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Microplastic contamination in highly consumed wild and cultured Asian seabass from a subtropical coastal region: Exposure and consumer risk assessment

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ABSTRACT

This study provides a novel assessment of Microplastics (MPs) contamination in wild and cultured Asian seabass (*Lates calcarifer* Bloch, 1790), a significant species in global aquaculture and seafood consumption. A total of 30 samples were analyzed using H_2O_2 digestion, density separation and FTIR spectroscopy to quantify and characterize MPs based on abundance, morphological features and polymers. The average MP abundance in muscle of wild and cultured seabass was (2.60 ± 0.99 items/g) and (1.92 ± 0.94) respectively with particles predominantly in the size range of < 0.5 mm. Polyethylene (PE), Polyethylene Terephthalate (PET), and Polystyrene (PS) were the most common polymers identified, suggesting contamination sources linked to various anthropogenic activities. Risk indices, Pollution Load Index (PLI), and Contamination Factor (CF), indicated a moderate to high pollution level, underscoring the ecological risk posed by MPs in their environments. Both wild and cultured seabass exhibited moderate Polymer Hazard Index (PHI) values for PE and PET, indicating category II polymer-associated risks (PHI: 1–10). Furthermore, Estimated Daily Intake (EDI) for adult and children were 1.59 and 1.24 g/day for wild seabass and 1.17 g/day and 0.91 g/day respectively for cultured seabass. Given the high consumption of Asian seabass, these findings support food safety guidance.

1. Introduction

Microplastics (MPs), characterized as plastic particles of < 5.0 mm in diameter (Arthur et al., 2009), have generated considerable interest as global contaminants due to their negative environmental and biological impacts, such as entanglement, ingestion, and potential toxicity (GESAMP et al., 2019; Prata et al., 2021; Benson et al., 2022; Bostan et al., 2023). Plastic debris constitutes about 60–80 % of all marine litter, reaching up to 90–95 % in some regions (Wang et al., 2016). In comparison to large plastics, MPs are more readily distributed owing to their tiny size. making them ubiquitous in oceans and other environments, including water, ice, salt, and sediments (Nur et al., 2022; Hossain et al., 2023; Liu et al., 2023; Riya et al., 2024).Various marine organisms, such as zooplankton, bivalves, fish, and copepods, have been confirmed to ingest MPs, leading to their accumulation in tissues like gills, digestive glands, guts, and circulatory systems (Hossain et al., 2024). Furthermore, MPs are transported through food chains, transferring from plankton to fish, and from mussels to crabs, among other

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Abbreviations: MPs, Microplastics; NMPs, Nano- and Microplastics; PET, Polyethylene Terephthalate; PP, Polypropylene; PS, Polystyrene; PE, Polyethylene; FTIR, Fourier-Transform Infrared Spectroscopy; CCA, Canonical Correspondence Analysis; PCA, Principal Component Analysis.

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pathways (Jinadasa et al., 2023; Zhao et al., 2025).

MPs in the environment act as vectors for various contaminants, including pesticides, heavy metals, hormones, additives, pharmaceuticals, and persistent organic pollutants (POPs). These contaminants can bioaccumulate and transfer through marine organisms, from planktivores to larger fish and mammals, thereby impacting marine food chains (Shu et al., 2023; Gao et al., 2024;). MPs accumulate in marine organisms, leading to adverse effects such as intestinal blockage, inflammation, internal abrasion, oxidative damage, and growth failure (Ding et al., 2023., Jia et al., 2023; Rashid et al., 2024). In humans, MPs pose potential health risks by disrupting digestive processes. Studies have shown that MPs, including polyethylene (PE), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET), and polylactic-co-glycolic acid (PLGA), interfere with lipid digestion. Among these, PS MPs exhibit the highest inhibition, as they interact with lipid droplets and digestive enzymes, forming large aggregates due to their hydrophobic nature. This process reduces lipid bioavailability, alters lipase activity, and disrupts enzyme conformation, potentially leading to malabsorption, steatorrhea, and nutrient deficiencies (Tan et al., 2020). Additionally, MPs can penetrate biological barriers by cellular uptake, entering the lymphatic and circulatory systems through the lungs or gut. While the full extent of their effects on human tissues remains unclear (Wright and Kelly., 2017; Rubio et al., 2020;), existing evidences suggested that MPs act as both chemical and physical stressors. Their presence in the respiratory, digestive, and circulatory systems has been linked to health concerns, including endocrine disruption, metabolic disorders, cancer, and cardiovascular, reproductive, and developmental issues (Alharbi et al., 2018; Volschenk et al., 2019).

MPs have been widely detected in seafood, raising concerns about their potential accumulation in our body via the food chain (Jinadasa et al., 2023; Giri et al., 2024; Silva et al., 2024). Therefore, it is crucial to comprehend the hazards that commercial seafood contaminated with MPs poses to human health. Globally, seafood products, especially fish, contribute approximately 15 % of the animal protein intake in the human diet (FAO, 2012). In Bangladesh, fish constitutes the principal source of protein, representing around 60 % of total animal protein intake, with a per capita fish consumption of 62.58 g per day, surpassing the daily protein requirement of 60 g (Akter et al., 2019). Asian seabass (*Lates calcarifer*), an euryhaline fish extensively found in the coastal regions of Bangladesh, is valued in both commercial fisheries and aquaculture due to its fast growth and high market demand (Hassan et al., 2021). It has a broad biogeographic distribution across the Indo-West Pacific, from the Persian Gulf to northern Australia and Southeast Asia (Venkatachalam et al., 2018). This species is euryhaline, tolerating salinity ranges from 0 % to 56 %, and is found in fresh, brackish, and marine waters (Sen et al., 2019). *L. calcarifer* is carnivorous, preying on crustaceans, smaller fish, and mollusks (Ganzon-Naret, 2013). Juveniles typically measure around 2.2 cm, while adults can grow up to 2000 g within a year (Hassan et al., 2021). Females generally attain larger sizes than males of the same age (Hassan et al., 2021)). This species migrates between estuarine and marine environments for spawning and growth (Venkatachalam et al., 2018). In Bangladesh, it plays a crucial role in aquaculture and significantly contributes to local fish consumption. While consuming seafood offers significant benefits, it also increases the risk of exposure to harmful chemicals carried by MPs that leach into animal guts (Bakir et al., 2014; Koelmans et al., 2020; Saliu et al., 2020). Despite growing concerns over MP contamination in aquatic ecosystems, significant knowledge gaps remain regarding human exposure through fish consumption and its potential health impacts. In particular, the extent to which MPs accumulate in commonly consumed fish species and their subsequent risks to human health remain inadequately understood. To address these uncertainties, it is essential to establish and apply standardized techniques that provide consistency and dependability in data collecting, hence facilitating more precise risk assessments.

