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Microplastic pollution in the Belawan Estuary, Indonesia based on aquatic biota and polymer characterization

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Abstract. *Muhtadi A, Leidonald R, Maiyah N, Ishak MY, Mukra R. 2025. Microplastic pollution in the Belawan Estuary, Indonesia based on aquatic biota and polymer characterization. Biodiversitas 26: 2002-2010.* Microplastic pollution causes widespread contamination of coastal and marine environments. Although microplastic pollution has been studied in marine and estuarine environments across Indonesia, studies in North Sumatra are lacking. This study assessed microplastics (Mps) contamination of aquatic organisms in the Belawan Estuary. Aquatic biota was captured using *ambai* fishing gear, and the intestines were dissected for analysis. After degrading the organic material using an alkaline digestion method, microplastic particles were identified based on their shape, size, and quantity. Four types were identified: fibers, films, fragments, and pellets. Pellet microplastics were the most abundant, with an average of 24.21 particles per gram in fish and an average of 13.62 particles per gram in crustaceans, followed by fibers, fragments, and films. The size of the microplastic particles ranged from 27 to 1940 μm. The abundance of MPs was higher in fish (average: 63.899 particles per g) than in crustaceans (average: 30.97 particles per gram). Carnivorous fish species were most contaminated with microplastics, including *Epinephelus areolatus*, *Plotosus lineatus,* and *Neotrygon kuhlii,* all of which are demersal. Fourier-transform infrared spectroscopy identified six polymers: polypropylene, polystyrene, polyethylene, polyvinyl chloride, polyethylene terephthalate, and polyamide. This study highlights severe microplastic contamination in the Belawan Estuary and underscores the need for urgent action to address this environmental threat.

Keywords: Belawan Estuary, crustacea, fish, microplastic, North Sumatra

INTRODUCTION

Empirical research conducted across global marine ecosystems has identified plastic waste as the predominant component of marine debris, with estimates indicating that it comprises 60-80% of the total debris accumulation (GESAMP 2021; Cordova et al. 2022). The widespread use of plastic materials and other synthetic substances in the fishing industry over the past 35 years has contributed significantly to the prevalence of abandoned fishing gear in marine and coastal waters. In addition, food, and beverage packaging, which is now predominantly made of plastic, is commonly found on beaches and at sea. Plastic waste can also originate from tourists or urban areas, enter rivers, and ultimately end up in oceans or estuaries (NOAA 2013; Basri et al. 2021; GESAMP 2019, 2021).

Microplastics (Mps), synthetic polymer particles smaller than 5 mm, pose a serious threat to marine ecosystems because they disrupt the food chain and accumulate in aquatic organisms, potentially infiltrating their tissues (GESAMP 2016; Galloway et al. 2017; Basri et al. 2021; Bhuyan 2022). Marine organisms ingest microplastics when these particles resemble food (GESAMP 2016; Basri et al. 2021; Bottari et al. 2024). Microplastics can be categorised based on their size, density, chemical composition, and shape (NOAA 2013; GESAMP 2016, 2019; Michida et al. 2019). These polymer particles break down into smaller pieces that are chemically stable and difficult to degrade (Pan et al. 2019). All aquatic environments, including estuaries, contain significant quantities of pervasive microplastics of various types (Michida et al. 2019; Cordova 2020, 2021; Huang et al. 2020a, b).

Microplastics can contain numerous hazardous compounds such as Polychlorinated Biphenyls (PCBs), metals, and Polybrominated Diphenyl Ethers (PBDEs) (GESAMP 2019; Michida et al. 2019; Cordova 2021, 2024). These compounds pose significant health risks when accumulated in the human body (Basri et al. 2021; Bhuyan 2022). Microplastics have been widely detected in water (Galloway et al. 2017; GESAMP 2019, 2021; He et al. 2021; Ma et al. 2024), sediments, and various aquatic organisms (Jabeen et al. 2017; Huang et al. 2020b; Zhang et al. 2020, 2023; Pequeno et al. 2021; Kılıç and Yücel 2022; Mahu et al. 2023). Consequently, microplastic pollution has become a global issue that requires urgent attention. The presence of microplastics in marine debris has raised public concern because of their contamination in coastal and marine areas. Despite extensive research on microplastic pollution in Indonesia (Cordova et al. 2022, 2024), no studies have examined the contamination of aquatic organisms in the Belawan Estuary, a key industrial and shipping hub along the Malacca Strait. Understanding the presence here is essential for assessing the potential ecological and human health risks.

