Journal of Fisheries
Volume 14 Issue 1 April 2026
Peer Reviewed | Open Access

eISSN 2311-3111
pISSN 2311-729X

DOI: https://doi.org/10.17017/j.fish.1208

Original Article

Microplastic pollution in edible marine fish from the northwestern Bay of Bengal, Bangladesh: A comprehensive assessment of occurrence, characteristics and associated ecological risks

Maria Zaman[1] • Ihsanul Haque[1] • Md. Mahmud Hasan[1] • Abdullah Fahim Chowdhury[2] • Md. Baki Billah[3] • Md. Hasan Faruque[4]

[1] *Department of Marine Fisheries and Aquaculture, Bangladesh Maritime University, Mirpur 12, Dhaka 1216, Bangladesh*
[2] *Department of Environmental Sciences, Jahangirnagar University, Savar, Dhaka 1342, Bangladesh*
[3] *Department of Zoology, Jahangirnagar University, Savar, Dhaka 1342, Bangladesh*
[4] *Department of Fisheries, University of Dhaka, Dhaka 1000, Bangladesh*

Correspondence
Md. Hasan Faruque; Department of Fisheries, University of Dhaka, Dhaka 1000, Bangladesh
hasanfaruque28@du.ac.bd

Manuscript history
Received 25 January 2026 | Accepted 28 February 2026 | Published online 4 March 2026

Citation
Zaman M, Haque I, Hasan MM, Chowdhury AF, Billah MB, Faruque MH (2026) Microplastic pollution in edible marine fish from the northwestern Bay of Bengal, Bangladesh: A comprehensive assessment of occurrence, characteristics and associated ecological risks. Journal of Fisheries 14(1): 141217. DOI: 10.17017/j.fish.1208

Abstract
Microplastic (MP) pollution is an emerging environmental issue with serious implications for marine ecosystems and potential risks to human health. This study assessed MP contamination in the gastrointestinal tracts of 130 individuals representing 13 species (n=10 species^{-1}) from the Bay of Bengal, Bangladesh. A total of 892 MP particles were detected, confirming ubiquitous contamination across all species. MP abundance ranged from 3.70–12.00 items per individual (mean±SD: 6.87±1.08 items fish^{-1}). Five morphotypes: fibers, films, foams, pellets, and fragments were identified, with fibers constituting the dominant category. Most MPs were <5 mm, and red was the most common color. MP abundance exhibited a moderate positive correlation with body length (r=0.41), indicating that larger individuals tended to contain higher numbers of MP. Benthopelagic species exhibited the highest MP ingestion (7.85±2.58 items fish^{-1}), while carnivorous fishes showed greater contamination (7.13±2.59 items fish^{-1}) among trophic guilds. Risk assessment revealed that contamination factor (CF) ranged from 1.00–3.24, indicating moderate to high levels of MP contamination. The overall polymer load index (PLI) was 1.76, corresponding to a low pollution risk category. However, polymer hazard index (PHI) analysis revealed dominance of moderate-risk polymers, including polyester and PP–PE copolymer, with high-risk polymers such as nylon (PHI = 8.80) and PVC (PHI = 7.00) contributing substantially to overall hazard. These findings provide baseline evidence of MP contamination in Bangladeshi marine fisheries and highlight the need for future studies integrating polymer toxicity, trophic transfer, and human exposure pathways to support effective mitigation strategies.

Keywords: Bay of Bengal; FTIR; gastrointestinal tract; marine fish; microplastics; MPs; risk assessment

1 | INTRODUCTION

Plastics are synthetic polymers primarily derived from fossil fuels and widely used due to their durability, light-weight structure, and versatility across sectors such as packaging, construction, manufacturing, and medicine (Andrady 2011; Guzzetti *et al*. 2018). Global plastic production has increased dramatically, reaching approximately 430.9 million tons in 2024, resulting in the widespread accumulation of persistent plastic debris in terrestrial and aquatic environments (Plastics Europe 2025). Due to their resistance to biodegradation, plastics can persist for decades, posing serious threats to ecosystem health, particularly in marine environments (Issac and Kandasubramanian 2021; Khan and Setu 2022).

Marine ecosystems are major sinks for plastic pollution, with plastics accounting for approximately 75% of marine debris and threatening over 800 species through ingestion and entanglement (Karbalaei *et al*. 2019). Plastic production is projected to exceed 1,000 million tons by 2050, further increasing environmental exposure (Khan and Setu 2022). Coastal regions contribute substantially to this burden, generating approximately 275 million tons of plastic waste annually, of which 2–5% enters marine systems (Hossain *et al*. 2019). Environmental degradation processes fragment larger plastics into microplastics (MPs; <5 mm), which are classified as primary MPs, intentionally manufactured at microscopic sizes, or secondary MPs, formed through fragmentation driven by ultraviolet radiation, mechanical abrasion, and microbial activity (Ivleva *et al*. 2017). Their distribution within aquatic systems is influenced by physicochemical properties such as size, density, and shape (Ferdous *et al*. 2023).

Due to their small size and resemblance to natural prey, MPs are readily ingested by marine organisms across trophic levels, facilitating their entry into aquatic food webs (Karbalaei *et al*. 2019). Ingestion is considered the primary exposure pathway and may result in trophic transfer and bioaccumulation (Barboza *et al*. 2018; Saikumar *et al*. 2024; Toha *et al*. 2024). In addition to physical impacts, MPs can adsorb and transport hazardous contaminants, including heavy metals, pesticides, persistent organic pollutants, and pathogenic microorganisms (Akter *et al*. 2024). Exposure to MPs has been associated with oxidative stress, tissue damage, endocrine disruption, and impaired reproduction in marine organisms, particularly fish (Ghosh *et al*. 2021; Khan and Setu 2022; Thi *et al*. 2025).

Microplastic contamination also presents potential risks to human health through seafood consumption. As humans occupy upper trophic levels, fish represent a major pathway for MPs exposure (Parvin *et al*. 2022; Zhang *et al*. 2026). MPs may release toxic additives and associated contaminants into tissues, potentially contributing to endocrine disruption, reproductive disorders, and carcinogenic effects (Hossain and Shams 2020; Haque *et al*. 2023; Thi *et al*. 2025). Consequently, MPs have emerged as contaminants of global concern due to their persistence, bioavailability, and capacity for trophic transfer (Barboza *et al*. 2020; Kibria 2023; Nguyen *et al*. 2025).

In Bangladesh, where fish constitute a major dietary protein source, recent studies have reported widespread MPs contamination in commercially important marine and estuarine fish species (Hossain *et al*. 2019; Ghosh *et al*. 2021; Jamal *et al*. 2025). Over 40% of consumers in Bangladesh procure seafood from local fish markets, while the remaining proportion obtain seafood directly from fishers or from larger wholesale markets. Thus, a large fraction of coastal families is regularly exposed via typical diets to local marine fish, which are demonstrably contaminated with MPs (Roy *et al*. 2025). For instance, three popular marine species (bigeye tuna *Thunnus obesus*, Chinese pomfret *Pampus chinensis*, and *Acanthopagrus datnia*) from the northern Bay of Bengal all contained MPs – the gills and guts had 1.4–8.7 MP items g^{-1} and muscle had 0.2–0.475 MP g^{-1} (Jamal *et al*. 2025). Similarly, 10 species of commercial Bay-of-Bengal fish were all contaminated: on average 2.2±0.89 MPs per fish (Ghosh *et al*. 2021). Commonly consumed species, including hilsa (*Tenualosa ilisha*) and other marine fish from the Bay of Bengal, have been reported to contain between 2 and 51 MP particles per individual (Siddique *et al*. 2022). Given the high dependence on fish as a dietary staple in Bangladesh, exposure assessments estimate that fish consumption alone could result in ingestion of approximately 1.24 × 106 MP particles per person per year (Jamal *et al*. 2025). Despite increasing evidence, data on MPs occurrence, characteristics, and ecological risks in many commercially important marine fish species from Bangladesh remain limited. Therefore, this study aims to (i) quantify MPs occurrence and abundance in selected edible marine fish species, (ii) characterize ingested MPs based on shape, size, and color, (iii) compare MP ingestion among species with different trophic guilds and feeding strategies, (iv) examine the relationships between MP abundance and fish length, and (v) evaluate the associated ecological risks using established indices.

2 | METHODOLOGY

2.1 Study area

Our study area focuses on the northwestern Bay of Bengal, centering on the proximity of Kuakata region (Figure 1). The northwestern Bay of Bengal is an ecologically significant marine zone known for supporting diverse and commercially important fish species (Hossain *et al*. 2019). Kuakata, located in the Patuakhali district of Bangladesh, was selected as the study site because of its proximity to important fishing grounds and its potential to receive riverine debris, which may contribute to MPs pollution. Given the region's high levels of human activity, including as shipping, fishing, and waste disposal, determining the degree of MPs pollution is essential for evaluating food safety and environmental health (Ghosh *et al*. 2021).

2.2 Sample collection

In order to evaluate MPs exposure pathways pertinent to human consumption, the study focused on commercially important and widely consumed marine fish species. A total of 130 individuals representing 13 species (*n* = 10 per species) were collected, encompassing a range of habitats (demersal, benthopelagic, and pelagic) and feeding strategies (carnivorous, and planktivorous). The selection of 10 individuals per species was based on methodological precedent in marine microplastic studies, where 5–15 specimens per species are commonly used due to the labor-intensive nature of digestion and polymer identification procedures (e.g. Karbalaei *et al*. 2019; Ghosh *et al*. 2021; Akter *et al*. 2024). From a statistical perspective, a balanced design with *n* = 10 per group provides sufficient replication to estimate species-level means and variability, and offers acceptable statistical power (≥0.70 at α = 0.05) to detect moderate-to-large interspecific differences in MP abundance using ANOVA or equivalent non-parametric tests (Cohen 2013). An overview of the collected fish samples is presented in Table S1. Following collection, the fish samples were kept on ice in an icebox, transported to the laboratory, and subsequently stored in a freezer at −20°C until analysis. Prior to examination, the samples were thawed at room temperature.

