são convidadas a refletir sobre o tema através de cartilhas, teatro, dança, música, oficinas e palestras!



Agora que você já conhece sobre esse problema vamos fazer nossa parte!!

CONHEÇA OS AUTORES



Maria Lindalva Oliveira Fernandes é professora de Geografia na escola estadual irmã Carla Giussani, especialista em educação ambiental, especialista em gestão escolar, tem mestrado em gestão pública pela Universidade de Trás os Montes e Alto D'ouro (Portugal) Ambientalista, articuladora do Fórum dos secretários Municipais de meio ambiente do estado do Pará (Fopesmma), Facilitadora da Rede Paraense de educação ambiental (Rede Paea), da Rede Brasileira de educação ambiental (Rebea), pesquisadora do Geamaz (Ufpa), presidente do Instituto de Inclusão Social Sol Nascente e idealizadora do projeto Recicleia adote essa ideia.

Autora de mais de 30 publicações entre cartilhas, paradidáticos e ebook da Recicleia Pet Canudos, conhecida carinhosamente como Recy.

Emarielle Coelho Pardal é Licenciada em Ciências Biológicas, com Mestrado em Biologia Ambiental, ambos pela Universidade Federal do Pará (UFPA), possui Doutorado em Geociências pela Universidade Federal de Pernambuco (UFPE). Está com projeto de Pós Doutorado em andamento no Instituto de Pesquisas Científicas e Tecnológicas do Amapá (IEPA) e, compõe a Rede Paraense de Educação Ambiental (Rede PAEA), como facilitadora.



CONHEÇA OS AUTORES



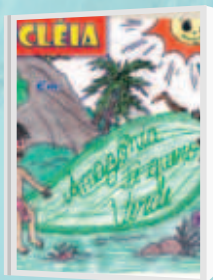
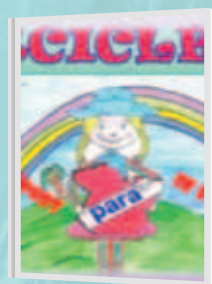
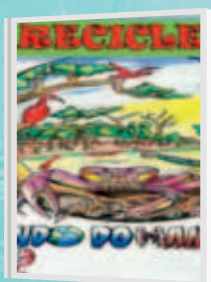
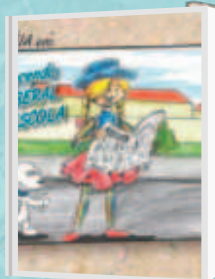
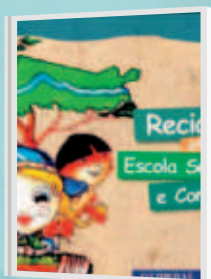
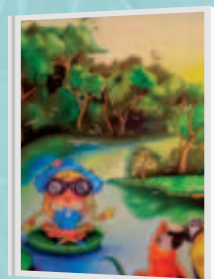
Possui bacharelado (2004) e licenciatura (2006) em Ciências Biológicas pelo Instituto de Biociências da USP. Concluiu mestrado (2007) e doutorado (2013) no Instituto Oceanográfico da USP. Foi professor substituto na UNESP campus São Vicente (2008) e professor assistente na Universidade Federal do Pará (UFPA) a partir de 2009. Atualmente é professor associado no Instituto de Geociências da UFPA. Tem experiência na área de Oceanografia Biológica, Biologia Marinha, Limnologia, Ecologia Aquática, Ciências Ambientais e Impactos ambientais. Atua principalmente no estudo de impacto ambientais emergentes na Amazônia.

Raqueline Monteiro é Bacharela e Mestra em Oceanografia pela Universidade Federal do Pará - UFPA (2015) e Universidade Federal de Pernambuco - UFPE (2018). Atualmente, ela é pesquisadora de Doutorado no Programa de Pós-Graduação em Ecologia Aquática e Pesca (PPGEAP) na UFPA e também Jovem embaixadora do Oceano Atlântico (2020-) representando o Brasil na All-Atlantic Ocean Research Alliance (AANCHOR). Jovem cientista da Amazônia atuante em pesquisas sobre poluição plástica em ambientes costeiros e oceânicos. Possui também experiência em educação ambiental, cultura oceânica e comunicação científica.