The Belawan Estuary is located in the northern part of Medan City, North Sumatra Province, and is strategically positioned along the Malacca Strait. It developed into an international port that serves the western region of Indonesia. The Belawan Estuary is also a hub for industrial growth in Medan City, hosting various activities, including the Medan Industrial Zone, Belawan Ocean Fisheries Port, Pelindo (Indonesia Port Corporation), a steam power plant, and residential areas (Medan City Regulation 2022). Activities in the surrounding areas, as well as those upstream of the Belawan River (Karo District and Deli Serdang District), significantly affect the water quality of the Belawan Estuary (Mirandha and Irvan 2021). The Belawan waters function as an estuarine system that receives inputs from the Belawan River and other nearby rivers around Medan. Currently, the Belawan River is highly polluted by waste from various anthropogenic sources, including domestic and industrial wastes (Mirandha and Irvan 2021; Muhtadi et al. 2023), as well as marine debris (Cordova et al. 2022). Given the high levels of industrial and anthropogenic pollution in the Belawan Estuary, microplastic contamination is likely, yet baseline data are lacking. Without such data, effective estuarine management remains a challenge. Therefore, this study aimed to assess microplastic contamination in aquatic organisms within the Belawan Estuary.

MATERIALS AND METHODS

Study area

Fish and crustacean samples were collected from the Belawan Estuary in the North Sumatra Province, Indonesia (Figure 1). This study was conducted between October and November 2023. Sampling was conducted over 3°46'27.24"N at 98°40'24.11"E locations. The location of this study is a fishing area for the community. However, based on the results of the latest research, the research location, and the area around Belawan have been polluted by organic matter (Muhtadi et al. 2025b), heavy metals (Sulistyowati et al. 2023), and also microplastics in water (Muhtadi et al. 2025a) and sediment (Leidonald et al. 2024).

Procedures

Aquatic biota sampling

All samples were dissected to collect the digestive organs, specifically the intestines. The intestines were weighed to determine initial wet and dry weights. Samples were classified according to species, feeding habits, economic and ecological significance, and habitat type (pelagic vs demersal). Aquatic biota samples were collected from multiple sites within the Belawan Estuary using Ambai fishing gear, a net designed to protect against currents during low tide. The N fish and N crustaceans were collected and measured for length (cm) and weight (g), respectively. The specimens were then categorised according to species, feeding habits, economic and ecological significance, and habitat (pelagic or demersal).