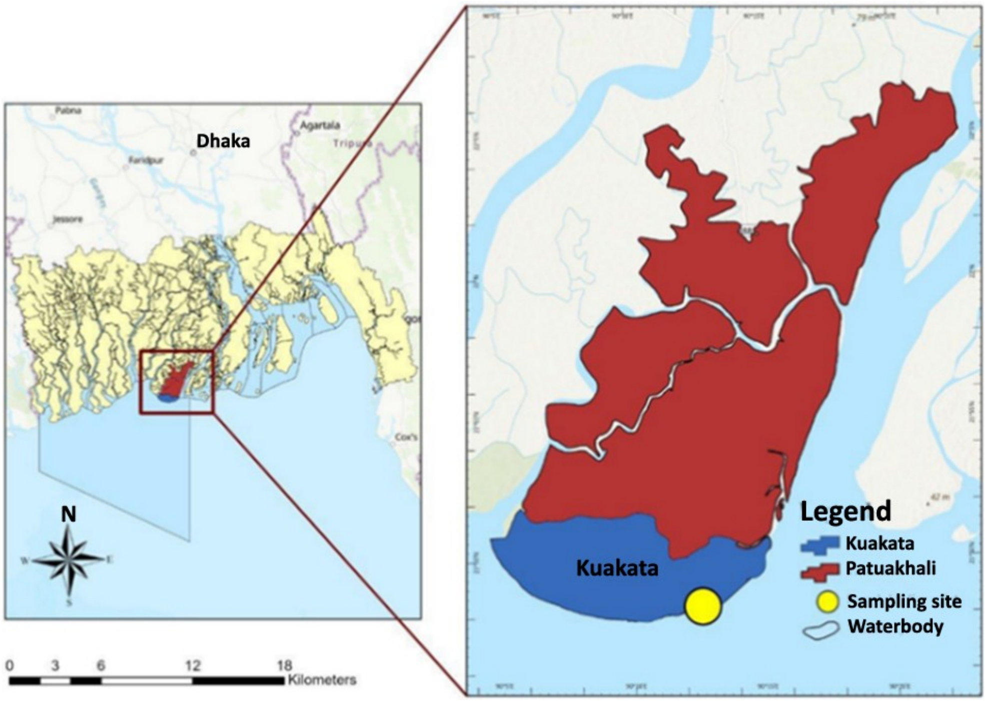

FIGURE 1 Map showing sampling location for microplastic analysis in Northwestern Bay of Bengal and its nearby coastal areas.

2.3 Sample preparation

Following thawing, the weight and total length of each fish sample were recorded before the gastrointestinal tracts (GIT) was carefully removed and placed in sterile beakers. Organic matter digestion was performed using 30% hydrogen peroxide (H_2O_2). Each sample was treated with 100 mL H_2O_2 and incubated at 65°C for 24 hours. The digestion process was repeated with additional 10mL H_2O_2 where necessary until the solution became clear and free of visible organic residues (Hossain *et al*. 2024). Complete digestion was confirmed through visual inspection under a stereomicroscope, ensuring no remaining biological tissues or organic debris prior to filtration. After digestion, the GIT samples were placed in a laminar airflow cabinet and left to stabilize at room temperature for two to three days. Afterward, vacuum filtration equipment was used to filter the materials twice through 0.40 µm Whatman Glass Microfiber Filter paper (Parvin *et al*. 2022). After drying, the filter sheets were sealed in glass Petri plates, allowed to air dry, and prepared for optical analysis and microplastic polymer identification. To reduce contamination, strict measures were implemented, including donning lab coats and gloves, filtering all solutions, cleaning all tools thoroughly, and conducting method blanks (Yuan *et al*. 2019).

2.4 Observation and identification of MPs

The filtered samples were visually examined using a stereomicroscope (Plan1X, Micros Austria) equipped with an Olympus DP22 camera to capture images of suspected MP particles at magnifications of 2X, 3X, and 4X. LAS EZ 3.4.0 software was used to connect the microscope to a desktop computer, and detailed imaging was performed using a digital camera with a total magnification range of 8–35X (Figure S1). According to their properties, the detected MPs were visually evaluated, divided into five groups: fibers, filaments, foams, fragments or pellets and given colors for identification (Tanaka and Takada 2016; Hossain *et al*. 2019). The closest millimeter scales were used to measure the length and width of each MP. The minimum reliable detection limit under the applied optical magnification was approximately 0.1 mm; therefore, particles smaller than this threshold were not quantified, potentially leading to underestimation of ultra-fine microplastics.

2.5 Fourier Transform Infrared spectroscopy (FTIR)

A representative subsample comprising 20% (n = 178) of the total 892 visually identified MP particles was randomly selected for polymer characterization. These particles were manually separated from the filter paper and individually transferred onto a potassium bromide (KBr) crystal for analysis. Polymer types were subsequently identified using FTIR spectroscopy (IR Prestige-21). The absorption bands were identified by comparison with reference spectra from the SpectraBaseTM database. Measurements were conducted in transmission mode over a wavenumber range of 400–4000 cm^{-1} (Tanaka and Takada 2016). To minimize potential misidentification associated with automated library matching, the absorption bands were further verified by cross-referencing characteristic spectral features following standard literature (e.g. Noda *et al*. 2007; Jung *et al*. 2018). Subsampling a proportion (typically 10–30%) of visually sorted particles for spectroscopic confirmation is a widely accepted approach in microplastic research due to the time-intensive and resource-demanding nature of FTIR analysis, while still providing reliable characterization of overall polymer composition (Hidalgo-Ruz *et al*. 2012; Hossain *et al*. 2019; Ghose *et al*. 2021; Hossain *et al*. 2024).

2.6 Visual identification of MPs using scanning electron microscope (SEM) and dispersive x-ray spectroscopy (EDX)

A high vacuum scanning electron microscope (InTouchScope™ SEM, JSM-7610F) was used to take high resolution images that show the topography and elemental composition of selected MP samples after the MPs were identified using optical microscopy (Akhtar *et al*. 2018). Additionally, the qualitative chemical makeup of the compounds adhering to the MP surfaces was examined using energy dispersive x-ray spectroscopy (EDX).

2.7 Risk assessment of MPs

The contamination factor (CF), pollution load index (PLI), and polymer hazard index (PHI) are frequently employed to assess ecological risk in terrestrial and aquatic environments (Lithner *et al*. 2011; Nithin *et al*. 2022; Das *et al*. 2025; Jamal *et al*. 2025). The PLI and CF values were categorized following the criteria proposed by (Wang *et al*. 2020), while the PHI was determined according to the method described by Lithner *et al*. (2011).

2.7.1 Contamination factor (CF)

The degree of environmental pollution was illustrated using the CF. Although the CF was traditionally used to evaluate the concentration of MPs have lately been the subject of several studies using this technique. The CF was calculated using the following equation (Ranjani *et al*. 2021a; Wang *et al*. 2020):

$$CF_i = C_i / C_o$$

Where C_0 = baseline concentration value, and C_i = abundance of a species. The lowest concentration from each different technique was used to calculate the MPs background value.

2.7.2 Pollution load index (PLI)

The MPs concentration level associated with the PLI was determined using the following equations (Jamal *et al*. 2025):

$$PLI = \sqrt{CF_i}$$

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times CF_4 \times \dots\dots\dots\dots\dots\dots . \times CF_n}$$

2.7.3 Polymer hazard index (PHI)

To evaluate possible human risk, the PHI for ingesting MPs containing fish was established. PHI assesses the toxicity of the plastic polymers' monomers and related chemicals. The PHI caused by MPs can be evaluated using the formula below:

$$PHI = \sum P_n \times S_n$$

Where, P_n = percentage of specific plastic polymers, and S_n = hazard score of plastic polymers obtained from Lithner *et al*. (2011).

2.7.4 Quality assurance and quality control

Fish were separated and dissected in a clean bench environment using sterile metalware, glassware, and appropriate personal protective equipment. To avoid contamination, their GITs were placed in covered petri plates. All glassware and dissection equipment were rinsed three times with filtered water, and all liquids used in the assays were passed through Whatman GF/B glass microfiber filter to reduce the procedural contamination. A blank sample without fish GIT was also prepared. Fish collected from fishers at the landing center without controls for MPs contamination during harvesting was one of the study's limitations. Consequently, the samples were cleaned with MP-free distilled water to remove externally attached plastic (Lusher *et al*. 2017; Hossain *et al*. 2019).

2.8 Data analysis

Microsoft Excel (2020) was used to calculate descriptive statistics, including means, standard deviation, and risk assessment–related metrics for all analytical data. OriginPro (2022) and PAST (PAleontological STatistics) software were employed to generate bar charts, correlation analyses, create graphical outputs, and visualize FTIR spectra. ArcGIS Pro was used to prepare the sampling location map based on the GPS coordinates of the study sites. As the dataset satisfied the assumptions of normality, as verified by the Shapiro-Wilk test ($p > 0.05$), Pearson's correlation coefficient was applied to examine the relationship between microplastic abundance and fish total length. An independent-samples *t*-test ($\alpha = 0.05$) was conducted to assess differences in microplastic abundance between carnivorous and planktivorous species. Furthermore, one-way analysis of variance (ANOVA) was performed to evaluate differences in microplastic abundance among demersal, pelagic, and benthopelagic species, followed by Fisher's least significant difference (LSD) post-hoc test for pairwise species comparisons.

3 | RESULTS

3.1 Prevalence of MPs in fish

MPs were detected in all examined fish species. A total of 892 MP particles were identified and recorded from the GITs of the sampled individuals (Table 1). The mean abundance ranged from 3.70 to 12.00 items per species, with an overall average of 6.87±1.08 items per individual. When standardized to biological parameters, MPs abundance ranged from 0.15 to 0.52 MPs cm^{-1} of total length (0.27±0.12 MPs cm^{-1} TL) and from 0.01 to 0.16 MPs g^{-1} of body weight (0.07±0.04 MPs g^{-1} BW). Based on GIT measurements, abundance varied from 0.14 to 1.02 MPs cm^{-1} of GIT length (0.68±0.67 MPs cm^{-1} GIT) and from 0.81 to 3.91 MPs g^{-1} of GIT weight (2.12±1.31 MPs g^{-1} GIT) (Table 1). Among the investigated species, *Lobotes surinamensis* exhibited the highest MP burden (n = 120 particles), whereas *Cynoglossus semilaevis* showed the lowest (n = 37 particles). These results indicate widespread microplastic contamination across all sampled species.

3.2 Microplastic attributes: shape, size and color

3.2.1 Shapes

MPs of various morphotypes were identified in all examined fish species, with five distinct shapes observed: fibers, films, foams, pellets, and fragments (Figure 2A; Figure S2). Among the 892 MPs detected, fibers were the most prevalent (34.15%), followed by films (27.77%), foam (13.44%), pellets (12.21%), and fragments (12.43%) (Figure 2A).

TABLE 1 Overview of the 13 studied fish species (n = 10 individuals per species) and their corresponding level of microplastics (MPs) ingestion.

