

Research article

Mangrove Filters or Microplastic Traps? Insights from Microplastic Ingestion in *Polymesoda erosa* in Butuan Bay, Philippines

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Received: 18 April 2025, Revised: 25 June 2025, Accepted: 1 September 2025, Published: 1 December 2025

Abstract

Microplastic pollution threatens ecosystems, particularly in mangrove environments where complex ecological interactions occur. This study investigated the ingestion of microplastics by *Polymesoda erosa*, a mangrove-dwelling bivalve and evaluated whether mangroves function as natural filters or inadvertent traps for microplastics. A total of 135 specimens were collected from three mangrove sites along a transect in Butuan City, Philippines. Microplastics were extracted from the gastrointestinal tract and characterized by type, color, shape, and polymer composition using stereomicroscopy and ATR-FTIR analysis. The results revealed a prevalence of microplastics across all sites, with fibers being the most dominant shape and blue and black the most frequently observed colors. Statistical analysis using the Kruskal-Wallis test indicated no significant differences ($p = 0.787$) in microplastic abundance among the sampling sites. Polymer analysis identified polyethylene, polyethylene terephthalate, and ethylene-vinyl acetate among the common materials ingested. These findings suggest that mangroves may serve a dual role: acting as filters that retain microplastics while also becoming traps that expose benthic and filter-feeding organisms to microplastic contamination. However, the study is limited by the small sample size, short sampling duration, and lack of sediment MP analysis, which constrain broader ecological generalizations. Despite these constraints, the findings offer valuable insights into the role of tropical mangrove ecosystems in influencing microplastic bioavailability and microplastic accumulation that may compromise bivalve health, disrupt food webs, and pose potential risks to human consumers. This study highlights the urgent need for improved plastic waste management and further research into the long-term impacts of microplastic exposure in mangrove-associated biota.

Keywords: microplastic ingestion; *Polymesoda erosa*; mangrove ecosystems; Philippine coastal; environment

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<https://doi.org/10.55003/cast.2025.267224>

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1. Introduction

Mangrove ecosystems are dynamic intertidal habitats that thrive at the interface between terrestrial and marine environments. Found predominantly in tropical and subtropical regions, mangroves offer a suite of vital ecological services: they stabilize coastlines, attenuate wave energy, sequester atmospheric carbon, and serve as breeding, feeding, and nursery grounds for numerous aquatic and terrestrial species (Alongi, 2008). They also function as biogeochemical filters, trapping fine sediments, nutrients, heavy metals, and organic pollutants from upstream catchments before they reach open marine systems (Sultana et al., 2023). While this filtration ability underscores the ecological importance of mangroves in mitigating pollution, it simultaneously raises critical concerns in the face of emerging environmental threats, particularly the widespread proliferation of microplastics. Microplastics are plastic particles less than 5 mm in diameter that have rapidly become one of the most insidious forms of pollution in aquatic ecosystems. These particles originate from the degradation of larger plastic debris (secondary microplastics) or are directly manufactured at microscopic sizes for industrial and commercial applications (primary microplastics) (Song et al., 2024). Their small size, persistence, and ubiquity enable them to infiltrate even the most remote environments, including deep-sea sediments (Van Cauwenberghe et al., 2013), Arctic ice (Bergmann et al., 2017), and coastal wetlands (Zhang et al., 2024). Once present in the environment, microplastics can adsorb a variety of hazardous contaminants such as heavy metals, polycyclic aromatic hydrocarbons (PAHs), and persistent organic pollutants (POPs), thereby acting as vectors for toxic substances (Zhu et al., 2023).

Mangroves, because of their low-energy hydrodynamic conditions and fine-grained sediments, are highly susceptible to the accumulation of microplastics. Recent studies have confirmed the presence of microplastics in mangrove sediments in regions across Southeast Asia, including Malaysia (Tan & Zanuri, 2023), Indonesia (Lewaru et al., 2024), Thailand (Chaisanguansuk et al., 2023), and Vietnam (Dung et al., 2021). However, there is a lack of comprehensive data on how this contamination affects the fauna inhabiting these environments, particularly benthic filter-feeding organisms that constantly interact with the sediment and the water column (Sandgaard et al., 2023).

