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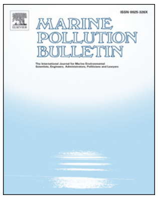

Baseline

Microplastics in subsurface waters of the western equatorial Atlantic (Brazil)

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ABSTRACT

We provide a baseline assessment of the density and types of microplastics in the western equatorial Atlantic. The highest microplastics density was found in coastal stations near urbanized sites, large tropical estuaries, and fishing grounds. With regard to microplastics composition, most of the identified particles were fibers/filaments, styrofoam, hard and soft plastic, paint, and glass/acrylic. Fibers/filaments were the most abundant (~80%) and occurred at all stations, in both types of mesh nets. Hard plastic particles were frequent (78%) only in the 120 μm mesh net. The mean density recorded in the 120 μm mesh net was about seven times greater than that in the 300 μm mesh net, suggesting that the larger mesh size net did not lead to an accurate description of microplastics density in the pelagic environment or the degree of risk to which organisms are exposed.

Plastic debris is accumulating in marine ecosystems (Derraik, 2002), reaching remote areas of the world's oceans (Chiba et al., 2018) and threatening ecosystem goods and services (Barnes et al., 2018; Hardesty et al., 2019). Of particular concern is the occurrence of smaller pieces of plastic debris, including those not visible to the naked eye, which are referred to as microplastics, in the world's oceans (Andrady, 2011; Avio et al., 2017). The terms 'microplastics' and 'microlitter' have been defined differently by various researchers (Andrady, 2011) and can be classified as being of primary (purposefully manufactured to be of microscopic size) or secondary (derived from the fragmentation of macroplastic items) origin (Wright et al. 2013; Rezania et al., 2018).

Despite the increased research on microplastics along the subtropical and temperate coasts of the southwestern Atlantic Ocean, baseline knowledge from the western equatorial Atlantic (or Brazilian Equatorial Margin) remains scarce (Fig. 1), as noted in a review by Castro et al. (2018). This region harbors important ecosystems of global relevance, including one of the largest areas of mangroves worldwide and extensive coral reefs (Lacerda et al., 2019; Soares et al., 2017). Circulation dynamics such the North Brazil current connect the study site to the Amazon coast, thereby transporting microplastics and threatening the goods and services of this important coast. These results call for further investigations of microplastic distribution and concentrations on this tropical coast.

Our main aims were to: 1) provide a baseline assessment on the density and characteristics of microplastics and 2) compare the microplastic structures (types and density) collected by two different net mesh sizes (120 and 300 μm). We also tested the hypothesis that the smaller mesh size would collect a higher density of microplastics.

The area is located on the Brazilian Equatorial Margin (Fig. 1) in the western equatorial Atlantic under oligotrophic conditions. It is located on a coastline of ~650 km long and 35–90 km shelf width. This zone is immersed in the continuous subequatorial atmospheric circulation of the trade winds, which are persistent and intense throughout the year (Gomes et al., 2014). Moreover, the study area is of scientific interest owing to the occurrence of an easterly flowing equatorial current (North Brazil current) that links the western equatorial Atlantic and the Amazon coast at this tropical latitude. In the coastal area, there are estuaries and dunes, and the relief comprises relatively flat bottoms, with submerged and intertidal tropical reefs and algae banks (Soares et al., 2017). The fisheries activity in the area is high, mainly characterized by artisanal fishing using various types of fishing gear and methods to target different types of fisheries resources.

Plankton samples were collected by the National Institute of Science and Technology of Materials Transfer at the Continent-Ocean Interface (INCT-TMCOcean) in July and October 2010 (Supplementary material I). A coast-parallel profile was set to 18 sampling stations (Fig. 1;

