



# Microplastic in the gastrointestinal tract of Bombay duck (*Harpadon nehereus*) in the Patenga Beach of the Bay of Bengal, Bangladesh: occurrence, abundance, and physicochemical features

Sabah tuz Zohora<sup>1</sup>, Shahida Arfine Shimul<sup>1</sup>, Saifuddin Rana<sup>1</sup>, Antar Sarkar<sup>1</sup>, Sui Naing Aye Marma Milky<sup>1</sup>, Khing Khing U Marma<sup>1</sup>, Kaji Mohammad Sirajum Monir<sup>1</sup>, Farhan Azim<sup>1</sup>, Tapos Kumar Chakraborty<sup>2</sup> and Sk. Ahmad Al Nahid<sup>1\*</sup>

<sup>1</sup>Department of Fisheries Resource Management, Chattogram Veterinary and Animal Sciences University (CVASU), Chattogram 4225, Bangladesh

<sup>2</sup>Department of Environmental Science, Jashore University of Science and Technology (JUST), Jashore 7408, Bangladesh

## ARTICLE INFO

**Received** February 1, 2024

**Revised** July 16, 2024

**Accepted** September 2, 2024

**Published on** October 29, 2024

## \*Corresponding author

Sk. Ahmad Al Nahid

**E-mail** nahid83bau@gmail.com

**Background:** Ingestion of microplastics (MPs) by commercially important fish, such as Bombay duck (*Harpadon nehereus*) can lead to the transport of MPs to humans and negatively impact health and physiology. Thus, assessment of the presence, type, and features of MP in this species is necessary to understand the possible impacts and adopt management measures. The purpose of this study was to determine the presence, occurrence and physicochemical features of MPs in the gastrointestinal tract of Bombay duck (*H. nehereus*) from the Patenga Sea Beach of the Bay of Bengal, Bangladesh. This area faces high amount of plastic discharge from the Karnaphuli River, industries, tourists, and urban households. Ninety-six fish were collected from the fishing trawlers of the Patenga Sea Beach. Their total length, body weight was measured and gastrointestinal tracts were separated for analysis. The samples underwent digestion, density separation, measurement, microscopic observation, and quantification. The color, type, and size were observed with microscopic image analysis software and polymer composition was determined with Fourier transform infrared spectroscopy method.

**Results:** The total items of MPs ranged from 25 to 198 per fish with a mean of  $98.34 \pm 53.11$ . There was a significant difference in the items of MPs among different sized fish ( $H = 74.656, p < 0.05$ ). A significant positive correlation ( $\rho = 0.952, p < 0.05$ ) was found between total length of fish and the number of MPs. Total 05 colors, 04 types and 03 size classes were observed. Filament type, blue color, and  $500 \mu\text{m}$  to  $< 1 \text{ mm}$  sized MPs were dominant. Four (04) types of polymers, polyethylene, polyurethane, polyamide, and polystyrene, were found.

**Conclusions:** The findings and insights from this study will help to understand the nature and extent of MP pollution in commercially important marine fish and possible impacts on the environment and humans.

**Keywords:** Bay of Bengal, Bombay duck, fisheries, microplastic, Patenga Sea Beach

## Introduction

Microplastics (MPs) are plastic particles with less than 5 mm in size (Anderson et al. 2016; Avio et al. 2017). They can negatively impact aquatic organisms, environment, and human health and thus MP pollution has become a concerning issue worldwide (Akdogan and Guven 2019). Plastic trash degrades mechanically and thermally into pieces of various sizes and shapes (Andrady 2011; Barnes et

al. 2009; Thompson et al. 2009) and takes the form of MPs. The primary drivers of the accumulation of MPs in the oceans include industrial manufacturing, agriculture, and landfilling of solid waste (Driedger et al. 2015; Vandermeersch et al. 2015). Primary and secondary MPs are the two categories of MPs (Karim et al. 2020). Primary MPs are commonly defined as ingredients required to create plastic products and the microbeads found in personal care and health goods (Duis and Coors 2016). The degradation

© 2024 The Author(s) **Open Access**



This article is licensed under a Creative Commons Attribution (CC BY) 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>. The publisher of this article is The Ecological Society of Korea in collaboration with The Korean Society of Limnology.

and weathering of plastic objects are typically the source of secondary MPs (Geyer et al. 2017). The common polymers of MPs found in marine environments include polyvinyl chloride, polyethylene (PE), polyethylene terephthalate (PET), and polypropylene (PP) (Avio et al. 2015; EFSA CONTAM Panel 2016; Mercogliano et al. 2020).

MPs have been discovered in a range of habitats, including the oceans, deep-sea, oceanic trenches, rivers, and lakes (Kanhai et al. 2020; Lima et al. 2021; Villegas et al. 2021). Huge amounts of plastic use and irrational dumping of plastic waste is the prime cause of MP pollution. Approximately 275 million tons of plastic garbage are produced annually by coastal nations and 2%–5% of this waste ends up in the oceans (Jambeck et al. 2015). Release from various rivers causes a dumping of between 1.15 and 2.41 million tons of plastics into the oceans each year (Lebreton et al. 2017). Lighter plastics stay suspended in the water column or float on the surface, but denser plastics ( $> 1.02 \text{ g/cm}^3$ ) settle on the ocean floor (Karim et al. 2020).

Plastic waste is a serious environmental issue due to its difficulties in decomposing (Barnes et al. 2009). MPs are highly persistent and hamper aquatic organisms and ecosystems (Guzzetti et al. 2018). Fish may intentionally consume MPs because MPs resemble small plankton and prey (Ory et al. 2017). Fish can accidentally consume MPs also when their prey adheres to or consumes MP particles (Jovanović 2017). Top consumers at the trophic level, such as marine mammals (Deudero and Alomar 2015) and humans (Crawford and Quinn 2017) may accumulate higher amounts of MPs through the food chain.

MPs are detrimental to organisms because they cause cell toxicity, change feeding and reproductive behavior, clog digestive tract, cause physical injury and inflammation, and lower the progeny survival rate (Cole et al. 2015; Prokić et al. 2019; Savoca et al. 2019; Strungaru et al. 2019). After being consumed by organisms, MPs may retain in their digestive tract or may pass through the stomach and exert negative physiological effects (Browne et al. 2008). MP pollution is an emerging concern for the aquatic environment and organisms of Bangladesh. In several parts of Bangladesh, including the Karnaphuli River estuary (Rakib et al. 2022; Shimul et al. 2023), Kutubdia (Siddique et al. 2023), St. Martin's Island (Tajwar et al. 2022a) and Cox's Bazar (Tajwar et al. 2022b), several studies have revealed a notable amount of MP pollution in water, sediment, and fish. There is an estimated health risk of consuming an average of 85,710.08 MP particles per year per capita among the people of Bangladesh (Sultan et al. 2023). Therefore, studies on MP pollution in water, sediment, and aquatic organisms are necessary.

