

## ABUNDANCE, COMPOSITION, AND DISTRIBUTION OF MICROPLASTICS IN AMAZONICAL ON A NON-URBANIZED BEACH

### A ABUNDÂNCIA E DIVERSIDADE DE MICROPLÁSTICOS EM DIFERENTES AMBIENTES COSTEIROS: COMPARAÇÃO ENTRE RESTINGA E MESOLITORAL EM UMA PRAIA NÃO URBANIZADA

Article received on: 6/1/2026

Article accepted on: 7/4/2026

**Chrystian Braga Carvalho\***

\*Universidade Ceuma (CEUMA), São Luís, Maranhão, Brasil  
[chrystiancarvalho006@gmail.com](mailto:chrystiancarvalho006@gmail.com)

**Lorena Silva e Silva\***

\*Universidade Ceuma (CEUMA), São Luís, Maranhão, Brasil  
[lorenaasilva109@gmail.com](mailto:lorenaasilva109@gmail.com)

**Flávia Melyssa da Silva Rabelo\***

\*Universidade Ceuma (CEUMA), São Luís, Maranhão, Brasil  
[flavia014@outlook.com](mailto:flavia014@outlook.com)

**Ronald da Silva de Jesus\*\***

\*\*Universidade Federal do Rio Grande do Norte (UFRN), Natal, Rio Grande do Norte, Brasil  
[ronaldsilva100@gmail.com](mailto:ronaldsilva100@gmail.com)

**Eduardo Henrique Costa Rodrigues\***

\*Universidade Ceuma (CEUMA), São Luís, Maranhão, Brasil  
[eduardo.rodrigues88@outlook.com.br](mailto:eduardo.rodrigues88@outlook.com.br)

The authors declare that there is no conflict of interest

#### Abstract

Microplastic pollution has become a global environmental issue, affecting all aquatic environments, especially coastal ecosystems. This study investigated the abundance and diversity of microplastics in two coastal environments (restinga and mid-littoral zone) on a non-urbanized beach: Itatinga Beach, in Alcântara, Maranhão. The objective was to understand the distribution and characteristics of these particles deposited in the studied area. A total of 220 particles classified as micro- and mesoplastics were collected and analyzed using flotation, drying, visual inspection, and classification methods based on origin, shape, color, and type. The results showed a higher overall abundance of microplastics in the restinga, with an average of  $23.8 \pm 8.54$  items/m<sup>2</sup>, compared to the mid-littoral zone, which had an average of  $20.8 \pm 5.56$  items/m<sup>2</sup>. The diversity of colors and the Microplastic Diversity Index (MDI) were also higher in the restinga, especially at sampling point P3, indicating multiple sources of pollution, mainly waste from human activities and the degradation of fishing materials. The predominant morphologies were fragments and

#### Resumo

A poluição por microplásticos tem se tornado um problema ambiental em nível global afetando todos os ambientes aquáticos, especialmente em ecossistemas costeiros. Este estudo investigou a abundância e diversidade de microplásticos em dois ambientes costeiros (restingas e mesolitoral) em uma praia não urbanizada: a praia de Itatinga, Alcântara, Maranhão. O objetivo foi compreender a distribuição e características dessas partículas depositadas na área estudada. Foram coletadas e analisadas 220 partículas classificadas como micro e mesoplásticos, utilizando métodos de flotação, secagem, visualização e classificação quanto à origem, formato, cor e tipo. Os resultados indicaram maior abundância geral de microplásticos na restinga, com média de  $23,8 \pm 8,54$  itens/m<sup>2</sup>, comparada ao mesolitoral, cuja média foi de  $20,8 \pm 5,56$  itens/m<sup>2</sup>. A diversidade de cores e o índice de diversidade de microplásticos (IDM) foram mais elevados na restinga, sobretudo no ponto P3, indicando múltiplas fontes de poluição, principalmente resíduos provenientes de atividades humanas e do desgaste de materiais de pesca. A morfologia



fibers, associated with fishing debris. The microplastics found pose environmental risks, affecting marine biodiversity and potentially human health due to bioaccumulation and ingestion by marine organisms. The findings highlight the need for appropriate monitoring and management strategies to reduce contamination and the ecological and public health impacts related to the presence of microplastics in non-urbanized coastal environments.