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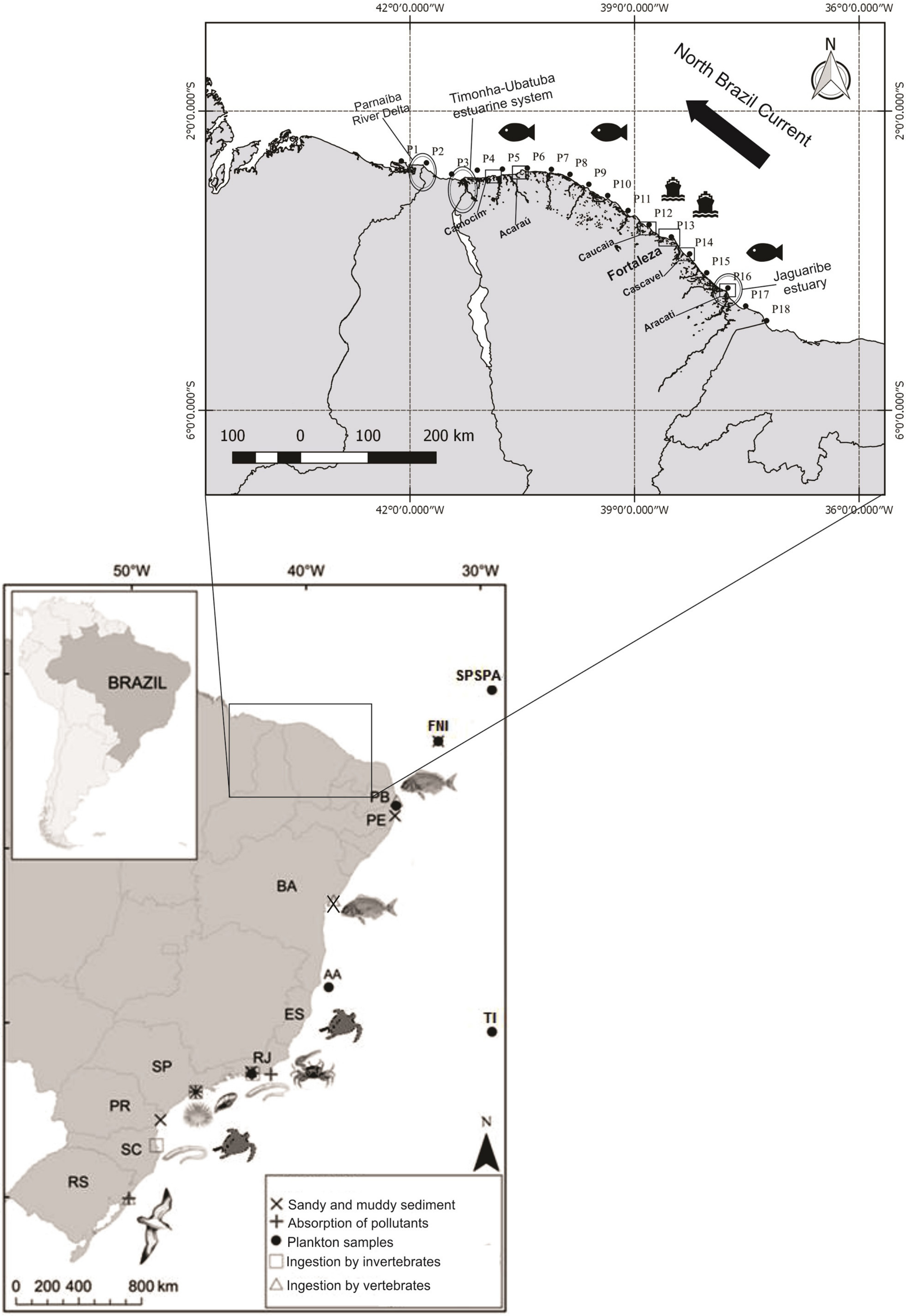

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Fig. 1. Study area in the western equatorial Atlantic (WES), with indication of the sampling stations (P1–P18). Harbor (⚓) and major fishing areas (🐟) (above). Below the map are records of microplastic studies in southwestern Atlantic (modified from Castro et al., 2018) and the knowledge gap regarding the WES (Brazilian Equatorial Margin). Above the map are the 18 stations (P1–P18) and coastal features (currents and main estuaries) along the study area. SPSPA = Saint Paul and Saint Peter Archipelago, FNI = Fernando de Noronha Island. Brazilian states: PB = Paraíba, PE = Pernambuco, BA = Bahia, ES = Espírito Santo, RJ = Rio de Janeiro, SP = São Paulo, PR = Paraná, SC= Santa Catarina, RS = Rio Grande do Sul.