The study area, Patenga Sea Beach, is situated 14 km south of Chattogram City, the port city of Bangladesh and this area is adjacent to the mixing zone of the Karnaphuli River and the Bay of Bengal (Dey et al. 2017). The Patenga

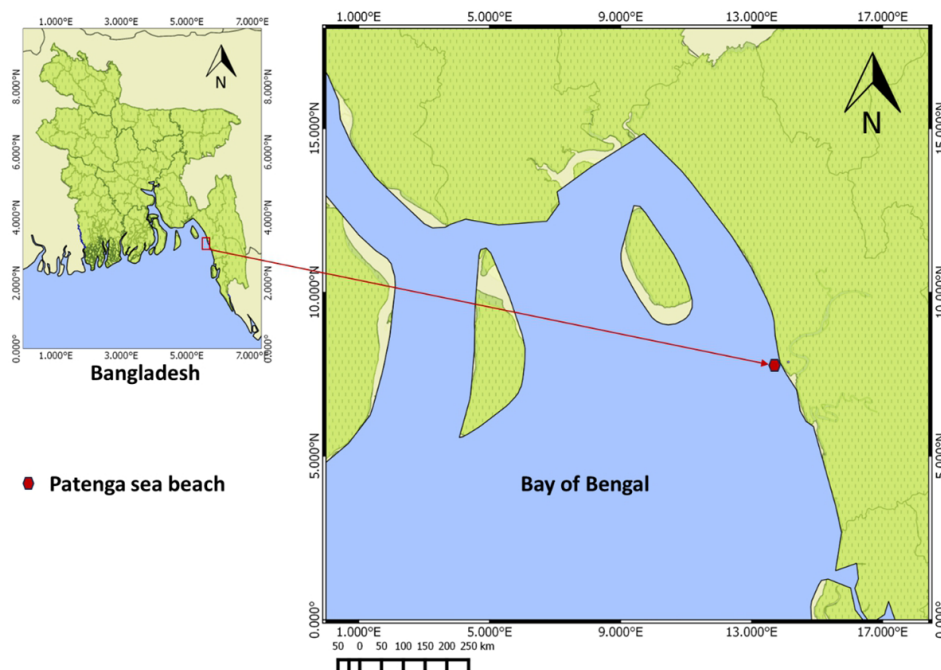
region is one of the industrial hotspots of Chattogram for ports, navigation facilities, and fisheries. The area of the Bay of Bengal near the Patenga Sea Beach faces extreme pollution coming from the Karnaphuli River discharge, ship breaking debris, industrial wastage, and the dumping of garbage from Chattogram City (Shill et al. 2021). The area is significant for catching and selling commercially important marine fish. Among these fishes, Bombay duck (*Harpadon nehereus*) is a significant contributor which is the second-largest commercial single-species fishery in Bangladesh contributing about 35% of the world's output in 2019 and 10.32% of the national marine fisheries catch (68,101 metric tons) (Alam et al. 2022; Department of Fisheries 2018). Therefore, this fishery plays an important role in the socio-economic sector of Bangladesh by providing employment and supporting food and nutrition of people.

Bombay ducks are consumed in both fresh and dried form. They are typically dried without processing and the gut contents are not removed most of the time (Hossain et al. 2019). Thus, the chances of MP exposure upon dried Bombay duck consumption remain high among its consumers. Bombay ducks swallow planktonic food, tiny fish, and aquatic organisms, and a large volume of water passes through their gills (Ghosh 2014). As a result, MPs retain in their gill rakers and MPs present in their prey or food reach their gastrointestinal (GI) tracts (Daniel et al. 2020; Prusty et al. 2023). Moreover, Bombay ducks serve as prey for larger carnivorous fish in marine environments where transfer and accumulation of MPs take place to higher trophic level organisms. Different studies revealed significant levels of MPs in the GI tracts of Bombay ducks (Hasan et al. 2022, 2023; Hossain et al. 2019; Prusty et al. 2023) but no study was conducted in the Patenga region. Therefore, the present study aimed to observe the occurrence, abundance, and physicochemical characteristics (type, color, shape, size, and polymer composition) of MPs in the GI tract of Bombay duck (*H. nehereus*) collected from the Patenga Sea Beach area, Bangladesh. Such research can aid in comprehending the extent and effects of MP pollution on marine ecology and commercially significant fish of the Bay of Bengal. Information on the number, abundance and features of MPs can reveal how MPs are distributed throughout the food chain and endanger higher predators and human health.

## Materials and Methods

### Study area, sample collection and preparation

Ninety-six specimens of Bombay duck (*H. nehereus*) were collected randomly from the fishing boats of Bay of Bengal near the Patenga Sea Beach (22° 14' 8.0952" N, 91° 47' 29.256" E) in November 2022 (Fig. 1). The collected specimens were preserved at  $-5^\circ$  Celsius during collection



**Fig. 1** Map showing the sampling point near the Patenga Sea Beach ( $22^{\circ} 14' 8.0952''$  N,  $91^{\circ} 47' 29.256''$  E) area adjacent to the Bay of Bengal, Bangladesh.

and brought to the laboratory for subsequent analysis in an ice box. The total body weight (TW) and total length (TL) of the collected fish was measured with an electric balance. The GI tracts from the esophagus to the anus were removed carefully, and kept in Petri-dish. The TL of the fish ranged from 24.3 cm to 38.2 cm and TW ranged from 147.9 g to 210.9 g. The collected fish were grouped into 03 size classes ( $n = 32$ ) based on the TL (cm) for comparing the presence of MPs among different sized Bombay duck: Size class 1 (24.3–28.4 cm), Size class 2 (24.3–28.4 cm), and Size class 3 (32.8–38.2 cm) respectively.

### Digestion

The method described by Avio et al. (2015) was followed with some modifications for this process. The separated GI tracts were taken in 800 mL beakers and 200 mL of 30% hydrogen peroxide ( $H_2O_2$ ) was added to the beakers (Li et al. 2015; Su et al. 2016). Then, the beakers were covered with aluminum foil papers and placed in a thermal oscillator at  $38^{\circ}C$  and 80 rpm (revolution per minute) for 7 days.

### Density separation and filtration

The density separation was done to separate the MPs from organic matter and debris. The method described by Coppock et al. (2017) was followed with some modifications in this process. In each beaker, 250 mL of zinc-chloride ( $ZnCl_2$ ) (500 g/L) solution was added and the beakers were kept for 2–3 days or up to 7 days based on the state of organic matter settlement. The layers of MPs floated upwards, whereas undissolved organic residues and inorganic matters subsided at the bottom of the beakers. The supernatant from the density separator was filtered with a vacuum pump filter (Rocker 300; Rocker, New Taipei City, Tai-

wan) using cellulose nitrate filter paper (pore size:  $0.45 \mu m$ , diameter: 47 mm).

### Quantification and observation of microplastics

The filter papers were examined under a stereo-microscope (B-192; OPTIKA srl, Ponteranica BG, Italy) at  $40 \times$  magnification. The presence of MPs was confirmed and the MP particles present on the filter paper were counted under microscope. The lengths of MPs were measured with the method described by Kovač Viršek et al. (2016) with some modifications. Images of the observed MPs were taken with a digital microscope camera (OPTIKA CB3) and the images were observed with “Optika Proview” software for determining types and measuring sizes of MPs. During the observation, MPs were distinguished from any debris following the guidelines by Hidalgo-Ruz et al. (2012). Information on the size, color, type, and shape of MPs was obtained from the microscopic observation.

### Determination of polymer composition of microplastics

The polymer composition of the collected MPs was determined with an Fourier transform infrared spectroscopy (FTIR) device (NICOLET IS20, Thermo Fisher Scientific, Waltham, MA, USA) in attenuated total reflection (ATR) mode within a spectral range of 500–4,000 per cm. The parameters in FTIR were fixed according to the manufacturer’s instructions in order to determine the transmittance percentage (%T). The polymer composition of MP was ascertained by carefully examining and analyzing the acquired spectral peaks in the FTIR device.

## Quality control

Fishes were collected, handled, transported, refrigerated, and thawed carefully to prevent any contamination or damage. All equipment, including Petri-dishes, scissors, scalpels, and forceps were rinsed with filtered water. The working place was cleaned and disinfected before and after work. Windows in the laboratory were kept closed during the experiment to prevent air-borne fibers and debris. Presence of airborne particle was observed using a blank filter paper. All the glassware was handled carefully and rinsed with filtered water. Only non-plastic equipment was used to avoid plastic contamination. Gloves and cotton lab coats were used and carefully cleaned after each use.