Scientific Name	English name	Feeding habitat	Feeding group	Total MPs	Mean (±SD) values: MPs	Total length (cm)	Body weight (g)	Gut length (cm)	Gut weight (g)	Mean MPs / cmTL	Mean MPs / g BW	Mean MPs / cmGIT	Mean MPs /g GIT
Antigonia rubescens	Indo-Pacific boarfish	B	C	73	7.30±1.06	14.16±2.41	51.99±7.68	7.89±1.43	3.56±0.44	0.52	0.14	0.93	2.05
Cynoglossus semilaevis	Tongue sole	D	C	37	3.70±0.67	24.26±4.11	37.48±4.94	25.59±3.63	1.26±0.47	0.15	0.10	0.14	2.93
Harpadon nehereus	Bombay duck	B	C	46	4.60±0.97	29.99±4.23	55.49±5.07	9.97±0.63	1.75±0.58	0.16	0.08	0.46	2.63
Lates calcarifer	Asian sea bass	D	C	86	8.60±0.97	24.30±3.93	110.11±13.02	9.81±1.81	2.52±1.00	0.35	0.08	0.88	3.42
Lobotes surinamensis	Atlantic tripletail	B	C	120	12.00±1.49	39.20±5.39	2275.80±352.94	14.66±3.44	26.17±4.93	0.31	0.01	0.82	0.46
Lutjanus russellii	Russell snapper	D	C	73	7.30±1.25	32.42±4.66	171.72±15.81	10.85±2.59	8.00±1.07	0.23	0.04	0.67	0.91
Otolithoides pama	Long-finned croaker	B	C	73	7.30±1.06	22.54±3.80	98.94±11.90	7.13±1.45	7.32±1.54	0.32	0.07	1.02	1.00
Pennahia argentata	Silver white croaker	B	C	66	6.60±1.07	30.31±4.71	167.81±11.18	7.80±1.48	7.05±1.50	0.22	0.04	0.85	0.94
Sardinella longiceps	Sardine	P	P	53	5.30±1.06	25.87±0.83	93.71±18.75	8.08 ±2.18	6.53±1.38	0.20	0.06	0.66	0.81
Setipinna taty	Scaly hairfin anchovy	P	P	53	5.30±1.25	30.59±1.50	151.61±6.08	14.56±1.37	2.37±0.53	0.18	0.04	0.37	2.28
Sillago parvisquamis	Small scale whiting	D	C	46	4.60±0.97	20.28±4.27	56.36±11.47	6.46±1.23	1.27±0.31	0.23	0.08	0.71	3.62
Tenualosa toli	Toli shad	P	P	73	7.30±0.95	17.54±2.34	44.47±8.38	8.42±1.21	2.77±0.55	0.42	0.16	0.87	2.63
Trichiurus lepturus	Largehead hairtail	B	C	93	9.30±1.25	56.87±5.62	100.08±11.50	20.07±3.45	2.38±0.59	0.16	0.09	0.46	3.91

Feeding habitat: B, benthopelagic; D, demersal; P, pelagic.
Feeding group: C, carnivore; P, planktivore

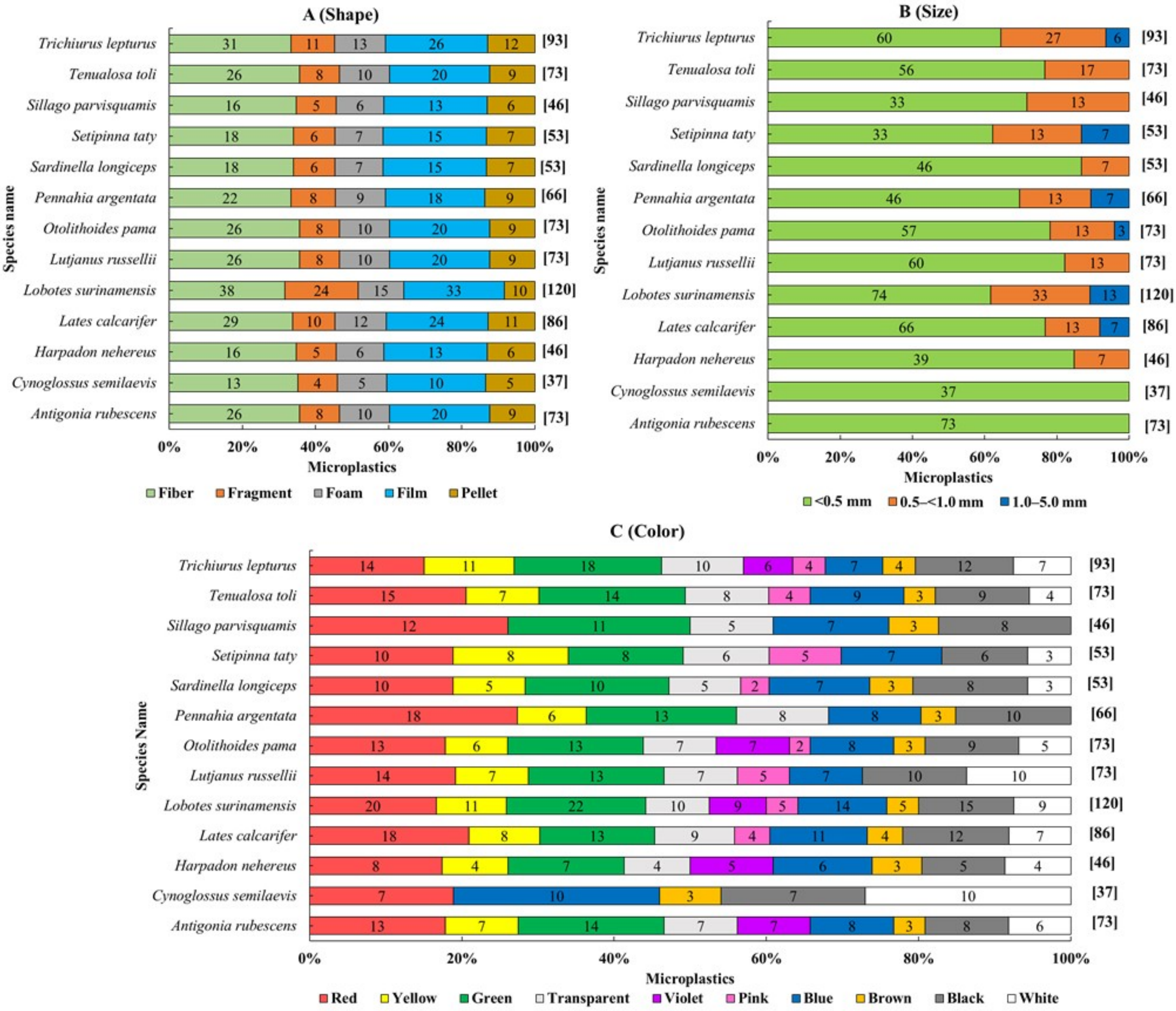

FIGURE 2 Percentage distribution of MPs extracted from the gastrointestinal tracts (GITs) of marine fish species based on (A) shape, (B) size, and (C) color. The numbers in parentheses indicate the number of plastic pieces found in each species.

Comparison among species showed a consistent dominance of fiber-shaped MPs, with markedly higher counts in *L. surinamensis* (38), *Trichiurus lepturus* (31), and *Lates calcarifer* (29) relative to other taxa. Film-shaped MP particles were the second most abundant form and were particularly elevated again in *L. surinamensis* (33) and *T. lepturus* (26), distinguishing these species from those with more evenly distributed shapes. Fragment abundance varied considerably, with *L. surinamensis* exhibiting a notably higher count (24) compared to all remaining species. Foam particles occurred at moderate levels overall but were comparatively more prominent in *T. lepturus* (13) and *L. calcarifer* (12). Pellet-shaped microplastics were least abundant across most species, though *T. lepturus* (12) and *L. calcarifer* (11) showed relatively higher values than others.

Species such as *C. semilaevis* and *Pampus argentata* displayed consistently lower counts across all shape categories. Pelagic species, including *T. toli* shad and *L. russellii* exhibited nearly identical shape profiles dominated by fibers and films. The data reveal clear interspecific variability in MPs shape composition despite a broadly similar dominance pattern.

3.2.2 Size

MPs were categorized into three size classes: <0.5 mm, 0.5–<1.0 mm, and 1.0–5.0 mm. Among the 892 MPs detected, particles <0.5 mm were predominant, accounting for 76.15% of all items and occurring in all examined species (Figure 2B). MPs measuring 0.5–<1.0 mm and 1.0–5.0 mm comprised 18.92% and 4.93%, respectively. Across species, the <0.5 mm size class was predominant in all fishes, indicating a strong prevalence of very fine MPs. The 0.5–<1.0 mm size class occurred at moderate levels, with relatively higher abundances in *L. surinamensis* (33) and *T. lepturus* (27). In contrast, 1.0–5.0 mm MPs were rare and detected mainly in larger predatory species such as *L. surinamensis* (13), *L. calcarifer* (7), and *P. argentata* (7).

3.2.3 Colors

The color of MPs reflects the diversity and widespread use of plastic products in daily life, contributing significantly to plastic pollution. Analysis of GITs samples revealed ten distinct MPs colors: red, green, blue, black, transparent, yellow, white, brown, violet, and pink. Among the 892 MPs detected, red was the most abundant (19.26%), while pink was the least prevalent (3.47%). Green (17.47%), black (13.33%), and blue (12.21%) were also frequent, followed by transparent (9.63%), yellow (9.07%), white (7.61%), brown (4.14%), and violet (3.81%). All 10 colors were identified in *O. pama*, *T. lepturus*, and *L. surinamensis*, whereas red, blue, and black MPs were present in all species examined (Figure 2C).

3.3 Influences of MPs ingestion in characteristics of fishes

The relationship between total length (cm) and MP abundance per species was assessed using a scatter plot (Figure 3). A moderate positive correlation was observed (r = 0.41), indicating a general tendency for microplastic counts to increase with fish size. This relationship was statistically significant at the 0.01 level.

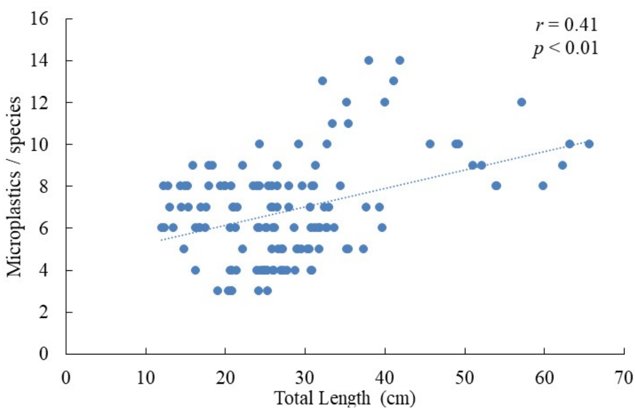

FIGURE 3 Relationship between total length and microplastic (MP) abundance per species. Each point represents an individual fish. A moderate positive correlation (r = 0.41) indicates that MP counts tend to increase with body length, and this relationship is statistically significant ($p < 0.01$).