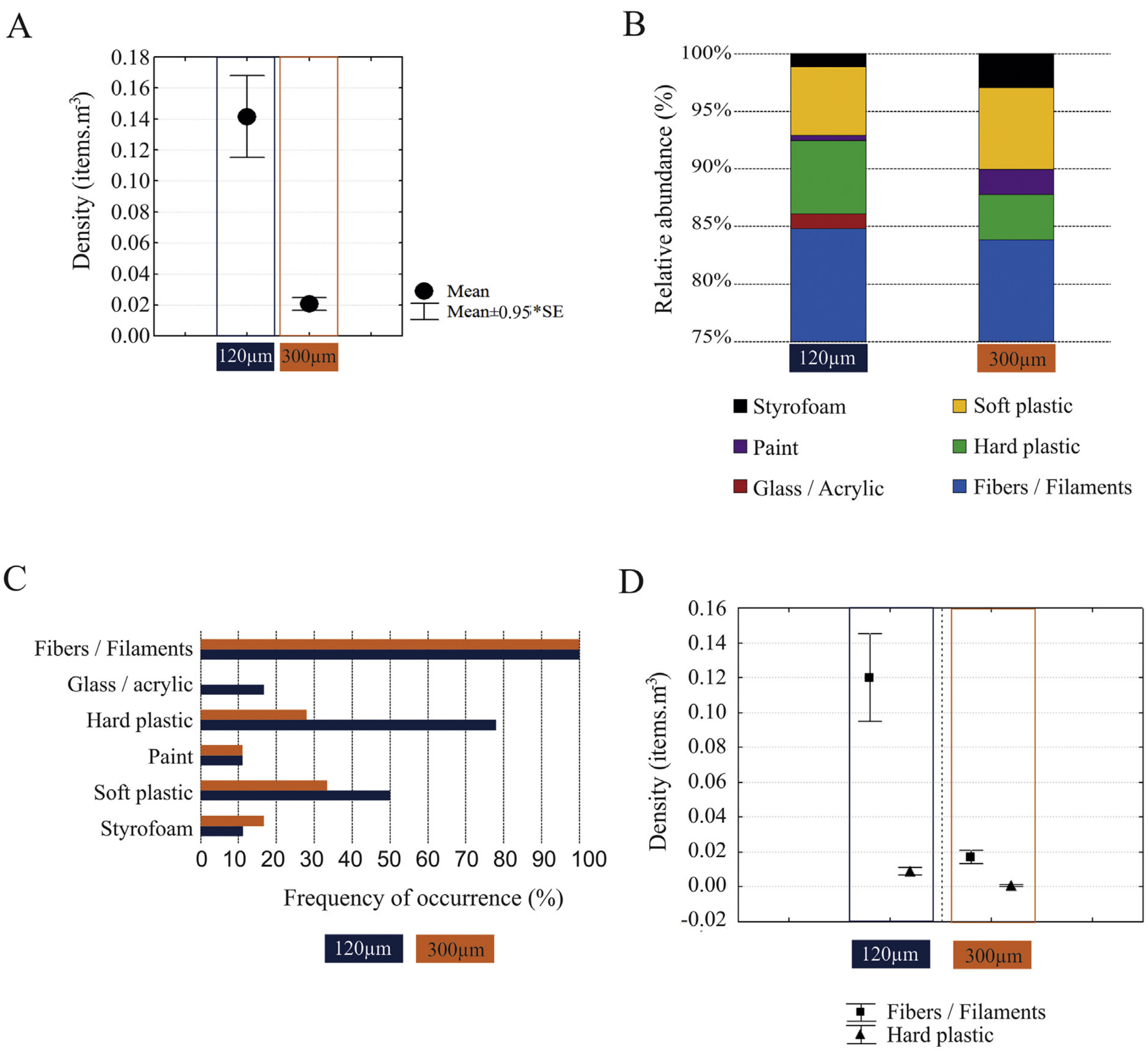

Fig. 2. Microplastics in two mesh nets from Western Equatorial Atlantic: (A) Density (items·m^{-3}), (B) Relative abundance (%), (C) Frequency of occurrence (%), (D) Fibers/filaments and hard plastic density (items·m^{-3}).

P1–P18). At each station, paired plankton samples were collected using two cylindrical-conical nets with mesh sizes of 120 and 300 μm. Calibrated flowmeters (Model, 2030R, General Oceanics) were mounted midway between the center and the net rim for measurement of the filtered water volumes (m^3). The nets were rinsed thoroughly from the outside to ensure that all microplastics were washed into the end of each net.

