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Original Article

Microplastics in the Gastrointestinal Tract and Gills of Fish (*Dormitator latifrons*) from Monterrico Multiple Use Natural Reserve, Guatemala

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Abstract

Microplastic (MP) pollution is a growing global concern due to its persistence in the environment, widespread distribution, and potential ecological risks, particularly in aquatic ecosystems. MPs are readily ingested by fish, either directly or accidentally, posing threats to organismal health and food webs. In Guatemala, fish biodiversity in protected coastal areas plays a key role in maintaining ecosystem services and supporting local communities' food security. However, the extent of MP contamination in these regions remains poorly understood. To address this gap, we investigated the abundance and composition of MPs in the gastrointestinal tracts (GIT) and gills of *Dormitator latifrons*, a species of ecological and economic significance for artisanal fisheries. A total of 89 specimens were sampled across three field campaigns conducted in April, June, and October 2021 in Monterrico Multiple Use Natural Reserve, Guatemala. MPs collected in the GIT particles were higher than in the gills ($p < 0.01$). Fibers were the predominant MP type, with blue being the most frequently observed color in both organs. These results reinforce previous findings of MP ingestion by fish and highlight the need for ongoing monitoring of microplastic pollution in Guatemala's aquatic ecosystems.

Keywords: Estuary, Fibers, Fish, Ingestion, Plastic particles

INTRODUCTION

The global production and use of plastics is projected to increase significantly, from 464 million tonnes (Mt) in 2020 to an estimated 884 Mt by 2050 (Dokl *et al*., 2024). A substantial portion of this plastic waste ultimately enters natural ecosystems, transported via rivers, wind, and ocean currents, where it undergoes degradation driven by environmental and physical processes (Zalasiewicz *et al*., 2019). This breakdown of larger plastic debris leads to the formation of microplastics (MPs), defined as plastic particles smaller than 5 mm in diameter (Barboza *et al*., 2020). MPs can be classified into two main types: primary MPs, which are intentionally manufactured for use in products such as cosmetics, paints, and industrial pellets; and secondary MPs, which are produced by the abrasion of larger plastic items during use, as well as by the fragmentation of larger plastic waste in the environment (Thompson *et al*., 2024). It is estimated that between 10 and 40 million tonnes of MPs are released into the environment each year, a figure that could double by 2040 under current production and waste management trends (Thompson *et al*., 2024). As a result, MPs are now considered ubiquitous contaminants, capable of interacting with a wide range of organisms across diverse ecosystems worldwide (Thompson *et al*.,

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2004).

MPs have been previously reported in brackish-water and freshwater fish in Guatemala (Mazariegos-Ortíz *et al*., 2021; Oliva-Hernández *et al*., 2021). Several studies reveal that MPs are ubiquitous in freshwater ecosystems (Wang *et al*., 2019). The main sources of MPs pollution are terrestrial, primarily from urbanization and anthropogenic activities (Eerkes-Medrano *et al*., 2015). This causes various organisms to be exposed to these contaminants and, therefore, to be consumed by different taxa throughout the food chain (Wang *et al*., 2019). The organisms most used as bioindicators of MPs contamination are fish, since they have restricted mobility and tend to stay in the same place for long periods of time, making them prone to ingesting MPs (Wesch *et al*., 2016).

The ingestion of microplastics not only affects the physical health of fish but also alters their behavior. In a study conducted with goldfish (*Carassius auratus*), a significant reduction in predatory behavior was observed when exposed to MP fibers (Liang *et al*., 2023). These behavioral changes can compromise vital fish activities, such as feeding and reproduction, directly affecting populations and ecological balance. Furthermore, MPs can induce abnormal physiological responses in fish, such as increased oxidative stress and increased accumulation of malondialdehyde, suggesting cellular damage (Wang *et al*., 2024). These alterations in fish physiology can decrease their ability to survive, grow, and reproduce, affecting not only the individual health of aquatic organisms but also the sustainability of fisheries globally (Wang *et al*., 2024).

