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ORIGINAL RESEARCH PAPER

Microplastic contamination in different tissues of commercial fish in estuary area

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ABSTRACT

BACKGROUND AND OBJECTIVES: The coasts around West Java, Indonesia are prospective fishing grounds due to their commercial fish diversity. The presence of neighboring settlements discharging waste, including microplastics, poses a threat to the estuarine ecosystem. This study aimed to quantify and classify microplastics in the tissues of *Mugil cephalus, Eleutheronema tetradactylum*, and *Scatophagus argus.*

METHODS: This study takes place in the estuary of the Blanakan River, Subang Regency, an area renowned for its wide variety of commercially valuable fish. Four fish sampling sites were identified according to the predominant land use, with settlements in the upper reaches, ponds in the central area, and mangrove forests in the lower reaches. Fish samples were taken the gastrointestinal tract, gills and muscle to calculated the microplastic content and identify its shape and size. Raman spectroscopy was applied to verify the polymer of microplastic. Statistical analysis was conducted to evaluate variations in microplastic levels at the individual level across these fish species.

FINDINGS: The findings indicated the presence of microplastics in the muscle, gastrointestinal tract, and gills of three commercially caught fish from Blanakan, with the muscle being identified as the edible part and the gastrointestinal tract and gills as the non-edible parts. The microplastics were classified according to shape and size and were found in the following order of abundance: *Mugil cephalus, Scatophagus argus, Eleutheronema tetradactylum*. *Mugil cephalus* contained the most microplastics (210.8 particles per individual), with the lowest amount recorded in *Eleutheronema tetradactylum* (41.9 particles per individual). The tissues of Eleutheronema tetradactylum exhibited varying levels of microplastic contamination, with the highest concentration found in the gastrointestinal tract, followed by the gills and muscles. In contrast, in the tissues of *Mugil cephalus and Scatophagus argus*, microplastics were found in the following order of abundance from high to low: muscle, gastrointestinal tract, gill. The muscle of *Mugil cephalus* contained the highest microplastic concentration (28.71 particles per gram wet weight), while the lowest was recorded in the muscle of *Eleutheronema tetradactylum* (3.42 particles per gram wet weight). Microplastics ranging from 300 to 1000 micrometers in size, in the form of fibers and fragments, were commonly found in fish tissues.

CONCLUSION: Microplastic content is found most abundantly in the gastrointestinal tract and muscle. This indicates that feeding and ingestion play a role in the entry of microplastics into the fish's body. Given that the fish falls under the category of commercial and consumption fish, there is a significant concern regarding environmental pollution caused by microplastics and the potential health hazards linked to its consumption.

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INTRODUCTION

The marine environment contains minuscule plastic particles known as microplastics, which have been well-documented in marine fish intended for global commercial consumption (Jaafar *et al.*, 2021). Typically measuring less than 5 millimeter (mm) in size (Piyawardhana *et al.*, 2022), microplastics can be classified into two categories. The initial category consists of primary microplastics, which are plastic particles deliberately produced in small sizes. This includes microbeads used in cosmetics, personal care items, industrial abrasives, and pellets utilized in various manufacturing processes. Secondary microplastics, found in the second category, are tiny plastic particles formed when larger plastic items like bottles, bags, and other waste break down and fragment (Zhang *et al.*, 2020). Takarina *et al.* (2022) outlined multiple pathways through which these fragments may be introduced into the environment, such as direct disposal, stormwater runoff, river transport, wastewater discharges, marine activities, natural degradation, industrial processes, and atmospheric deposition. The examination of microplastic levels in coastal waters and sediment has attracted substantial interest from the global scientific community, with research undertaken in diverse Asian areas. Wu *et al.* (2021) discovered varying microplastic abundances in sediments, ranging from 28 to 208 items per killogram (items/kg) along the west coast of the Taiwan Strait and 10 to 246 items/kg along the east coast, with higher levels associated with different local economic development and human activities. Surface seawater in the Taiwan Strait contained microplastic abundances ranging from 0.004 to 0.058 items per cubic meter (items/m^3), with a mean abundance of 0.026 items/m^3. The central region of the Taiwan Strait exhibited higher values, whereas a decreasing trend was detected on both sides. In Jakarta Bay, for instance, water samples were found to contain 1532 particles, while sediment samples contained 1419 particles (Takarina *et al.*, 2022). The study encompassed 12 locations representing Ancol, Muara Baru, and Muara Angke – Muara Karang. Fiber, film, fragment, and pellet were the main microplastic shapes found in both water and sediment samples, with fiber and film being the most dominant. In another study, Fathoniah and Patria (2021) discovered that microplastic film was the most prevalent type found in water and sediment samples taken from Kamal Muara, Jakarta Bay. The average microplastic abundance in water was 13.15 particles per liter (particles/L), while in sediment, it was 0.92 particles per gram (particles/g) of dry sediment. Ingestion of microplastics by commercial fish is a growing concern, besides their presence in seawater and sediment. Numerous studies have been carried out on the consumption of microplastics by commercial fish, given the significant importance of these fish as both a food source and economically. A study in Malaysia investigated microplastic ingestion in several species of commercial fish, including *Oreochromis mossambicus*, *Cyclocheilichthys apogon*, *Clarias gariepinus*, *Anabas testudineus*, *Pangasius hypophthalmus*, and *Oxyeleotris marmorata*, in the polluted Skudai River, which is known for fishing activities (Sarijan *et al.*, 2019). According to the study, 40% of the captured fish, which is 24 out of 60 individuals, were found to have ingested microplastics. On average, each fish had ingested 1.07 ± 1.76 (mean ± SD) microplastic items. Notably, *P. hypophthalmus*, commonly known as *Pangasius catfish*, had the highest average, with 4.00 ±3.16 microplastics ingested per fish. The majority of the microplastics isolated from the gastrointestinal tract (GT) and gills of commercial marine fish from Malaysia were found to comprise fibers, fragments, filaments with value of 80.2, 17.7, 3.1 percent (%) (Jaafar *et al.*, 2021). The study also uncovered that the microplastics consisted of a range of plastic polymers, including polyethylene (PE), polypropylene (PP), acrylonitrile butadiene styrene (ABS), polystyrene (PS), and polyethylene terephthalates (PET). The study revealed the distinct surface characteristics of microplastics, which were attributed to their exposure to the environment. The high usage of microplastics is linked to their popularity in industries such as manufacturing and production (Karbalaei *et al.*, 2019). Human consumption relies heavily on fish, as they fulfill about 60% of the global protein needs (Sichewo *et al.*, 2014). In Indonesia, particularly West Java, fish accounts for 38.68% of animal food consumption in 2023 (NFA, 2023). The criteria can be met as estuaries in Indonesia, specifically those along the shores of West Java, boast a high level of fish diversity and abundance, which includes commercially valuable species. According to Partasasmita *et al.* (2015), the ecosystems on the West Java Coast, along with their estuaries, are known to have high populations of fish species, including families of Arridae (*Netuma thalassina*), Bothidae, Clupeidae, Haemulidae, Leiognathidae (*Leiognathus* spp.), Nemipteridae (*Nemipterus hexodon*), Plotosidae, Sciaenidae (*Pennahia* spp.), and Synodontidae (*Saurida*