For analysis of microplastic particles, the samples were observed under a stereomicroscope. All debris items were removed from each sample and placed in a labeled container for subsequent identification. The particles were sorted into six form categories (types) with morphological characteristics according to Lima et al. (2014): (i) fibers/filaments, (ii) hard plastic, (iii) soft plastic, (iv) glass/acrylic, (v) paint, and (vi) Styrofoam. The color characteristics of each item were also registered. The entire procedure was standardized to avoid possible microplastic contamination, mainly those contaminants that were in the air or adhered to the lab equipment. All apparatuses were rinsed thoroughly with distilled water prior to use. Microplastics density (items·m^{-3}) was calculated for each sample using counts and water volume filtered through the net. Data were tested for normal distribution by the Shapiro–Wilks test using Statistica 7.0 software. Since normality was not observed in the whole dataset, the nonparametric Mann–Whitney U test was applied to test for significant differences between the 120 and 300 μm mesh sizes according to our initial hypothesis.

Detectable levels of secondary microplastics were found in all samples (Supplementary material I). The microplastics density was statistically higher in 120 μm mesh net (0.14 ± 0.11 items·m^{-3}) than in 300 μm mesh net (0.02 ± 0.01 items·m^{-3}) (Mann-Whitney; $p < 0.01$) (Fig. 2A). The highest microplastics density of 120 μm mesh net was found at station P7 (0.46 items·m^{-3}), whereas for the 300 μm mesh net, the sample with the highest value was P8 (0.06 items·m^{-3})

Table 1
Microplastic particles mean (value ± S.D., items·m^{-3}) and frequency of occurrence (FO %) sampled with 120 and 300 μm mesh nets.

			120 μm		300 μm	
			Mean ± S.D. (items·m^{-3})	FO (%)	Mean ± S.D. (items·m^{-3})	FO (%)
Fiber/filaments	Blue		7.3 ± 8.1	88.9	0.8 ± 0.8	77.8
	White		0.0 ± 0.1	5.6	0	–
	Black		1.4 ± 1.6	66.7	0.5 ± 0.7	66.7
	Pink		0	–	0.0 ± 0.1	11.1
	Transparent		0	–	0.0 ± 0.1	5.6
	Green		0.3 ± 0.5	27.8	0.1 ± 0.2	16.7
	Red		3.1 ± 2.9	72.2	0.4 ± 0.5	50
Hard plastic		Blue	0.3 ± 0.5	38.9	0.0 ± 0.1	16.7
		Black	0.2 ± 0.4	38.9	0.0 ± 0.1	5.6
		Pink	0.1 ± 0.4	5.6	0	–
		Green	0.1 ± 0.4	16.7	0.0 ± 0.1	11.1
		Red	0.1 ± 0.3	11.1	0	–
Soft plastic		Blue	0.5 ± 1.6	27.8	0.1 ± 0.2	16.7
		White	–	–	0.1 ± 0.3	5.6
		Orange	–	–	0.0 ± 0.1	5.6
		Black	0.2 ± 0.6	22.2	0.0 ± 0.1	5.6
		Green	0.1 ± 0.2	11.1	0	–
		Red	0.1 ± 0.2	11.1	0	–
Paint		Blue	0.0 ± 0.2	5.6	0.0 ± 0.1	5.6
		Black	0.0 ± 0.1	5.6	0.0 ± 0.1	5.6
Glass/Acrylic			0.2 ± 0.4	16.7	0	–

(Supplementary material I).

In relation to microplastics composition, most of the secondary fragments consisted of fibers/filaments, Styrofoam, hard and soft plastic, paint, and glass/acrylic (Fig. 2B; Table 1). The quantities of fibers/filaments and hard plastic densities were statistically higher (Mann-Whitney, $p < 0.01$) in the 120 μm mesh net (Fig. 2D). Fibers/filaments were the most abundant (around 80%) and occurred at all stations in both mesh net sizes (Fig. 2B). Hard plastic was frequent (78%) (Fig. 2C) only in the 120 μm mesh net. Different colored materials were found, of which blue, red, black, and green were the most common (Table 1).

The distribution of microplastic in both nets was heterogeneous (Fig. 3). Data collected in the 120 μm mesh net showed higher density at the P3, P7, P8, P10, P13, P15, and P18 sampling stations. Concerning the microplastics density in 300 μm mesh net, four stations (P3, P8, P11, and P14) had values higher than 0.04 items·m^{-3}.