The bioaccumulation of MPs in fish can also pose risks to human consumers. In a study conducted in the Tyrrhenian Sea (Italy), MPs were detected in the gills and muscles of fish species such as *Mugil cephalus*, *Diplodus annularis*, and *Mullus barbatus* (Squillante *et al*., 2023). Fish contaminated with MPs not only pose risks to marine ecosystems but also to humans, as the consumption of contaminated fish can be a route of transfer of MPs and adsorbed contaminants, such as heavy metals, pesticides, polycyclic aromatic hydrocarbons, polychlorinated biphenyls and perfluoroalkyl acids, as vectors through the food chain, increasing the risk to human health (Kibria, 2023; Du *et al*., 2020).

Dormitator latifrons (Family: Elotridae) is known by several common names, including Pacific fat dormilón, chopopo, chame, puyeque, and popoyote. Its distribution ranges from southern California in the United States of America to Peru. In the Pacific of Mexico, it is used for human consumption, while in Ecuador, it is farmed in an artisanal way for consumption and export (Badillo *et al*., 2018). This species is listed by the Food and Agriculture Organization of the United Nations (FAO) as an important aquaculture species that can be grown in shallow fresh and salt water (Bastos-Rosales *et al*., 2019). The diet of *D. latifrons* is mainly based on detritus, plant matter, and animal matter, which ultimately helps to transform the energy from detritus into higher trophic chain layers (Castro *et al*., 2005).

MPs contamination in protected areas has received increasing attention in recent years due to the critical role these regions play in preserving marine, coastal, and freshwater biodiversity (De-la-Torre *et al*., 2023). MPs have emerged as ubiquitous pollutants in such areas, raising global concern because of their harmful effects on both organism health and ecosystem integrity (Kutralam-Muniasamy *et al*., 2021). The Monterrico Multiple Use Natural Reserve (RNUMM) is a protected area located in the coastal region of the Pacific Ocean at 120 km southeast of Guatemala City, consisting of marine-coastal and estuarine ecosystems with a wide diversity of animal and plant species, including mangroves (Mazariegos-Ortiz *et al*., 2021). The RNUMM is contaminated by domestic, industrial, and agricultural wastewater from the southern region (Oliva *et al*., 2007). Emerging pollutants, on the other hand, are synthetic or natural chemicals that are not commonly studied in the RNUMM and may have the potential to be hazardous for organisms and humans (Wang *et al*., 2024). MPs are among the pollutants whose small size facilitates uptake by organisms across various trophic levels and feeding strategies; however, their pathways and effects in many species remain poorly characterized, despite emerging reports (Mazariegos-Ortíz *et al*., 2021; Yang *et al*., 2021). Thus, the purpose of the study was to determine the presence of microplastics in specimens of *D. latifrons*, an important species for local fishing in the RNUMM, as well as to assess the relationship of MPs with biometric variables. The authors hypothesized that, in addition to ingestion, a proportion of MPs adheres to the gills of *D. latifrons*, and that these MPs are related to health indicators, such as the condition factor.

MATERIALS AND METHODS

Study Area

The RNUMM is a protected area in Guatemala established to conserve vital ecosystems (SEGEPLAN, 2014). Located on the southern Pacific coast, it spans approximately 1,800 hectares between longitudes 90º26’21” and 90º30’14” W, and latitudes 13º58’28” and 14º0’38” N (Figure 1). Around 65% of its area consists of freshwater bodies and mangroves, and the region is characterized by a combination of estuarine and marine ecosystems. Five communities are situated within the protected area, connected by water channels and roads (Castillo-Cabrera, 2012).