**Keywords:** Coastal Pollution. Conservation. Environment. Restinga.

*predominante foi de fragmentos e fibras, associadas a resíduos de pesca. Os microplásticos encontrados representam riscos ambientais, afetando a biodiversidade marinha e potencialmente a saúde humana devido ao bioacúmulo e ingestão por organismos marinhos. Os resultados destacam a necessidade de estratégias de monitoramento e manejo adequadas para reduzir a contaminação e os impactos ecológicos e de saúde pública relacionados à presença de microplásticos em ambientes costeiros não urbanizados.*

**Palavras-chave:** Poluição Costeira. Conservação. Meio Ambiente. Restingas.

## 1 INTRODUCTION

Plastic is one of the most widely used materials globally due to its durability, light weight, and low cost, being applied in a variety of products (Moyal *et al.*, 2023). However, these same characteristics make its improper disposal a serious environmental issue, especially when plastic waste reaches natural ecosystems as a result of inadequate waste management and sanitation systems (Vivekanand *et al.*, 2021). The first records of microplastics detected in the environment date back to the 1970s, and since then, they have become a growing concern due to their increasing pollution in aquatic environments (Vargas *et al.*, 2022). Today, microplastics are present throughout the oceans, including remote habitats such as deep-sea sediments and polar sea ice, and are believed to pose a threat to ecosystem health (Wang *et al.*, 2021).

On beaches, plastics undergo accelerated degradation caused by waves, wind, sunlight, and oxygen, fragmenting into smaller particles known as microplastics (<5 mm) (He *et al.*, 2022). These particles are now among the main forms of solid pollution worldwide, particularly concentrated on sandy beaches near urban areas, where there is greater interaction between human and oceanic activities (Vargas *et al.*, 2022). In Brazil, several studies have already confirmed the presence of microplastics in coastal ecosystems (Maia *et al.*, 2023; Olivatto *et al.*, 2018).

The impacts are extensive: microplastics persist in the environment, transport toxic pollutants, and enter the marine food chain. Their sources include textile fibers,

packaging, and personal care products, which disperse globally—even reaching remote oceanic regions (Saha *et al.*, 2024; Harsha *et al.*, 2024). When ingested by marine organisms, microplastics can cause physical harm, ecological imbalances, and may reach humans through seafood consumption, potentially leading to inflammation and hormonal disruption (Harsha *et al.*, 2024).

On beaches, plastic fragmentation is intensified by the mechanical action of waves and wind, breaking down larger debris into microplastics (Deus *et al.*, 2024; Andrady, 2011). Paradoxically, while beaches act as natural filters retaining particles in the sand through wave action (Sewwandi *et al.*, 2023) this process increases the concentration of microplastics in these ecosystems, exacerbating their impact on biodiversity (Billings *et al.*, 2023).

The widespread occurrence of plastic debris in marine ecosystems represents one of the most significant current impacts of marine pollution. As a result, most recent research on microplastics has focused on pollution status, dominant polymer types, adsorption, toxicology, and the diversity and variability of microplastic particles (He *et al.*, 2022). Globally, such information is supported by the regular publication of scientific studies. Only recently have studies addressing this topic (De Carvalho *et al.*, 2025; Pegado *et al.*, 2021) been published with data from Maranhão despite the state having the second-longest coastline in Brazil (640 km) highlighting a scarcity of data and significant research gaps on the subject.

Given this scenario, the present study aimed to compare the abundance and diversity of microplastics at two points along a non-urbanized beach on the coast of Maranhão, providing essential data to better understand the distribution of this contaminant in preserved coastal areas.