3.4 MPs contamination in fishes with respect to feeding habitat and feeding group

3.4.1 Feeding habitat

Our findings indicate that fish microhabitat strongly influences MPs ingestion. Mean MPs concentrations varied across habitats: benthopelagic species (n = 6) exhibited the highest ingestion (7.85±2.58 MPs individual^{-1}), with *L. surinamensis* being the dominant species. Demersal species (n = 4) showed moderate levels (6.05±2.22 MPs/individual), with *L. calcarifer* being the prevalent species, whereas pelagic species (N = 3) had the lowest concentrations (5.97±1.43 MPs individual^{-1}), with *T. toli* being the predominant species (Table 1 and Figure 4A). Fish from benthopelagic habitats exhibited significantly greater MP loads than those from pelagic and demersal habitats ($p < 0.01$), whereas no significant difference was detected between pelagic and demersal species (p = 0.879).

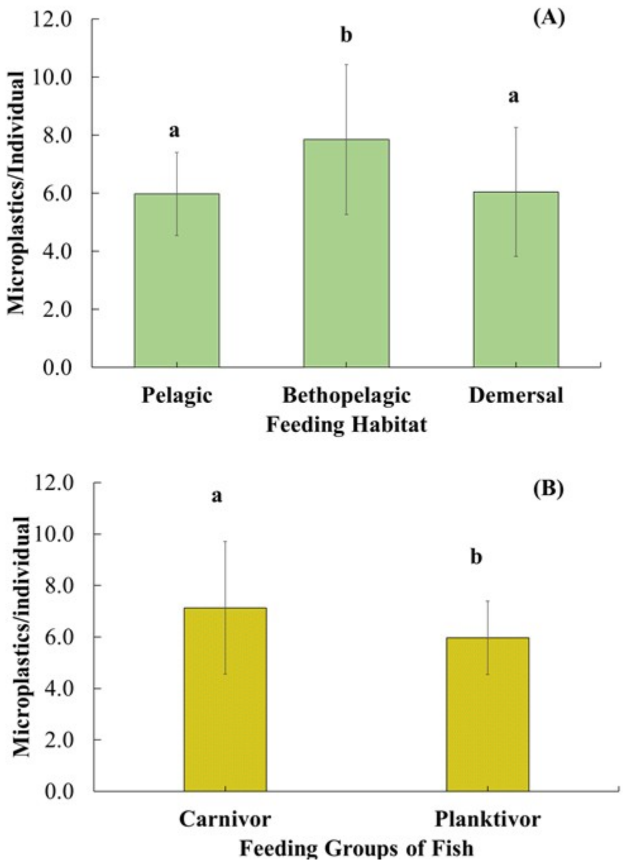

FIGURE 4 Comparison of microplastic (MP) abundance among fish groups based on (A) feeding habitat and (B) feeding groups. Bars represent mean microplastic counts per individual, with error bars indicating standard deviation. (A) Among feeding habitats, benthopelagic fish contained significantly higher MP loads compared to both pelagic and demersal species ($p < 0.01$), while no significant difference was observed between pelagic and demersal fish (p = 0.879). (B) Among feeding guilds, carnivorous fish exhibited significantly higher MP abundance than planktivorous fish (p = 0.02). Different lowercase letters above the bars indicate statistically significant differences.

3.4.2 Feeding group

Among 13 species analyzed (~77% carnivores, ~23% planktivores; Table 1), carnivores displayed higher mean

MPs concentrations (7.13±2.58 MPs individual^{-1}) than planktivores (5.97±1.43 MPs individual^{-1}) (Table 1 and Figure 4B). Carnivorous species such as *L. surinamensis* (12.00±1.49 MPs) and *T. lepturus* (9.30±1.25 MPs) exhibited the highest contamination. Planktivores such as *S. longiceps* (5.30±1.06 MPs) showed comparatively lower contamination levels. Although the lowest MPs concentration was observed in the carnivorous species, percentage-based analysis relative to morphometric characteristics indicated a lower MPs concentration in planktivores. A significant difference in microplastic abundance was observed between planktivorous and carnivorous species at the 0.05 significance level (p = 0.020).

3.5 µ-FTIR analysis and chemical characterization of polymers

Characterizing the chemical composition of MPs provides insight into their sources and potential environmental impacts. In this study, µ-FTIR analysis was performed on 20% of the suspected MP particles. Of the 892 recovered MP particles, 178 were randomly selected for polymer identification; among these, 174 were confirmed as microplastics, while four remained unidentified due to inconclusive spectral matches.

The dominant polymer types were PP-PE copolymer (51%), polyester (PES, 20%), nylons (11%), PVC (7%), LDPE/LLDPE (5%), ABS (2%), nitrile (2%), and unidentified (2%) (Figure 5). The FTIR spectra for PP-PE copolymer displayed characteristic peaks at 2958, 2914, 2832, 1455, 1377, and 717 cm^{-1} (Figure S3), consistent with both PP and PE, while other polymers were confirmed by reference spectra.

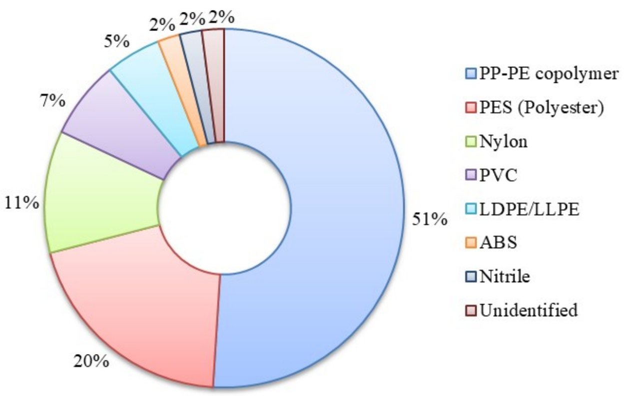

FIGURE 5 Proportion of polymer identified in the fish samples from the northwestern Bay of Bengal of Bangladesh.

3.6 Comprehensive surface analysis MPs using SEM and EDX

Scanning Electron Microscopy (SEM) was used to examine the surface morphology of MPs collected from fish in the Bay of Bengal. SEM images revealed grooves on fibers, films, and foams; adhering particles and cracks on all polymer types; pits on fibers, fragments, and films; and flaking on films and foams (Figure 6). Energy Dispersive X-ray (EDX) analysis detected elements including Si, Na, Mg, Cu, S, Ca, Cd, Cl, Zr, C, and O on the surface of MPs (Figure 6). Carbon and oxygen are inherent to the polymer matrix, while the other detected elements likely originate from environmental contamination or additive chemicals. Variations in elemental composition between MPs and surrounding matrices may result from the extraction process or the localized detection area of EDX.

3.7 Risk assessment of MPs contamination

3.7.1 CF and PLI

In this study, CF values ranged from 1.00 (*C. semilaevis*) to 3.24 (*L. surinamensis*), indicating moderate to high MP contamination across most species. Elevated CF values were particularly observed in benthopelagic and demersal carnivores, including *T. lepturus* (2.51) and *L. calcarifer* (2.32). Although species-specific PLI values were not calculated, the overall pollution level remained within Category I (PLI <10), suggesting a relatively low aggregate environmental load (Table 2).

3.7.2 PHI

In the present study, microplastic polymer composition was dominated by PP-PE copolymer (51%), polyester (20%), nylon (11%), and PVC (7%). Based on Pollution Hazard Index (PHI) values, most detected polymers were classified within Hazard Category II, indicating a moderate hazard level according to polymer-specific toxicity scores. Despite their lower abundance, nylon (PHI = 8.80) and PVC (PHI = 7.00) contributed most substantially to hazard due to their higher toxicity scores, while PP-PE copolymer (PHI = 5.61) and polyester (PHI = 6.00) also contributed notably to overall risk (Table 3).

4 | DISCUSSION

4.1 Prevalence of MPs in fish

The presence of MPs in all examined fish species demonstrates extensive plastic contamination in the studied marine environment. Fish are likely exposed to MPs through direct ingestion, by mistaking plastic particles for prey, or indirectly through trophic transfer from contaminated organisms (Watts *et al*. 2014; Worm *et al*. 2017). The MPs levels observed in this study are comparable to those reported from the South China Sea off Guangdong Province (Zhang *et al*. 2020b) and the northeastern Arabian Sea (Debbarma *et al*. 2022). In contrast, higher concentrations have been reported from highly polluted regions such as Tema fishing harbor, Accra (Gurjar *et al*. 2021) and Haizhou Bay, Yellow Sea (Feng *et al*. 2019), indicating the influence of local anthropogenic activities and waste management practices.

In Bangladesh, commercial fish have been reported to contain between 0.5 and 19.13 MP items per individual

(Hasan *et al*. 2022). Studies from the northern Bay of Bengal documented mean abundances of 2.2±0.89 and 5.90±2.76 items per fish (Hossain *et al*. 2019; Ghosh *et al*. 2021), while penaeid shrimp exhibited concentrations ranging from 6.60±2 to 7.80±2 items per species (Hossain *et al*. 2020). Similarly, MPs abundance in the Meghna River estuary was reported as 7.16±4.33 items per individual. Earlier investigations generally reported lower MPs concentrations, whereas more recent studies documented levels comparable to those observed in the present study, suggesting a progressive increase in plastic pollution in Bangladeshi marine and estuarine ecosystems. Notably, *Tenualosa ilisha* showed the highest recorded ingestion rate (19.13±10.77 items per individual) in previous studies (Siddique *et al*. 2022), reflecting increasing MP accumulation in the Bay of Bengal.