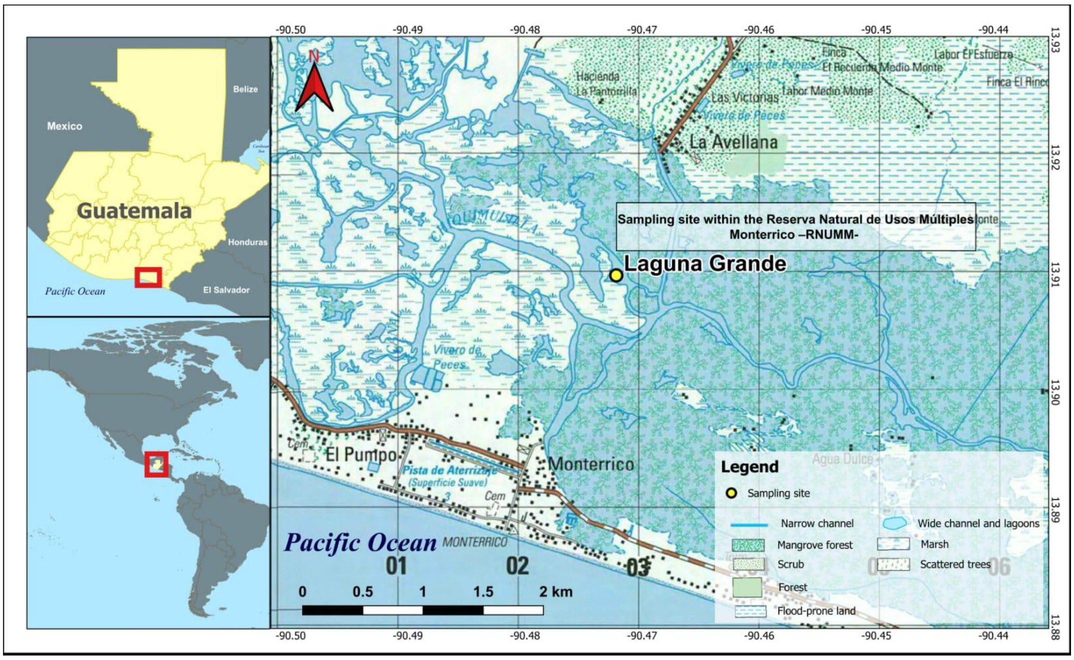

Figure 1. Map of Guatemala with the area of Monterrico Multiple Use Natural Reserve enlarged at the right.

Fish sampling, microplastic extraction, and classification

Fish sampling was conducted in the RNUMM with the assistance of local fishermen, using a 3 × 3 m fishing net with a 5.0 cm mesh size (Figure 2A). Collections took place at multiple sites within the area called Laguna Grande (N 13 55 25.5 W 090 29 16.9), during three sampling months: April, June, and October 2021, between 5:00 a.m. and 10:00 a.m. A total of 89 specimens of *Dormitator latifrons*, each measuring 10.0 cm or more, were selected for MP analysis. Fish were transported at 4 °C and kept frozen in the laboratory until further processing. *D. latifrons* is the most important fish for artisanal fisheries, which serve as an economic income and provide a protein source for local communities (Hernández-Padilla *et al*., 2020).

Fish were dissected to remove the digestive tract, which was then placed in a 250 mL glass beaker for organic matter digestion (Figure 2B). Each sample received 25 mL of a 20% KOH solution and was heated to 50 °C on a hot plate for 15 minutes, with constant stirring using a glass rod to aid alkaline digestion. Following digestion, samples were diluted with 125 mL of ultrapure water and vacuum filtered through a 47 mm Whatman glass fiber filter with a pore size of 45 µm (Roch *et al*., 2020).

MPs recovered from filters were examined with a microscope (Kyowa Optical, model SD-2PL). The number of microplastics present in the filters from the GIT and gills of each organism was counted and then classified by shape into fibers, films, fragments, foams, and sponges (Roch *et al*., 2020). Verification that the fibers were of synthetic or natural origin was carried out by bringing a hot needle close to the particles and observing whether the fibers shrank or stretched due to the heat (Kumar *et al*., 2018).