tumbil). The West Java Coast, including Blanakan is part of the the Fisheries Management Area of the Republic of Indonesia (WPP RI) 712 (Khatami *et al*., 2019), which characterized by high fish biodiversity with a fisheries potential of 1.34 million tons/year (MMt/y). Yet despite their diversity, estuaries here is also vulnerable to the presence of microplastics (Purwiyanto *et al*., 2022). Takarina *et al*. (2023) have documented the presence of microplastic pollution in the Blanakan region. The study showed that levels of microplastic in water both from river and brackishwater pond reach about 300 particles/L, while in sediment, within range of 200 – 2200 particles/kg. Through water channels, the river and ponds are connected to the estuary, enabling the dispersion of microplastics to a wider area in the coastal and marine settings. The study by Takarina *et al.* (2023) was lack data of microplastic in commercial fish. Since, several commercial fish which economically important are captured in Blanakan area, it is urgent to investigate the content of microplastic in those kind of fish. The level of microplastics in commercial fish tissues is not well-documented. This poses a significant concern regarding the ingestion of microplastics by commercial fish and its potential impact on food safety (Zhang *et al*., 2020). Specific knowledge in this area will support the safe consumption of fish, especially for the West Java community. This study aimed to analyze the morphology (size and shape) and abundance of microplastic in gill, digestion, and muscle of commercial fish taken from the coast of Blanakan, Subang, West Java, in 2023.

MATERIALS AND METHODS

This study included both field and laboratory work. Fieldwork entailed defining the study area and gathering samples. The laboratory tasks consist of dissecting fish, extracting and observing microplastics (in terms of shape, size, and polymer), and analyzing the collected data.

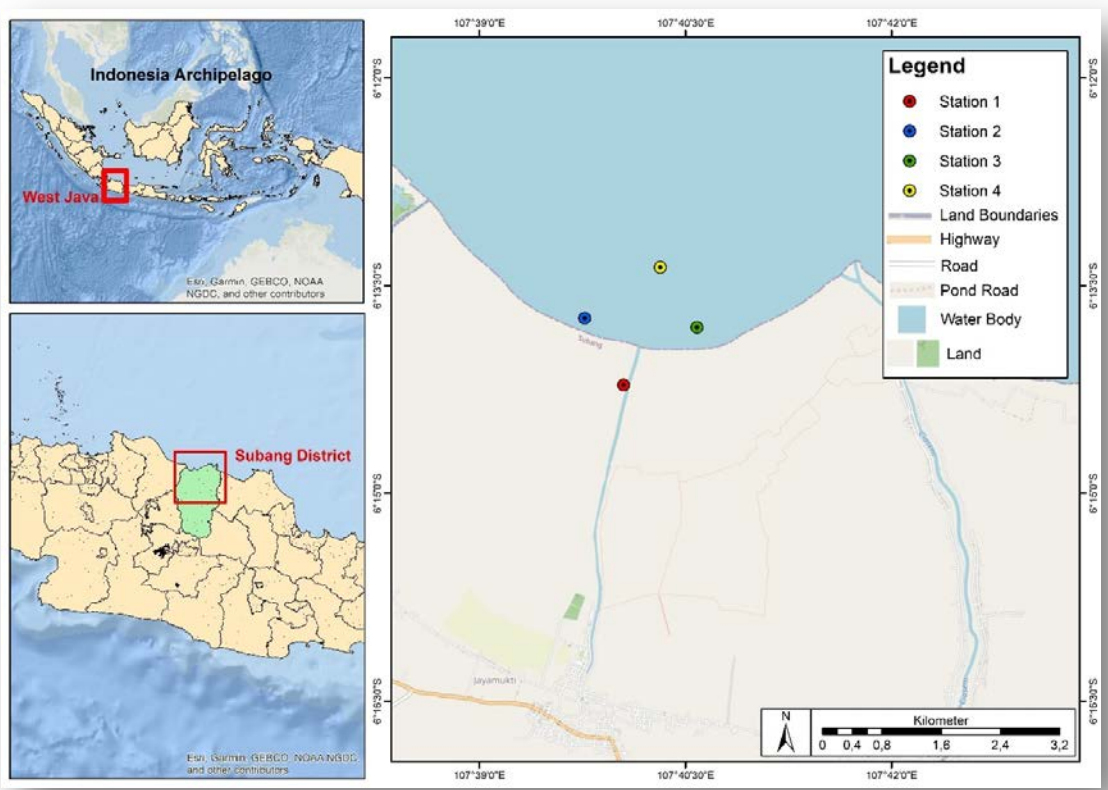


Fig. 1: Geographic location of the study arae and commercial fish collection stations in the Blanakan Estuary, West Java, Indonesia

Study area

The study area comprised the Blanakan Estuary in coastal areas of West Java, Blanakan District, Subang Regency, Indonesia. The selection of these locations was based on the significance of the Blanakan Estuary as a vital fishing area with a wide variety of valuable fish species (Fig. 1). Four stations were established as fish sampling points. Water from the Blanakan River flows into the estuary, which is characterized by settlements, fishponds, and mangrove forests in the upstream, mid-section, and downstream areas. The presence of settlements in the upstream areas contributes to the discharge of anthropogenic waste, which may contain plastics that subsequently degrade into microplastics. Global positioning system (GPS) was utilized to pinpoint the sampling sites, which were selected using a purposive sampling approach near the mouth of the Blanakan River. Four stations, approximately one kilometer apart, were selected. Station 1 represented the downstream area of the Blanakan River, Station 2 was in an estuary dominated by mangroves, Station 3 was in an area with high fishpond activity, and Station 4 was the furthest sampling location from land still affected by sedimentation.