Bivalves such as clams and mussels are of special concern due to their feeding mechanisms and ecological roles. Filter feeders continuously siphon large volumes of water, extracting organic matter and inadvertently ingesting suspended pollutants, including microplastics (Khanjani et al., 2023). These organisms are not only key players in nutrient cycling and ecosystem functioning, but also form an integral part of coastal diets, raising concerns about human exposure through seafood consumption (Silva et al., 2025). Bivalves are increasingly being recognized as bioindicators for environmental pollution, especially for microplastic studies, given their sedentary lifestyle and high bioaccumulation potential (Ochoa-Esteso et al., 2024).

Polymesoda erosa, commonly known as the mud clam in some Philippine regions, is a euryhaline, sediment-burrowing bivalve species widely distributed across Southeast Asian mangrove forests (Elvira & Jumawan, 2017). It inhabits estuarine and brackish environments and plays a critical role in sediment bioturbation, organic matter recycling, and trophic interactions (Sangodkar & Gonsalves, 2024). In the Philippines, *P. erosa* is locally harvested for food and traditional medicine, making it economically and culturally significant, and though national-scale harvest data is limited, regional estimates suggest that thousands of kilograms are collected annually across Visayas and Mindanao, where mud clams are commonly sold in local markets and roadside stalls (Dolorosa & Dangan-

Galon, 2014). Its popularity as a food item, ease of collection, and consistent presence in intertidal sediments make it an ecologically and socioeconomically relevant indicator species for microplastic exposure and potential transfer to human consumers. Its close contact with mangrove sediments and ability to accumulate pollutants through filter feeding make it an ideal candidate for assessing microplastic ingestion and potential bioaccumulation risks in mangrove ecosystems (Cho et al., 2021).

Despite growing global interest in microplastics, studies focusing on mangrove-associated species in the Philippines remain limited. Most existing research has centered around microplastic contamination in marine (Osorio et al., 2021) and freshwater surface waters (Arcadio et al., 2023), beach sediments (Sajorne et al., 2022), or fish (Cabansag et al., 2021; Paler et al., 2021; Espiritu et al., 2023; Similatan et al., 2023; Felicitas et al., 2025), often in more industrialized coastal areas. Few studies have explored microplastic pollution in lesser-studied regions such as northeastern Mindanao, and even fewer have focused on benthic fauna in mangrove habitats. This data gap is particularly concerning in areas like Butuan City, which lies at the mouth of the Agusan River and is subject to increasing urbanization, waste discharge, and agricultural runoff, conditions that may significantly influence the input and retention of microplastics in mangrove environments.

Understanding the extent to which benthic invertebrates like *P. erosa* are ingesting microplastics in these systems is crucial for assessing ecological health, informing risk assessments, and shaping local environmental management strategies (Courtene-Jones et al., 2017). Additionally, evaluating the characteristics of ingested microplastics, such as their abundance, shape, color, and polymer composition, can offer insights into their potential sources and behavior in sedimentary environments.

This study aims to investigate microplastic ingestion in *Polymesoda erosa* collected from mangrove sediments in three distinct sites along a transect in Butuan City, Philippines. Specifically, the research objectives are: (1) to determine the abundance of microplastics ingested per individual clam; (2) to classify the ingested microplastics based on physical characteristics (color and shape); (3) to identify their polymer types using spectroscopic analysis and (4) evaluate whether mangroves function as natural filters or inadvertent traps for microplastics. By examining the role of mangrove environments as both natural filters and potential microplastic traps, this study contributes valuable baseline data for a region with minimal microplastic monitoring and enhances our understanding of the ecological impacts of plastic pollution in tropical estuarine systems.