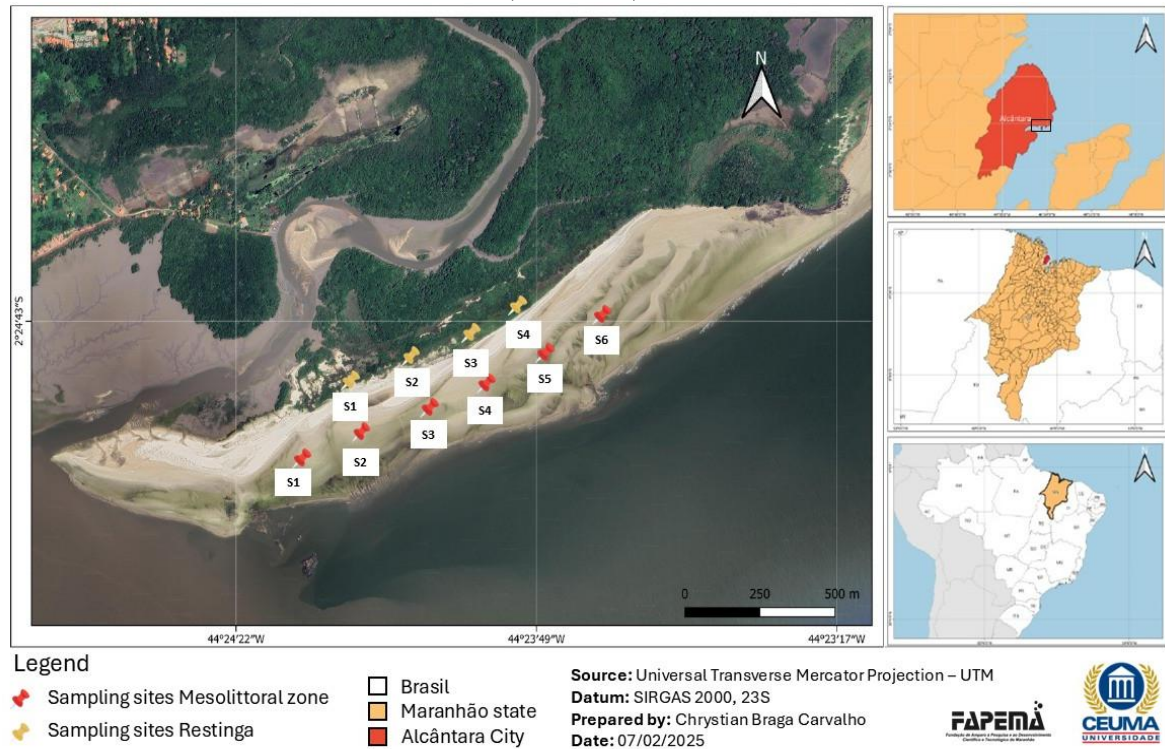
## 2 MATERIALS AND METHODS

### 2.1 Study area

The municipality of Alcântara, located in the Northern Mesoregion of Maranhão, has a population of 21,851 inhabitants, of which only 6,399 live in urban areas. With a total area of 1,457.916 km<sup>2</sup> and a population density of 14.70 inhabitants/km<sup>2</sup>, it is

situated in the Pericumã River basin, bordering the Atlantic Ocean, São Luís, and other neighboring municipalities (Figure 01). The city is part of the Environmental Protection Area (APA) of the Reentrâncias Maranhenses, created in 1991 and recognized as a RAMSAR Site due to its ecological importance. The region is home to extensive mangroves and rich coastal fauna, such as the scarlet ibis (*Eudocimus ruber*), and holds significant historical and cultural value, with colonial houses, churches, and traditional festivals that attract tourists throughout the year. The area features a macrotidal semi-diurnal tidal regime, with average tidal ranges of 4 meters and maximums exceeding 7 meters, along with currents greater than 4 ms<sup>-1</sup> (Queiroz *et al.*, 2022). The region is located near the Port of Itaqui (16.7 km), a strategic area in economic, social, and environmental terms. The climate is humid tropical, with a dry season (July to December) and a rainy season (January to June), and an average temperature of 26°C (Teixeira *et al.*, 2009).

Figure 1: Distribution of sampling points on Itatinga Beach (mesolittoral zone and restinga), in the city of Alcântara, Maranhão, Brazil.



Source: Prepared by the authors, 2025.

## 2.2 Data collection and analysis

Sampling was conducted along the mean high tide line, where particles deposited by seawater on the sandy beach in the mid-littoral zone were collected after high tide. At each sampling point, a 0.5 x 0.5 m quadrat was used. A total of ten points were sampled: four in the restinga area and six in the mid-littoral zone of Itatinga Beach. Fragments were collected from the surface sediment layer using a metal tweezer and, when possible, sorted on site. Samples were stored in labeled metal containers according to the collection location, following the methodology of Novaes (2018). In the laboratory, plastic materials were separated from the sediment using flotation with a sodium chloride solution. The samples were dried in an oven at 60°C for 24 hours. After drying, the samples were visually identified and counted following the methodology adapted from Hidalgo-Ruz (2012). Classification was based on origin (primary and secondary), type (fiber, soft plastic, rigid plastic), shape (elongated, entangled, irregular), and color (blue, transparent, black, red, green, yellow, orange, purple, white, translucent, opaque, etc.).