Several studies have documented microplastic contamination in the muscle, gut, and gills of various fish species from both coastal and freshwater environments in Bangladesh (Parvin et al., 2021; Hossain et al., 2024; Sultana et al., 2024). However, research specifically assessing MP contamination in wild and cultured Asian seabass (*L. calcarifer*) from the coastal waters of Bangladesh remains absent, despite the species' high consumption and economic significance. This critical knowledge gap limits our understanding of MP exposure through this species and its potential implications for food safety. To address this gap, the present study aims to (1) quantify the concentration and characteristics of MPs in the muscle and gut of wild and cultured Asian seabass and (2) assess the potential human health risks associated with their consumption. Given the commercial and dietary importance of Asian seabass in the region, evaluating its MP contamination status is essential. Furthermore, the lack of established threshold limits for MP exposure in seafood emphasized the urgent need for comprehensive data on commonly consumed fish species. Such data will be helpful in informing evidence-based food safety guidelines and establishing permissible consumption limits through both local and international regulatory frameworks. By fulfilling this knowledge gap, the study provides essential insights for policymakers, regulatory agencies, and public health authorities, facilitating the development of scientifically grounded risk assessments and mitigation strategies to ensure food safety.

2. Materials and methods

2.1. Fish collection and sample preparation

Wild Asian seabass samples were obtained from fish landing centers, while cultured Asian seabass were sourced from fish farms in two coastal districts, Noakhali and Chittagong, Bangladesh. A total of 30 specimens (15 wild and 15 cultured) were collected in June 2024, ensuring representative sampling of both environments. Wild seabass specimens had mean individual weight of 1451 ± 54 g, and cultured seabass specimens had a mean individual value of 1489 ± 8 g. The collected fish were preserved in an icebox and subsequently transported to the Laboratory for Ecology, Environment, and Biodiversity, where they were stored at −20 °C for MP analysis. The preserved fish specimens were defrosted in a metal tray and rinsed in the laboratory with distilled water. The overall length and body weight of each specimen were documented. The specimens were individually dissected in a metal tray using forceps, scissors and a scalpel. The gastrointestinal tract and muscle were separated, placed in a petri dish, weighed, and subsequently transferred to a 1 L glass beaker.

2.2. Digestion of tissues

Samples were subjected to an adapted wet peroxide digestion protocol based on Hossain et al. 2024, and Parvin et al., 2021. Extraction procedure is outlined in supplementary Fig. S1. Approximately 200 mL of 30 % H_2O_2 was administered to each beaker to facilitate the digestion of organic debris, based upon the mass of the soft tissue in each beaker. Numerous investigations have determined that H_2O_2 solution was more successful in digesting biogenic material than HCl and NaOH. The beakers were sealed and positioned in an oscillation incubator at 65 °C and 80 rpm for 24 hours, subsequently maintained at room temperature for 24–48 hours, contingent upon the digestive efficacy of the soft tissue (Avila et al., 2023; Khan and Setu, 2022). A NaCl solution, filtered and saturated at a density of 1.2 g/mL, was formulated. To enable the segregation of plastics from the dissolved materials, 300 mL of filtered NaCl solution was added to the vial. The solution was agitated overnight to observe the elimination phase. The solution was subsequently filtered through Whatman AE98 cellulose nitrate membrane filter sheets with a pore size of 5.0 μm and a diameter of 47 mm, utilizing a vacuum pump. Subsequent to the filtration operation, the filters were maintained in sterile Petri dishes with lids for microscopic examination of the plastic items.

The filter papers were positioned within sealed glass made Petri plates, and examined using a light stereomicroscope (Leica EZ4E, Germany) at magnifications ranging from 8 × to 35 × (Hidalgo-Ruz et al., 2012). The particles were classified in accordance with the protocols established for plastic pollution monitoring studies (GESAMP et al., 2019) and categorized based on their morphology (fibres, pieces, films, pellets, and foams) and colour (black, blue, clear, multicolour, among others). Each quadrate of the filter paper was meticulously examined to tally the MPs. The MPs count in each sample was manually evaluated under microscope via visual inspection and tallying. Furthermore, in certain instances, photographs of each quadrat were captured and analyzed with software, while size measurements were obtained from images taken with a high-resolution camera affixed to the microscope. The size of microplastics was determined using ImageJ software (version 2.0.0) (Laglbauer et al., 2014). The non-plastic chemicals were eliminated using a hot needle test (De Witte et al., 2014). Then the classification, colour, and dimensions of MPs were established (Hossain et al., 2021). To distinguish different polymer types, MPs larger than 0.1 mm were selected for further polymer identification.

To ensure the dependability of MP extraction from fish specimens, rigorous quality control protocols were followed. Each batch included procedural blanks to identify potential contamination, and all glassware and equipment were pre-rinsed using filtered deionized water. Sample processing was conducted within a laminar flow hood to reduce airborne contamination. Furthermore, only procedural blanks devoid of contamination were utilized for data validation.