Fish survey and collection

Fish survey techniques were implemented and adjusted according to the research conducted by Agustriani *et al*. (2020). The survey was conducted from 8.00 ante meridiem (a.m.) to 2.00 post meridiem (p.m.) Gillnet was used to capture fish. The fish that were gathered were subsequently treated with a 10% formaldehyde solution for preservation. The fish species were classified according to their morphological features utilizing the identification key outlined in the fish identification guidebook written by Kottelat *et al*. (1993). The collected specimens were adult fish with body lengths of more than 10 centimeter (cm) since adult fish contain trace elements.

Microplastic extraction

The fish sample was prepared by allowing it to thaw after being taken out of the freezer. After that, fish morphometric data such as wet weight and body length were measured using scales, rulers and calipers with an accuracy of 0.5 g, 0.5 mm and 0.1 mm. The fish is dissected in order to extract the gastrointestinal tract, gills, and muscle by utilizing stainless steel dissection scissors. The gastroinstestinal tract was collected by cutting parts of the body from the anus dorsally to the linea lateralis then heading anteriorly to the back of the head and down to the bottom of the fish's stomach (Jantz *et al*., 2013). To reach the gill, a cut is made from the back of the head to the area around the mouth (Amponsah *et al*. 2024). The muscle was harvested by filleting the flesh, removing the scales, and dissecting the gastrointestinal tract and gills as described by Daniel *et al*. (2020). The dissected part of fish samples were each weighed by wet weight and digested using a method adapted from Karami *et al*. (2017) and Gulizia *et al*. (2022). Organs and tissues that have been dissected are each added with 10% potassium hydroxide (KOH) (Merck, Germany, ≥ 85%, ACS reagent grade) for 48 hours (h) with a ratio of 1:10 of the wet weight of the fish organ or tissue sample to KOH (Karami *et al*., 2017). The extraction process utilizes KOH as a caustic reagent due to its ability to maintain the polymer's reactivity, prevent damage to fragments, and exhibit color changes at high exposure temperature (Gulizia *et al*., 2022). 40 millilter (ml) of supernatant on the surface was taken using a pipette and then filtered using 0.45 µm Whatman cellulose nitrate filter paper using a vacuum pump (Takarina *et al*., 2022).

Microplastic identification

Microplastic identification was carried out by observing microplastic particles on filter paper in a petri dish using an Olympus CX22 microscope with 4 x and 10 x objective magnification and an Indomicro View camera lens connected to a laptop. Identification of microplastics is based on combining the identification criteria of Horton *et al*. (2017) and Suteja *et al*. (2021). Utilizing the Indomicro View software on the laptop, the observation and documentation of microplastic particles was conducted to enable a thorough examination of each particle's unique characteristics. After that, the identified microplastics are grouped by composition based on shape (fiber, film, fragment, pellet, foam), size (<300 µm, 300-500 µm, 500-1000 µm, >1000 µm), and their abundance can be calculated.

Microplastic polymer analysis

Microplastic polymer analysis was conducted using the Raman spectroscopy method with a HORIBA

microscope – The LabRAM HR Evolution Raman Microscope with a 785 nanometer (nm) laser beam and 600 gram per millimeter (g/mm) grating. The microplastic particles' spectrum from the Raman spectroscopy test was analyzed and compared to the polymer type in the spectrum database through Open Specy (Cowger *et al.*, 2021).

Control contamination

It is essential to adhere to cleanliness standards for procedures, tools, and materials in order to minimize microplastic contamination during research, as outlined in the Guidelines for the Monitoring and Assessment of Plastic Litter in The Ocean. The work space is periodically cleaned, and the tools are sterilized by being washed and dried in the oven. When working on samples, laboratory coats and gloves are used. Materials such as distilled water and destruction solutions are filtered –before use. Samples were exposed to ambient air while being analyzed. Contamination control is implemented in the preparation and digestion stages by using a blank solution or filtered distilled water. The accuracy of the observation data is maintained by visually inspecting the samples under a microscope (GESAMP, 2019). The blank solution was made placing the filtered