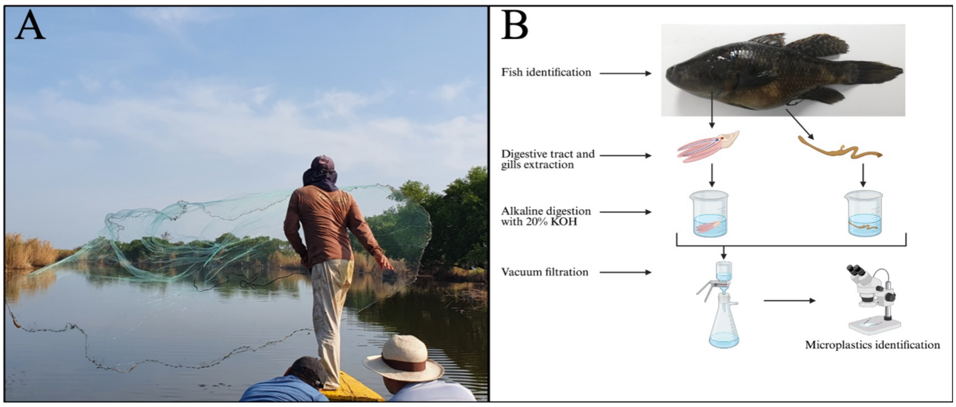

Figure 2. (A) Sampling of fish using a fishing net and (B) an illustration of the analytical procedure.

Quality control

Control measures to prevent cross-contamination from external plastic particles included cleaning the work surface, using glassware, laboratory instruments, and supplies made of glass, metal, or paper, and wearing a cotton lab coat. Work was also carried out under controlled laboratory conditions, avoiding the use of air conditioning and external drafts that could retain fibers in the environment. Finally, control samples were placed and evaluated around the work area to verify the presence of external plastic particles.

Data analysis

Data are presented as percentages for shape and color, and as means (standard deviations) for biometric variables. Shapiro-Wilk was employed to assess normality. Since data did not follow the normality assumption, the Mann-Whitney (or known as the Wilcoxon rank sum test) test was employed to analyze the difference between MPs in the GIT and MPs in gills. The occurrence factor (OF) was calculated using the following equation:

$$OF = \frac{MPsF}{n} \times 100 \qquad (1)$$

where
MPsF = number of fish in which MPs were detected
n = total number of fish analyzed.

Additionally, the condition factor (K) was calculated as an indicator of fish health using the following equation:

$$K = \frac{TW}{L^3} \times 100 \qquad (2)$$

where
TW = total weight (g)
L = total length (cm) of each fish.

To assess the relationship between K and the number of MPs, linear regression and Kendall's rank correlation were applied, with a 95% confidence interval. Statistical significance was set at $p < 0.05$. All analyses were performed in RStudio, and visualizations were created using the ggplot2 package (R Core Team, 2025).

RESULTS AND DISCUSSION

A total of 89 specimens were analyzed in this study. MPs were detected in the GIT of 51 individuals (57.3%) and the gills of 28 individuals (31.5%). A total of 98 MPs were identified in the GIT (Figure 3), with fibers being the most common shape (42), followed by fragments (27), film (22), and foam (7) (Figure 3A). Regarding colors of the MPs in the GIT, red (33%), blue (22%), and transparent (19%) particles were the most frequent (Figure 3B). A similar trend to the GIT was observed for the MPs' shape in gills, where fibers were also predominant (26), followed by fragments (6) and film (1) (Figure 3C). The color predominant in the MPs found in the gills was black (18) (Figure 3D). A previous study conducted in the RNUMM protected area reported the presence of MPs in 15 fish species, including *D. latifrons*, with an occurrence rate of 35% (Mazariegos-Ortiz *et al.*, 2021). In contrast, our study found MPs in 57% of *D. latifrons* specimens. This discrepancy may be attributed to differences in sampling season, environmental conditions, or methodological factors (e.g., target organism versus non-selective sampling). Nonetheless, our findings contribute to the growing body of evidence on MP pollution in Guatemalan freshwater ecosystems. For example, a study in Lake Amatitlán found that 96.9% of *Oreochromis niloticus* (tilapia) contained MPs in their gastrointestinal tracts (Oliva-Hernández *et al.*, 2021). Similarly, in Lake Petén Itzá, 81.2% of *Petenia splendida* and *Parachromis managuensis* individuals were found to contain MPs in the GIT (Oliva *et al.*, 2023, see supplemental information).