2.3. Fourier transformed infra-red spectrometry (FTIR) analysis

FTIR analysis of the MPs was performed using an Agilent Cary 630 FTIR equipped with an Attenuated Reflective Spectroscopy (ATR) accessory. The instrument was configured to take 16 background scans and 16 sample scans, with a resolution of 4, covering the range of 4000–650 cm^{-1}. The differentiation between high-density polyethylene (HDPE) and low-density polyethylene (LDPE) was made following the methodology of Jung et al. (2018). To improve the identification process, an automated comparison with an extensive spectrum library was employed. Additionally, the FTIR spectra were cross-referenced with those from previous studies (Noda et al., 2007; Jung et al., 2018) to ensure precise identification, thereby avoiding sole dependence on automated libraries.

2.4. Contamination and health hazard assessment of plastic particles in fish

The contamination factor (CF) and pollutant load index (PLI) are commonly employed as diagnostic tools to assess pollution risk in aquatic ecosystems (Tomlinson et al., 1980; Hossain et al., 2021; Rakib et al., 2022). The CF precisely measures the extent of contamination by contrasting the concentration of a specific pollutant in a sample with its relevant background or reference level. This is determined by applying the following formula:

$$CFi = \frac{Ci}{Co} \tag{1}$$

Here, CFi is the ratio of plastic particle concentration in a sample (Ci) to the minimum observed concentration (Co), while PLI is the geometric mean of all CF values (Suresh et al., 2012). The formula for calculating the PLI is as follows:

$$PLI = \sqrt{CFi} \tag{2}$$

2.5. Polymeric chemical risk of MPs

The polymer hazard index (PHI) for MPs in wild and cultured Asian seabass muscle was calculated using polymer types, their proportions, and hazard scores from Lithner et al. (2011), following the method of Xu et al. (2018); higher PHI values indicate greater chemical risk.

$$\mathrm{PHI} = \sum \mathrm{Pn} \times \mathrm{Sn} \tag{3}$$

here, Pn represents the % of each polymer type in the sample, and Sn denotes the hazard score for each polymer as defined by Lithner et al. (2011).

2.6. Assessing health risk of MPs

The estimated daily intake (EDI) of MPs from processed foods was calculated to assess dietary exposure across three population groups: male adults, female adults, and children. The formula for EDI is as below:

$$\mathrm{EDI} = \frac{C \quad \times IR}{BW} \tag{4}$$

here, C is the median MP levels (items/g); IR is the weekly fish intake based on EFSA (European Food Safety Authority) guidelines—300 g for adults and 50 g for children (EFSA, 2014); BW is the average body weight—66.0 kg for adults (Ferrante et al., 2022) and 35.0 kg for children (Trabelsi et al., 2008).

2.7. Statistical analysis

Prior to analysis, data normality and variance homogeneity were assessed using the Shapiro–Wilk and Levene's tests, respectively. Descriptive statistics (mean, median, SD, range) were calculated for MP abundance and fish body metrics. Permutational multivariate analysis of variance (PERMANOVA) test was done to identify specific group differences. Pearson's correlation test was utilized to examine the relationships between biological traits (such as body size and weight) and MP abundance, and regression analysis was subsequently employed to model the relationship between MP contamination and fish body characteristics formally. Principal Component Analysis (PCA) was performed using PAST (PAleontological Statistics; Version 4.03) to reduce data dimensionality and identify key factors influencing MP contamination. Graphical representations of the results were created using Origin 2024. All statistical analyses were conducted using Origin Pro 2024, R (Version 4.3.2) with RStudio, employing packages such as ggplot2 for data visualization. The significance level was set at p-value< 0.05 or p-value < 0.01.

3. Results and discussion

3.1. Abundance of MPs in wild and cultured seabass

All replicates of wild and cultured seabass from two districts were pooled to assess the concentration of MPs in the muscle and GIT. The total numbers of MPs in muscle and GIT of wild seabass were (2.6 ± 0.9) and (7.1 ± 1.3) items/g, respectively. MPs abundance in muscle and GIT of cultured seabass was (1.9 ± 0.9) and (5.7 ± 1.5) items /g respectively. PERMANOVA was done to assess the effect of fish type (wild vs. cultured seabass) on MPs abundance. The results demonstrated a statistically significant difference between the two groups ($F = 39.1$, $p = 0.01$), with fish type explaining 58.3 % of the total variance in MPs abundance ($R^2 = 0.58$). The residual variation accounted for 41.7 % of the total variance, which may be attributed to several biological and environmental factors. Possible contributors to the residual variation include individual dietary differences, as wild seabass exhibit opportunistic feeding behaviors, consuming prey with variable MP loads. Additionally, variations in habitat contamination levels across different locations may influence MP exposure in wild fish. Physiological differences, such as metabolism and gut retention time, may also affect MP retention across individuals. In cultured seabass, despite controlled feeding practices, differences in aquaculture water quality, feed contamination, or farm management practices could contribute to variability in MP accumulation.

MPs found in the muscle tissue of fish likely originate from the digestive system, as indicated by their high abundance in the gastrointestinal tract. The translocation of small MPs from the digestive system to other tissues, such as muscle, may be facilitated by digestive processes and internal fluid dynamics, including circulatory transport. According to Karami et al. (2017), MPs can enter fish muscles through direct pathways like the gills, skin, and gastrointestinal tract. The entry of plastic particles into the bloodstream depends on factors such as fish species, particle size, and ingestion conditions (Akhbarizadeh et al., 2018). Smaller microplastic particles, particularly those < 20 μm, have a higher likelihood of entering the bloodstream (Guistra et al., 2024).