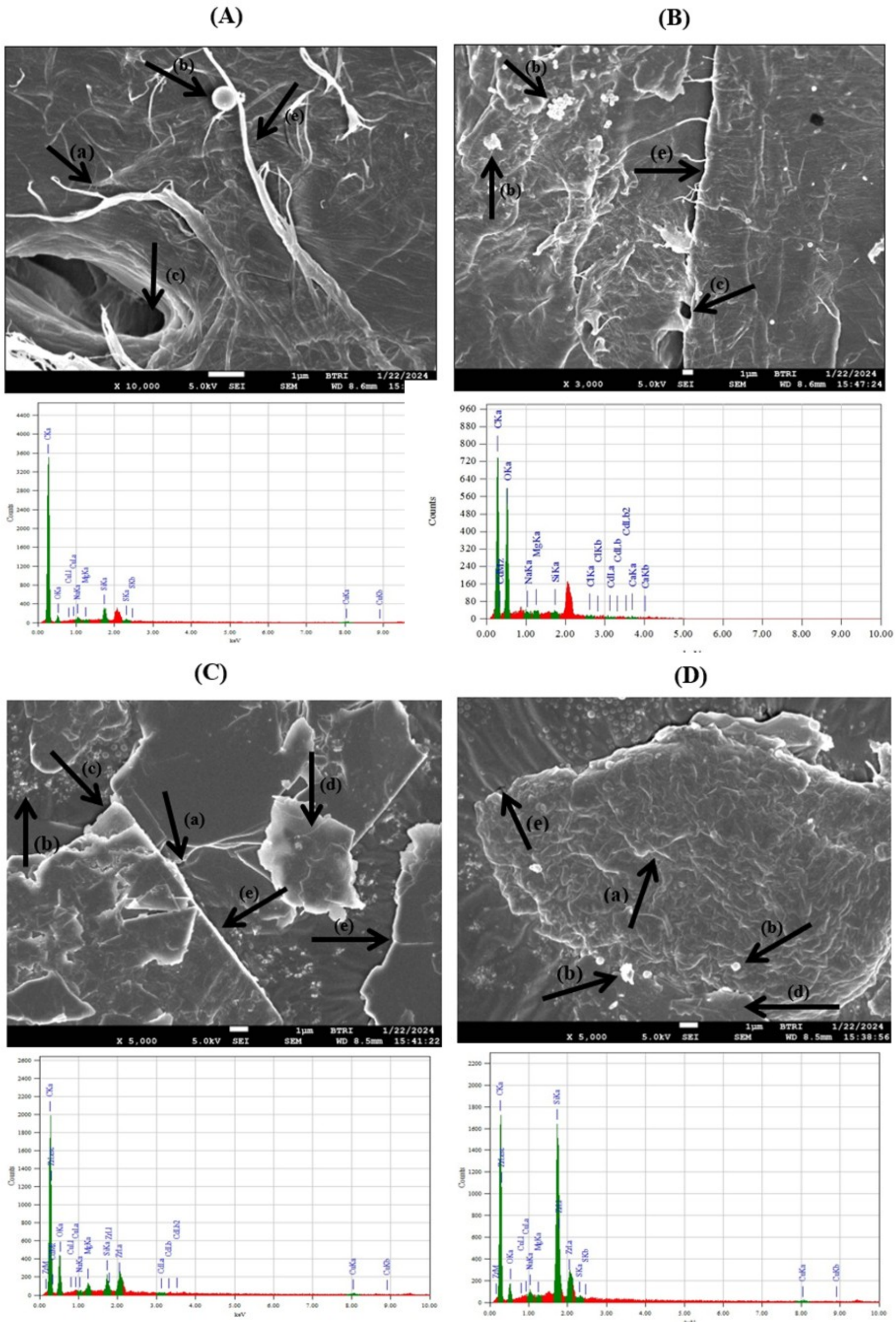

FIGURE 6 Surface texture analysis of microplastics (MPs) using SEM-EDX; focusing on (A) fiber, (B) fragment, (C) film, and (D) foam shapes MPs retrieved from marine fish gastrointestinal tracts (GITs). SEM imagery highlights feature like (a) grooves, (b) adhering particles, (c) pits, (d) flakes, and (e) cracks on the MP surfaces, with EDX spectra obtained at an accelerating voltage of 15 kV.

TABLE 2 Risk assessment of MPs contamination in different species.

Species	Mean Microplastics (MPs) ± SD	CF*	[a]CF Risk category	PLI*	[b]PLI Risk Category
Antigonia rubescens	7.30 ± 1.06	1.97			
Cynoglossus semilaevis	3.70 ± 0.67	1.00			
Harpadon nehereus	4.60 ± 0.97	1.24			
Lates calcarifer	8.60 ± 0.97	2.32			
Lobotes surinamensis	12.00 ± 1.49	3.24	<1 (low)		<10 (I)
Lutjanus russellii	7.30 ± 1.25	1.97	1–3 (moderate)	1.76	10–20 (II)
Otolithoides pama	7.30 ± 1.06	1.97	2–6 (high)		20–30 (III)
Pennahia argentata	6.60 ± 1.07	1.78	>6 (very high)		>30 <10 (IV, polluted)
Sardinella longiceps	5.30 ± 1.06	1.43			
Setipinna taty	5.40 ± 1.35	1.46			
Sillago parvisquamis	4.60 ± 0.97	1.24			
Tenualosa toli	7.30 ± 0.95	1.97			
Trichiurus lepturus	9.30 ± 1.25	2.51			

* CF = Contamination factor, * PLI = Pollution load index.
[a, b] Signify the method of Wang *et al.* (2020)

TABLE 3 Polymers identified in fish and the estimated hazard risk assessment.

Polymers	Proportion (%) - Pn	[a]Hazard Score (Sn)	PHI	[b]Hazard Category	[b]Risk Category
PP-PE copolymer	51	11	5.61	II (1-10)	Medium
PES (Polyester)	20	30	6.00	II (1-10)	Medium
Nylon	11	80	8.80	II (1-10)	Medium
PVC	7	100	7.00	II (1-10)	Medium
LDPE/LLDPE	5	11	0.55	I (<1)	Minor
ABS	2	30	0.60	I (<1)	Minor
Nitrile	2	100	2.00	II (1-10)	Medium

[a]Signifies the method of Lithner *et al.* (2011); b Signifies that of Ranjani *et al.* (2021b).

The widespread ingestion of MPs by marine fish may have adverse ecological consequences, including physical injury, reduced feeding efficiency, and exposure to associated toxic chemicals (Li *et al*. 2025; Zhang *et al*. 2026). Moreover, the contamination of commercially important fish species underscores potential risks to food safety and human health. Collectively, the present results, in conjunction with recent regional studies, reveal a growing burden of MP pollution in coastal and marine ecosystems, emphasizing the urgent necessity for enhanced waste management practices and the implementation of long-term monitoring programs.

4.2 Microplastic attributes: shape, size and color

4.2.1 Shape

The morphology of MPs provides insight into their sources, with symmetrical particles typically primary MPs and asymmetrical particles representing secondary MPs formed through environmental fragmentation (Lehtiniemi *et al*. 2018; Park *et al*. 2020). Secondary MPs generally dominate aquatic environments (Barnes *et al*. 2009). Fibers are primarily derived from wastewater effluents, household laundry, and the breakdown of fishing gear, ropes, and recreational equipment (Browne *et al*. 2011; Zhang *et al*. 2020a). In Bangladesh, the textile and ready-made garment industry contributes substantially to microfiber pollution during manufacturing (Belzagui *et al*. 2019; Akter *et al*. 2024), explaining the predominance of fibers in our samples, consistent with both local and global observations (Compa *et al*. 2018; Digka *et al*. 2018; Ghosh *et al*. 2021). Films, the second most abundant morphotype, likely originate from mismanaged plastic waste and single-use plastic bags along the Bay of Bengal basin. Fibrous MPs are more persistent in fish gastrointestinal tracts and exhibit higher toxicity than other MP forms (Au *et al*. 2015; Lei *et al*. 2018). Ingestion of fragments and irregularly shaped MPs may cause physical damage, including gastrointestinal abrasion, blockage, and impaired digestion (Gregory 2009). Pellets, the fourth most abundant morphotype, may be attributed to the approximately 3,000 tons of plastic waste generated daily in Bangladesh, accounting for roughly 8% of national waste (Islam 2019).

4.2.2 Size

The predominance of smaller MPs reflects their widespread formation and persistence in marine environments. Plastics entering the ocean from inland sources undergo fragmentation through mechanical abrasion, photodegradation, biodegradation, thermal decay, and other processes, resulting in particles predominantly <0.5 mm in size (Andrady 2011; Arat 2024). Similar observations have been reported globally, including in the South China Sea, Adriatic Sea, Eastern Pacific Ocean, and the Northeast Atlantic, where MPs <1 mm are commonly detected in fish and water samples (Zhu *et al*. 2019; Mistri *et al*. 2022; Prata *et al*. 2022). Smaller MPs pose greater ecological and toxicological risks due to their high surface-area-to-mass ratio, which enhances the adsorption of hazardous contaminants (Wang *et al*. 2019; Ghosh *et al*. 2021). Smaller particles are more readily ingested by fish and their prey, enhancing the potential for bioaccumulation (Derraik 2002; Bessa *et al*. 2018). Recent studies in Bangladesh have reported a high proportion of smaller MPs in commercial fish (Ghosh *et al*. 2021; Parvin *et al*. 2021). Consistent with these reports, the present findings demonstrate that MPs < 0.5 mm dominate across marine fish species in the Bay of Bengal. Given their higher ingestion probability and potential for trophic transfer, the predominance of fine-sized MPs highlights the need for continued monitoring due to possible implications for fish health and overall marine ecosystem functioning.

4.2.3 Color

Globally, blue and black MPs are commonly reported in marine fish, including those from the Azores archipelago and the northeastern Arabian Sea, aligning with our findings (Pereira *et al*. 2020; Oza *et al*. 2024). However, in this study red and green MPs were predominant, followed by black and blue. Variations in MP coloration are primarily attributed to the original polymer composition, incorporated pigments, and chemical additives, which often persist even after prolonged environmental degradation (Al-Malaika *et al*. 2017; Rabari *et al*. 2022).

The ingestion of colored MPs by fish is influenced by their resemblance to natural prey. Foraging species are more likely to ingest MPs that mimic food-like colors (Roch *et al*. 2020). The high prevalence of green MPs may reflect their similarity to phytoplankton or result from trophic transfer via contaminated prey. Similarly, red MPs may resemble zooplankton such as copepods, mysids, and euphausiids, which are abundant and often exhibit reddish pigmentation in marine ecosystems (Fernández de Puelles *et al*. 2019; Hall and Lewandowska 2022). In contrast, transparent MPs are likely ingested incidentally during routine feeding (Lusher *et al*. 2013).

4.3 Influences of MPs ingestion in characteristics of fishes

The observed variability suggests that factors beyond body size influence MPs ingestion in marine fish. While some studies have reported a strong positive correlation between fish size—both body length and weight—and MPs abundance (Hossain *et al*. 2019; Ghosh *et al*. 2021; Ferdous *et al*. 2023), others have found no significant relationship (Parvin *et al*. 2021; Haque *et al*. 2023). Larger fish are generally considered at greater risk due to higher energy requirements and increased food consumption, which may enhance the probability of encountering and ingesting MPs (Haque *et al*. 2023; Seetapan and Prommi 2023). The presence of considerable inter- and intraspecific variation highlights the influence of additional ecological and behavioral factors, such as feeding strategy, habitat, and prey selection, in determining MPs ingestion patterns across different fish species (Hossain *et al*. 2019).