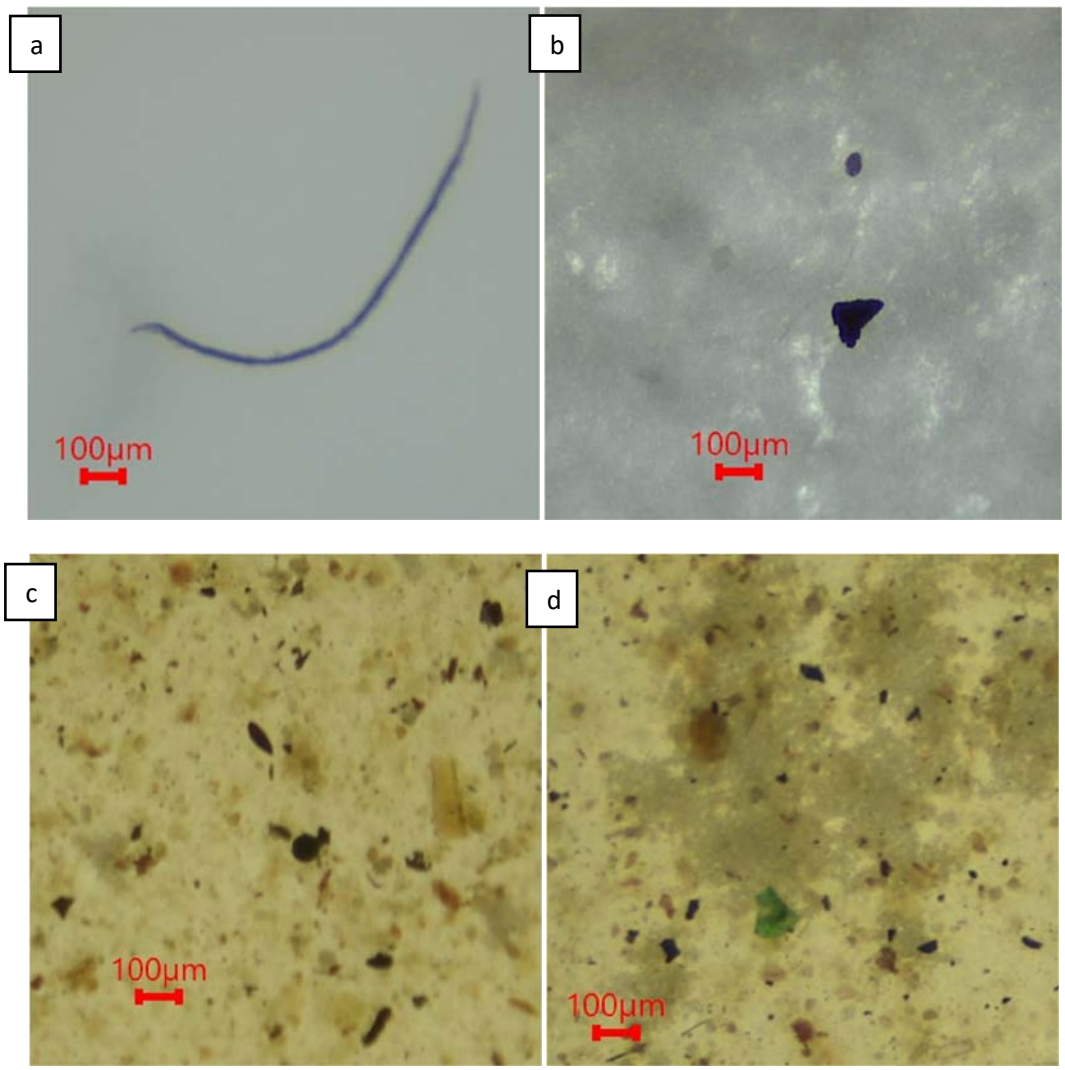


Fig. 2: Microplastic shapes found in fish tissues (counterclockwise): a) fiber, b) fragment, c) pellet, d) film

water and KOH solution in different petridish during microplastic extraction and identification (Daniel *et al.* 2020). The analysis of microplastics in the control solution utilized for the study revealed the absence of any microplastic particles, including fibers, fragments, pellets, and films.

Statistical analysis

Statistical analyses were performed to assess the difference in microplastic abundance at the individual level among the *E. tetradactylum*, *M. cephalus*, and *S. argus*. The Shapiro-Wilk test was conducted to assess the normality of the data, revealing a normally distributed dataset. At the tissue level, differences were noted among the GT, muscle, and gill of each species. To test the differences, a one-way analysis of variance (ANOVA) was performed with a significance level (P) of < 0.05. A post hoc test; Turkey's test was performed to accompany the ANOVA test.

RESULTS AND DISCUSSION

The study results indicated that microplastics were effectively detected and presented in three types of commercial fish in Blanakan: *Scatophagus argus*, *Mugil cephalus*, and *Eleutheronema tetradactylum*. Variations in microplastic levels, abundance, and dispersion were observed among the three fish varieties.

Microplastic shapes in fish tissues

The following microplastic particle counts were observed in three different fish species: *Scatophagus argus*, *Mugil cephalus*, and *Eleutheronema tetradactylum*. Four different shapes of microplastic were identified in the tissues of the fish samples, as shown in Fig. 2. Additionally, four size categories were observed, with some differences in the distribution of these shapes among the various species and tissues (Figs. 3 and 4). In *Scatophagus argus*, 747.6 microplastic particles were recorded, with 403.3 particles in the GT, 273.3 particles in muscle, and 117 particles in gill. Fiber-shaped microplastics were found in abundance in the gill and muscle tissues, whereas fragments were the most common in the gastrointestinal tract (GT). In *Mugil cephalus*, 2108.6 microplastic particles were found, with the highest number in the GT (1010.6), followed by gill (511) and muscle (587). Similarly, fiber-shaped microplastics were dominant in all organs, and <300 micrometer (µm) microplastics were prevalent in each organ. In

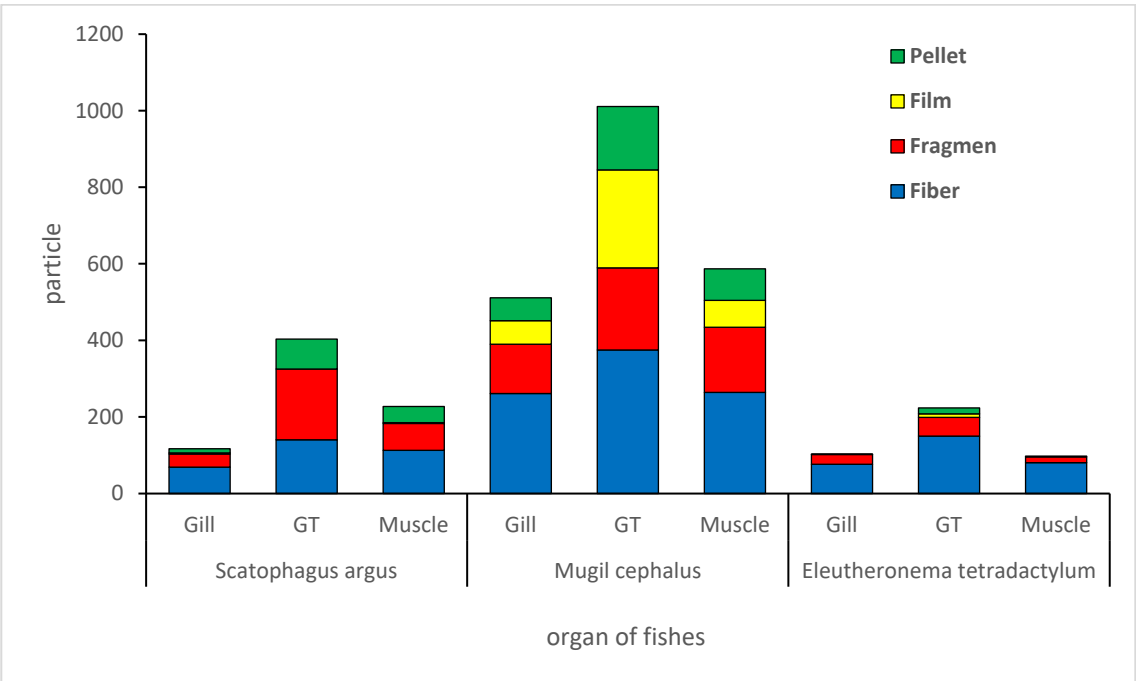


Fig. 3: Distribution of microplastic shapes in fish tissues (muscle, gill, and GT)