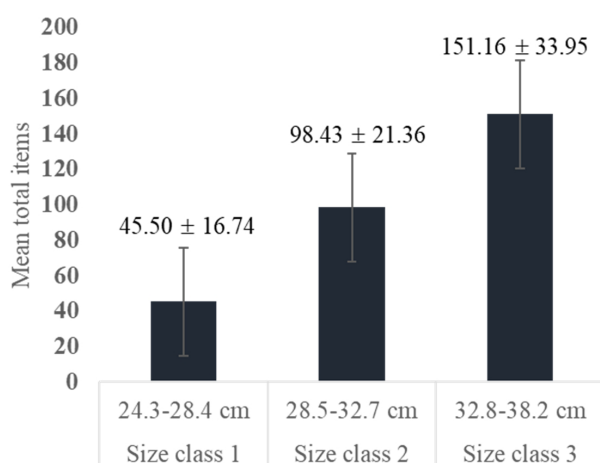
## Statistical analysis and interpretation

The collected data on the number of MPs and their physicochemical features were documented and categorized for statistical analysis. Statistical analysis was performed with Microsoft Excel (version 2019; Microsoft, Redmond, WA, USA) and IBM SPSS (version 26; IBM Co., Armonk, NY, USA). Kruskal–Wallis H test was performed to determine possible variations of MPs among the three size classes. Spearman correlation analysis was conducted to assess the relationship between TL (cm) and total item of MPs.

## Results

### Total items of microplastic

Total items of MPs ranged from 25–198 per fish with a mean of  $98.34 \pm 53.11$  per fish. Highest total items per fish were found in the size class 3 ( $151.16 \pm 33.95$ ), followed by size class 2 ( $98.43 \pm 21.36$ ) and lowest in the size class 1 ( $45.50 \pm 16.74$ ) (Fig. 2). The Kruskal–Wallis H test revealed a statistically significant difference in the total items of



**Fig. 2** Mean total items of microplastics found in the gastrointestinal tracts of different sized (based on total length: cm) Bombay duck (*Harpadon nehereus*) from the Bay of Bengal, Bangladesh.

MPs among the 03 size classes ( $H = 74.656$ ,  $p < 0.05$ ). The Spearman correlation analysis revealed a strong positive correlation between TL (cm) and total items of MPs ( $\rho = 0.952$ ,  $p < 0.05$ ). This suggests that as the size of the Bombay duck increased, the number of MPs also tended to rise (Fig. 3B).

## Physicochemical features of microplastics

### Color

Five (05) colors of MPs, black, blue, red, white and green, were observed. Among them, blue (36.95%) and black (31.71%) MPs were most dominant followed by white (15.66%) and red (8.28%), and green (7.41%) MPs were observed in lowest proportion (Fig. 4A).

### Type

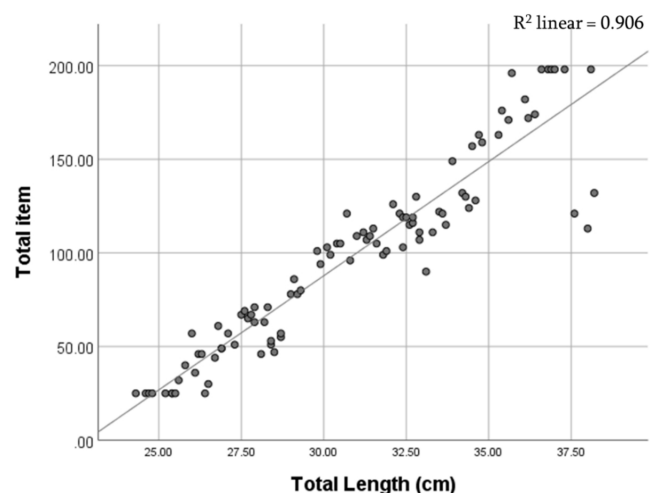
Total 04 types of MPs were observed which were filament, fragment, granule and flakes (Fig. 5). Among these, filaments were mostly found (32.57%), followed by fragments (28.57%), granules (19.88%) and flakes were found in least proportion (18.98%) (Fig. 4B).

### Size

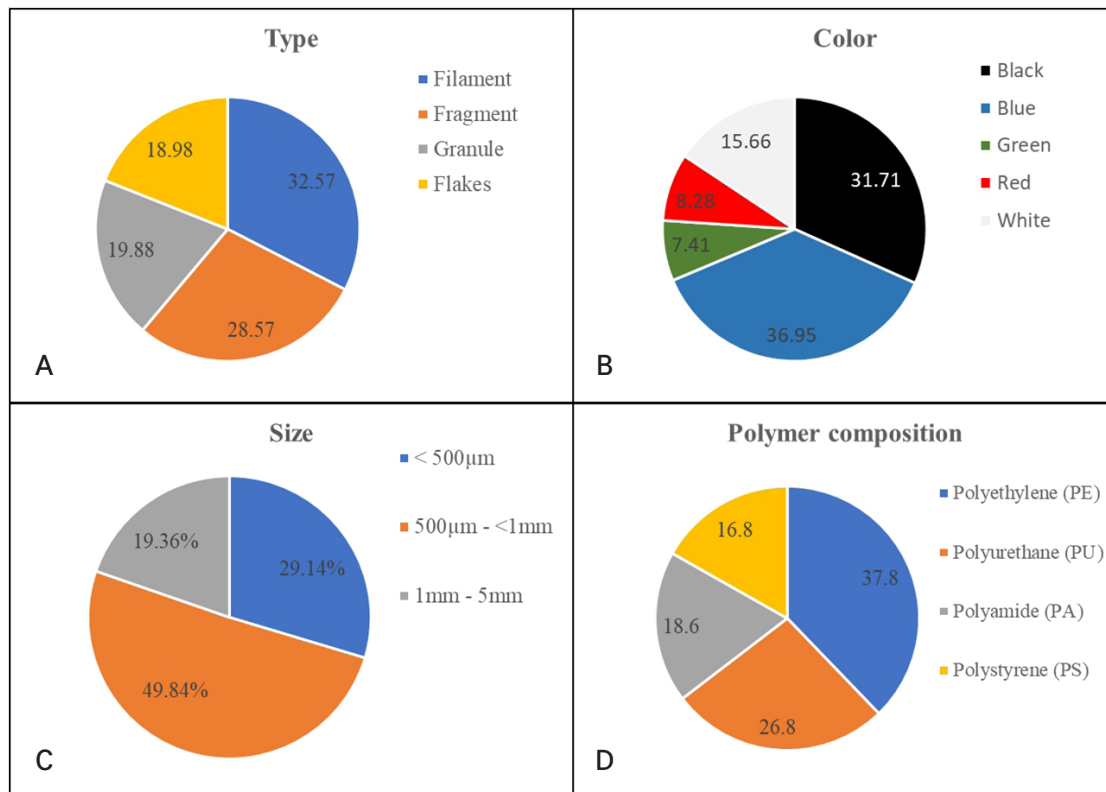
Three size classes of MPs, '500  $\mu\text{m}$  to < 1 mm', '< 500  $\mu\text{m}$ ' and '1 to 5 mm' were identified. The highest proportion of MPs was observed of the size class 500  $\mu\text{m}$  to < 1 mm (49.84%) followed by < 500  $\mu\text{m}$  (29.14%) and least was observed of 1 to 5 mm (19.36%) size class (Fig. 4C).