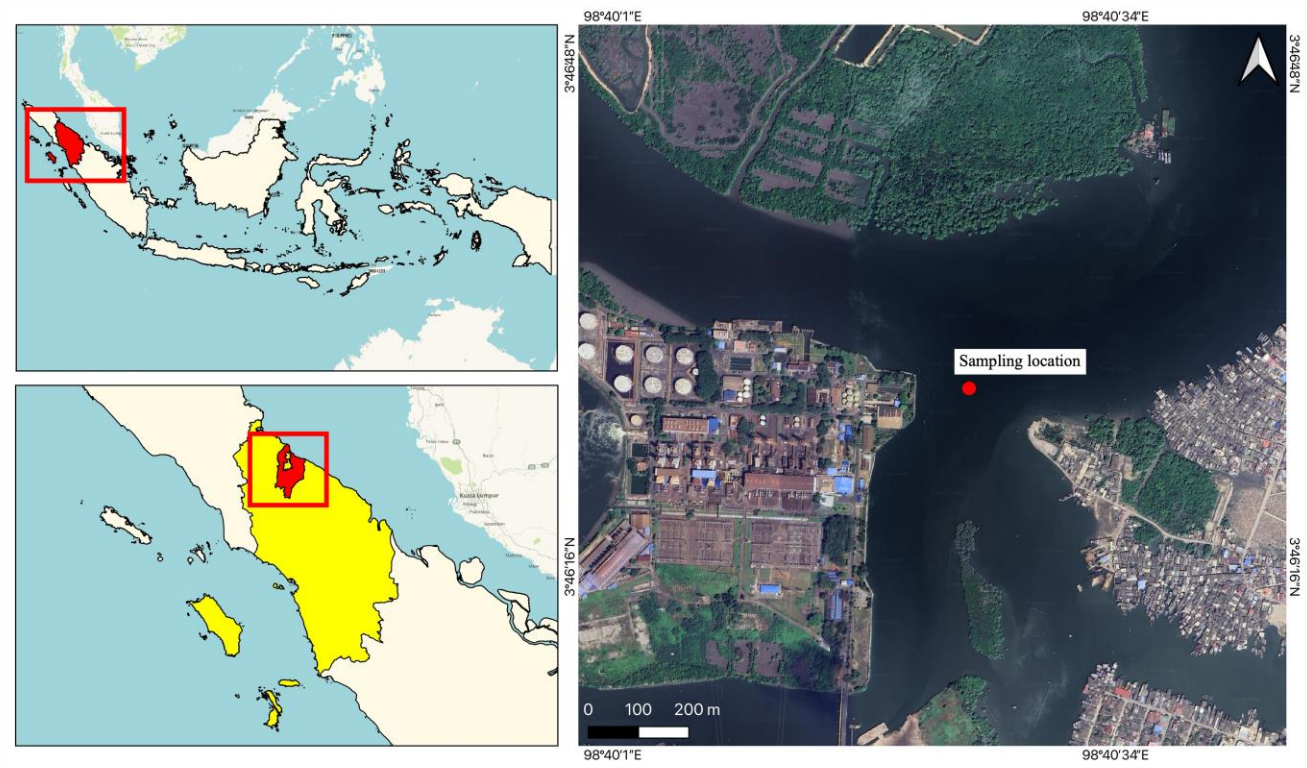

Figure 1. Location of Belawan Estuary, North Sumatra Province, Indonesia

Laboratory procedure

Each intestinal sample (X g) was digested with 40 mL of 10% KOH in an Erlenmeyer flask, following a modified protocol from Jabeen et al. (2017) and Ding et al. (2018). The mixture was incubated at 60°C for 24 h to ensure complete digestion. The digestate was filtered using vacuum filtration with Whatman No. 42 filter paper (1.2 µm pore size) to isolate microplastic residues. The filtered material was dried at room temperature in a covered Petri dish before analysis.

Microplastic identification using a microscope

Microplastic particles were identified using an NZ1703-P stereomicroscope with a magnification range of 20-160x. The filter paper was placed in a petri dish and examined under controlled lighting conditions. Identification was based on morphological characteristics (colour, shape, and texture) following the criteria of Viršek et al. (2016) and Yona et al. (2021). To prevent contamination, all samples were processed in a clean laboratory environment and procedural blanks (filtered ultrapure water) were used as controls. Suspected microplastic particles were manually sorted and categorised into fibers, fragments, and films.

Fourier-Transform Infrared (FT-IR) spectroscopy analysis

Fourier-Transform Infrared (FT-IR) spectroscopy was conducted to identify the polymer types of microplastics based on their functional groups. The samples were analysed using an FT-IR spectrometer (Shimadzu IRPrestige-21) at the Research Centre Laboratory, Faculty of Pharmacy, Universitas Sumatera, North Sumatra Province. Polymers were identified based on FT-IR spectral peak (4000-600 cm^{-1} with 4 cm^{-1} resolution) comparisons with reference databases (Imhof et al. 2012; Nor and Obbard 2014; Viršek et al. 2016).

Suspected microplastic particles were analysed using an Attenuated Total Reflectance (ATR) module over a spectral range of 4000-600 cm^{-1} with a resolution of 4 cm^{-1}. Spectral peaks were compared with reference IR spectra from published databases (Imhof et al. 2012; Nor and Obbard 2014; Viršek et al. 2016) to determine the polymer composition.

Data analysis

Data analysis was carried out with the assistance of Microsoft Excel and Past 5.2 for the one-way ANOVA test and Mann-Whitney U test. The abundance of microplastics in the sediments was calculated using the following equation (Ding et al. 2018):

$$Microplastic\ abundance = \frac{Number\ of\ microplastic\ particles}{Dry\ weight\ of\ biota\ samples\ (grams)}$$

RESULTS AND DISCUSSION

Types and sizes of microplastics

The microplastics identified in the digestive tract of aquatic biota in the Belawan Estuary consisted of four types: fibers, fragments, films, and pellets. Microplastic pellets were the most abundant, with 0-98.25 particles per gram (average 24.21±23.74 particles gr^{-1}) in fish and 0.85-28.30 particles per gram (average 13.62±9.20 particles gr^{-1}) in crustaceans, followed by fibers, fragments, and films (Figure 2). Pellets are a type of microplastic with hard, round, or cylindrical shapes that exhibit a regular appearance. This type of microplastic is commonly found in beauty products, cosmetics, and scrubs. Pellet microplastics, or beads, are considered primary microplastics, deliberately produced in small or micro sizes as raw materials for the manufacture of plastic-based products (Viršek et al. 2016; GESAMP 2016, 2019). However, other studies on marine organisms have shown that the most commonly found microplastics in aquatic biota are fibers, with fragments found in smaller quantities (Table 2). Pellets were the most abundant, whereas others found that fibers dominated This is caused by industrial activities, flows, or weak regional waste management practices, which result in waste from these activities being "wasted" and polluting waters.