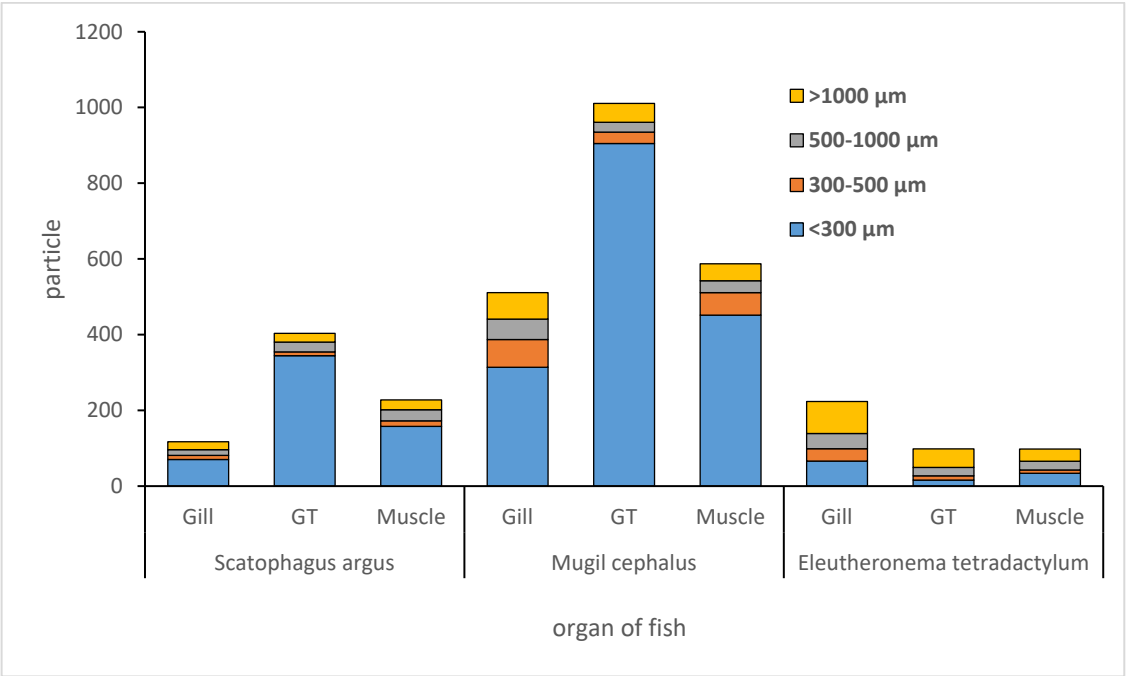


Fig. 4: Distribution of microplastic sizes in fish tissues (muscle, gill, and GT)

Table 1: Polymer of microplastic detected in fish samples.

Fish sample	Polymer
Mugil cephalus	PP
Eleutheronema tetradactylum	PP
Scatophagus argus	PET

Eleutheronema tetradactylum, 419.02 microplastic particles were observed, with fiber and fragment-shaped microplastics dominating in fish organs and muscle. The presence of pellet-shaped microplastics was limited to muscle and GT, with gill and GT being the only locations where film-shaped microplastics were found. The <300 µm microplastics were most prevalent in the muscle, while the gill and GT were dominated by microplastics >1000 µm in size.

Types of microplastic polymers in fish tissues

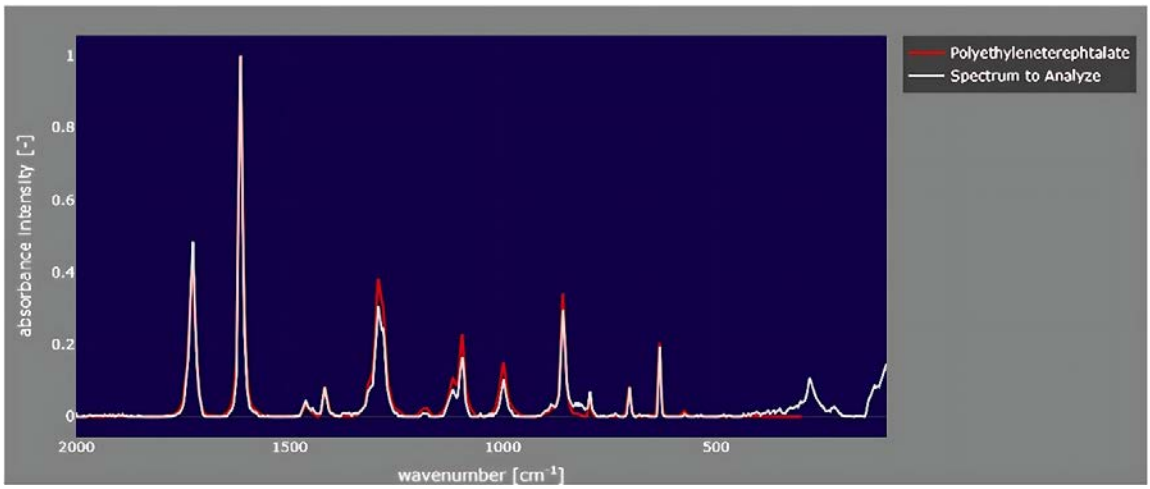
Table 1 displays the polymer analysis findings for the three commercial fish examined in this study.. Based on the tests, two types of microplastic polymers were found in the three fish species studied. The presence of PP was indicated for both *M. cephalus* and *E. tetradactylum*. Meanwhile, the microplastic polymer PET was found in *S. argus* tissue. The polymer analysis test results are shown in Fig. 5.