The present study provides a baseline assessment of the types and regional accumulation of microplastics on the subsurface waters off the Brazilian Equatorial Margin. This might lead to a better understanding of one of the least-known regions worldwide and promote strategies for the reduction of microplastic inputs to the oceans. Most of the previous studies of microplastics in the western Atlantic were conducted at single sites and/or based on the subtropical/temperate southwest Atlantic (Castro et al., 2018). Our data provide baseline information on a large (~600 km) geographic area for multiple coastal sites with data collected using the same methodology. Furthermore, they provide useful information for the comparative analysis of future data regarding increases or decreases of microplastics density and types in this tropical region.

The choice of mesh size is paramount to accurately quantify the presence of microplastics in aquatic environments and provide useful baseline assessments. Our hypothesis regarding the effect of mesh size on the density of these contaminants was verified in the present study, as the 120 μm net proved to be more efficient. The mean density recorded in the 120 μm mesh net was about seven times greater than that observed in the 300 μm mesh net, suggesting that the larger mesh size net did not produce an accurate description of microplastics density in the pelagic environment or of the degree of vulnerability to which marine organisms are exposed.

Although there is still some debate over the most appropriate size to use as a definition of microplastics, particles that pass through a 500 μm sieve have been widely reported as "microplastics" (Gregory and Andrady, 2005; Thompson, 2015). In marine biology studies, the widespread use of coarse plankton nets (200–330 μm) has led researchers to greatly underestimate the abundance of smaller species, although they can be numerically dominant in several plankton communities (Altukhov et al., 2015). The same question should apply to microplastic studies because large mesh sizes (> 120 μm) have been used worldwide (Lima et al., 2014; Zhao et al., 2014; Faure et al., 2015; Olivatto et al., 2019). It is possible that microplastics could be underestimated when large mesh size plankton nets are used during sampling (Green et al., 2018; Figueiredo and Vianna, 2018); however, comparative studies such as this one (120 versus 300 μm) are scarce in the literature.

The highest particle densities recorded were those of fiber/filaments (most abundant), styrofoam, hard and soft plastic, paint, and glass/acrylic. Martinelli Filho et al. (2019) also found that fibers were the dominant microplastic particle on a relatively preserved coastal sandy beach on the Amazon coast (Brazil). Greater densities of microplastics were found in stations near highly urbanized sites (e.g., the Fortaleza metropolitan region), large tropical estuaries such the Parnaíba and Jaguaribe rivers (Fig. 1), and major fishing areas. We hypothesized that the greater presence of fiber-type microplastic might have its origin in the fragmentation of fishing gear, as fishing is an important activity in the region (Soares et al., 2017). Accordingly, Neto et al. (2019) found that 77% of microplastic pollution was derived from fishing net fiber in a bay in southeast Brazil. The distribution pattern of microplastic in the marine environment can be directly influenced by anthropic actions, particularly in regions that present these activities (Barnes, 2009). However, our understanding of the combination of physical factors and microplastic sources that lead to greater accumulation at specific sites and influence spatial distribution patterns is still limited (Thompson, 2015).

One of the hotspots of accumulation found in our study was on the extreme eastern coast of the sampling area (P18 in Fig. 4A); this area has the formation of a permanent gyre that probably accumulates