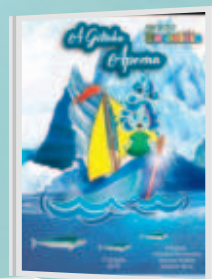


CONHEÇA OUTRAS OBRAS

Cartilhas



Paradidáticos



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CONHEÇA OUTRAS OBRAS

Ebook



Livros Acadêmicos



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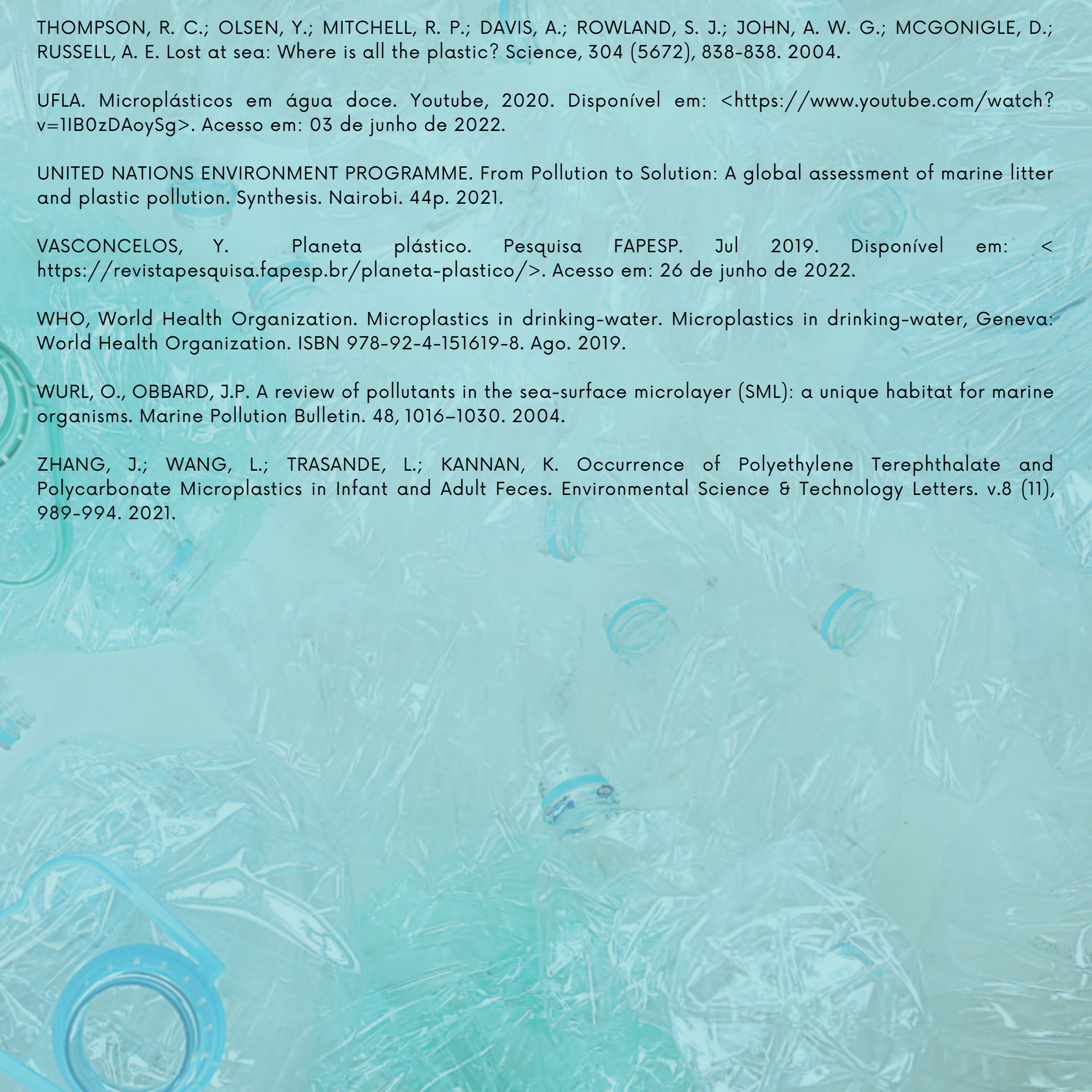
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