Fragment classification was carried out at the Environmental Sciences Laboratory (LACAM) at CEUMA University. Quantitative data were initially processed using univariate descriptive statistics (relative and absolute frequencies, presented in charts and tables). A comparison of particle abundance between the studied regions was performed using the Student's t-test. Data processing was carried out using Excel and the PAST software (Hammer, 2001). To assess the diversity of particles, the Microplastic Diversity Index (MDI) was applied, based on the Simpson diversity index. The index was calculated using the color data of the particles (Ding *et al.*, 2022).

$$q = n_i/N_i \quad (1)$$

$$MDI = 1 - \sum q^2 \quad (2)$$

where

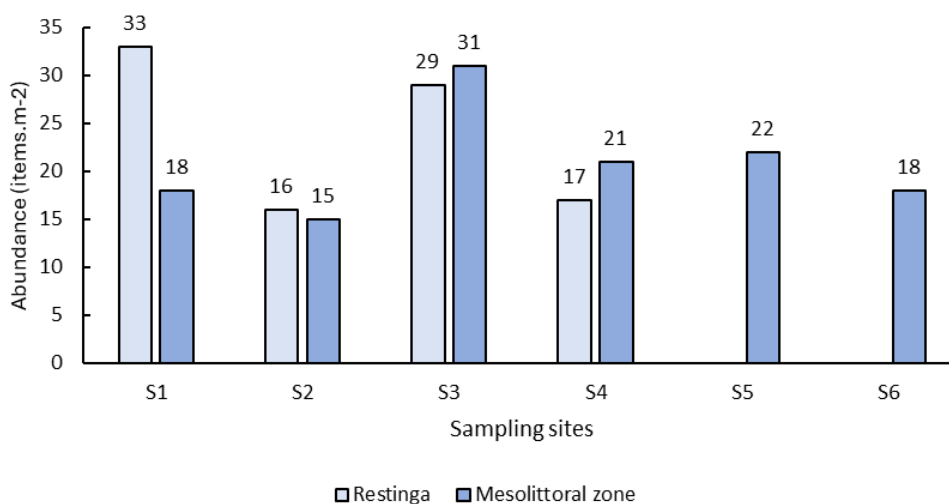
$n_i$  is the number of individuals of the  $i$ -th type of microplastic,  $N$  is the total number of microplastics,  $S$  is the total number of microplastic types, and  $q$  is the proportion of the different types of microplastics. The MDI ranges from 0 to 1; values closer to zero indicate lower diversity

of plastic particles (Li *et al.*, 2020).

### 3 RESULTS AND DISCUSSION

Microplastic pollution has become a global environmental issue, affecting all aquatic environments, particularly coastal ecosystems. The contamination data from the environments investigated in this study highlight the need to monitor non-urbanized coastal areas. A total of 220 particles classified as micro- and mesoplastics were identified across ten sampling points four located in the restinga zone and six in the mesolittoral zone of Itatinga Beach with abundances ranging from 15 to 33 items m<sup>-2</sup> (Figure 02). In this study, 100% of the identified particles were classified as secondary plastics. The restinga zone showed the highest overall microplastic abundance, with the highest values observed at points P1 and P3, and an average abundance of  $23.8 \pm 8.54$  items m<sup>-2</sup>. The mesolittoral zone presented similar quantities, and at some points (P3, P4, P5, and P6), even higher values, with a mean abundance of  $20.8 \pm 5.56$  items m<sup>2</sup>. Sampling point P1 in the restinga zone showed the highest absolute concentration of microplastics, with 33 items/m<sup>2</sup> identified. There was no statistically significant difference in microplastic abundance between the restinga and mesolittoral zones (t-test,  $p > 0.05$ ).

Figure 2: Variation in microplastic particle abundance on Itatinga Beach, Alcântara, Maranhão.



Source: Prepared by the authors, 2025.

Figure 03 shows the relative distribution of microplastic colors found at different sampling points (P1 to P6) in the mesolittoral zone and (P1 to P4) in the restinga zone. A total of 13 colors were recorded across the sampling points in both regions.

In the mesolittoral zone, blue was the most dominant color at all sampling points, being especially prevalent at P1, P3, P5, and P6, where it accounted for over 60% of the total particles. Green was the second most frequent color, particularly at points P2, P3, P4, and P6. Less common colors such as red, yellow, purple, and gray appeared in smaller quantities, being more noticeable at P5 and P6. Notably, point P5 exhibited the highest color diversity, including red, yellow, purple, and gray particles, indicating greater heterogeneity in microplastic composition at this site.