Fibers were the second most abundant microplastic, with 299 particles per gram. A one-way ANOVA was conducted to assess the differences in microplastic abundance among fish and crustaceans, revealing significant differences ($p<0.05$). The dominance of pellet microplastics (14.30±11.10) suggests a specific pollution source, potentially linked to industrial discharges. Fiber microplastics are characterised by their resemblance to fibers or fishing nets. Fishing activities are a significant source of fiber microplastics because most fishing nets are made of fibers. Additionally, fiber microplastics may originate from ropes or fishing gear such as plastic sacks. Waste from the production of clothing, ropes, fishing gear, and nets contributes to this form of microplastic (Viršek et al. 2016; GESAMP 2016, 2019). According to Hidalgo et al. (2012), most microplastics found in intertidal and estuarine areas are fibers. The critical roles of hydrodynamic and sedimentary factors in governing microplastic distribution within the water column were highlighted by Priya et al. (2025) as one of the environmental transport mechanisms linking estuarine currents with accumulation. The dominance of fiber microplastics has also been observed in several other studies, including those in the Jakarta estuary (Hastuti et al. 2019), the Estuary from the Coast of Portugal (Pequeno et al. 2021), and in the beaches and estuaries of the Atlantic (Guilhermino et al. 2021; Kılıç and Yücel 2022; Mahu et al. 2023).

The next most common type of microplastic was fragments, with 203 microplastic particles in the form of fragments. These fragments were obtained from discarded beverage containers in the water body, as plastic bottles were found along the route to the sampling station. The source of these fragmented microplastics can be attributed to human activity. This is in line with the research by Wang et al. (2019), which indicated that fragments are a form of microplastics that can originate from the use of hard plastic items such as household goods. Fragmented microplastics originate from the breakdown of larger plastic debris due to mechanical stress, ultraviolet (UV) radiation, and microbial degradation (Yadav and Mantri 2025). The relatively high abundance of fragments suggests ongoing degradation of macroplastic waste in the Belawan Estuary. One of the human activities contributing to the presence of microplastics in water is the use of fishing nets (Viršek et al. 2016; GESAMP 2016, 2019). The least abundant type of microplastic was film, with 148 particles per gram in fish and 8 particles per gram in crustaceans. According to Hastuti et al. (2019), films have lower density than other types of microplastics, making them more easily transported.

The largest microplastic particles in this study ranged in size from 27 to 1940 µm (Table 1). The fiber type had the largest size, ranging from 203 µm to 1940 µm, with an average of 969.8 µm. In contrast, pellets had the smallest particle size, ranging from 27 µm to 480 µm, with an average size of 176.85 µm. Hastuti et al. (2019) found the size of fiber microplastics in various fish species to be between 20 to 3000 µm (Table 2). Jabeen et al. (2017) found even larger fiber sizes, reaching up to 5000 µm. The smaller microplastic size in this study likely resulted from the dynamic environment of the estuary, with high turbidity, biological activity, and frequent abrasion-enhancing degradation. In contrast, slower degradation in the beach and open ocean areas was due to lower microbial activity, less abrasion, and limited UV exposure.

The abundance of microplastics in fish and crustaceans

The analysis of microplastic abundance in 30 fish species revealed the highest abundance at 178 particles per gram in *Neotrygon kuhlii*, and the lowest at 12.9 particles per gram in *Scatophagus argus* (Figure 3). According to Van Sebille et al. (2015), the abundance of microplastics in marine fish ranges from 20,000 to 449,000 particles g^{-1}. Hastuti et al. (2019) found the highest abundance in *Sardinella fimbriata* (20.00±8.0 MP g^{-1}) and the lowest in *S. argus* (5.89±4.2 MP g^{-1}). Suwartiningsih et al. (2020) reported 7.35±4.48 MP g^{-1} in *Johnius heterolepis* and the highest at 95.65±38.80 MP g^{-1} in *Auxis thazard*. Generally, the abundance of microplastics in Belawan's fish ecosystem is higher than that in the Jakarta Estuary (Hastuti et al. 2019), Baron Beach in Yogyakarta (Suwartiningsih et al. 2020), Barranglompo in Makassar (Sawalman et al. 2021), Coastal China (Jabeen et al. 2017), and the Estuary of the Coast of Portugal (Pequeno et al. 2021). Several factors influence the presence of MPs in fish, such as habitat, feeding habits, size, density, water pollution sources, and migration patterns of aquatic biota (Van Sebille et al. 2015; Jabeen et al. 2017; Pan et al. 2019; Bos et al. 2023). Pelagic fish may ingest microplastics suspended in the water column, while demersal species are exposed to sediment-associated plastics (Keerthika et al. 2023). The higher microplastic abundance in the Belawan Estuary may be attributed to its proximity to densely populated areas, as shown in the sampling location map in Figure 1. Increased human activity in these areas likely contributes to higher microplastic pollution in the water, leading to greater concentrations in local fish species.