### Polymer composition

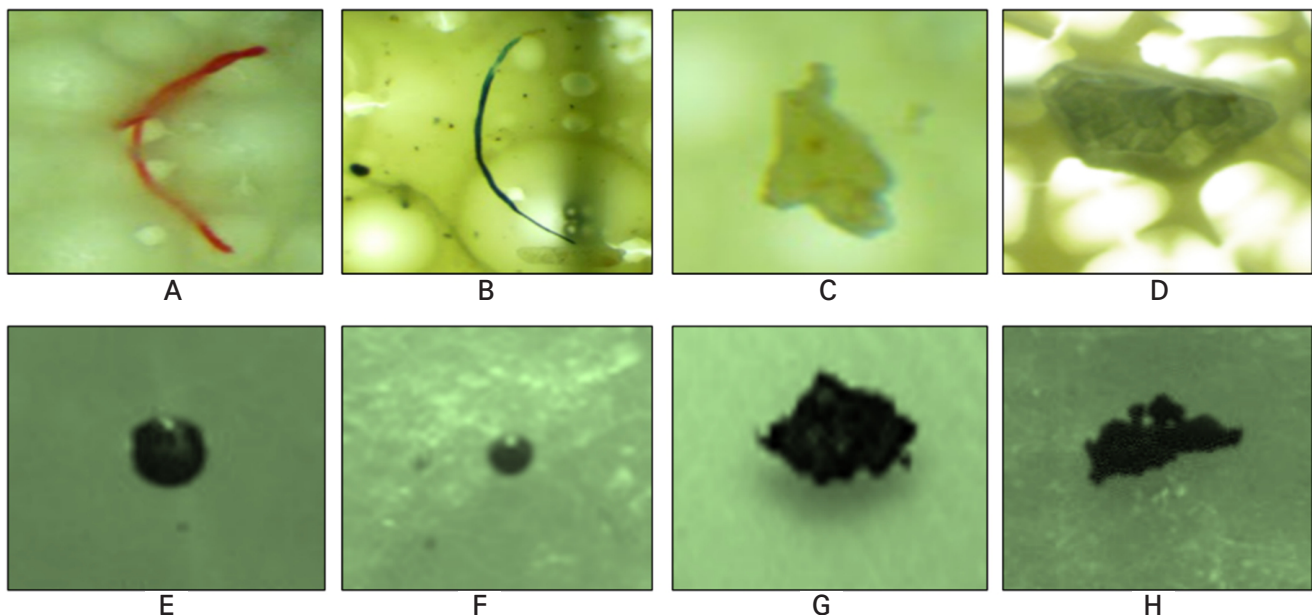
Four different types of MP polymers, PE (37.8%), polyurethane (PU) (26.8%), polyamide (PA) (18.6%) and poly-



**Fig. 3** Scatter plot illustrating strong positive correlation between total length (cm) and total items of microplastics in the Bombay duck (*Harpadon nehereus*) from the Bay of Bengal, Bangladesh. Each point represents a fish specimen, with x-axis indicating total length (cm) and y-axis showing number of microplastic items respectively.



**Fig. 4** Physicochemical properties of microplastics observed in the gastrointestinal tract of Bombay duck (*Harpadon nehereus*). (A) Type, (B) color, (C) size, (D) polymer composition.



**Fig. 5** Microscopic images of different types of microplastics found in the gastrointestinal tract of Bombay duck (*Harpadon nehereus*). (A, B) Filament, (C, D) fragments, (E, F) granules, and (G, H) flakes.

styrene (PS) (16.8%), were found in ATR-FTIR analysis. PE (37.8%) was the most abundant and PS (16.8%) was the least abundant type of polymer (Fig. 4D).

## Discussion

The present study observed the occurrence and physicochemical characteristics (type, color, shape, size, and polymer composition) of MPs in a commercially important

marine fish, Bombay duck (*H. nehereus*) collected from the Patenga beach area of the Bay of Bengal, Bangladesh. The study revealed that significant level of MP contamination was present in the GI tracts of all observed specimens ( $n = 96$ ). Similarly, all observed specimens of *H. nehereus* were found contaminated with MPs by Prusty et al. (2023) from the principal fishing harbors of the northwest coast of India, Hossain et al. (2019) in the Northern Bay of Bengal, Bangladesh and Hasan et al. (2022) from the Kuakata and Cox's Bazar region of Bangladesh. Such findings indicate that MP contamination has largely spread in the aquatic environment and food chain. Presence of MP in significant level in Bombay duck could be attributed from food and water.

Various factors affect how easily fish can absorb MPs. Filter feeding fish are more likely to ingest MPs because they eat less selectively (Lusher et al. 2020; Wesch et al. 2016). Bombay duck swallow planktonic food, tiny fish, and aquatic organisms and large volumes of water pass through their gills (Ghosh 2014). As a result, gill rakers trap MP from water, and MPs already present in their prey are transported to their GI tracts (Daniel et al. 2020; Prusty et al. 2023).

Presence of MPs can vary with different size of fish. For example, the presence of MPs significantly varied ( $p < 0.05$ ) among different sized fish in the study by Siddique et al. (2024) in six tropical fish species from the Saint Martin's Island. This difference of the presence of MPs among different sized fish is compatible with our study. In this study, the strong positive correlation between total items of MPs and size of fish was compatible to the findings of Hossain et al. (2019) in *H. nehereus*. Similarly, Khan and Setu (2022) found that the occurrence of MPs was significantly correlated with size and body weight in some herbivore, carnivore, and omnivore fishes from the Jamuna River, Bangladesh. In contrast, Wiczorek et al. (2018) reported no significant difference ( $p > 0.05$ ) in the MP counts among different mesopelagic species of the Northern Atlantic.

Fish ingest more MPs as their size increases (Pegado et al. 2018). Presence of plastics in their surrounding environment can also play role in determining the ingestion of MPs (Carbery et al. 2018). Area-specific extent of plastic pollution can influence the occurrence and abundance of MPs in fish (Jabeen et al. 2017). Therefore, understanding which factors most influence MP ingestion in fish is crucial. Larger fish may move through various environments with higher plastic pollution levels than smaller fish. Their larger size means they filter more water through their gills while swimming and feeding, increasing their intake of MPs. Additionally, larger fish often consume more food and a wider variety of prey, which may have already ingested MPs, leading to secondary ingestion. These could be the reasons for the presence of higher number of MPs with increasing size of Bombay duck in this study.

Variation of the presence of MPs in fish can be interspecies and intraspecies. In case of interspecies comparison, MP contamination can vary with size, trophic level, different feeding habits, and digestive physiology (De Frond et al. 2021; Li et al. 2015). In case of interspecies comparison, the variation could come from different ages of specimens and different geographical locations (Bom and Sa 2021; Daniel et al. 2020).

In case of color of MPs, Prusty et al. (2023) reported similar dominant colors (black and blue) in *H. nehereus*. Similar findings in other species were reported by Wiczorek et al. (2018), Ningrum and Patria (2019), Daniel et al. (2020) and Bom and Sá. (2021). Hossain et al. (2019) found white/transparent (26%–68%) colored MPs as dominant in Bombay duck (*H. nehereus*) which contrasts with the dominant color found in this study. Different-colored MPs were found in the fish guts, likely because the appearance and color of the MPs resemble prey and other food items, making them more attractive for the fish to ingest (Ory et al. 2017; Wiczorek et al. 2018). The sources of different colored MPs can be related to the weathering and degradation of different types of plastic products. For instance, the dominant colors, Blue and black MPs, could be generated from the large-scale use of blue and black colored nets and ropes during fishing (Sathish et al. 2020).