In comparison with previously reported studies, the present investigation revealed relatively higher microplastic (MP) abundance in both the gastrointestinal tract (GIT) and muscle tissues of *L. calcarifer* from Bangladesh. The GIT MP abundance in wild (7.8 ± 1.34 items/individual) and cultured seabass (5.67 ± 1.47 items/individual) was notably higher than that reported for most carnivorous species globally. For instance, Su et al. (2019) observed MPs ranging from 0.3 to 5.3 items/individual in *Lateolabrax maculatus* from Hangzhou Bay and Yangtze estuary, while Park et al. (2020) recorded 22.0 ± 16.0 items/individual in bass (*M. salmoides*) from the Han River, although no MPs were detected in muscle tissues in either case. Jabeen et al. (2017) reported lower MP levels in *Sillago sihama* (0.8 ± 0.6), *Callionymus planus* (1.3 ± 1.3), and *Centropomus undecimalis* (0.75 ± 0.8) in the GIT, with minimal muscle contamination. Similarly, the muscle MP concentrations in the present study (2.6 ± 0.99 in wild and 1.92 ± 0.94 in cultured seabass) were higher than values reported for other species such as *Larimichthys crocea* (0.01 ± 0.01), *Konosirus punctatus* (0.04 ± 0.03) (Wu et al., 2020), and *Lutjanus synagris* (0.02 ± 0.02) (Jimenez-Cárdenas et al., 2022). Elevated MP concentrations in the current study may be attributed to increased plastic pollution in the Bay of Bengal, differences in trophic level, feeding behavior, and habitat-specific exposure. The larger body size and predatory nature of *L. calcarifer* may also facilitate greater ingestion of MPs through trophic transfer or direct ingestion of contaminated prey.

The scatter plots illustrate the relationship between body weight (g) and MP abundance in wild and cultured seabass. In wild seabass, a moderate positive correlation ($R^2 = 0.60$) is observed, indicating that MP accumulation increases with body weight. This trend suggests that larger wild seabass tend to accumulate more MPs due to prolonged exposure to contaminated environments. Bioaccumulation of MPs has been documented in various marine species across different trophic levels. Previous studies have reported that larger fish exhibit higher MP loads compared to smaller individuals; however, smaller fish tend to contain more translocated particles per gram of wet weight (Miller et al., 2020; McIlwraith et al., 2021). Additionally, wild seabass displays opportunistic feeding behaviors, consuming a diverse range of prey, including both benthic and pelagic organisms from MP-contaminated habitats. This varied diet increases their exposure to MPs through trophic transfer. Furthermore, direct ingestion of MPs from the water column contributes to the observed positive correlation between body weight and MP abundance.

In contrast, cultured seabass exhibits a weak negative correlation ($R^2 = 0.12$), indicating a minimal relationship between body weight and MPs load. This can be attributed to the controlled conditions in aquaculture systems, where fish are provided with formulated feed, reducing the likelihood of MP ingestion from natural prey. Furthermore, aquaculture facilities implement water quality management strategies, including filtration, sedimentation, and periodic water exchange, which limit MP exposure. The relatively shorter lifespan of cultured seabass compared to wild counterparts also reduces the cumulative effect of MP accumulation over time. These controlled conditions lead to more uniform MP exposure across different size groups, resulting in the lack of a significant correlation between body weight and MPs abundance.

3.2. Morphological characteristics of MPs

Among the identified MPs particles in the wild and cultured seabass, fibers were predominant (Fig. 2). In wild seabass muscle, fibers constituted 89.46 % of the total MPs, followed by fragments at 9.04 %, sheets at 9.42 %, and foams at 3.77 %. In cultured seabass muscle, fibers were even more dominant, making up 95.18 % of the MPs, with fragments at 8.24 %, sheets at 0.94 %, and foams at 0.47 %. These findings confirm that fibers are the most abundant form of MPs in both wild and cultured seabass, aligning with patterns observed in other coastal and marine environments in Bangladesh. Previous studies have similarly shown that fibers and films are the most prevalent plastic types in marine species (Ghosh et al., 2021; Hossain et al., 2023; Pingki et al., 2025). This study reinforces these findings, particularly the high prevalence of fibers. Consistent with previous studies, the current research confirms the prevalence of similar microplastic types in the fish species examined. These fibers may originate from various sources, including residential wastewater (Browne et al., 2011), the degradation of fishing nets and lines (Cole et al., 2013), or airborne deposition (Dris et al., 2018). The observed films in fish samples may result from the breakdown of larger plastic bags and wraps (Jiao et al., 2022), while the fragmentation of plastic bottles or other items could contribute to foam and irregular plastic fragments.

Among the identified MPs particles pooled from the muscle and GIT of wild and cultured seabass, transparent particles emerged as the most predominant, constituting 84.27 % of MPs in wild seabass and 63.99 % in cultured seabass. In wild seabass, violet particles followed at 6.03 %, then blue (4.17 %), red (1.96 %), and pink (1.87 %). For cultured seabass, violet and blue particles were more prominent at 12.24 % each, followed by red (4.90 %) and pink (3.35 %). These findings suggest a significant abundance of transparent MPs, possibly due to the widespread use of transparent plastics in consumer products, which may lead to their high prevalence in marine environments. Similar color trends have been documented in other studies, where transparent and violet MPs are commonly detected in marine species (Jabeen et al., 2017; Ghosh et al., 2021; Hossain et al., 2023). This aligns with the assumption that transparent and visually appealing plastics are prevalent due to their frequent use and subsequent release into the aquatic environment.

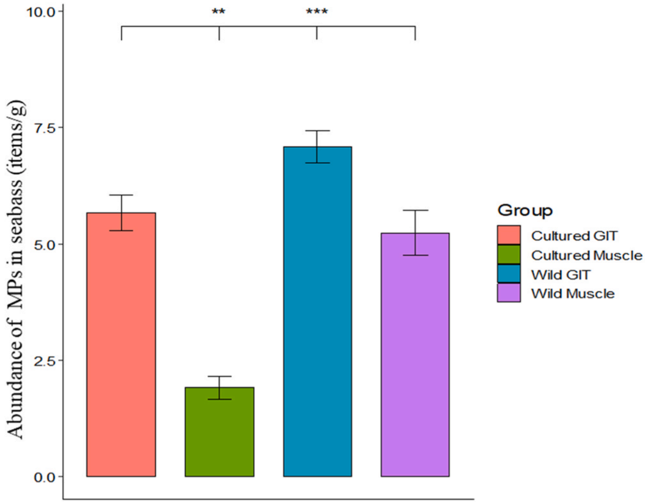

Fig. 1. The abundances of MPs calculated per unit weight in wild and cultured seabass. The data were expressed as the mean ± S.E. Significant differences were accepted at * = $p < .05$, ** = $p < .01$ and *** $p < .001$.
The ** and *** on the graph indicated significant differences were existed between wild and cultured seabass.