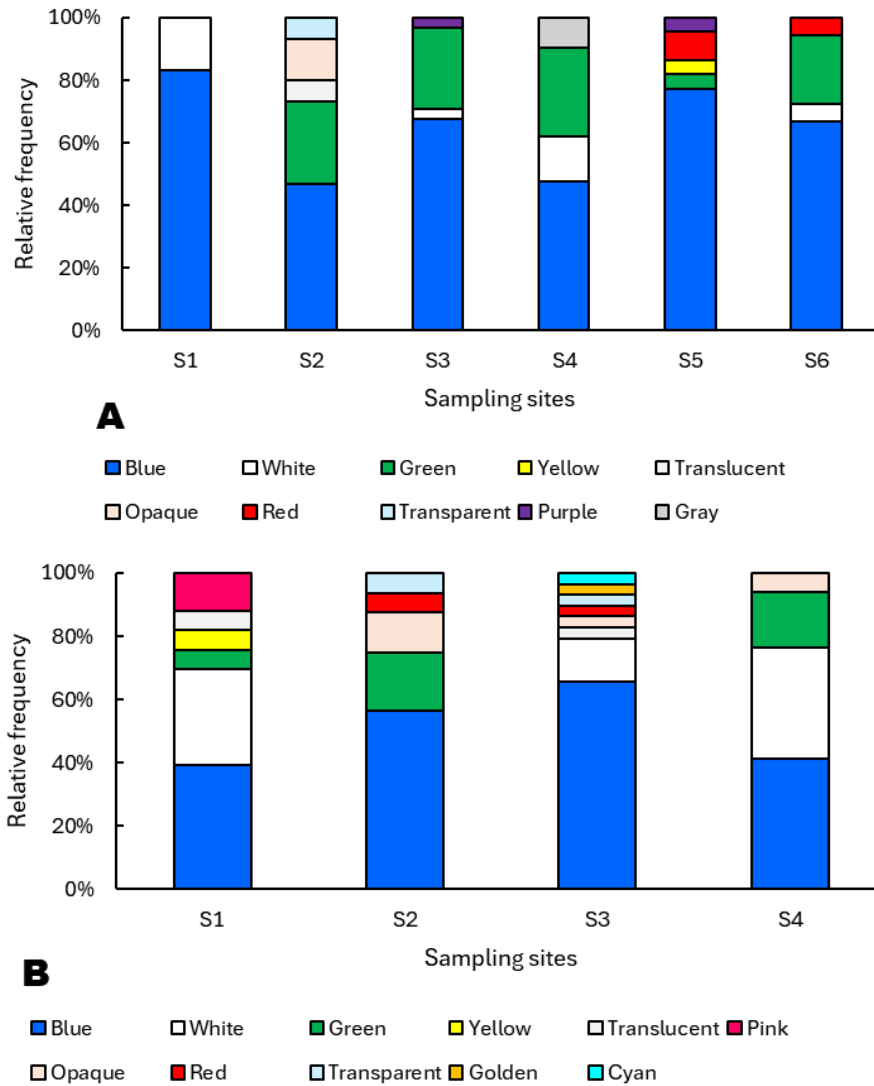
In the restinga zone, blue was also the predominant color at all points, especially at P3 and P4. White had a significant presence, mainly at points P1 and P4. Green appeared in greater proportions at P2 and P4, suggesting variation in microplastic composition at those sites. Colors such as pink, red, yellow, cyan, and gold were found in smaller proportions, especially at P1 and P3, with the latter showing the greatest diversity.

The color of microplastic particles serves as an important indicator in environmental studies. Bird, fish, and turtle species are often attracted to colors that resemble natural prey (e.g., blue, which mimics small fish or gelatinous organisms). Additionally, certain colors are associated with specific product origins (for example, white or transparent from packaging; black from tire or electronic fragments). Changes in coloration can also indicate exposure time or weathering level—faded or yellowed particles tend to be older.

In both regions studied, results showed that blue was the most common microplastic color, followed by green and various other colors in lower proportions (Figure 03A and 03B). A study by Ferreira *et al.* (2025) in São José Bay also identified blue as the most frequent color across different environmental matrices (sediment and water), confirming the findings of this study. The predominance of blue particles aligns with other studies (Da Costa *et al.*, 2023; Queiroz *et al.*, 2022; Zamprogno *et al.*, 2021), and corresponds to findings that blue is the most commonly ingested plastic color by fish (Lim *et al.*, 2021). Other studies, however, have reported different dominant colors, such

as white (47%) (Ding *et al.*, 2022; Carvalho, Silva, & Costa *et al.*, 2021) and transparent (Menezes *et al.*, 2025; Wang *et al.*, 2018).

Figure 3: Variation in the coloration of microplastic particles on Itatinga Beach, Alcântara, Maranhão. A – Mesolittoral; B – Restinga.