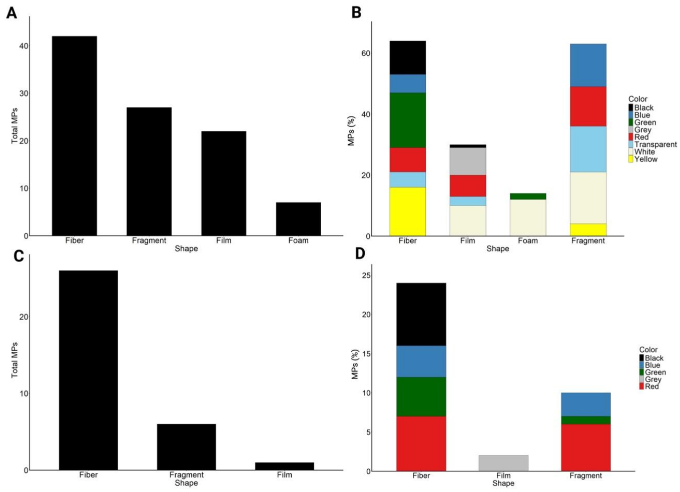

Figure 3. Comparative analysis of microplastic presence in *D. latifrons*. Panels **A** and **B** illustrate the total microplastics found in the gastrointestinal tract, differentiated by shape and color, respectively. Panels **C** and **D** present similar classifications for microplastics detected in the gills. Each color in the bars in **B** and **D** represents the color of a group of MPs as indicated by the shapes.

Similar results were reported in three species of sole fish, *Achirus klunzingeri*, *A. mazatlanus*, and *A. scutum*, from Buenaventura Bay, Colombian Pacific. Among the results, MPs in the form of fibers were observed in the digestive tract of these three species, which share similar feeding patterns to *D. latifrons* (Tafurt-Villarraga *et al.,* 2021). The authors suggested that the fibers came from the washing of poorly managed clothing and fishing gear. These results are similar to those reported in this research, given that around the

RNUMM, there are communities dedicated to fishing and use the water for domestic purposes. Furthermore, the color of the MPs can influence the ingestion of these particles by different fish species, and this will largely depend on environmental and ecological factors. For example, the blue color in plastic fibers is more frequently found in the environment because these have greater resistance to UV degradation, compared to other colors and shapes (Ríos, 2022). However, other studies associated the ingestion of MPs with the ecological role of organisms, since these colors seem to be attractive to several species of fish that confuse them with their prey (Vidal *et al*., 2021).

The number of microplastics (MPs) was higher in the GIT (total MPs = 98) than in the gills (total MPs = 33), with a statistically significant difference ($W = 5225$, $p < 0.001$). The occurrence factor (OF) was 57% for the GIT and 31% for the gills. The average condition factor (K) was 1.38 (± 0.25). A weak positive correlation was observed between K and the total number of MPs per fish, though it was not statistically significant (Kendall's Tau = 0.09, $p = 0.21$). Linear regression analysis showed a low explained variance ($R^2 = 0.04$, $p = 0.04$). Conversely, no significant relationship was found between gill weight and the number of MPs (Kendall's Tau = –0.01, $p = 0.93$), which was also reflected in the regression results ($R^2 = –0.03$, $p = 0.77$). These findings indicate that the RNUMM is contaminated with MPs, which are ingested by fish, as illustrated in Figure 4 and summarized in Table 1, Supplementary Material. This ingestion may result from fish mistaking MPs for food, accidental ingestion during feeding, or trophic transfer through the food web (Bhatt & Chaulan, 2023). MPs in the gills of *D. latifrons* had not been previously analyzed. Studies suggest that MPs present in the gastrointestinal tract (GIT) may be related to selective eating patterns, while the presence of MPs in the gills would be linked to non-selective mechanisms such as water flow that favor the retention of particles in these structures (Yin *et al*., 2022). *D. latifrons* is a demersal, herbivorous species (Robertson *et al*., 2015), and such ecological traits have been linked to higher MPs accumulation in other fish species (Huang *et al*., 2020, Amponsah *et al*., 2024). Therefore, we consider that a higher occurrence of MPs in the GIT and gills is due to *D. latifrons*' feeding behavior and MPs in water rather than selectivity. Additionally, our findings did not reveal a strong relationship between the number of MPs and the condition factor; however, more research will be needed to explore the effects of MPs on wild fish from mangrove ecosystems such as RNUMM.