MPs come in a variety of types which affect their availability and occurrence in the aquatic ecosystem (Mithun et al. 2023). Among the four types of MPs found in this study, dominance of the filament type was compatible to the findings of Prusty et al. (2023) who reported thread or filament as the dominant type in *H. nehereus*. In contrast, Hossain et al. (2019) found fiber (54%) as the dominant type in *H. nehereus* followed by particle (24%) and fragment (22%) type. Hasan et al. (2022) found fibers as the dominant type of MPs (41%–64%) in *H. nehereus* from the two sites of the Bay of Bengal. Presence of irregular fragments, flakes and granules found in this study was similar to the findings of Hossain et al. (2019) who reported presence of irregular shaped MPs (37%–43%) in *H. nehereus*, *Harpadon translucens*, and *Sardinella gibbosa* in the Northern Bay of Bengal. Choi et al. (2018) also found irregular form MPs in Seepshead minnows (*Cyprinodon variegatus*) from the Republic of Korea. However, the different types found in these mentioned studies were not consistent. Types of plastic use in the surrounding areas, the extent of plastic pollution, feeding habits, and the choice of ingestion by different species of fish could cause variations in the types of MPs (Cabansag et al. 2021; Chatterjee and Sharma 2019; Sultan et al. 2023). Thus, identifying proper sources of different types of MPs is challenging. Filaments could derive from fishing nets, gears, and threads while fragments from an array of terrestrial and aquatic pollution sources (Khan and Setu 2022). These different shaped MPs can remain in digestive system after ingestion, or may pass through the

stomach and have detrimental physiological effects (Browne et al. 2008). Ingestion of irregular and sharp-edged MPs can damage the stomach wall of aquatic organisms (Jabeen et al. 2017).

Different sources, polymer types, and degrees of weathering and breakdown processes produce various sizes of MPs in aquatic environments. In marine settings, larger MPs gradually break down into smaller particles through mechanical action, photo-oxidation, and biodegradation (Arhant et al. 2019; Tosin et al. 2012), resulting in a high abundance of smaller MPs. Recent studies, including Newell et al. (1995), Li et al. (2015), and Kumar et al. (2018), have reported the presence of MPs of various sizes in fish guts. Hossain et al. (2019) found that most MPs (35%–41%) in *H. translucens* and *H. nehereus* were within the 500  $\mu\text{m}$  to 1 mm size range. Hasan et al. (2023) discovered that the majority of MPs in *H. nehereus*, *Trichiurus lepturus*, and *Setipinna phasa* were less than 0.5 mm (39.66%) and between 0.5–1.0 mm (37.67%). Prusty et al. (2023) reported a different dominant size class of 1–2 mm in *H. nehereus*. These findings, while not identical, support the presence of different-sized MPs observed in our study.

The source of MPs can be predicted using the chemical composition (Abayomi et al. 2017). The polymer composition from ATR-FTIR analysis found in this study was compatible to the findings by Hasan et al. (2022) who found three different types of polymers - PE (35%–45%), PS (20%–30%), and PA (30%–45%) in the dried samples of *H. nehereus*. Prusty et al. (2023) found the chemical composition of extracted MPs containing PE, PS, and PU. Hossain et al. (2019) found 66 PA and 13 PET particles in pink Bombay duck (*H. nehereus*), white Bombay duck (*H. translucens*), and Gold-stripe sardine (*S. gibbosa*). Sultan et al. (2023) found the dominant polymer types containing PP, PE, and ethylene-vinyl acetate in the gut samples of different species of fish and shellfish in the mangrove estuary of Bangladesh. In all these discussed findings, PP and PE were common types of polymers and it indicated that PP and PE could be significant contributors to MP pollution in the aquatic ecosystem of Bangladesh. Toy items, packing films, squeezable bottles, housewares, supermarket bags, wire insulation, and other items contain PE (Yeung et al. 2021). PS is frequently utilized in fishing nets and gears, ionic membranes, plastic models, and one-time-use cutleries (Giani et al. 2019). Adhesives, sealing agents, and fishing equipment are potential sources of PU (Capillo et al. 2020).

Upon the consumption of MPs, fish may suffer negative effects since the particles stay in their digestive systems for a long time and even cause death (Ory et al. 2017). In aquatic species, MPs can cause neurotoxicity and genotoxicity as well as interfere with immunological response, energy systems, and neurotransmission (Avio et al. 2015; Barboza et al. 2018). Moreover, exposure to MP may change the expression of important genes involved in several regu-

latory processes (Rochman et al. 2014). MPs can be transported along the food chain (van Raamsdonk et al. 2020). Drinking water and seafood are two major ways MPs can enter the human food chain (Bergmann et al. 2015; Gray et al. 2018). The potential risks of transfer of MPs to edible portions of fish and subsequent toxicity effects are highly problematic for humans because fish comprise a large portion of human diet (Neves et al. 2015). MPs can carry hazardous pollutants, such as heavy metals and toxic compounds (plasticizers, polychlorinated biphenyls, and polybrominated diphenyl ether) (Jaafar et al. 2021).

The study revealed the presence, feature, and extent of MPs in the Bombay duck (*H. nehereus*) which would contribute to the impact assessment of MPs in its body and possible transformation to the human through the food chain. This study suggests assessment of MP occurrence and identification of the features in other commercially important marine fish of Bangladesh. Moreover, rigorous study on the impact of MP on humans, environment and aquatic ecosystem of Bangladesh is recommended. Further studies on MP transmission and intake into this commercially important fish consumption in the future are required to properly address human health risks.

## Conclusions

This study found a significant level of MPs of different types, shapes, colors, sizes, and contents in the digestive tract of Bombay ducks (*H. nehereus*). The presence of MPs in this edible fish raises concerns about the impact of MPs on the aquatic food chain and human health. The results and insights of this study can inform researchers about the potential for further research and raise awareness among managers, policymakers, and the public about the impacts of MP pollution. There is a need to assess MPs in other commercially important marine fish species in the Patenga Beach area and beyond and to investigate spatial and temporal patterns of MP pollution. Additionally, future studies can be conducted on MP exposure and bioaccumulation to evaluate their impacts on ecology, environment and human health. Regulatory bodies and policymakers must translate scientific research into effective plastic waste management. It is crucial to raise public awareness through educational campaigns to promote the responsible use of plastic.

## Supplementary Information

Supplementary information accompanies this paper at <https://doi.org/10.5141/jee.24.016>.

**Table S1.** Total length and body weight data of *H. nehereus*.

## Abbreviations

MPs: Microplastics  
 PE: Polyethylene  
 PET: Polyethylene terephthalate  
 PP: Polypropylene  
 TW: Total body weight  
 TL: Total length  
 GI: Gastrointestinal  
 FTIR: Fourier transform infrared spectroscopy  
 ATR: Attenuated total reflection  
 PU: Polyurethane  
 PA: Polyamide  
 PS: Polystyrene  
 EVA: Ethylene-vinyl acetate

## Acknowledgements

The authors acknowledge the laboratory officers and supporting staffs of the "Aquatic Ecology Laboratory" of Chattogram Veterinary and Animal Sciences University for their supports throughout this research. The authors are thankful to the Jashore University of Science and Technology (JUST) Bangladesh for the laboratory support for polymer composition analysis.

## Authors' contributions

STZ conceptualized the study and did research design sampling, laboratory analysis, data collection, and curation. SNAMM, KKUM, KMSM, and FA assisted in sample collection, laboratory analysis, and data collection. TKC helped in polymer composition analysis. SAS and AS wrote the original manuscript and edited and reviewed it. SR did the data analysis, visualization, editing, and reviewing. SAAN supervised the sample collection, laboratory analysis, project administration, resource procurement, supervision, reviewing, and editing. All authors read and approved the final manuscript.