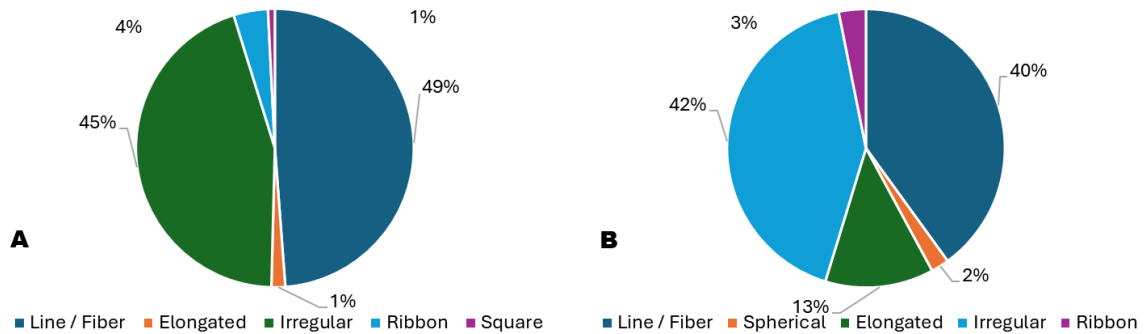
Source: Prepared by the authors, 2025.

The morphology of the particles was diverse and showed a similar distribution between the studied locations. Six categories were identified: line/fiber, elongated, irregular (deformed), ribbon, square, and spherical. Irregular and line/fiber plastics were the most abundant (Figure 04A and 04B). In the restinga zone, elongated plastics were the third most frequent category (13%), differing from the mesolittoral zone.

A significant portion of the fibrous material consisted of fragments of fishing nets, which aligns with the predominant activity in the region. Ribbon-shaped plastics (4% and 3%) represented only a small percentage of the total microplastics (Figures 4A and 4B) and were identified as fragments of transparent packaging and/or labels, indicating the transport of domestic waste into the impacted area.

A study by Ding *et al.* (2022) found that fragmented (37%) and fibrous (32%) particles were the most abundant in the South China Sea, emphasizing the importance of wear and tear from fishing gear as a source of microplastic contamination a result similar to that reported by Silva *et al.* (2022). Additionally, Da Costa *et al.* (2023) found that filament-type (line) particles were the most commonly sampled and catalogued in their study.

Figure 4: Morphological characteristics of microplastics on Itatinga Beach, Alcântara. A – meslittoral zone; B – restinga.



Source: Prepared by the authors, 2025.

The classification of microplastic particle shapes is important because it provides relevant information about their origin, behavior in the environment, and potential ecological impacts (Ugwu *et al.* 2021). Each shape such as fibers, irregular fragments, films, pellets, or spheres is generally associated with different pollution sources (Vargas *et al.*, 2022). For example, fibers are typically derived from synthetic textiles found in domestic wastewater, while fragments may result from the breakdown of larger plastic items, such as packaging. The presence of pellets may indicate that the area is affected by industrial processes, and when fragments and other irregular shapes dominate, it may suggest a rapid degradation process of macro- and mesoplastics (Ugwu *et al.*, 2021). The

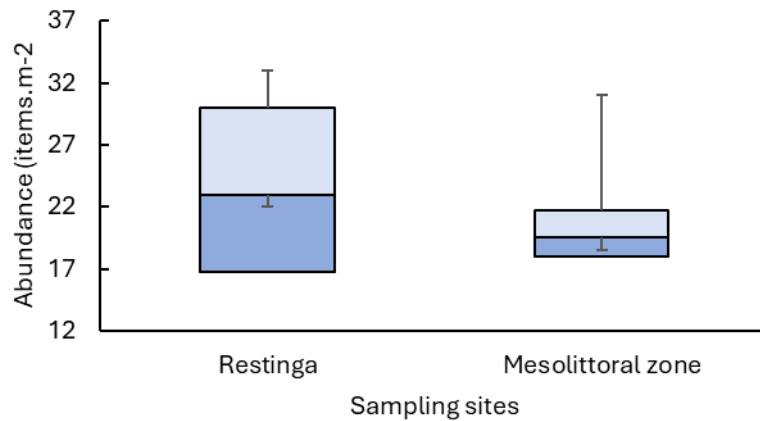
data observed for Itatinga Beach indicate a predominance of secondary particles, with 100% of the identified material consisting of particulate plastics.

Additionally, particle shape directly influences transport, deposition, and bioavailability in ecosystems. For example, fibers can remain suspended in the water column for longer periods, while denser fragments tend to settle into sediments (Da Silva *et al.*, 2022). This affects how aquatic organisms interact with microplastics, potentially increasing accidental ingestion and toxic effects, depending on the type and shape of the particle. According to Lim *et al.* (2021), the most commonly ingested plastic shape by fish is fiber, followed by fragments.