Microplastic abundance in individual fish and their organs and muscle

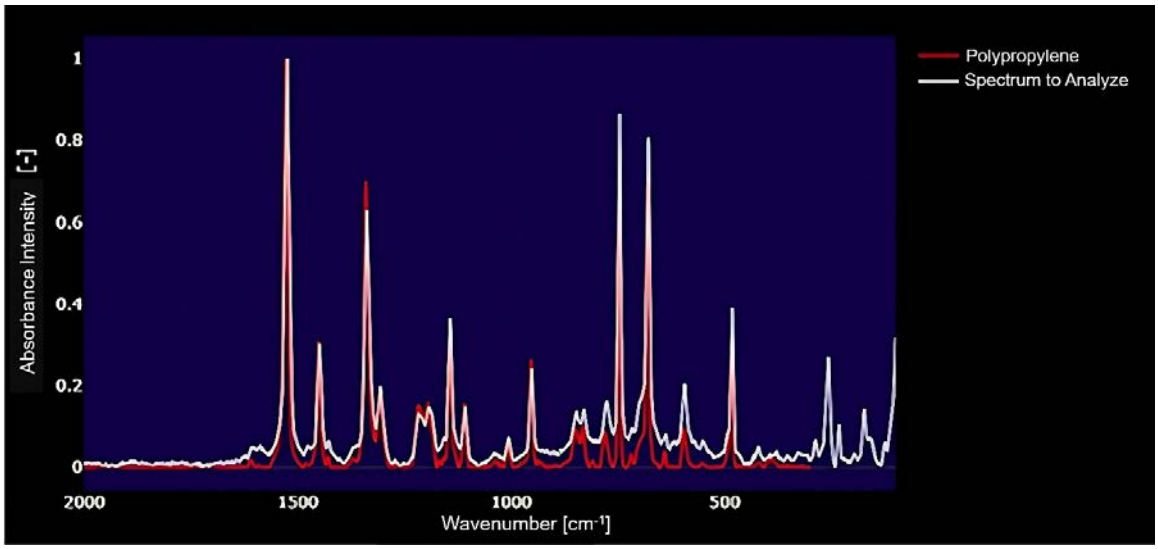
The abundance of microplastics found in each fish species differed significantly ($P < 0.05$, Table 2). *M. cephalus* had the highest microplastic mean values of 210.8 particles/individual (partcles/ind), followed by *S. argus* and *E. tetradactylum*, at 74.7 and 41.9 particles/ind.

The abundance of microplastics in the organs and muscle of the three fish exhibited differences (Table 3). High levels of microplastics were found in muscles of *S. argus* and *M. cephalus*, while in *E. tetradactylum*, the highest concentration was detected in GT. The muscle tissue of *E. tetradactylum* also exhibited the lowest microplastic content.

The present study describes the distribution and



a



b

Fig. 5: Spectrum of microplastic polymer detected in fish sample : a) PET, b) PP

prevalence of microplastics in three distinct tissues (gills, muscles, and GT) of three coastal commercial fish species (*E. tetradactylum*, *M. cephalus*, and *S. argus*). Previous studies mainly concentrated on measuring microplastics in general, whereas this research highlights the importance of analyzing fish tissues, particularly those that are edible like muscle. The elevated presence of microplastics in the muscle of *M. cephalus* and *S. argus* can be attributed to the translocation of microplastics through the digestive system of these fish species. According to Barboza *et al.* (2018), microplastics with size < 150 µm possess the capacity to traverse the digestive system and accumulate in the tissue of the muscle. Incomplete excretion of microplastics through feces or urine occurs due to the accumulation and fragmentation of these particles within the digestive tract (Utomo and Muzaki, 2022). Sawalman *et al.* (2021) discovered comparable characteristics between microplastics present in the digestive tract

Table 2: Post hoc ANOVA test for comparison of microplastic mean values (particles/ind) among fish species

Species	*E. tetradactylum*	*M. cephalus*	*S. argus*
Mean values (particles/individual)	41.9*	210.8	74.7*

*significant at P < 0.05

Table 3: Post hoc ANOVA test for comparisons of microplastic mean values (particles/gr WW) among fish species and tissues

E. tetradactylum			*M. cephalus*			*S. argus*		
Muscle	Gill	GT	Muscle	Gill	GT	Muscle	Gill	GT
3.42*	12.56*	17.60*	28.71*	20.74*	25.26*	17.18*	8.4*	8.52*

*significant at P < 0.05

Table 4: Comparison of microplastic levels (particles/ind) in this study and several other studies in various locations and regions

Species	Country	Study Site	Microplastic level	Source
M. cephalus	Turkey	Lake Cernek	0 - 6	Terzi (2023)
	China	Guangdong	5.2	Zhang *et al.* (2020)
	India	Adyar Creek	7.1	Harikrishnan *et al.* (2023)
	India	Ennore Creek	5.5	Harikrishnan *et al.* (2023)
	Indonesia	Jakarta	2-27	Hastuti *et al.* (2019)
	Indonesia	Blanakan	210.8	This study
E. tetradactylum	China	South Yellow Sea	5.19	Zhang *et al.* (2023)
	Indonesia	Dumai	10	Yoswaty *et al.* (2021)
	Indonesia	Cilacap	21.33	Hidayati *et al.* (2023)
	Indonesia	Jakarta	0 - 16	Hastuti *et al.* (2019)
	Indonesia	Blanakan	41.9	This study
S. argus	India	Ennore Creek	6.3	Harikrishnan *et al.* (2023)
	China	Maowei Sea	14	Zhu *et al.* (2019)
	China	Beibu Gulf	2	Koongolla *et al.* (2022)
	Indonesia	Blanakan	74.7	This study

and those found in the muscle, which facilitating the potential translocation of microplastics to other tissues. The gastrointestinal tract of E. tetradactylum shows notable concentrations of microplastics. The gastrointestinal tract serves as the main storage area for both food and non-food items that are consumed by the fish through hunting and swallowing using the mouth (Buwono *et al.* 2021). Microplastics found in the gills are believed to have entered through accidental exposure during seawater filtration and direct contact with the surrounding environment, potentially becoming trapped within these organs (Collard *et al.* 2017). Table 4 indicates that the levels of microplastics found in fish in the Blanakan and West Java Coasts exceed those reported in other research for different locations and regions. The discrepancy may be related to the location of this study. The estuary in Blanakan, West Java Coast, is situated near the river mouth of the Blanakan River, the upstream areas of which are dominated by settlements. The plastic waste from these communities is released in the form of packaging material, which breaks down into microplastics. The varying levels of microplastics were also found to be linked to the fish's habitat. The findings of this study reveal that the fish species investigated exhibit a preference for upstream habitats and feeding on bottom mud, thereby increasing their vulnerability to microplastics, especially those that are concentrated in sediments.