The abundance of microplastics in the crustacean group was 30.965 particles per gram (Figure 4). The highest abundance was found in the mud crab *Scylla serrata* (47.25 particles per gram), while the lowest was found in *Scylla olivacea* (12.82 particles per gram). A total of 97 pellet particles, 81 fiber particles, 37 fragment particles, and 8 film particles were identified across all crustacean samples (average 30.97±12.71 particles g^{-1}). The high number of pellet particles is likely due to the proximity of the plastic waste recycling centre to the research location, which increases the presence of pellet microplastics in both crustaceans and nekton. Ogunola et al. (2022) found that fibers are the most common microplastic form in crustaceans, originating from textile fibers, often from household waste, such as laundry water dumped into rivers. The presence of microplastics in crustaceans is likely due to the negative buoyancy of most microplastics, which causes them to sink into the water column or benthic zone, serving as a habitat for biota, including crustaceans.

The abundance of microplastics in fish was higher (average: 63.899 particles per gram) than that in crustaceans (average: 30.97 particles per gram) (Figure 5). The high presence of MPs in fish is attributed to their omnivorous nature and role as predators of crustaceans, leading to the accumulation of microplastics in their digestive tracts. In addition, their diet, including that of shrimp, introduces microplastics into the food chain (Pan et al. 2019; Suwartiningsih et al. 2020). Furthermore, Neves et al. (2015) also stated that microplastics can enter aquatic organisms either through ingested water or through food containing microplastics.

Table 1. Microplastic particle size types (µm)

Particle types	Range	Average size of microplastic particles
Fiber	203-1940	969.80
Fragment	42-1419	431.05
Film	70-1545	441.55
Pellet	27-480	176.85

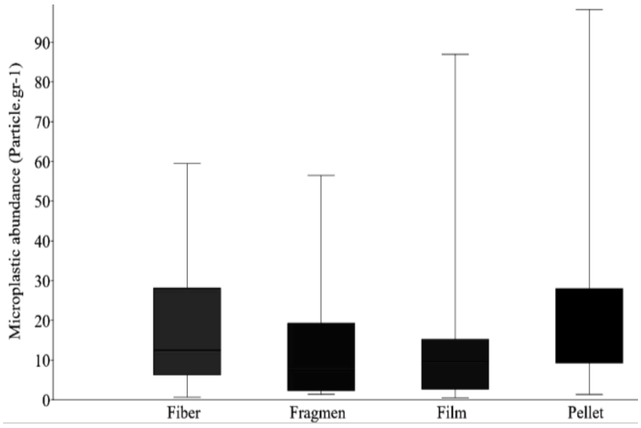

Figure 2. Types of microplastics in the digestive tracts of aquatic biota in the Belawan Estuary, North Sumatra Province, Indonesia

Table 2. The abundance of microplastics found in this study compared to other estuary areas (microplastics in biota)

Sampling location	Aquatic biota	Microplastic (MP) abundance (MP g^{-1})* or (particles individual^{-1})**	Size range (µm)	MP dominance	frequency of occurrence (%)	References
Indonesia, Jakarta (Estuary)	*Scatophagus argus*	(5.89±4.2)*	20-3000	Fibers	97	(Hastuti et al. 2019)
	Crenimugil seheli	(9.17±11.9)**			100	
	Mugil cephalus	(10.07±6.4)**			100	
	Sardinella fimbriata	(20.00±8.0)**			100	
	Siganus canaliculatus	(18.06±10.8)**			100	
	Abalistes stellaris	(16.33±11.1)**			100	
	Anodontostoma chacunda	(14.00±7.9)**			100	
Sayung, Demak, Central Java, Indonesia	*Perna viridis*	4111 N/ind.	-	Film	-	(Muhammad et al. 2022)
	Penaeus monodon	6131 N/ind.	-	Fragment	-	
	Lates calcarifer	6596 N/ind.	-	Fiber	-	
Pantai Baron, Yogyakarta, Indonesia	*Johnius heterolepis*	(7.35±4.48)**	0-600	Fragment	-	(Suwartiningsih et al. 2020)
	Nemipterus japonicus	57.50 ±37.61		Film	-	
	Auxis thazard	95.65 ±38.80		Fibers	-	
	Katsuwonus pelamis	21.90±11.94		Fibers	-	
Barranglompo, Makassar, Indonesia	*Hemiramphus far*	(2,480±0.656)**	1000-5000	Line	100	(Sawalman et al. 2021)
	Siganus virgatus	(19,000±2.844)**			100	
	Lethrinus lentjan	(0,980±0.147)**			100	
Coastal of China	Coastal Fish	(0.2-17.2)*	40-5000	Fibers		(Jabeen et al. 2017)
Estuarine from the Coast of Portugal	Mussel *(Mytilus galloprovincialis)*	0.18±0.31	889.55±488.87	Fibers	44	(Pequeno et al. 2021)
	Scrobicularia plana	0.07±0.15	926.73±478.69	Fibers		
	Marphysa sanguinea	0.19±0.43	223.08±233.77	-	83	
	Trachurus trachurus	0.018±0.016	1,090±1.011	Fibers	70	
	Scomber colias	0.015±0.026	-	Fibers	55	
	Marphysa sanguinea	24±15	-			
South China	*Mugil cephalus*	7.2 items/ind.	-	Fragment	60	(Zhang et al. 2023)
Zhanjiang Mangrove Wetland		2.83±1.84 items/ind.	-	Fibers	-	(Huang et al. 2020a)
Atlantic Ocean		67.2 items/ind.	-	Fibers	-	(Mahu et al. 2023)
Northeastern Mediterranean		46.4 items/ind.	-	Fibers	-	(Kılıç and Yücel 2022)
Estuary of Minho River, Atlantic Ocean	*Mugil cephalus*	0.3±0.1	-	Fibers	-	(Guilhermino et al. 2021)
	Platichthys flesus	0.2±0.2	-	-	-	