4.4 MPs contamination in fishes with respect to feeding habitat and feeding group

4.4.1 Feeding habitat

The observed differences likely reflect habitat-related exposure patterns. Benthopelagic and demersal fish forage near the seafloor, where MPs are frequently reported to accumulate in sediments (Bellas *et al*. 2016; Ghosh *et al*. 2021). Although environmental MP levels in water and sediments were not directly measured in this study, the habitat-based variation observed here is consistent with previously documented distribution patterns (Ghosh *et al*. 2021, Hossain *et al*. 2024).

MPs can bioaccumulate through marine food webs, leading to higher concentrations in species feeding at multiple trophic levels. Consequently, demersal and benthopelagic fish often exhibit elevated MPs burdens via trophic transfer (Miller *et al*. 2020; Saikumar *et al*. 2024). In contrast, pelagic fish inhabit open water, farther from sediment-associated MPs, and feed predominantly on plankton and small fish, reducing direct exposure. Additionally, stronger currents in the pelagic zone may disperse MPs, lowering local concentrations (Zhao *et al*. 2023). These patterns highlight the critical role of microhabitat in MPs exposure, demonstrating that bottom-associated and vertically mobile species are at greater risk. However, some studies suggest that pelagic feeders may ingest anthropogenic particles more frequently, likely due to the high prevalence of low-density polymers such as polyethylene and polypropylene in open-water environments (Lusher *et al*. 2013; Bessa *et al*. 2018).

4.4.2 Feeding group

MP ingestion in fish is influenced not only by trophic level and feeding strategy (Aktar and Moonajilin 2017; Wootton *et al*. 2021) but also by particle characteristics and digestive physiology (Miller *et al*. 2020). Carnivorous species exhibited higher MP loads, which may reflect trophic transfer of MPs from contaminated prey, particularly fibers and fragments that persist longer in the gastrointestinal tract due to their elongated shape and resistance to egestion (Miller *et al*. 2020; Wang *et al*. 2021). In addition, the predominance of smaller MPs (<0.5 mm) observed in this study may enhance retention and facilitate translocation within digestive tissues, increasing exposure in higher trophic level species. Polymer composition may also contribute to differential accumulation, as low-density polymers such as polyethylene and polypropylene are widely distributed in the water column and readily incorporated into prey organisms, facilitating indirect uptake by predators (Wright *et al*. 2013; Liu *et al*. 2020).

4.5 µ-FTIR analysis and chemical characterization of polymers

The prevalence of PP, PE, and PES aligns with previous reports indicating these polymers as the most common MPs in marine fish and ecosystems (Halstead *et al*. 2018; Hasan *et al*. 2022). Single-use plastics, particularly PP and PE, dominate the marine environment due to their extensive use in packaging, textiles, agriculture, and fisheries. Sources of MPs in the Bay of Bengal likely include mismanaged plastic waste, urban runoff, aquaculture, fishing gear, and maritime traffic (Ghosh *et al*. 2021; Parvin *et al*. 2021; Oza *et al*. 2024). PES in aquatic systems primarily originates from wastewater effluents (Browne *et al*. 2011; Neves *et al*. 2015). LDPE and PP monofilaments may also derive from fishing nets and ropes (Toha *et al*. 2024).

Identifying polymer types is crucial for understanding their environmental interactions, including the sorption of contaminants. PE, PP, and PES exhibit high sorption capacities for pollutants such as polycyclic aromatic hydrocarbons and chlorinated benzenes (Bakir *et al*. 2016). Polymer characterization further informs assessment of additive content, which has implications for ecological and human health risks. µ-FTIR analysis confirms that the MPs ingested by fish in the Bay of Bengal primarily originate from anthropogenic activities, with dominant polymers reflecting local plastic use and disposal patterns.

4.6 Comprehensive surface analysis MPs using SEM and EDX

The observed surface features indicate that MPs in the Bay of Bengal have undergone substantial environmental weathering and mechanical degradation, which can modify their physicochemical properties and increase their potential for biological uptake and ecological toxicity (Liu *et al*. 2020; Ramsperger *et al*. 2020; Zhang *et al*. 2020b; Parvin *et al*. 2022). Abrasion from sediments, metals, or other debris likely forms grooves and pores, enhancing the MPs' capacity to adsorb environmental pollutants and increasing ecological and health risks (Kowalski *et al*. 2016; Karbalaei *et al*. 2019). The detection of various metals on the MPs' surface suggests that environmental chemical adsorption is widespread, potentially adding toxicological significance. Surface weathering and fragmentation may also facilitate the formation of nanoplastics, which pose additional hazards to aquatic biota and may increase the risk to humans via seafood consumption.

4.7 Risk assessment of MPs contamination

4.7.1 CF and PLI

Although the CF and PLI indices were originally developed for sediments, recent literature supports their extension to biota (Ranjani *et al*. 2021; Jamal *et al*. 2025; Mossotto *et al*. 2025). Their application to biota provides a useful relative framework for assessing species-specific contamination and ecological exposure gradients (Rajnani *et al*. 2021). In this study, higher CF values in benthopelagic and demersal carnivores likely reflect increased exposure through sediment-associated MPs and trophic transfer, as these species occupy higher trophic levels and feed on contaminated prey and benthic organisms (Li *et al*. 2025; Wootton *et al*. 2021). CF values for Bay of Bengal fishes have been reported between ~1.1 and 2.8, with carnivorous species typically exhibiting higher contamination (Ahmed *et al*. 2025). Similarly, studies in freshwater fishes of southwestern Bangladesh documented low-to-moderate MPs loads, though CF and PLI were not explicitly computed (Akter *et al*. 2024). Comparable trends have been noted in other regions, such as the Danube Basin, where MPs were detected in market fish using alternative risk indices (Simionov *et al*. 2023). While few studies have applied CF/PLI frameworks directly, the moderate contamination levels observed here are consistent with prior evidence of widespread but variable MPs presence in fishes across diverse aquatic habitats.

4.7.2 PHI

These findings are broadly consistent with previous reports. For example, Akter *et al*. (2024) found polyethylene (73.08%), polypropylene (21.15%), and polystyrene (5.77%) dominated freshwater fishes, with PE (PHI = 8.04) and PS (PHI = 1.73) falling in Category II, whereas PP was classified as Category I (0.21). Similarly, (Ahmed *et al*. 2025) reported PP-PE and polyester as dominant polymers in marine fishes, with nylon and PVC driving hazard contributions. In contrast, (Das *et al*. 2025) documented higher PHI totals (512–701, Hazard Category IV) in estuarine fishes, reflecting substantially elevated risk linked to higher proportions of toxic polymers such as nylon. The comparison highlights the variability of polymer-related hazards across ecosystems, emphasizing that polymer composition strongly influences risk categorization. While the present study aligns with prior findings in showing a predominance of medium-risk (Category II) polymers, the elevated PHI associated with toxic polymers in other regions underscores the potential for local conditions to amplify ecological and human health risks. It is important to note that the PHI represents a hazard-based metric reflecting the relative toxicity potential of polymer types and does not constitute a direct assessment of human health risk (Lithner *et al*. 2011; Ho *et al*. 2025), as exposure pathways, intake rates, and consumption scenarios were not evaluated in the present study. Nevertheless, the presence of polymers with higher hazard scores highlights their potential environmental concern and underscores the need for further investigation incorporating exposure-based risk assessment frameworks.

5 | LIMITATIONS AND FUTURE DIRECTIVES

5.1 Limitations

The sample size, although encompassing multiple species and habitats, may not fully capture seasonal or spatial variability in MP exposure, particularly given the dynamic nature of coastal currents and pollutant sources. The µ-FTIR and SEM–EDX analyses were performed on a subset of recovered MPs, which may limit the representation of overall polymer diversity, surface weathering, and associated contaminants. Trophic transfer and bioaccumulation were inferred primarily from associations with feeding habits and habitat, without direct quantification through isotopic or gut-content analyses. In addition, particle size detection was constrained by the resolution of visual and spectroscopic techniques, potentially leading to an underestimation of nano- and submicron plastics. Risk assessment indices such as CF, PLI, and PHI, while informative, represent relative measures and do not account for cumulative ecological effects or potential human health toxicity. In addition, environmental MP levels in sediment and water were not measured, limiting mechanistic interpretation of habitat-specific exposure.

5.2 Future directives

Future research should aim to address these limitations by expanding spatial and temporal sampling across multiple seasons and including additional species to better represent the entire marine food web. Integration of advanced analytical techniques, such as Raman spectroscopy or pyrolysis–GC/MS, could improve detection of nano and sub-micron plastics and allow precise identification of polymer additives and sorbed contaminants. Controlled experimental studies on trophic transfer, bioaccumulation, and physiological effects would provide mechanistic insight into how MPs impact fish health and ecosystem function. Coupling MP contamination data with environmental parameters, including sediment and water quality assessments, could elucidate sources, transport pathways, and hotspots of pollution. Moreover, comprehensive human health risk assessments, incorporating dietary intake patterns and polymer-specific toxicity, are essential to evaluate the implications of seafood consumption. Finally, long-term monitoring programs and the development of standardized, harmonized methodologies for MPs quantification and risk assessment in Bangladesh's marine environment would enable evidence-based management strategies to mitigate ecological and public health risks associated with microplastic pollution.

6 | CONCLUSIONS

This study provides a comprehensive assessment of MP contamination in 13 commercially important marine fish species from the northwestern Bay of Bengal, revealing the pervasive presence, diversity, and potential ecological risks associated with MPs. MPs were detected in all species, exhibiting considerable variability in abundance, size, shape, color, and polymer composition. Fibers were the most prevalent morphotype, followed by films, foams, pellets, and fragments, with over 76% of particles smaller than 0.5 mm, indicating a dominant contribution from fragmented inland and coastal sources. Red and green MPs were consistently the most frequent colors, likely reflecting the widespread use of colored plastics in daily life and their resemblance to natural prey. Feeding habits, trophic level, and microhabitat significantly influenced MP ingestion, with benthopelagic and demersal carnivores, including *L. surinamensis*, *T. lepturus*, and *L. calcarifer*, exhibiting the highest MP loads. Risk assessment indices, including CF, PLI, and PHI, indicate moderate overall environmental contamination, while polymer-specific hazard analysis highlighted the elevated risk posed by nylon and PVC despite their lower abundance. µ-FTIR and SEM–EDX analyses confirmed that the MPs originated primarily from anthropogenic activities, showing surface weathering, mechanical damage, and adsorption of environmental contaminants, which may enhance bioavailability and toxicity. This study establishes critical baseline data for MP contamination in Bangladeshi marine fisheries and emphasizes the importance of future research integrating polymer toxicity, trophic transfer, and human exposure pathways to inform effective mitigation strategies.