Within the RNUMM there are five communities with an estimated 11,400 people, whose sources of economic income include artisanal fishing of estuarine fish (González-Bernat & Clifton 2021). Likewise, 11 fish species are targeted in the RNUMM, with *D. latifrons* being the most abundant and captured by locals, who use this species for consumption and marketing in the region (Hernández-Padilla *et al*., 2020). As mentioned before, the ingestion of MPs that adsorb contaminants, such as heavy metals, pesticides, and hydrocarbons, might represent a threat to the food chain and biodiversity. Thus, the presence of MPs in *D. latifrons* needs to be further assessed to provide more information regarding the risks and effects on ecosystems, especially for human health (Kibria, 2023; Squillante *et al*., 2023; Fatema *et al*., 2024). Finally, the authors recommend that the Ministry of Environment and Natural Resources and the municipalities of the region take action to reduce plastic pollution through better solid waste management and environmental education programs.

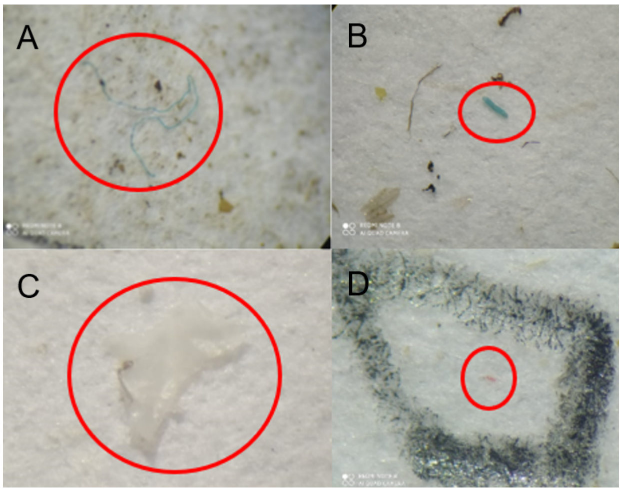

Figure 4. Fibers found in GIT and gills of *Dormitator latifrons*: **A.** Blue fiber found in GIT; **B.** Blue fragment found in GIT; **C.** White film found in GIT; **D.** Fiber found in gills.

CONCLUSION

This study provides results on the occurrence of MPs in the digestive tract and gills of the fish *D. latifrons*, from the Monterrico Multiple Use Natural Reserve (RNUMM). This fish species is of great importance in the region, since it is the main species caught by artisanal and subsistence fishers, who market this fish in the region, and it serves as part of the food supply for families in the communities of Monterrico, La Avellana, Agua Dulce, La Curvina, and El Pumpo. Therefore, it is important to conduct further research to measure the potential impacts on the environment, the organisms that inhabit it, and humans.

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AUTHOR CONTRIBUTIONS

JFPS*: conceptualization, investigation, formal analysis, data Curation, supervision, funding acquisition, resources, writing-original draft, writing-review & editing. **GQL:** investigation, methodology. **MXS:** investigation, methodology, formal analysis, resources, writing-review & editing. **FSR:** investigation, methodology. **CMO:** investigation, formal analysis, data curation, methodology, resources, writing-review & editing. **MSMR:** investigation, methodology, resources, writing original draft. **BEOH:** conceptualization, investigation, data curation, supervision, funding acquisition, resources, writing-review & editing.

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