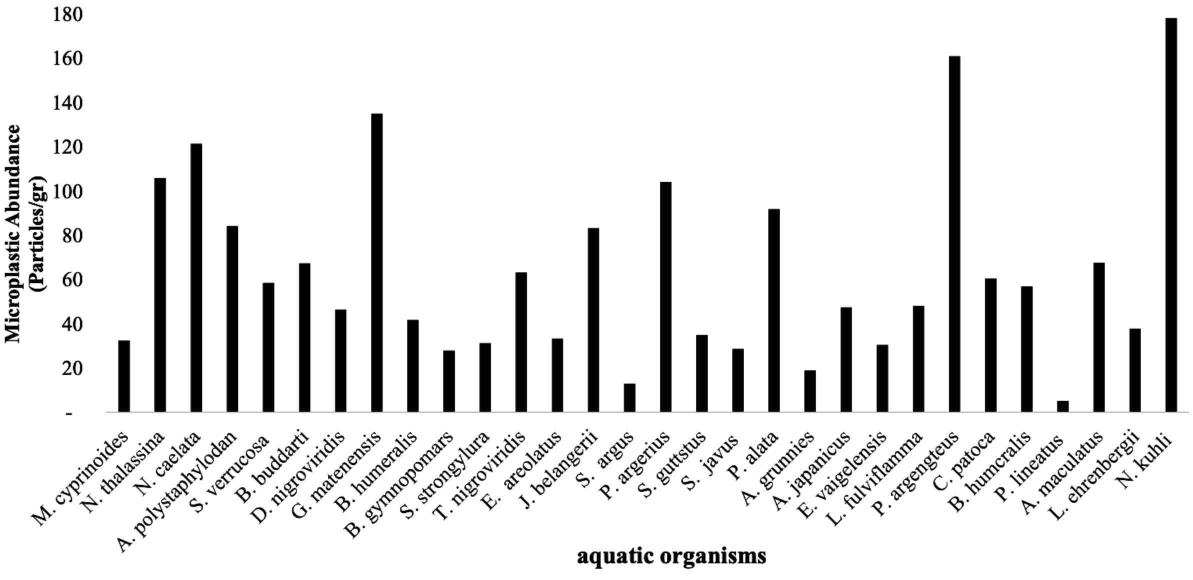

Figure 3. The abundance of microplastics in fish

Microplastic abundance in fish feeding habits

The analysis of microplastic abundance in fish based on feeding habits found that carnivorous fish species had the highest microplastic abundance, with 76.84 particles per gram (Figure 6). A one-way ANOVA revealed significant differences in microplastic ingestion among the feeding groups ($p<0.05$), with carnivorous fish showing the highest contamination levels. Post-hoc analysis indicated that omnivorous fish had significantly lower microplastic accumulation than carnivores and herbivores. The most contaminated fish species were carnivores and demersal (Figures 6 and 7), including *Epinephelus areolatus*, *Plotosus lineatus*, and *N. kuhlii*. Microplastics can enter the bodies of these fish through several possible factors, such as the consumption of prey that have already ingested microplastics (Cole et al. 2016). Demersal fish such as *E. areolatus* are exposed to microplastics through benthic feeding, as sediments serve as major sinks for microplastics because of their high density and biofilm formation (Pingki et al. 2025). Additionally, during predation, the sediment surface, which may contain microplastics, is stirred, leading to further ingestion (Wang et al. 2019; Bos et al. 2023). This sediment-bound exposure route can explain the high microplastic load in bottom-dwelling carnivores.