Figure 05 presents a comparison of microplastic abundance between the studied areas. The results indicate that the restinga zone shows a higher abundance of microplastic particles compared to the mesolittoral zone. This may be explained by several factors, such as ocean current dynamics, wind action, and the characteristic vegetation of the restinga, which can act as a natural barrier, trapping microplastic particles. Moreover, the graph shows greater data dispersion in the restinga, suggesting a significant variation in the amount of microplastics found. This pattern may result from multiple pollution sources, such as waste transported by wind and tides or directly deposited by human activities in the region.

In contrast, the mesolittoral zone exhibited lower microplastic abundance and a more uniform distribution of data. This suggests that, in this environment, microplastics may be more easily removed by natural processes such as wave and tidal action, or they may be more concentrated in specific areas that were not sampled. The lower variability in the mesolittoral zone indicates a more predictable distribution, which could facilitate monitoring and mitigation strategies.

Figure 5: Comparison of the abundance of microplastic particles identified in the restinga and mesolittoral zone.



Source: Prepared by the authors, 2025.

The restinga zone generally exhibited greater color diversity in plastic particles compared to the mesolittoral zone, with higher Diversity Index (IDM) values at almost all analyzed points (Table 01). Sampling point P3 in the restinga showed the highest index (0.974), indicating that this location has the greatest diversity of plastic particle colors, while point P1, located in the beach (mesolittoral) zone, presented the lowest index (0.278), indicating the lowest color diversity. The comparative analysis between the two environments revealed statistically significant differences in microplastic particle concentrations ( $p < 0.05$ ), highlighting the need to include such areas in plastic pollution monitoring programs.

Table 1: Variation of the Microplastic Diversity Index (MDI) among sampling points on Itatinga Beach in the restinga and mid-littoral areas.

Sampling points	S1	S2	S3	S4	S5	S6
<b>Restinga</b>	0,882	0,941	0,974	0,841	-	-
<b>Mesolittoral zone</b>	0,278	0,684	0,472	0,662	0,388	0,500

Source: Prepared by the authors, 2025.

## 4 CONCLUSION

Itatinga Beach is affected by microplastic pollution, occurring both in the mesolittoral zone and in the restinga area. The quantity of particles observed in both areas is relatively similar; however, the results suggest that the restinga exhibits a greater diversity of microplastics, while the mesolittoral zone shows points with lower color diversity in plastic particles. This difference may be related to factors such as waste deposition dynamics, tidal and wind action, and the specific environmental characteristics of each location. Additionally, the restinga area may function as a microplastic filter, retaining particles for a certain period.

The predominant color (blue) and shapes (fiber and irregular) identified in the study area are consistent with the scientific literature for similar environments. The implementation of public policies aimed at reducing improper plastic disposal, combined with public awareness about the environmental impacts of such waste, is essential to minimize its adverse effects. Furthermore, continuous research efforts can support the development of more effective measures for the conservation of coastal ecosystems and the biodiversity they support.

## ACKNOWLEDGEMENTS

The authors of this research thank the Foundation for Research Support of the State of Maranhão (FAPEMA) for granting master's scholarships to the first and second authors of this study (grant numbers BM-03951/23 and BM-06563/24), Ceuma University, and all those who directly or indirectly contributed to the completion of this research.

## REFERENCES

- CARVALHO, Julia PS; SILVA, Thaianie S.; COSTA, Monica F. Distribution, characteristics and short-term variability of microplastics in beach sediment of Fernando de Noronha Archipelago, Brazil. **Marine Pollution Bulletin**, v. 166, p. 112212, 2021.
- CHATTOPADHYAY, I. Role of microbiome and biofilm in environmental plastic degradation. **Biocatalysis and Agricultural Biotechnology**, v. 39, p. 102263, 2022.