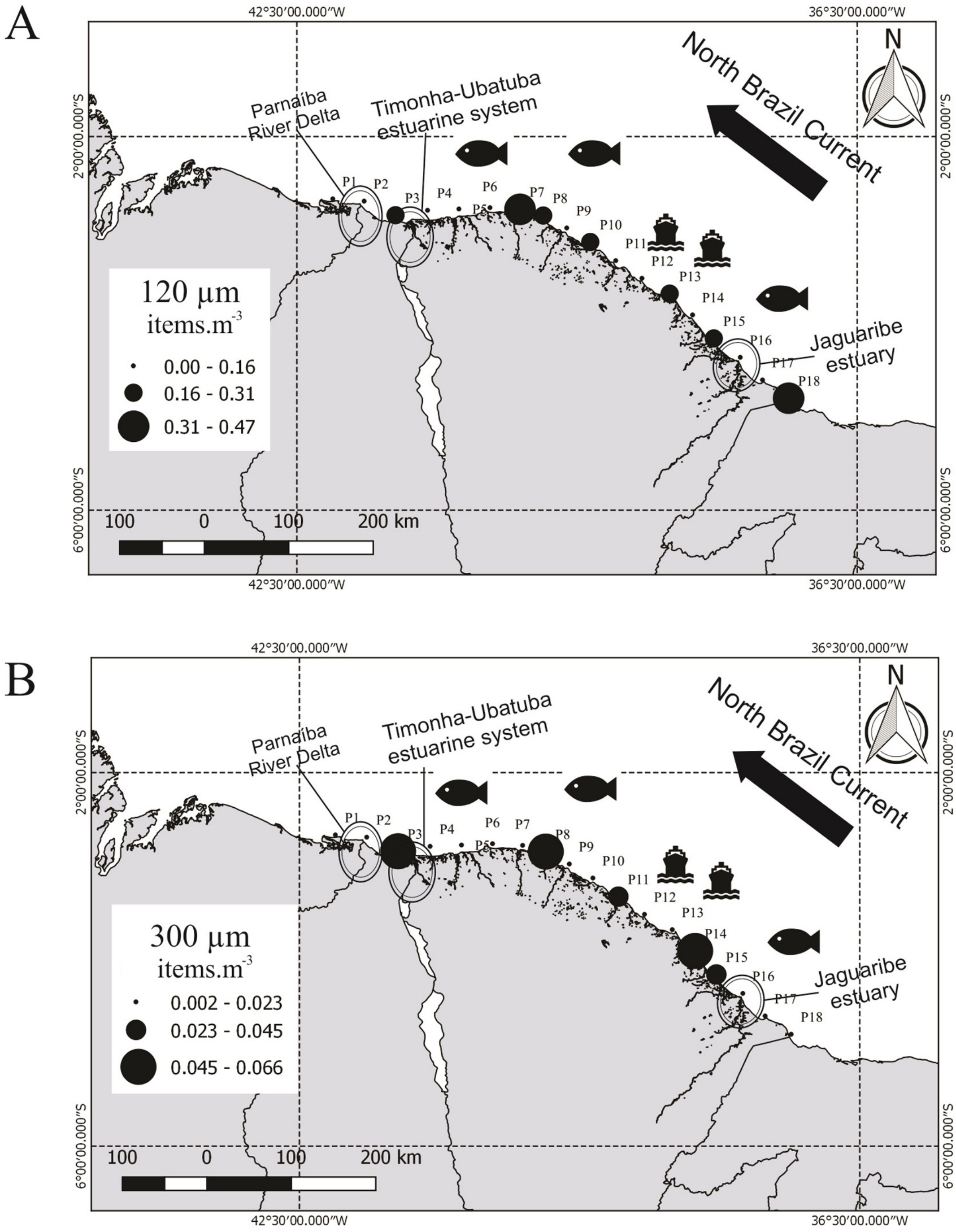

Fig. 3. Distribution of microplastic particles collected with 120 and 300 µm mesh nets. Note the difference in scale.

microplastics of a smaller size (Gomes et al., 2014). Another important area of accumulation of microplastics was near the Fortaleza metropolitan region (P13 and P14), one of Brazil's most developed and densely populated areas, and one of the most heavily modified by coastal engineering structures (~4 million inhabitants). The abundance of microplastics found in this study is probably related to the nearby urbanization and coastal dynamics. Overall, the discharges of cities and estuaries can be significant sources of microplastics to coastal ecosystems (Figueiredo and Vianna, 2018) and the ocean (Andrady, 2011). The pattern of microplastic distribution can also be influenced by ocean currents (Yu et al., 2018) and tides that can act to accumulate these pollutants on the urban shorelines (e.g., jetties) and enclosed/semi-enclosed bays found near the metropolitan urban area of Fortaleza (Paula et al., 2013).

In conclusion, the impacts of smaller plastics on marine resources and blue growth programs cannot be adequately projected in actual policy programs, partly because the focus has been on individual sites and no direct comparison at wide spatial scales has ever been attempted using baseline research projects with standardized approaches and sampling protocols (Avio et al., 2017). Microplastics can negatively affect ecosystems in this tropical area (Pegado et al., 2018) at many levels of biological organization, from organisms to populations and communities, through a wide range of mechanisms. Some effects reported in the literature to date are interaction with organisms at the base of food webs and at higher trophic levels by ingestion (copepods, zooplankton, mussels, oysters, shrimps, fishes, and whales), strangulation, or poisoning; as a source of hazardous chemicals (Auta et al., 2017); and by the spread of invasive species, toxic algae, and pathogenic microorganisms (Arias-Andres et al., 2019).

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.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.marpolbul.2019.110705.

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