ACKNOWLEDGEMENTS

We thank Laboratory of Marine Fisheries and Aquaculture Laboratory of Bangladesh Maritime University, Bangladesh alongside, Wazed Miah Science Research Center, Jahangirnagar University, Bangladesh for instrumental supports and analysis.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHORS' CONTRIBUTION

Maria Zaman: Conceptualization, Data Curation, Formal analysis, Methodology, Funding acquisition, Supervision, Project administration, Writing original draft, Writing review and editing. Ihsanul Haque: Sampling, Data Curation, Methodology, Formal Analysis, investigation, software, Data Curation, Visualization, Writing original draft, Writing review and editing. Md. Mahmud Hasan: Sampling, Data Curation, Methodology, Formal Analysis, investigation, software, Data Curation, Visualization, Writing original draft, Writing review and editing. Abdullah Fahim Chowdhury: Methodology, Formal Analysis, software, investigation, Writing original draft. Md. Baki Billah: Conceptualization, Formal analysis, Methodology, Supervision, resources, Validation, investigation, Writing original draft, Writing review and editing. Md. Hasan Faruque: Conceptualization, Formal analysis, Methodology, Software, Validation, Supervision, Writing original draft, Writing review and editing.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available within the article [and/or] its supplementary materials.

REFERENCES

Ahmed MS, Saifullah MK, Khatun MA, Chakraborty A, Tasnim A, … Iqbal MM (2025) Microplastics in certain commercial finfish and shellfish from Cox's Bazar fish landing center, Bangladesh: evaluating abundance and risks. Scientifica 1: 9515482.

Akhtar K, Khan SA, Khan SB, Asiri AM (2018) Scanning electron microscopy: principle and applications in nanomaterials characterization. Handbook of Materials Characterization: 113–145.

Aktar P, Moonajilin MS (2017) Assessment of water quality status of Turag River due to industrial effluent. International Journal of Engineering and Information Systems 1(6): 105–118.

Akter MS, Chakraborty TK, Ghosh GC, Nice MS, Zaman S, Khan AS (2024) Microplastics and heavy metals in freshwater fish species in the southwestern region of Bangladesh: an emerging concern for public health. Emerging Contaminants 10(3): 100325.

Al-Malaika S, Axtell F, Rothon R, Gilbert M (2017) Additives for plastics. Brydson's Plastics Materials: Eighth Edition: 127–168.

Andrady AL (2011) Microplastics in the marine environment. Marine Pollution Bulletin 62(8): 1596–1605.

Arat SA (2024) An overview of microplastic in marine waters: sources, abundance, characteristics and negative effects on various marine organisms. Desalination and Water Treatment 317(17): 100138.

Au SY, Bruce TF, Bridges WC, Klaine SJ (2015) Responses of *Hyalella azteca* to acute and chronic microplastic exposures. Environmental Toxicology and Chemistry 34(11): 2564–2572.

Bakir A, O'Connor IA, Rowland SJ, Hendriks AJ, Thompson RC (2016) Relative importance of microplastics as a pathway for the transfer of hydrophobic organic chemicals to marine life. Environmental Pollution 219: 56–65.

Barboza LG, Lopes C, Oliveira P, Bessa F, Otero V, … Guilhermino L (2020) Microplastics in wild fish from North East Atlantic Ocean and its potential for causing neurotoxic effects, lipid oxidative damage, and human health risks associated with ingestion exposure. Science of the Total Environment 717: 134625.

Barboza LGA, Vethaak AD, Lavorante BRBO, Lundebye AK, Guilhermino L (2018) Marine microplastic debris: an emerging issue for food security, food safety and human health. Marine Pollution Bulletin 133: 336–348.

Barnes DKA, Galgani F, Thompson RC, Barlaz M (2009) Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B: Biological Sciences 364(1526): 1985–1998.

Bellas J, Martínez-Armental J, Martínez-Cámara A, Besada V, Martínez-Gómez C (2016) Ingestion of microplastics by demersal fish from the Spanish Atlantic and Mediterranean coasts. Marine Pollution Bulletin 109(1): 55–60.

Belzagui F, Crespi M, Álvarez A, Gutiérrez-Bouzán C, Vilaseca M (2019) Microplastics emissions: microfibers detachment from textile garments. Environmental Pollution 248: 1028–1035.

Bessa F, Barría P, Neto JM, Frias JPGL, Otero V, … Marques JC (2018) Occurrence of microplastics in commercial fish from a natural estuarine environment. Marine Pollution Bulletin 128: 575–584.

Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, … Thompson R (2011) Accumulation of microplastic on shorelines worldwide: sources and sinks. Environmental Science and Technology 45(21): 9175–9179.

Cohen J (2013) Statistical power analysis for the behavioral sciences. Routledge, New York.

Compa M, Ventero A, Iglesias M, Deudero S (2018) Ingestion of microplastics and natural fibres in *Sardina pilchardus* (Walbaum, 1792) and *Engraulis encrasicolus* (Linnaeus, 1758) along the Spanish Mediterranean coast. Marine Pollution Bulletin 128: 89–96.

Das RS, Mahatab Uddin SM, Gündoğdu S, Afrin JK, Jahan N, … Siddique MA (2025) Unveiling microplastics in commercial brackish water fishes from the lower Meghna River estuary of Bangladesh. Bulletin of Environmental Contamination and Toxicology 114(5): 68.

Debbarma N, Gurjar UR, Ramteke KK, Shenoy L, Nayak BB, … Xavier M (2022) Abundance and characteristics of microplastics in gastrointestinal tracts and gills of croaker fish (*Johnius dussumieri*) from off Mumbai coastal waters of India. Marine Pollution Bulletin 176: 113473.

Derraik JGB (2002) The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin 44(9): 842–852.

Digka N, Tsangaris C, Torre M, Anastasopoulou A, Zeri C (2018) Microplastics in mussels and fish from the

Northern Ionian Sea. Marine Pollution Bulletin 135: 30–40.
Feng Z, Zhang T, Li Y, He X, Wang R, … Gao G (2019) The accumulation of microplastics in fish from Haizhou Bay, China. Science of the Total Environment 696: 133948.
Ferdous SR, Amin A, Hasan J, Alam MS, Shahjahan M (2023) Prevalence of microplastics in commonly consumed fish species of the river Old Brahmaputra, Bangladesh. Environmental Science and Pollution Research 30(36): 85639–85654.
Fernández de Puelles ML, Gazá M, Cabanellas-Reboredo M, Santandreu MD, Irigoien X, … Hernández-León S (2019) Zooplankton abundance and diversity in the tropical and subtropical ocean. Diversity 11(11): 203.
Ghosh GC, Akter SM, Islam RM, Habib A, Chakraborty TK, … Wahid MA (2021) Microplastics contamination in commercial marine fish from the Bay of Bengal. Regional Studies in Marine Science 44: 101728.
Gregory MR (2009) Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philosophical Transactions of the Royal Society B: Biological Sciences 364(1526): 2013–2025.
Gurjar UR, Xavier KAM, Shukla SP, Deshmukhe G, Jaiswar AK, Nayak BB (2021) Incidence of microplastics in gastrointestinal tract of golden anchovy (*Coilia dussumieri*) from northeast coast of the Arabian Sea: the ecological perspective. Marine Pollution Bulletin 169: 112538.
Guzzetti E, Sureda A, Tejada S, Faggio C (2018) Microplastic in marine organism: environmental and toxicological effects. Environmental Toxicology and Pharmacology 64: 164–171.
Hall CAM, Lewandowska AM (2022) Zooplankton dominance shift in response to climate-driven salinity change: a mesocosm study. Frontiers in Marine Science 9: 861297.
Halstead JE, Smith JA, Carter EA, Lay PA, Johnston EL (2018) Assessment tools for microplastics and natural fibres ingested by fish in an urbanised estuary. Environmental Pollution 234: 552–561.
Haque MR, Ali MM, Ahmed W, Siddique MAB, Akbor MA, … Rahman MM (2023) Assessment of microplastics pollution in aquatic species (fish, crab, and snail), water, and sediment from the Buriganga River, Bangladesh: an ecological risk appraisal. Science of the Total Environment 857: 159344.
Hasan J, Islam SMM, Alam MS, Johnson D, Belton B, … Shahjahan M (2022) Presence of microplastics in two common dried marine fish species from Bangladesh. Marine Pollution Bulletin 176: 113430.
Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M (2012) Microplastics in the marine environment: a review of the methods used for identification and quantification. Environmental Science & Technology 46(6): 3060–3075.
Ho CM, Feng W, Li X, Ngien SK, Yu X, … Liao H (2025) Microplastic distribution and its implications for human health through marine environments. Journal of Environmental Management 382: 125427.
Hossain M, Shams A (2020) Export potential of recycled plastic: a study on Bangladesh. Asian Social Science 16(3): 12–21.
Hossain MS, Rahman MS, Uddin MN, Sharifuzzaman SM, Chowdhury SR, … Chowdhury MSN (2020) Microplastic contamination in penaeid shrimp from the northern Bay of Bengal. Chemosphere 238: 124688.
Hossain MS, Saifullah ASM, Uddin MJ, Rahaman MH (2024) Assessment of microplastics in coastal ecosystems of Bangladesh. Ecotoxicology and Environmental Safety 281: 116622.
Hossain MS, Sobhan F, Uddin MN, Sharifuzzaman SM, Chowdhury SR, … Chowdhury MSN (2019) Microplastics in fishes from the northern Bay of Bengal. Science of the Total Environment 690: 821–830.
Islam M (2019) Bangladesh drowns in 8 lakh tonnes of plastic waste a year. The Business Standard, 7 November.
Issac MN, Kandasubramanian B (2021) Effect of microplastics in water and aquatic systems. Environmental Science and Pollution Research 28(16): 19544–19562.
Ivleva NP, Wiesheu AC, Niessner R (2017) Microplastic in aquatic ecosystems. Angewandte Chemie International Edition 56(7): 1720–1739.
Jamal NT, Islam MR, Sultana S, Banik P, Nur AA, … Hossain MB (2025) Microplastic contamination in some popular seafood fish species from the northern Bay of Bengal and possible consumer risk assessment. Food Control 171(21): 111114.
Jung MR, Horgen FD, Orski SV, Rodriguez CV, Beers KL, … Lynch JM (2018) Validation of ATR FT-IR to identify polymers of plastic marine debris, including those ingested by marine organisms. Marine Pollution Bulletin 127: 704–716.
Karbalaei S, Golieskardi A, Hamzah HB, Abdulwahid S, Hanachi P, … Karami A (2019) Abundance and characteristics of microplastics in commercial marine fish from Malaysia. Marine Pollution Bulletin 148: 5–15.
Khan HMS, Setu S (2022) Microplastic ingestion by fishes from Jamuna River, Bangladesh. Environment and Natural Resources Journal 20(2): 157–167.
Kibria G (2023) Impacts of microplastic on fisheries and seafood security: global analysis and synthesis. Science of the Total Environment 904: 166652.
Kowalski N, Reichardt AM, Waniek JJ (2016) Sinking rates of microplastics and potential implications of alteration by physical, biological, and chemical factors. Marine Pollution Bulletin 109(1): 310–319.