## Funding

The research was supported by the Chattogram Veterinary and Animal Sciences University (CVASU).

## Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Ethics approval and consent to participate

Not applicable.

## Consent for publication

Not applicable.

## Competing interests

The authors declare that they have no competing interests.

## References

- Abayomi OA, Range P, Al-Ghouti MA, Obbard JP, Almeer SH, Ben-Hamadou R. Microplastics in coastal environments of the Arabian Gulf. *Mar Pollut Bull.* 2017;124(1):181-8. <https://doi.org/10.1016/j.marpolbul.2017.07.011>.
- Akdogan Z, Guven B. Microplastics in the environment: a critical review of current understanding and identification of future research needs. *Environ Pollut.* 2019;254(Pt A):113011. <https://doi.org/10.1016/j.envpol.2019.113011>.
- Alam MS, Liu Q, Schneider P, Mozumder MMH, Chowdhury MZR, Uddin MM, et al. Length-based stock assessment for the data-poor bombay duck fishery from the northern bay of Bengal Coast, Bangladesh. *J Mar Sci Eng.* 2022;10(2):213. <https://doi.org/10.3390/jmse10020213>.
- Anderson JC, Park BJ, Palace VP. Microplastics in aquatic environments: implications for Canadian ecosystems. *Environ Pollut.* 2016;218:269-80. <https://doi.org/10.1016/j.envpol.2016.06.074>.
- Andrady AL. Microplastics in the marine environment. *Mar Pollut Bull.* 2011;62(8):1596-605. <https://doi.org/10.1016/j.marpolbul.2011.05.030>.
- Arhant M, Le Gall M, Le Gac PY, Davies P. Impact of hydrolytic degradation on mechanical properties of PET - towards an understanding of microplastics formation. *Polym Degrad Stab.* 2019;161:175-82. <https://doi.org/10.1016/j.polydegstab.2019.01.021>.
- Avio CG, Gorbi S, Regoli F. Experimental development of a new protocol for extraction and characterization of microplastics in fish tissues: first observations in commercial species from Adriatic Sea. *Mar Environ Res.* 2015;111:18-26. <https://doi.org/10.1016/j.marenvres.2015.06.014>.
- Avio CG, Gorbi S, Regoli F. Plastics and microplastics in the oceans: from emerging pollutants to emerged threat. *Mar Environ Res.* 2017;128:2-11. <https://doi.org/10.1016/j.marenvres.2016.05.012>.
- Barboza LGA, Dick Vethaak A, Lavorante BRBO, Lundebye AK, Guilhermino L. Marine microplastic debris: an emerging issue for food security, food safety and human health. *Mar Pollut Bull.* 2018;133:336-48. <https://doi.org/10.1016/j.marpolbul.2018.05.047>.
- Barnes DK, Galgani F, Thompson RC, Barlaz M. Accumulation and fragmentation of plastic debris in global environments. *Philos Trans R Soc Lond B Biol Sci.* 2009;364(1526):1985-98. <https://doi.org/10.1098/rstb.2008.0205>.
- Bergmann M, Gutow L, Klages M. *Marine anthropogenic litter*. 1st ed. Cham: Springer; 2015.
- Bom FC, Sá F. Concentration of microplastics in bivalves of the environment: a systematic review. *Environ Monit Assess.* 2021;193(12):846. <https://doi.org/10.1007/s10661-021-09639-1>.
- Browne MA, Dissanayake A, Galloway TS, Lowe DM, Thompson RC. Ingested microscopic plastic translocates to the circulatory system of the mussel, *Mytilus edulis* (L.). *Environ Sci Technol.* 2008;42(13):5026-31. <https://doi.org/10.1021/es800249a>.
- Cabansag JBP, Olimberio RB, Villanobos ZMT. Microplastics in some fish species and their environs in Eastern Visayas, Philippines. *Mar Pollut Bull.* 2021;167:112312. <https://doi.org/10.1016/j.marpolbul.2021.112312>.