- DA COSTA, Mercia Barcellos *et al.* Abundance, composition, and distribution of microplastics in intertidal sediment and soft tissues of four species of Bivalvia from Southeast Brazilian urban beaches. **Science of The Total Environment**, v. 857, p. 159352, 2023.
- DA SILVA, Elaine Ferreira *et al.* Evaluation of microplastic and marine debris on the beaches of Niterói Oceanic Region, Rio De Janeiro, Brazil. **Marine Pollution Bulletin**, v. 175, p. 113161, 2022.
- DE CARVALHO, Marina Rocha *et al.* Presence of microplastics in *Sciades herzbergii* (Bloch, 1794) captured in harbor areas of the Amazon coast, Maranhão, Brazil. **Marine Pollution Bulletin**, v. 215, p. 117862, 2025.
- DING, Yongcheng *et al.* Distribution pattern and influencing factors for the microplastics in continental shelf, slope, and deep-sea surface sediments from the South China Sea. **Environmental Pollution**, v. 309, p. 119824, 2022.
- Hammer, Ø., D. Manual de Referência PAST: Paleontological Statistics Software Package for Education and Data Analysis. 2001. Disponível em: <http://folk.uio.no/ohammer/past/>. Acesso em 00/02/2025
- He, S., Jia, M.; Xiang, Y.; Song, B., Xiong, W., Cao, J.; Zeng, G. Biofilm on microplastics in aqueous environment: Physicochemical properties and environmental implications. **Journal of Hazardous Materials**, 424, 127286. 2022
- Hidalgo-Ruz, V., Gutow, L., Thompson, R. C.; Thiel, M. Microplastics in the marine environment: a review of the methods used for identification and quantification. **Environmental science & technology**, 46(6), 3060-3075. 2012
- LIM, Kok Ping *et al.* A meta-analysis of the characterisations of plastic ingested by fish globally. **Toxics**, v. 10, n. 4, p. 186, 2022.
- Maia, D. S., da Silva, G. R., Paganini, P. P., Stoffler, R. V. Análise quali-quantitativa e espacial de poluição por microplástico ao longo da praia Tupi, Praia Grande–SP, Brasil. **Journal of Animal and Environmental Research**, 6(1), 710-724. 2023
- MENEZES, Karina Machado *et al.* Microplastic contamination in the mangroves of Piraquê-Açu and Piraquê-Mirim rivers, Aracruz (Brazil): An analysis in sediment, water, and biota. **Marine Pollution Bulletin**, v. 214, p. 117696, 2025.
- Moyal, J.; Dave, P. H.; Wu, M., Karimpour, S.; Brar, S. K., Zhong, H.; Kwong, R. W.. Impacts of Biofilm Formation on the Physicochemical Properties and Toxicity of Microplastics: A Concise Review. **Reviews of Environmental Contamination and Toxicology**, 261(1), 1-17. 2023
- Novaes, Gabriela de Oliveira *et al.* Microplásticos em praias flúvio-estuarinas amazônicas. 2018.

- Olivatto, G. P., Carreira, R., Tornisielo, V. L.; Montagner, C. C. Microplásticos: Contaminantes de preocupação global no Antropoceno. **Revista Virtual de Química**, 10(6), 1968-1989. 2018.
- PEGADO, Tamyris *et al.* Ingestion of microplastics by *hypanus guttatus* stingrays in the Western Atlantic Ocean (Brazilian Amazon Coast). **Marine Pollution Bulletin**, V. 162, p. 111799, 2021.
- QUEIROZ, Arnaldo Fabrício dos Santos *et al.* First assessment of microplastic and artificial microfiber contamination in surface waters of the Amazon Continental Shelf. *Science of The Total Environment*, v. 839, p. 156259, 2022.
- QUEIROZ, Jislene Brito Matos *et al.* Phytoplankton of the shipping sector of São Marcos Bay (Amazon Coast): A potential risk area for the establishment of non-indigenous species. **Regional Studies in Marine Science**, v. 49, p. 102121, 2022.
- Sooriyakumar, P.; Bolan, N.; Kumar, M.; Singh, L.; Yu, Y.; Li, Y.; Siddique, K. H. (2022). Biofilm formation and its implications on the properties and fate of microplastics in aquatic environments: a review. **Journal of Hazardous Materials Advances**, 6, 100077. 2022
- TEIXEIRA, Sheila Gatinho; SOUZA FILHO, Pedro Walfir Martins. Mapeamento de ambientes costeiros tropicais (Golfão Maranhense, Brasil) utilizando imagens de sensores remotos orbitais. **Revista Brasileira de Geofísica**, v. 27, p. 69-82, 2009.
- UGWU, Kevin; HERRERA, Alicia; GÓMEZ, May. Microplastics in marine biota: A review. **Marine pollution bulletin**, v. 169, p. 112540, 2021.
- VARGAS, J. G. M.; SILVA, V. B. D.; OLIVEIRA, L. K. D.; MOLINA, E. F. Microplásticos: uso na indústria cosmética e impactos no ambiente aquático. **Química Nova**, 45, 705-711. 2022
- VIVEKANAND, A. C.; MOHAPATRA, S.; TYAGI, V. K. Microplastics in aquatic environment: Challenges and perspectives. **Chemosphere**, 282, 131151. 2021.
- WANG, Wenfeng *et al.* Microplastics in surface waters of dongting lake and hong lake, China. **Science of the Total Environment**, v. 633, p. 539-545, 2018.
- ZAMPROGNO, Gabriela Carvalho *et al.* Spatial distribution of microplastics in the superficial sediment of a mangrove in Southeast Brazil: A comparison between fringe and basin. **Science of the Total Environment**, v. 784, p. 146963, 2021.