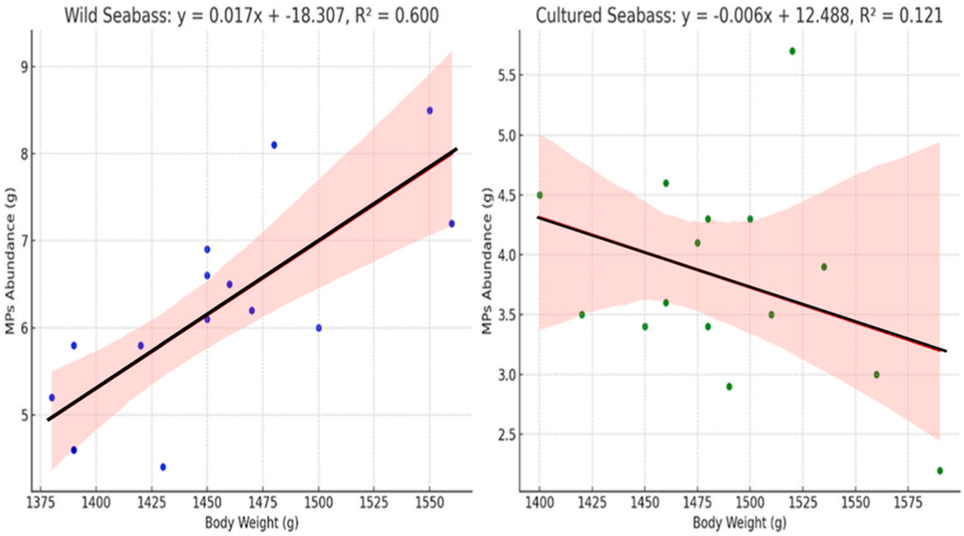

Fig. 2. Relationship between body weight (g) and MPs abundance (items/g) in wild and cultured seabass. Scatter plots with linear regression lines depict the correlation between body weight and MPs abundance in both wild (left) and cultured seabass (right). The regression equation and R^2 values for each group show a moderate positive correlation for wild seabass ($R^2 = 0.600$) and a weak negative correlation for cultured seabass ($R^2 = 0.121$).

The frequent use of colorful plastics, particularly transparent and violet, in consumer goods may contribute to their abundance in marine environments, as these plastics are often selected for their aesthetic appeal and attraction to consumers.

This study identified three distinct size categories for MPs particles: < 0.5 mm, 0.5–1 mm, and 1–5 mm, with MPs smaller than 0.5 mm being the most prevalent across all samples. In wild seabass, 95.12 % of MPs were < 0.5 mm, followed by 3.09 % in the 0.5–1 mm range, and 1.95 % in the 1–5 mm range. Similarly, in cultured seabass, MPs < 0.5 mm accounted for 93.60 %, with 2.56 % in the 0.5–1 mm range, and 3.83 % in the 1–5 mm range. These findings indicate a strong predominance of smaller MPs in both wild and cultured seabass, with MPs < 0.5 mm significantly outnumbering larger particles. The dominance of smaller MPs aligns with previous findings (Ghosh et al., 2021; Hossain et al., 2023; Hossain et al., 2024; Sultana et al., 2024), where smaller MPs were also found to be predominant in marine species. This

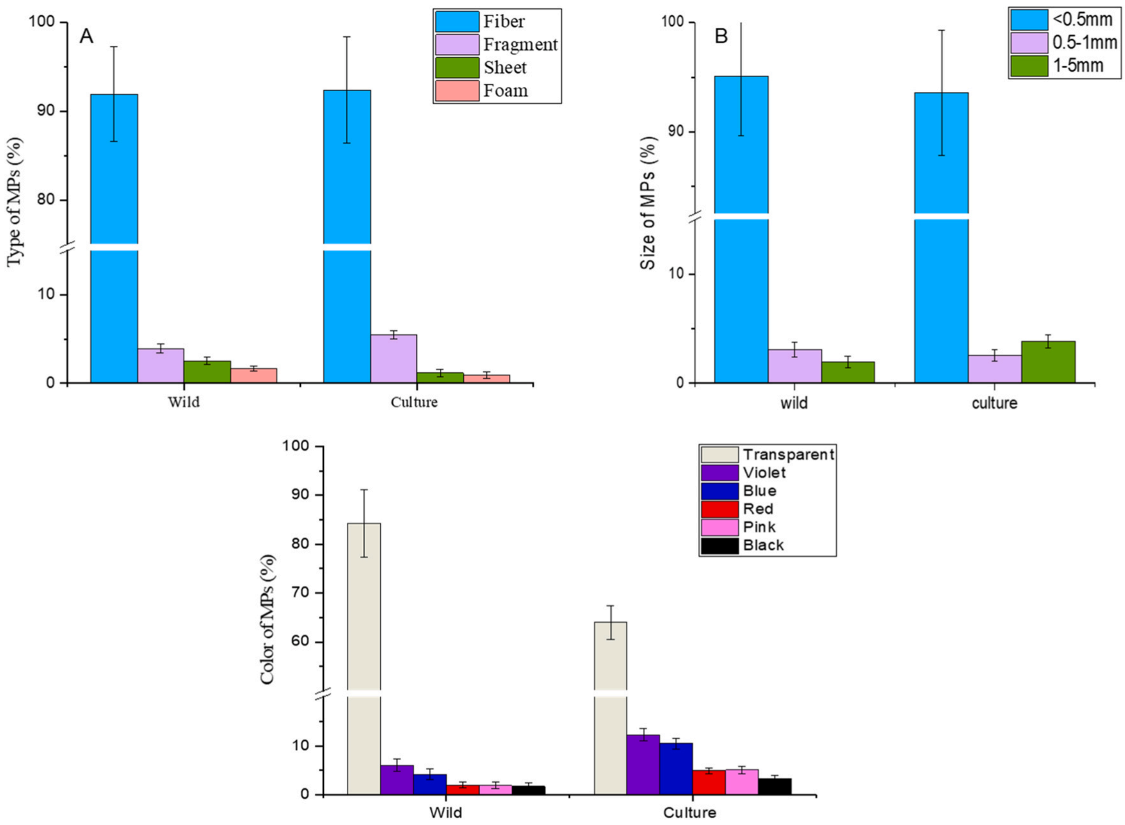

Fig. 3. Morphological characteristics of MPs: A) Type of MPs presented in percentage data with SD value.; B) Size of MPs presented in percentage data with SD value and C) Color of MPs presented in percentage data with SD value.