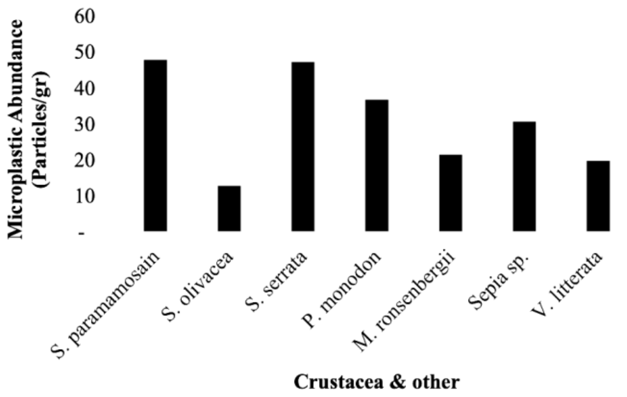

Figure 4. The abundance of microplastics in crustaceans

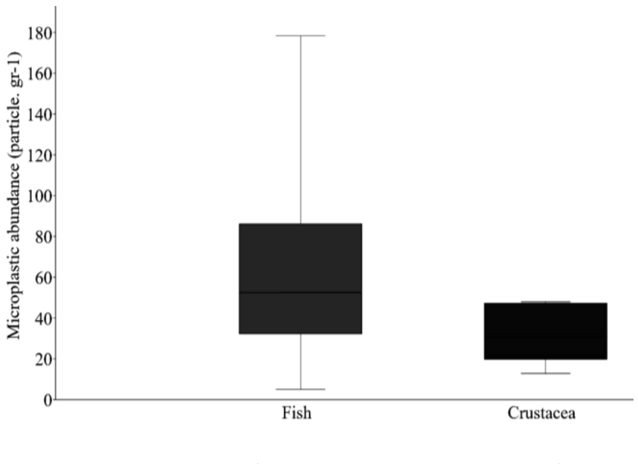

Figure 5. Comparison of microplastic abundance in fish and crustaceans

Microplastics in carnivorous fish may result from trophic transfer, in which prey organisms, including crustaceans and small fish, accumulate microplastics and pass them to higher predators (Patel et al. 2025). This process has been observed in marine food webs, where microplastic concentrations increase at higher trophic levels. Herbivorous fish had a microplastic content of 40.97 particles per gram (Figure 6). The low microplastic content in the digestive tract of these fish is likely due to their primary food source, phytoplankton, which tends to accumulate fewer microplastics than carnivorous fish, as there is no microplastic transfer from previous trophic levels (Hastuti et al. 2019). Although herbivorous fish primarily consume phytoplankton, studies have shown that microplastics can be adsorbed onto algal surfaces, leading to their ingestion by filter feeders (Ma and You 2025). The lower microplastic content in herbivores may have resulted from differential uptake efficiency rather than the absence of exposure. Carnivorous fish also have a shorter gut length than their body length because meat is easier to digest than plant fibers. The microplastic content in omnivorous fish was found to be the lowest at 46.50 particles per gram, as they consume a variety of foods, including phytoplankton, zooplankton, crustaceans, and copepods. Omnivorous fish exhibit dietary flexibility, which may reduce microplastic accumulation owing to varying feeding behaviours (Bora et al. 2025). However, differences in gut retention times between species could also influence the microplastic concentrations in the digestive tract.

FT-IR analysis of microplastic polymers

The polymer bonds identified through FT-IR testing revealed 6 types of polymers: Polypropylene (PP), Polystyrene (PS), Polyethylene (PE), Polyvinyl Chloride (PVC), Polyethylene Terephthalate (PET), and Polyamide (nylon) (Table 3). Among these, PP microplastics were found to be the most abundant in fish and crustacean samples based on FT-IR analysis. FT-IR analysis revealed that PP accounted for 29.82% of detected microplastics, making it the most abundant polymer. This was followed by PE (28.07%), PS (23.08%), and other polymers (PVC, PET, and polyamide). A one-way ANOVA confirmed significant differences in polymer abundance ($p<0.05$), with PP being significantly more prevalent than other polymers. PP is derived from materials such as ropes, bottle caps, and fishing nets. According to GESAMP (2016) and Smith et al. (2018), PP is the second most found microplastic polymer in the ocean after High-Density Polyethylene (HDPE). PP has a long recycling life, lasting 20-30 years, while PVC, also detected in the samples, has an even longer lifespan. Jung et al. (2018) stated that one type of microplastic, fiber, contains a chemical compound known as Tencel, which is used as a raw material in fabric production, including for sanitary pads and filtration materials. PS, another polymer detected, is difficult to recycle and takes a long time to degrade. PS is one of the aromatic polymers that can release styrene into food and is often used in food and beverage packaging. A significant proportion of low-density microplastics accumulate near their sources and within the top few centimeters of the water column due to local surface currents (Laiz et al. 2024).