- Capillo G, Savoca S, Panarello G, Mancuso M, Branca C, Romano V, et al. Quali-quantitative analysis of plastics and synthetic microfibers found in demersal species from Southern Tyrrhenian Sea (Central Mediterranean). *Mar Pollut Bull.* 2020;150:110596. <https://doi.org/10.1016/j.marpolbul.2019.110596>.
- Carbery M, O'Connor W, Palanisami T. Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health. *Environ Int.* 2018;115:400-9. <https://doi.org/10.1016/j.envint.2018.03.007>.
- Chatterjee S, Sharma S. Microplastics in our oceans and marine health. *Field Actions Sci Rep.* 2019;2019(special Issue 19):54-61.
- Choi JS, Jung YJ, Hong NH, Hong SH, Park JW. Toxicological effects of irregularly shaped and spherical microplastics in a marine teleost, the sheepshead minnow (*Cyprinodon variegatus*). *Mar Pollut Bull.* 2018;129(1):231-40. <https://doi.org/10.1016/j.marpolbul.2018.02.039>.
- Cole M, Lindeque P, Fileman E, Halsband C, Galloway TS. The impact of polystyrene microplastics on feeding, function and fecundity in the marine copepod *Calanus helgolandicus*. *Environ Sci Technol.* 2015;49(2):1130-7. <https://doi.org/10.1021/es504525u>.
- Coppock RL, Cole M, Lindeque PK, Queirós AM, Galloway TS. A small-scale, portable method for extracting microplastics from marine sediments. *Environ Pollut.* 2017;230:829-37. <https://doi.org/10.1016/j.envpol.2017.07.017>.
- Crawford CB, Quinn B. Microplastic pollutants. Amsterdam: Elsevier Science; 2017.
- Daniel DB, Ashraf PM, Thomas SN. Microplastics in the edible and inedible tissues of pelagic fishes sold for human consumption in Kerala, India. *Environ Pollut.* 2020;266(Pt 2):115365. <https://doi.org/10.1016/j.envpol.2020.115365>.
- De Frond H, Rubinovitz R, Rochman CM.  $\mu$ ATR-FTIR spectral libraries of plastic particles (FLOPP and FLOPP-e) for the analysis of microplastics. *Anal Chem.* 2021;93(48):15878-85. <https://doi.org/10.1021/acs.analchem.1c02549>.
- Department of Fisheries, Bangladesh. Yearbook of fisheries statistics of Bangladesh 2017-18. 2018. <https://fisheries.gov.bd/site/page/54ea4502-a4cb-4e33-9f29-4be8f09cf8a6/%E0%A6%AE%E0%A7%8E%E0%A6%B8%E0%A7%8D%E0%A6%AF-%E0%A6%AA%E0%A6%B0%E0%A6%BF%E0%A6%B8%E0%A6%82%E0%A6%96%E0%A7%8D%E0%A6%AF%E0%A6%BE%E0%A6%A8>. Accessed 22 Nov 2023.
- Deudero S, Alomar C. Mediterranean marine biodiversity under threat: reviewing influence of marine litter on species. *Mar Pollut Bull.* 2015;98(1-2):58-68. <https://doi.org/10.1016/j.marpolbul.2015.07.012>.
- Dey S, Uddin MS, Manchur MA. Physicochemical and bacteriological assessment of surface water quality of the Karnaphuli River in Bangladesh. *J Pure Appl Microbiol.* 2017;11(4):1721-8. <https://doi.org/10.22207/JPAM.11.4.10>.
- Driedger AGJ, Dürr HH, Mitchell K, Van Cappellen P. Plastic debris in the Laurentian Great Lakes: a review. *J Great Lakes Res.* 2015;41(1):9-19. <https://doi.org/10.1016/j.jglr.2014.12.020>.
- Duis K, Coors A. Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. *Environ Sci Eur.* 2016;28(1):2. <https://doi.org/10.1186/s12302-015-0069-y>.
- EFSA CONTAM Panel (EFSA Panel on Contaminants in the Food Chain). Statement on the presence of microplastics and nanoplastics in food, with particular focus on seafood. *EFSA J.* 2016;14(6):e04501. <https://doi.org/10.2903/j.efsa.2016.4501>.
- Geyer R, Jambeck JR, Law KL. Production, use, and fate of all plastics ever made. *Sci Adv.* 2017;3(7):e1700782. <https://doi.org/10.1126/sciadv.1700782>.
- Ghosh S. Fishery, reproductive biology and diet characteristics of Bombay duck *Harpodon nehereus* from the Saurashtra coast. *Indian J Geomarine Sci.* 2014;43(3):418-26.
- Giani D, Bainsi M, Galli M, Casini S, Fossi MC. Microplastics occurrence in edible fish species (*Mullus barbatus* and *Merluccius merluccius*) collected in three different geographical sub-areas of the Mediterranean Sea. *Mar Pollut Bull.* 2019;140:129-37. <https://doi.org/10.1016/j.marpolbul.2019.01.005>.
- Gray AD, Wertz H, Leads RR, Weinstein JE. Microplastic in two South Carolina Estuaries: occurrence, distribution, and composition. *Mar Pollut Bull.* 2018;128:223-33. <https://doi.org/10.1016/j.marpolbul.2018.01.030>.
- Guzzetti E, Sureda A, Tejada S, Faggio C. Microplastic in marine organism: environmental and toxicological effects. *Environ Toxicol Pharmacol.* 2018;64:164-71. <https://doi.org/10.1016/j.etap.2018.10.009>.
- Hasan J, Dristy EY, Anjumanara, Mondal P, Hoque MS, Sumon KA, et al. Dried fish more prone to microplastics contamination over fresh fish - higher potential of trophic transfer to human body. *Ecotoxicol Environ Saf.* 2023;250:114510. <https://doi.org/10.1016/j.ecoenv.2023.114510>.
- Hasan J, Islam SMM, Alam MS, Johnson D, Belton B, Hossain MAR, et al. Presence of microplastics in two common dried marine fish species from Bangladesh. *Mar Pollut Bull.* 2022;176:113430. <https://doi.org/10.1016/j.marpolbul.2022.113430>.
- Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M. Microplastics in the marine environment: a review of the methods used for identification and quantification. *Environ Sci Technol.* 2012;46(6):3060-75. <https://doi.org/10.1021/es2031505>.
- Hossain MS, Sobhan F, Uddin MN, Sharifuzzaman SM, Chowdhury SR, Sarker S, et al. Microplastics in fishes from the Northern Bay of Bengal. *Sci Total Environ.* 2019;690:821-30. <https://doi.org/10.1016/j.scitotenv.2019.07.065>.
- Jaafar N, Azfaralariff A, Musa SM, Mohamed M, Yusoff AH, Lazim AM. Occurrence, distribution and characteristics of microplastics in gastrointestinal tract and gills of commercial marine fish from Malaysia. *Sci Total Environ.* 2021;799:149457. <https://doi.org/10.1016/j.scitotenv.2021.149457>.
- Jabeen K, Su L, Li J, Yang D, Tong C, Mu J, et al. Microplastics and mesoplastics in fish from coastal and fresh waters of China. *Environ Pollut.* 2017;221:141-9. <https://doi.org/10.1016/j.envpol.2016.11.055>.
- Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady A, et al. Marine pollution. Plastic waste inputs from land into the ocean. *Science.* 2015;347(6223):768-71. <https://doi.org/10.1126/science.1260352>.
- Jovanović B. Ingestion of microplastics by fish and its potential consequences from a physical perspective. *Integr Environ Assess Manag.*