prevalence of minute MPs can be attributed to various hydrodynamic processes, including water currents, sedimentation, wind, wave action, and vertical water mixing, which contribute to the breakdown of larger plastic particles into smaller fragments. These minute MPs remain suspended in the environment, making them bioavailable to fish, which may ingest them through feeding or water circulation through their gills (Ghosh et al., 2021).

3.3. Polymer identification

Fourier Transform Infrared (FTIR) spectroscopy was conducted on selected samples to identify the types of polymers present in wild and cultured seabass. This subset, comprising 40 particle from the total samples, was chosen due to its representative variation of plastic debris commonly found in marine environments. Polymer identification was based on distinct FTIR spectra, with the polymers categorized according to their distribution percentage in each sample type (Fig. 3). In cultured seabass (Fig. 3A), the predominant polymers identified were polyethylene (PE, 40 %) and polyethylene terephthalate (PET, 40 %), with a smaller proportion of polystyrene (PS, 20 %). In contrast, wild seabass (Fig. 3 B) showed a more diverse distribution, with PE accounting for 40 %, followed by PET (30 %), and additional polymers, including polystyrene (PS, 10 %), polyvinyl chloride (PVC, 10 %), and polypropylene (PP, 10 %). These differences in polymer profiles between wild and cultured seabass are likely influenced by varying environmental exposures and dietary sources. The identified polymers are common environmental contaminants, with sources including discarded fishing gear, packaging materials, and other plastic waste originating from coastal industries, wastewater treatment facilities, and recreational activities. Notably, previous studies have shown that sources like wastewater treatment plants (WWTPs) are major contributors of MPs pollution, releasing fibers and particles that accumulate in marine organisms through water and sediment exposure (Xu et al., 2018).

3.4. Potential risk assessment of identified plastic particles

Currently, there is no unified approach to evaluating the pollution risk posed by MPs. To address this, a hazard grading method based on the polymer risk index has been developed to assess the potential adverse effects of plastics considering their diverse polymeric chemical structures (Huang et al., 2023; Nithin et al., 2022). Both wild and cultured seabass showed moderate PHI values for PE (4.4) and PET (1.2–1.6), placing them in hazard category II (PHI = 1–10), suggesting moderate risk from these polymers. This aligns with previous studies, such as Nithin et al. (2022) and Huang et al. (2023), which reported similar levels of risk for these polymers in fish species from India and other regions. In contrast, PP contamination was minimal, with PHI values of 0.1 for wild seabass and 0.2 for cultured seabass, placing it in hazard category I (PHI < 1), indicating low risk, consistent with findings from Miller et al. (2020), which highlighted that while PP poses minor risks, its transfer through food webs can still affect marine biota. A notable distinction was observed with PS, where wild seabass had a PHI of 3, indicating moderate risk, while cultured seabass had no PS contamination (PHI = 0). More critically, the PVC contamination in wild seabass was alarmingly high, with a PHI of 1000, placing it in hazard category IV (PHI $>$ 1000), indicating extreme danger. No PVC was detected in cultured seabass, suggesting that aquaculture environments may offer some protection from this hazardous polymer. The extreme PHI value for PVC in wild seabass is consistent with findings from Gholizadeh et al. (2024), which reported high PHI values for PS and other polymers in fish species from heavily polluted regions, categorizing them as significant risks to both marine life and human health.

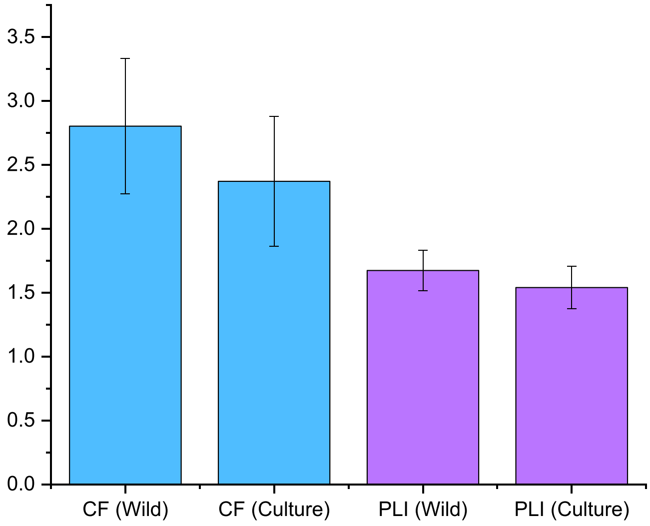

Fig. 5. Contamination Factor (CF) and Pollution Load Index (PLI) of wild and cultured seabass. Values greater than 1 indicate pollution.