In terms of shape, microplastic fiber was the predominant form noted across the different tissues examined. The study is situated in fishing grounds, where discarded fishing gear is utilized as the primary source of fiber. According to Wright *et al*. (2021), high levels of beached fishing litter, including fishing ropes, nets, and lines, are linked to fishing efforts and have the potential to release hundreds of microplastic pieces per meter. Microplastic fragments were the second most common microplastic shape observed. In *Eleutheronema tetradactylum*, the GT contained

the most fragments, followed by the gills. The GT of Scatophagus argus was also found to contain high levels of fragments, followed by the gills. Meanwhile, in *M. cephalus*, fragments were more common in the gills compared to the GT or muscle. This finding aligns with Kılıç and Yücel (2022) and Espiritu *et al*. (2023). In estuary ecosystems, the majority of microplastics found in all fish species were in the form of fragments, indicating the extensive use of plastics for packaging and their subsequent presence as riverine plastic debris in the environment widespread use of plastics for packaging and their environmental fate as riverine plastic debris.This aligned with the presence of upstream settlements in Blanakan, where plastic packaging is common. The microplastic fragments, which were the most dominant shape, potentially originated from degraded plastic products from these nearby settlements, including plastic containers (Zhang *et al.*, 2015), packaging materials (Derraik, 2002), and cleaning media (Nabi, *et al.* 2022). The high concentration of these particles found in fish tissues could be linked to uncontrolled waste disposal and poorly managed plastic waste, as indicated by the quantity of microplastics detected during sampling (Osorio *et al*., 2021). Due to improper waste management, plastic packaging-based microplastics enter the water body in estuary ecosystems and are absorbed by fish. Differences in microplastic sizes consumed by the fish in this study are linked to their specific habitat and feeding patterns. It is worth noting that E. tetradactylum was the exclusive demersal fish species analyzed in the study Lelono *et al*. (2021) and consumed large-size microplastics measuring > 1000 µm. As a carnivorous fish species, it consumes large prey, including penaeid shrimp, fish, and squid (Sugara *et al.*, 2022). Generally, E. tetradactylum feeds on penaeid shrimp and teleost fish (Iqbal *et al.*, 2023). The typical diet of E. tetradactylum consists of penaeid shrimp and teleost fish. In contrast, small-size microplastics were dominant in the tissues of *S. argus* and *M. cephalus*. Additionally, this coincides with the dimensions of the prey that these species hunt (Lopes *et al*., 2023). Both *S. argus* (Gupta, 2016) and *M. cephalus* (Kılıç and Yücel, 2022) are classified as omnivorous benthopelagic. Both species prey on non-fish and small organisms, such as worms, crustaceans, and insects, along with microalgae and detritus. The prey size corresponds to the size of the microplastics ingested. Microplastics accumulate in the GTs and gills of fish. The gastrointestinal tract (GT) is responsible for storing food and microplastics during digestion, whereas microplastics found in the gills are linked to the feeding habits and behavior of the fish. The species examined in this study are all filter-feeders, or passive-feeders, which results in the inadvertent intake of microplastics from the water around them. This contrasts with particulate feeder species; *Mullus barbatus*, *Alosa immaculata* (Atamanalp *et al*., 2021) *Sardina pilchardus*, *Engraulis encrasicolus* and *Trachurus trachurus* (Lopes *et al.*, 2023) which actively absorb microplastics from their prey. The feeding behavior of these fish plays a role in the introduction of microplastics into their tissues via the gills. Microplastics can result in physical harm by adhering to the gills, potentially causing hypoxia if they obstruct them and impede respiratory function (Jaafar *et al.*, 2021). Microplastics with smaller particles generally exhibit a larger specific surface area, resulting in enhanced pollutant absorption and increased toxicity levels (Zhang *et al.*, 2022). Smaller-sized microplastic particles are more readily absorbed by cells compared to their larger counterparts (Khan and Jia, 2023). The relationship between adsorption capacity and particle size shows that smaller particles have a higher capacity for adsorption (Sun *et al.*, 2023). The health implications of microplastics are contingent upon the entry and accumulation of microplastic particles within specific organs and body parts. The distribution and accumulation mechanisms of microplastics in organs such as the liver, kidneys, and intestines are largely influenced by the particle size (Deng *et al.*, 2017). A study by Jin *et al.* (2024) revealed the presence of microplastics in the tonsils (20.34–471.87 µm), small intestine (20.34–196.13 µm), large intestine (20.34–498.10 µm), and lungs (20.34–477.67 µm). Particles within the 20 to 100 µm range constituted more than half of the total in these organs: 64.76% ± 39.09% in the large intestine, 61.49% ± 46.84% in the small intestine, 76.83% ± 24.36% in the lungs, and 85.01% ± 34.82% in the tonsils. Microplastics were claimed to impact physical health by changing the structure of the microbiota in the intestines. Microplastics in fish can pose a threat to humans through several mechanisms, including persorption and endocytosis, known as the most common pathways by which microplastics in fish enter the human body (Bhuyan, 2022). Exposure to