- 2017;13(3):510-5. <https://doi.org/10.1002/ieam.1913>.
- Kanhai DK, Gardfeldt K, Krumpfen T, Thompson RC, O'Connor I. Microplastics in sea ice and seawater beneath ice floes from the Arctic Ocean. *Sci Rep.* 2020;10(1):5004. <https://doi.org/10.1038/s41598-020-61948-6>.
- Karim, ME, Sanjee SA, Mahmud S, Shaha M, Moniruzzaman M, Das KC. Microplastics pollution in Bangladesh: current scenario and future research perspective. *Chem Ecol.* 2020;36(1):83-99. <https://doi.org/10.1080/02757540.2019.1688309>.
- Khan HS, Setu S. Microplastic ingestion by fishes from Jamuna River, Bangladesh. *Environ Nat Resour J.* 2022;20(2):157-67. <https://doi.org/10.32526/enrj/20/202100164>.
- Kovač Viršek M, Palatinus A, Koren Š, Peterlin M, Horvat P, Kržan A. Protocol for microplastics sampling on the sea surface and sample analysis. *J Vis Exp.* 2016;(118):e55161. <https://doi.org/10.3791/55161>.
- Kumar VE, Ravikumar G, Jeyasanta KI. Occurrence of microplastics in fishes from two landing sites in Tuticorin, South east coast of India. *Mar Pollut Bull.* 2018;135:889-94. <https://doi.org/10.1016/j.marpolbul.2018.08.023>.
- Lebreton LCM, van der Zwet J, Damsteeg JW, Slat B, Andrady A, Reisser J. River plastic emissions to the world's oceans. *Nat Commun.* 2017;8:15611. <https://doi.org/10.1038/ncomms15611>.
- Li J, Yang D, Li L, Jabeen K, Shi H. Microplastics in commercial bivalves from China. *Environ Pollut.* 2015;207:190-5. <https://doi.org/10.1016/j.envpol.2015.09.018>.
- Li R, Yu L, Chai M, Wu H, Zhu X. The distribution, characteristics and ecological risks of microplastics in the mangroves of Southern China. *Sci Total Environ.* 2020;708:135025. <https://doi.org/10.1016/j.scitotenv.2019.135025>.
- Lusher AL, Welden NA, Sobral P, Cole M. Sampling, isolating and identifying microplastics ingested by fish and invertebrates. In: Nollet LML, Siddiqi KS, editors. *Analysis of Nanoplastics and Microplastics in Food*. 1st ed. Boca Raton: CRC Press; 2020. p. 119-48.
- Mercogliano R, Avio CG, Regoli F, Anastasio A, Colavita G, Santonicola S. Occurrence of microplastics in commercial seafood under the perspective of the human food chain. A review. *J Agric Food Chem.* 2020;68(19):5296-301. <https://doi.org/10.1021/acs.jafc.0c01209>.
- Mithun MH, Kar A, Sunny AR, Billah M, Sazzad SA, Salehin S, et al. Assessing impact of microplastics on aquatic food system and human health. *Preprints.* 2023:2023111092. <https://doi.org/10.20944/preprints202311.1092.v1>.
- Neves D, Sobral P, Ferreira JL, Pereira T. Ingestion of microplastics by commercial fish off the Portuguese coast. *Mar Pollut Bull.* 2015;101(1):119-26. <https://doi.org/10.1016/j.marpolbul.2015.11.008>.
- Newell RIE, Marshall N, Sasekumar A, Chong VC. Relative importance of benthic microalgae, phytoplankton, and mangroves as sources of nutrition for penaeid prawns and other coastal invertebrates from Malaysia. *Mar Biol.* 1995;123:595-606. <https://doi.org/10.1007/BF00349238>.
- Ningrum EW, Patria MP. Ingestion of microplastics by anchovies from east Lombok Harbour, Lombok Island, Indonesia. *AIP Conf Proc.* 2019;2120(1):040002. <https://doi.org/10.1063/1.5115640>.
- Ory NC, Sobral P, Ferreira JL, Thiel M. Amberstripe scad *Decapterus muroadsi* (Carangidae) fish ingest blue microplastics resembling their copepod prey along the coast of Rapa Nui (Easter Island) in the South Pacific subtropical gyre. *Sci Total Environ.* 2017;586:430-7. <https://doi.org/10.1016/j.scitotenv.2017.01.175>.
- Pegado TSES, Schmid K, Winemiller KO, Chelazzi D, Cincinelli A, Dei L, et al. First evidence of microplastic ingestion by fishes from the Amazon River estuary. *Mar Pollut Bull.* 2018;133:814-21. <https://doi.org/10.1016/j.marpolbul.2018.06.035>.
- Prokić MD, Radovanović TB, Gavrić JP, Faggio C. Ecotoxicological effects of microplastics: examination of biomarkers, current state and future perspectives. *Trends Analyt Chem.* 2019;111:37-46. <https://doi.org/10.1016/j.trac.2018.12.001>.
- Prusty K, Rabari V, Patel K, Ali D, Alarifi S, Yadav VK, et al. An assessment of microplastic contamination in a commercially important marine fish, *Harpadon nehereus* (Hamilton, 1822). *Fishes.* 2023;8(9):432. <https://doi.org/10.3390/fishes8090432>.
- Rakib MRJ, Hossain MB, Kumar R, Ullah MA, Al Nahian S, Rima NN, et al. Spatial distribution and risk assessments due to the microplastics pollution in sediments of Karnaphuli River Estuary, Bangladesh. *Sci Rep.* 2022;12(1):8581. <https://doi.org/10.1038/s41598-022-12296-0>.
- Rochman CM, Kurobe T, Flores I, Teh SJ. Early warning signs of endocrine disruption in adult fish from the ingestion of polyethylene with and without sorbed chemical pollutants from the marine environment. *Sci Total Environ.* 2014;493:656-61. <https://doi.org/10.1016/j.scitotenv.2014.06.051>.
- Rudnick RL, Gao S. 3.01 - Composition of the continental crust. In: Holland HD, Turekian KK, editors. *Treatise on Geochemistry*. Oxford: Pergamon; 2003.
- Savoca S, Capillo G, Mancuso M, Bottari T, Crupi R, Branca C, et al. Microplastics occurrence in the Tyrrhenian waters and in the gastrointestinal tract of two congener species of seabreams. *Environ Toxicol Pharmacol.* 2019;67:35-41. <https://doi.org/10.1016/j.etap.2019.01.011>.
- Shill E, Islam DM, Mahmud MA. Impact of marine pollution in coastal areas of Chittagong and guide lines for mitigation. *J Earth Ocean Sci.* 2021;48-68.
- Shimul SA, Bakeya Z, Ananna JN, Sarker A, Rana S, Nahid SAA. Microplastic pollution in two industrial locations of the Karnaphuli River, Bangladesh: insights on abundance, types, and characteristics. *Fish Aquat Sci.* 2023;26(12):715-25. <https://doi.org/10.47853/FAS.2023.e64>.
- Siddique MAM, Shazada NE, Ritu JA, Turjo KEZ, Das K. Does the mouth size influence microplastic ingestion in fishes? *Mar Pollut Bull.* 2024;198:115861. <https://doi.org/10.1016/j.marpolbul.2023.115861>.
- Siddique MAM, Uddin A, Bhuiya A, Rahman SMA, Kibria G. Occurrence, spatial distribution, and characterization of microplastic particles in the salt pans from the Southeastern part of the Bay of Bengal. *Reg Stud Mar Sci.* 2023;61:102846. <https://doi.org/10.1016/j.rmsa.2023.102846>.
- Strungaru SA, Jijie R, Nicoara M, Plavan G, Faggio C. Micro- (nano) plastics in freshwater ecosystems: abundance, toxicological impact and quantification methodology. *Trends Analyt Chem.* 2019;110:116-28. <https://doi.org/10.1016/j.trac.2018.10.025>.

- Su L, Xue Y, Li L, Yang D, Kolandhasamy P, Li D, et al. Microplastics in Taihu Lake, China. *Environ Pollut.* 2016;216:711-9. <https://doi.org/10.1016/j.envpol.2016.06.036>.
- Sultan MB, Rahman MM, Khatun MA, Shahjalal M, Akbor MA, Siddique MAB, et al. Microplastics in different fish and shellfish species in the mangrove estuary of Bangladesh and evaluation of human exposure. *Sci Total Environ.* 2023;858(Pt 1):159754. <https://doi.org/10.1016/j.scitotenv.2022.159754>.
- Tajwar M, Shreya SS, Gazi MY, Hasan M, Saha SK. Microplastic contamination in the sediments of the Saint Martin's Island, Bangladesh. *Reg Stud Mar Sci.* 2022a;53:102401. <https://doi.org/10.1016/j.rsma.2022.102401>.
- Tajwar M, Yousuf Gazi M, Saha SK. Characterization and spatial abundance of microplastics in the coastal regions of Cox's Bazar, Bangladesh: an integration of field, laboratory, and GIS techniques. *Soil Sediment Contam.* 2022b;31(1):57-80. <https://doi.org/10.1080/15320383.2021.1910622>.
- Thompson RC, Swan SH, Moore CJ, vom Saal FS. Our plastic age. *Philos Trans R Soc Lond B Biol Sci.* 2009;364(1526):1973-6. <https://doi.org/10.1098/rstb.2009.0054>.
- Tosin M, Weber M, Siotto M, Lott C, Degli Innocenti F. Laboratory test methods to determine the degradation of plastics in marine environmental conditions. *Front Microbiol.* 2012;3:225. <https://doi.org/10.3389/fmicb.2012.00225>.
- van Raamsdonk LWD, van der Zande M, Koelmans AA, Hoogenboom RLAP, Peters RJB, Groot MJ, et al. Current insights into monitoring, bioaccumulation, and potential health effects of microplastics present in the food chain. *Foods.* 2020;9(1):72. <https://doi.org/10.3390/foods9010072>.
- Vandermeersch G, Van Cauwenberghe L, Janssen CR, Marques A, Granby K, Fait G, et al. A critical view on microplastic quantification in aquatic organisms. *Environ Res.* 2015;143(Pt B):46-55. <https://doi.org/10.1016/j.envres.2015.07.016>.
- Villegas L, Cabrera M, Capparelli MV. Assessment of microplastic and organophosphate pesticides contamination in fiddler crabs from a Ramsar site in the estuary of Guayas River, Ecuador. *Bull Environ Contam Toxicol.* 2021;107(1):20-8. <https://doi.org/10.1007/s00128-021-03238-z>.
- Wesch C, Bredimus K, Paulus M, Klein R. Towards the suitable monitoring of ingestion of microplastics by marine biota: a review. *Environ Pollut.* 2016;218:1200-8. <https://doi.org/10.1016/j.envpol.2016.08.076>.
- Wieczorek AM, Morrison L, Croot PL, Allcock AL, MacLoughlin E, Savard O, et al. Frequency of microplastics in mesopelagic fishes from the Northwest Atlantic. *Front Mar Sci.* 2018;5:39. <https://doi.org/10.3389/fmars.2018.00039>.
- Yeung CWS, Teo JYQ, Loh XJ, Lim JYC. Polyolefins and polystyrene as chemical resources for a sustainable future: challenges, advances, and prospects. *ACS Mater Lett.* 2021;3(12):1660-76. <https://doi.org/10.1021/acsmaterialslett.1c00490>.