The Contamination Factor (CF) and Pollutant Load Index (PLI) were assessed to evaluate the level of plastic pollution in wild and cultured seabass. The CF values for wild seabass ranged from 2.0 to 3.86, while

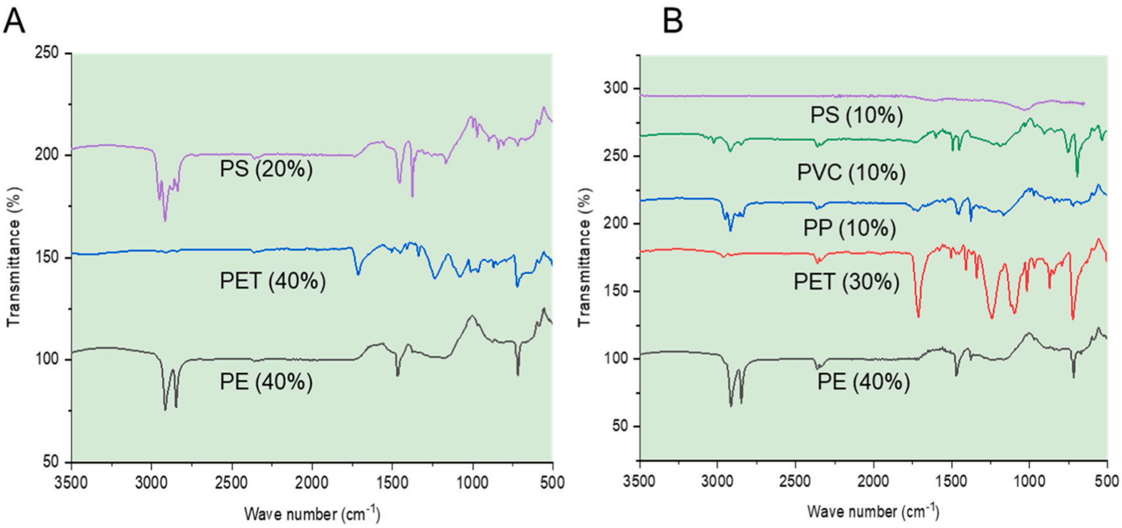

Fig. 4. Polymer identification of MPs found in cultured (A) and wild seabass (B).

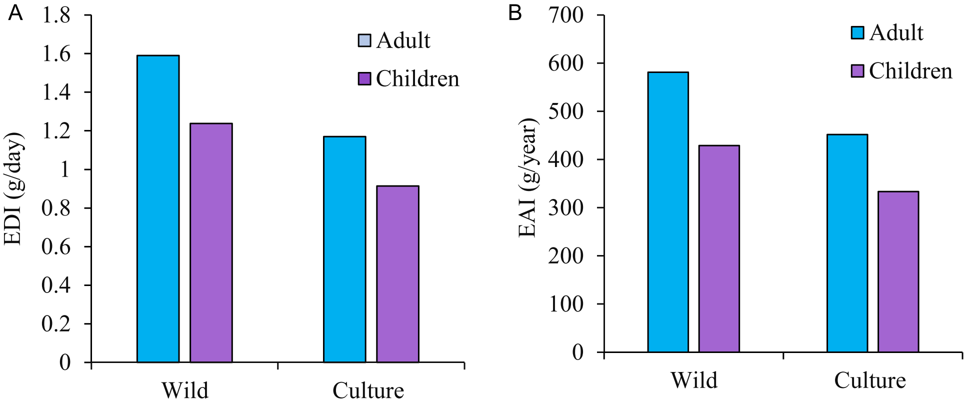

Fig. 6. (A) Estimated Daily Intake (EDI) (g/day) and (B) Estimated Annual Intake (EAI) (g/year) of MPs in wild and cultured seabass for adults and children.

Table 1
Comparison of MPs in different fish species across the world with their mean body weight, feeding habit and MPs concentration.

Study area	Fish species	Feeding habit	Body weight (g)	Mean GIT weight (g)	MPs abundance		References
					Muscle	GIT	
Hangzhou Bay and Yangtze estuary, China	Asian seabass *(Lateolabrax maculatus*	Carnivorous	NA	NA	No MPs detected in muscle	MPs varied from 0.3 to 5.3 items/individual	Su et al., 2019
Xiangshan Bay, China	Large yellow croaker *(Larimichthys crocea)*	Carnivorous	NA	NA	0.008 ± 0.006	NA	Wu et al., 2020
	dotted gizzard shad *(Konosirus punctatus)*	Carnivorous	NA	NA	0.044 ± 0.025	NA	
Han river, South Korea	bass *(M. salmoides*	Carnivorous	NA	NA	No MPs detected	22.0 ± 16.0 item/individual	Park et al., 2020
East China Sea and South China Sea	*Sillago sihama*	Carnivorous	25.1 ± 2.3	NA	5.7 ± 2.9	0.8 ± 0.6	Jabeen et al., 2017
	Callionymus planus	Carnivorous	36.4 ± 5.3	NA	3.6 ± 1.8	1.3 ± 1.3	
	Caranx hippos	Carnivorous	223.4 ± 37.0	NA	0.019 ± 0.02	0.015 ± 0.02	
	Centropomus undecimalis	Carnivorous	198.6 ± 57.9	NA	0.015 ± 0.02	0.75 ± 0.8	
Coral Reef and Mangrove in Isla Grande, Colombia	*Lutjanus synagris*	Carnivorous	181.7 ± 45.3	NA	0.020 ± 0.02	0.85 ± 1.3	Jimenez Cardenas et al., 2022
Bay of Bengal, Bangladesh	*Polynemus paradiseus*	Carnivorous	30.78 ± 4.22	1.58 ± 0.45	1.75 ± 1.20	0.33 ± 0.27	Sultana et al., 2024
	Lepturacanthus savala	Carnivorous	271.76 ± 37.38	20.96 ± 5.24	1.75 ± 1.20	0.75 ± 0.04	
	Lutjenus sanguineus	Carnivorous	1376.25 ± 134.36	47.63 ± 1.34	3.37 ± 2.28	1.63 ± 1.11	
Bay of Bengal, Bangladesh	*Carangoides chrysophrys*	Carnivorous	23.7 ± 4.0	0.8 ± 0.1	0.08	NA	Ghosh et al., 2021
	Coilia neglecta	Carnivorous	38.5 ± 3.2	1.6 ± 0.4	0.04	NA	
	Megalaspis cordyla	Carnivorous	55.2 ± 9.8	1.6 ± 0.3	0.02	NA	
	Otolithoides pama	Carnivorous	33.7 ± 6.5	1.5 ± 0.3	0.05	NA	
Bangladesh	*Lates calcarifer* (Wild seabass)	Carnivorous	1451.33 ± 53.52	69.93 ± 5.9	2.6 ± 0.99	7.8 ± 1.34	Present study
	Lates calcarifer (Cultured seabass*)*		1488.67 ± 48.38	70.33 ± 4.29	1.92 ± 0.94	5.67 ± 1.47	