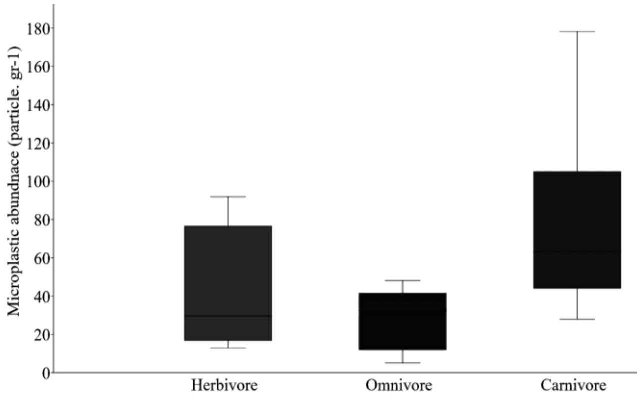

Figure 6. Microplastic abundance in fish feeding habitat

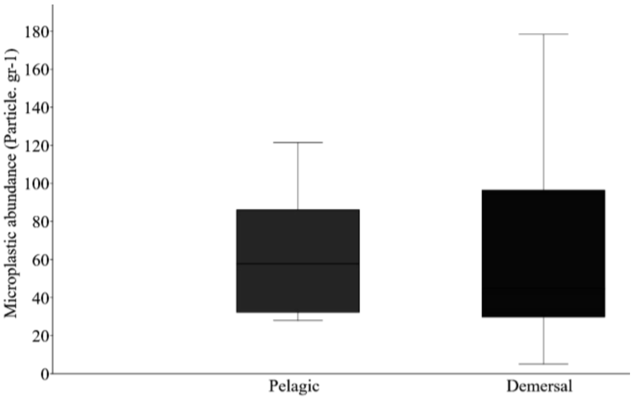

Figure 7. Microplastic abundance in fish habitat

Table 3. FT-IR analysis of fish and crustacean samples

Plastic resin	Percentage discovered	Usage/ derivatives
PVC	9.65	Films, containers, pipes
Polyethylene Terephthalate (PET/PETE)	1.75	Plastic beverage bottles
Polyamide (PA)	7.02	Nylon cloth
Polypropylene (PP)	29.82	Rope, bottle caps, nets
Polyethylene, Low Density (PE-LD/LDPE)	28.07	Plastic bags, six-pack rings, bottles, nets, straws
Polystyrene (PS)	23.68	Plastic equipment, food containers

The polyamide compound is indicated by the presence of an N-H stretch, characteristic of aliphatic primary amines, with a wavelength of 3373.5 cm^{-1} and a wavelength frequency range of 3400-3300 cm^{-1}. The nylon-charcoal composite shows the presence of an amide group (CO-NH) in the tested sample, which is attributed to the nylon thread, a polyamide that constitutes the membrane. In the membrane curve, the peak at 1637 cm^{-1} represents the main group of amides or primary amides, specifically the clear NH_2 group. Microplastics in the form of pellets typically originate from polymer types such as polyethylene, polystyrene, and polymethyl methacrylate. PS is commonly used in styrofoam, which is found in food containers, CD cases, and other products (Rathore et al. 2023).

Based on the results of this study, we conclude that aquatic organisms, both fish and crustaceans in the Belawan Estuary, have been contaminated with microplastics in their digestive tracts. Microplastics detected in the digestive tracts of aquatic organisms raise concerns about potential translocation into edible tissues. While some studies suggest limited microplastic penetration into muscle tissue (Saemi-Komsari et al. 2024), others report evidence of nanoplastic migration into fish fillets (Chang et al. 2022). Further investigation is needed to quantify microplastic bioavailability in fish meat and its implications for human exposure."

Although the health effects of microplastic ingestion in humans remain under investigation, studies suggest that plastic-associated contaminants and heavy metals could pose potential risks (Rahman et al. 2021). Further research is necessary to determine the bioavailability of these contaminants in seafood-dependent populations. Therefore, in the future, further studies are needed related to the distribution and frequency of microplastics in fish body tissue. Therefore, considering that the Belawan Estuary is one of the fishing areas in Medan City, future studies should focus on quantifying microplastic concentrations in fish fillets, assessing their bioaccumulation across trophic levels, and evaluating contamination levels in commercial fish species from the Straits of Malacca. Hence, to mitigate microplastic contamination, policymakers should enforce stricter regulations on plastic waste disposal near estuarine and marine habitats. Additionally, long-term monitoring programs should be established to assess microplastic levels in commercially important fish species. Encouraging the use of biodegradable fishing gear and sustainable aquaculture practices could also reduce plastic inputs into marine ecosystems (Goh et al. 2024).

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