microplastics can result in various health issues such as immune system disruption, cancer, oxidative stress, and damage to the nervous and reproductive systems. The evidence-based risk of microplastics to humans should then be supported by several metrics, including biomagnification and bioavailability measurements. Another study by Zhang *et al.* (2022) delineated the impact of microplastics at the cellular level, highlighting pronounced effects of 0.1 µm microplastic particles on intracellular reactive oxygen species (ROS) and consequential induction of oxidative stress, while 5 µm microplastic particles manifested effects at the cell membrane level, leading to mitochondrial depolarization. The size of the fish also influenced the microplastic contaminants. *M. cephalus* exhibits the greatest size in this study, while *E. tetradactylum* displays the smallest size.. The results confirm that *M. cephalus* has the most microplastics and *E. tetradactylum* has the least microplastics. This result supports a previous study that identified a positive relationship between body size and microplastic presence.This happens since larger fish will consume more, which increases the probability of microplastic ingestion (Horton *et al.*, 2024). The presence of PP and PET polymers found in the fish organs analyzed could be due to the significant prevalence of these polymers in the Blanakan Estuary, consequently elevating the likelihood of them being part of the fishes' diet (Makhdoumi *et al*., 2022). Microplastics from PP polymer, which is a major component of the single-use plastic packaging commonly used in coastal communities, can be ingested by *M. cephalus* and *E. tetradactylum*, which inhabit the bottom and surface of the water. This may occur due to the vertical sinking of microplastics caused by aggregation or biofouling (Song *et al*., 2018). *S. argus*, being a benthopelagic fish, is often in contact with PET polymers found both floating in the water column and settled on the seabed (Issac and Kandasubramanian, 2021). PET polymers originate from the waste discharged by industry and fisheries that lack proper waste management practices, leading to their disposal into water bodies (Lin *et al*., 2021). The influence of polymers PP and PET on human health has been the subject of thorough investigation. According to Jia *et al.* (2023), PP can lead to intestinal microbial apoptosis and impair intestinal barrier function. Furthermore, a study by Tamargo *et al*. (2022) found that PET polymers have the potential to change the microbial makeup of the human gut by facilitating microbial adhesion to the surface, ultimately resulting in the formation of biofilms. The Blanakan River is situated in Subang Regency, West Java, and it flows into the Java Sea. In the Blanakan river area, there are several local community activities, such as fishing community settlements (Pawitro *et al.*, 2015) and fish farms (Rahman *et al.*, 2015), among others. These community activities generate plastic waste, which ends up in the sea through the rivers, becoming the primary source of plastic pollution in the waters (Emmerik *et al.*, 2022). In Indonesia, West Java stands out as one of the three regions with the highest levels of microplastic pollution in its waters (Sari *et al.*, 2021). The most common forms of microplastics found in the marine environment are fibers (Acharya *et al.*, 2021) and fragments (Boettcher *et al.*, 2023). The production of synthetic textile fibers is the main contributor to fiber-shaped microplastics (Yang *et al.*, 2023) and fishing line fibers (Ningrum and Patria, 2022). Meanwhile, pieces of waste are created from household trash as they make their way through rivers or are disposed of in landfills (Takarina *et al.*, 2022). PP, polystyrene (PS), and PET are the three most prevalent polymers on a global scale (Faull *et al.*, 2024). The surge of plastic pollution in the sea, notably from single-use plastics crafted from polyethylene terephthalate and polypropylene, has caused a proliferation of these two polymers in the ocean (Khoironi *et al.*, 2020).

CONCLUSION

A total of 3275 microplastic particles in three types of commercial fish, namely *M. cephalus*, *E. tetradactylum* and *S. argus* were detected in GT, gill and muscle. There are four forms of microplastics with an abundance of fiber>fragment>film>pellet. In terms of size, small microplastics are dominant in *M. cephalus* and *S. argus* fish, while larger sizes are dominant in *E. tetradactylum*. PP and PET are the two polymers found in fish organs. Based on the abundance of microplastics per type of fish, *M. cephalus* > *S. argus* > *E. tetradactylum*. Variations in abundance may be impacted by factors such as size, feeding behavior, and habitat, all of which can affect the levels of microplastics present. This shows that large ominivorous fish have a greater risk of exposure to microplastics than small

carnivorous fish. *E. tetradacytilum* muscle shows the lowest level of microplastics in organs, while *M. cephalus* exhibits a higher concentration in comparison. This confirms that although both are consumption fish, *E. tetradactylum* is recommended for consumption, apart from being a demersal fish. Elevated concentrations of microplastics found in the flesh and digestive systems of fish suggest that their natural food sources and environments are being polluted by these tiny particles. The ingestion of particular sizes of microplastic overlapped with the fish feeding preferences and prey sizes. Fish that preyed on other fish were contaminated by microplastics measuring > 1000 µm, compared to contamination by microplastics measuring < 300 µm for those with small prey. The results shed light on the safety and health implications of consuming certain types of fish. Further studies are required to enhance our understanding of the factors influencing the occurrence of microplastics in fish and to conduct comprehensive health risk assessments. It is crucial to set up consistent monitoring initiatives in order to monitor the levels and spread of microplastics in fish and other marine creatures in their natural habitat. This program will offer important information for upcoming studies and help guide successful strategies for managing and preserving the environment.

AUTHOR CONTRIBUTIONS

N.D. Takarina, as the corresponding author, has contributed to funding, contribution to proposal, and drafting the manuscript; O.M. Chuan, conducted in preparation of the manuscript, reviewing proposals and data verification; A. Adiwibowo, drafted the manuscript, data analysis, and data interpretation; F.N.A. Jeffery, contributed to data tabulation MPs size; N.Z.A.B.N.M. Zamri, contributed to data tabulation in MPs shape; M.A. Adidharma, drafted and data interpretation.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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ABBREVIATIONS

%	Percent
µm	Micrometer
<	Less than
>	More than
a.m.	ante meridiem or before midday
ABS	Acrylonitrile Butadiene Styrene
ANOVA	Analysis of Variance
cm	Centimeter
/cm	Reciprocal centimeter
g	Gram

g/mm	Gram per millimeter
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
GPS	Global Positioning System
GT	Gastrointestinal tract
h	Hour
Items/ind	Items per individual
Items/kg	Items per kilogram
Items/m^3	Items per metercubic
kg	Kilogram
KOH	Potassium hydroxide
L	Liter
m^3	Metercubic
ml	Milliliter
mm	Millimeter
MMt/y	Million tons per year
NFA	National Food Agency
nm	Nanometer
p.m.	post meridiem or after midday
Particles/L	Particles per liter
Particles/g	Particles per gram
Particles/g WW	Particles per gram of wet weigh
PE	Polyethylene
PES	Polyester
PET	Polyethylene Terephthalates
PP	Polypropylene
PS	Polystyrene
SD	Standard deviation
WPP RI	Fisheries Management Area of the Republic of Indonesia in English; Wilayah Pengelolaan Perikanan Republik Indonesia in Indonesia
WW	Wet Weight

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