those for cultured seabass ranged from 1.37 to 3.56. According to pollution assessment standards, CF values between 1 and 3 indicate moderate contamination, and values above 3 suggest high contamination. This indicates that both wild and cultured seabass experience moderate plastic pollution, with certain wild samples exhibiting high contamination levels. Similarly, the PLI values, which provide a cumulative measure of pollution, were consistently above 1 for both wild (ranging from 1.41 to 1.96) and cultured seabass (1.17–1.88). A PLI value greater than 1 indicates pollution, confirming the presence of MPs in both wild and cultured seabass, with higher PLI values reflecting a more substantial degree of contamination. These findings align with studies of fish species from coastal and marine environments, where plastic particle accumulation is often driven by human activities such as industrialization, waste disposal, and tourism (Pan et al., 2021; Sreeparvathi et al., 2024; Sultana et al., 2024). The higher CF and PLI values in wild seabass can be attributed to their exposure to more polluted aquatic habitats, where sources of plastic pollution, such as illegal dumping and industrial runoff, are more prevalent. In contrast, cultured seabass is raised in controlled environments, potentially reducing their direct exposure to pollution, resulting in slightly lower CF and PLI values. Nevertheless, the presence of plastic particles in both groups highlights the pervasive nature of MPs contamination, raising significant environmental and health concerns.

3.5. Human health risk assessment

The Estimated Annual Intake (EAI) and Estimated Daily Intake (EDI) of MPs have been calculated in this study for the muscle tissue of wild and cultured seabass, as people do not consume the gut of fish. The EAI and EDI results show that adults consuming wild seabass have an EDI of 1.59 g/day and children 1.24 g/day, whereas for cultured seabass, the EDI is lower, at 1.17 g/day for adults and 0.91 g/day for children. The EAI follows a similar pattern, with adults consuming wild seabass exposed to 581.08 g/year of MPs compared to 428.88 g/year for cultured seabass. For children, the EAI is 451.87 g/year for wild seabass and 333.61 g/year for cultured seabass. MP consumption is influenced by the amount of fish ingested, with individuals potentially consuming more or less than the recommended amount. Thermal decomposition of MPs typically requires temperatures of 300–500°C (Liu et al., 2022), meaning cooking fish does not affect MP integrity, thus presenting a potential human exposure route. While data on MP ingestion thresholds for health effects are limited, MPs have been detected in human feces (Schwabl et al., 2019), blood (Leonard et al., 2024), and placenta (Ragusa et al., 2021), indicating translocation within the body. In the gut, MPs can release harmful monomers, additives, and toxins, leading to biological responses such as inflammation, oxidative stress, genotoxicity, and potentially carcinogenesis (Van et al., 2015; Wright and Kelly., 2017; Xuan et al., 2023). Additionally, MPs may contribute to chromosomal alterations linked to infertility, obesity, and cancer (Sharma and Chatterjee, 2017; Wang et al., 2023).

Plastic particles can adsorb and accumulate high levels of hydrophobic organic contaminants (HOCs), persistent organic pollutants (POPs), metals, non-metals, and additives/monomers. This raise concerns that MPs may transfer hazardous chemical contaminants to marine animals, which are consumed by humans, posing threats to both juvenile animals and humans. Even low doses of these contaminants can impact biological systems (Wright and Kelly., 2017; Sharma and Chatterjee, 2017; Adamu et al., 2024; Wang et al., 2024).

4. Conclusion

The study focused on the level of MPs contamination in one of the highly commercial marine fish species *L. calcarifer* (wild and cultured seabass) and its associated health risk to human. The results demonstrated that MP contamination was more prevalent in wild seabass compared to cultured seabass. Morphological characteristics of MPs showed higher prevalence of fiber and smaller MPs in both wild and cultured seabass. The detection of multiple polymers and high abundance of MPs in both wild and cultured seabass reflects the influence of human activity on aquatic contamination. Morphological and polymeric characteristics of MPs indicate their diverse origins, with PE, PET, and PS polymers being the most prevalent due to their extensive use in industrial and consumer products. The calculated pollution indices (PLI, PHI, and CF) confirm that Asian seabass habitats are moderately to highly impacted by plastic pollution, which may have direct and indirect ecological effects. Furthermore, dietary intake assessments (EDI and EAI) suggest that frequent consumption of seabass could contribute to human exposure to MPs, raising concerns over potential health risks. This study emphasizes the urgency of implementing effective waste management strategies, particularly in regions where seabass farming is prevalent. Continued monitoring of MPs in seafood is essential to evaluate the cumulative impacts on both environmental and human health. Future studies should focus on long-term assessments of MPs in diverse marine organisms and evaluate mitigation strategies to reduce MPs' bioavailability in the food chain.

CRediT authorship contribution statement

Md Badiul Alam Shufol: Writing – original draft, Resources, Funding acquisition, Formal analysis. **Md. Kamal Hossain:** Methodology, Investigation, Formal analysis, Data curation. **Khadijatul Kubra Riya:** Writing – original draft, Formal analysis, Data curation. **Takaomi Arai:** Resources, Investigation, Funding acquisition. **Mohammed Fahad Albeshr:** Writing – review & editing, Resources, Funding acquisition, Formal analysis. **Jimmy Yu:** Writing – review & editing, Software, Resources. **Hossain Mohammad Belal:** Writing – review & editing, Resources, Conceptualization. **Norhayati Ngah:** Visualization, Resources, Funding acquisition.

Author statement

There is no conclflict of interest. All authors are agreed to publish this manuscript.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jfca.2025.107867.

Data availability

Data will be made available on request.

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