Lehtiniemi M, Hartikainen S, Näkki P, Engström-Öst J, Koistinen A, Setälä O (2018) Size matters more than shape: ingestion of primary and secondary microplastics by small predators. Food Webs 17: e00097.

Lei L, Wu S, Lu S, Liu M, Song Y, … He D (2018) Microplastic particles cause intestinal damage and other adverse effects in zebrafish (*Danio rerio*) and nematode (*Caenorhabditis elegans*). Science of the Total Environment 619–620: 1–8.

Li Q, Zhu L, Pu X, Sui Q, Sun X, … Xia B (2025) Occurrence, trophic transfer and risk assessment of microplastics in fishery organisms from the Bohai Sea, China. Journal of Hazardous Materials 493: 138367.

Lithner D, Larsson Å, Dave G (2011) Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. Science of the Total Environment 409(18): 3309–3324.

Liu P, Zhan X, Wu X, Li J, Wang H, Gao S (2020) Effect of weathering on environmental behavior of microplastics: properties, sorption, and potential risks. Chemosphere 242: 125193.

Lusher AL, McHugh M, Thompson RC (2013) Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Marine Pollution Bulletin 67(1–2): 94–99.

Lusher AL, Welden NA, Sobral P, Cole M (2017) Sampling, isolating and identifying microplastics ingested by fish and invertebrates. Analytical Methods 9(9): 1346–1360.

Miller ME, Hamann M, Kroon FJ (2020) Bioaccumulation and biomagnification of microplastics in marine organisms: a review and meta-analysis. PLoS ONE 15(10): e0240792.

Mistri M, Sfriso AA, Casoni E, Nicoli M, Vaccaro C, Munari C (2022) Microplastic accumulation in commercial fish from the Adriatic Sea. Marine Pollution Bulletin 174: 113279.

Mossotto C, Anselmi S, Bentivoglio T, Gabetti A, Esposito G, … Prearo M (2025) High-mountain contamination: microplastic occurrence and risk assessments in fish from Nero Lake, Italy. Ecologies 6(4): 64.

Neves D, Sobral P, Ferreira JL, Pereira T (2015) Ingestion of microplastics by commercial fish off the Portuguese coast. Marine Pollution Bulletin 101(1): 119–126.

Nguyen MK, Lin C, Nguyen DD (2025) Microplastic pollution associated with probabilistic human health risks: potential hazards, critical factors, challenges, and limitations. Marine Pollution Bulletin 221: 118528.

Nithin A, Sundaramanickam A, Iswarya P, Babu OG (2022) Hazard index of microplastics contamination in various fishes collected off Parangipettai, southeast coast of India. Chemosphere 307: 136037.

Noda I, Dowrey AE, Haynes JL, Marcott C (2007) Group frequency assignments for major infrared bands observed in common synthetic polymers. In: Mark JE (Ed) Physical Properties of Polymers Handbook. Springer, New York, pp 395–406.

Oza J, Rabari V, Yadav VK, Sahoo DK, Patel A, Trivedi J (2024) A systematic review on microplastic contamination in fishes of Asia: polymeric risk assessment and future perspectives. Environmental Toxicology and Chemistry 43(4): 671–685.

Park TJ, Lee SH, Lee MS, Lee JK, Lee SH, Zoh KD (2020) Occurrence of microplastics in the Han River and riverine fish in South Korea. Science of the Total Environment 708: 134535.

Parvin F, Hassan MA, Tareq SM (2022) Risk assessment of microplastic pollution in urban lakes and peripheral rivers of Dhaka, Bangladesh. Journal of Hazardous Materials Advances 8: 100187.

Parvin F, Jannat S, Tareq SM (2021) Abundance, characteristics and variation of microplastics in freshwater fish species from Bangladesh. Science of the Total Environment 784: 147137.

Pereira JM, Rodríguez Y, Blasco-Monleon S, Porter A, Lewis C, Pham CK (2020) Microplastics in the stomachs of open-ocean and deep-sea fishes from the northeast Atlantic. Environmental Pollution 265: 115060.

Plastics Europe (2025) Plastics – the fast facts 2025. PlasticsEurope, Brussels. Available at: https://plasticseurope.org

Prata JC, Costa JP, Duarte AC, Rocha-Santos T (2022) Suspected microplastics in Atlantic horse mackerel (Trachurus trachurus) captured in Portugal. Marine Pollution Bulletin 174: 113249.

Rabari V, Patel K, Patel H, Trivedi J (2022) Quantitative assessment of microplastics in sandy beaches of Gujarat state, India. Marine Pollution Bulletin 181: 113900.

Ramsperger AF, Narayana VK, Gross W, Mohanraj J, Thelakkat M, … Laforsch C (2020) Environmental exposure enhances internalization of microplastic particles into cells. Science Advances 6(50): eabd1211.

Ranjani M, Veerasingam S, Venkatachalapathy R, Mugilarasan M, Bagaev A, … Vethamony P (2021) Assessment of potential ecological risk of microplastics in the coastal sediments of India: a meta-analysis. Marine Pollution Bulletin 163: 11196.

Roch S, Friedrich C, Brinker A (2020) Uptake routes of microplastics in fishes: practical and theoretical approaches to test existing theories. Scientific Reports 10: 4610.

Roy N, Imran SM, Siddiky A, Sultana S, Mahmud S, … Biswas KK (2025) Seafood safety and consumption in coastal Bangladesh: unpacking knowledge, attitudes, preferences, and environmental concerns. Journal of Nutritional Science 14: e35.

Saikumar S, Mani R, Ganesan M, Dhinakarasamy I, Palanisami T, Gopal D (2024) Trophic transfer and impact of microplastics on an estuarine food chain model. Journal of Hazardous Materials 464: 132927.

Seetapan K, Prommi TO (2023) Microplastics in commercial fish digestive tracts of freshwater fish from northern Thailand. Ecologica Montenegrina 68: 48–65.

Siddique MAM, Uddin A, Rahman SMA, Rahman M, Islam MS, Kibria G (2022) Microplastics in anadromous Hilsa shad (*Tenualosa ilisha*) from the Bay of Bengal. Marine Pollution Bulletin 174: 113195.

Simionov IA, Călmuc M, Iticescu C, Călmuc V, Georgescu PL, … Petrea ŞM (2023) Human health risk assessment of potentially toxic elements and microplastics accumulation in products from the Danube River Basin fish market. Environmental Toxicology and Pharmacology 104: 104307.

Tanaka K, Takada H (2016) Microplastic fragments and microbeads in digestive tracts of planktivorous fish. Scientific Reports 6: 34351.

Thi LAP, Nguyen VH, Do XD, Dang THL, Do HT, Nguyen TL (2025) Microplastics occurrence, contamination, and effects on human health: a critical review. Microplastics 451–479.

Toha M, Sikder S, Rahman MM, Muhib MI (2024) Microplastic occurrences in freshwater fish of Bangladesh. Pollution Annual Volume 25: 3. [Accessed 17 July 2024]

Wang C, Zhao J, Xing B (2021) Environmental source, fate, and toxicity of microplastics. Journal of Hazardous Materials 407: 124357.

Wang J, Liu X, Liu G, Zhang Z, Wu H, ... Zhang W (2019) Size effect of polystyrene microplastics on sorption of phenanthrene and nitrobenzene. Ecotoxicology and Environmental Safety 173: 331–338.

Wang S, Chen H, Zhou X, Tian Y, Lin C, … Lin H. (2020) Microplastic abundance, distribution, and composition in the mid-west Pacific Ocean. Environmental Pollution 264: 114125.

Watts AJR, Lewis C, Goodhead RM, Beckett SJ, Moger J, … Galloway TS (2014) Uptake and retention of microplastics by the shore crab *Carcinus maenas*. Environmental Science & Technology 48(15): 8823–8830.

Wootton N, Reis-Santos P, Gillanders BM (2021) Microplastic in fish – a global synthesis. Reviews in Fish Biology and Fisheries 31(4): 753–771.

Worm B, Lotze HK, Jubinville I, Wilcox C, Jambeck J (2017) Plastic as a persistent marine pollutant. Annual Review of Environment and Resources 42: 1–26.

Wright SL, Thompson RC, Galloway TS (2013) The physical impacts of microplastics on marine organisms: a review. Environmental Pollution 178: 483–492.

Yuan W, Liu X, Wang W, Di M, Wang J (2019) Microplastic abundance, distribution and composition in water, sediments, and wild fish from Poyang Lake, China. Ecotoxicology and Environmental Safety 170: 180–187.

Zhang C, Wang S, Pan Z, Sun D, Xie S, … Zou J (2020) Occurrence and distribution of microplastics in commercial fishes from estuarine areas of Guangdong, South China. Chemosphere 260: 127656.

Zhang G, Sun J, Zhan Y, Xiao B, Liu H, Wang L (2026) Bioaccumulation, trophic transfer, and health risk assessment of microplastics in the food web of Wuliangsuhai Lake, China: higher risk for children. Environmental Pollution 395: 127787.

Zhang Y, Pu S, Lv X, Gao Y, Ge L (2020) Global trends and prospects in microplastics research: a bibliometric analysis. Journal of Hazardous Materials 400: 123110.

Zhao S, Mincer TJ, Lebreton L, Egger M (2023) Pelagic microplastics in the North Pacific Subtropical Gyre: a prevalent anthropogenic component of the particulate organic carbon pool. PNAS Nexus 2(3): pgad070.

Zhu L, Wang H, Chen B, Sun X, Qu K, Xia B (2019) Microplastic ingestion in deep-sea fish from the South China Sea. Science of the Total Environment 677: 493–501.

M Zaman http://orcid.org/0009-0005-6268-5214
I Haque http://orcid.org/0009-0004-2998-2826
MM Hasan http://orcid.org/0009-0006-2470-918X
AF Chowdhury https://orcid.org/0000-0002-6463-4083
MB Billah https://orcid.org/0000-0002-1742-2774
MH Faruque https://orcid.org/0000-0003-3230-2284