2. Materials and Methods

2.1 Study area

This study was conducted in Butuan Bay, located in the province of Agusan del Norte in the northeastern region of Mindanao, Philippines. Butuan Bay forms part of the Bohol Sea (also known as the Mindanao Sea) and is recognized as a major fishing ground due to its abundant fishery resources. Sampling was conducted in three major locations: Nasipit, Buenavista, and Cabadbaran. Nasipit is situated on the northwestern portion of the bay and is notable for its major port terminal, while Buenavista and Cabadbaran host the majority of fish cages and fish pens in the province. The precise sampling stations within these areas are illustrated in Figure 1.

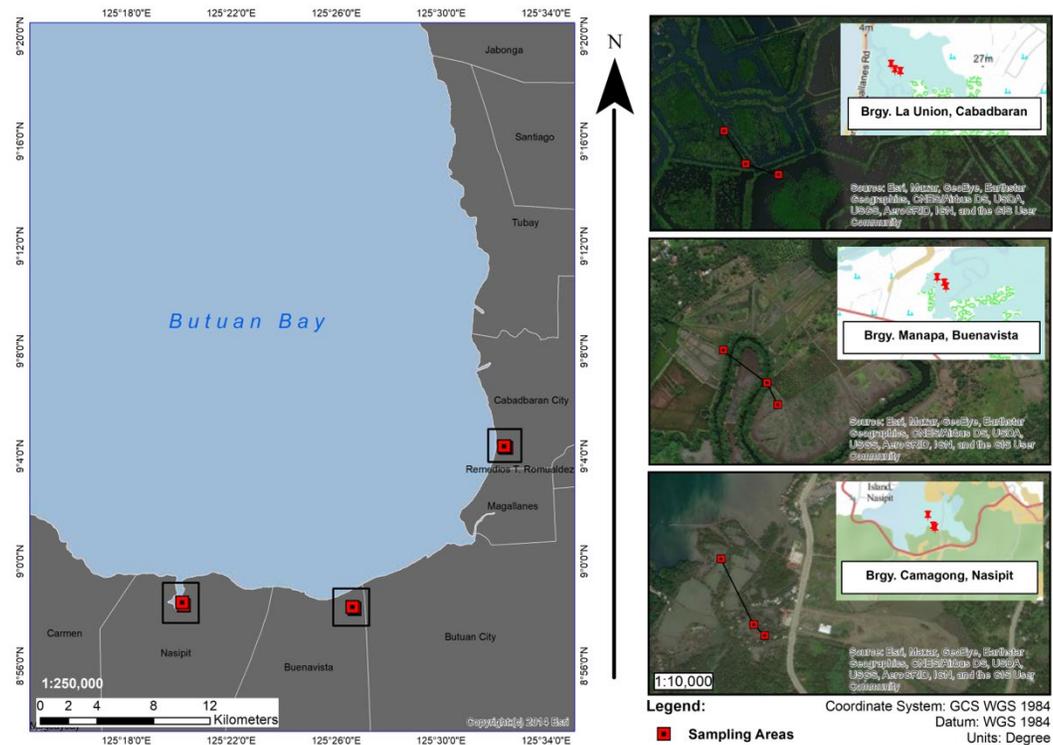


Figure 1. Geographic coordinates of the sampling sites and microplastic presence in mud clam (*Polymesoda erosa*) collected from Cabadbaran, Buenavista, and Nasipit along Butuan Bay

2.2 Sampling design and collection of bivalves

Each of the three sampling sites was subdivided into three stations, with each station having three 50-m transect lines running parallel to the shoreline. Three 10 m × 10 m quadrats were laid out along each transect at 10-m intervals. From the corners of each quadrat, adult individuals of *Polymesoda erosa* were manually collected by gleaning. A total of five individuals per quadrat were gathered, amounting to 45 individuals per site and 135 specimens overall. The average shell length and weight of the collected mud clams were 4.73 cm and 73.43 g, respectively. Specimens were immediately rinsed with ultrapure water to remove external sediments and debris, then wrapped in aluminum foil and transported to the Chemistry Laboratory of Caraga State University for further analysis.

2.3 Microplastic extraction and identification

The extraction of microplastics followed modified protocols from Similatan et al. (2023). Initially, the shell length and total weight of each mud clam were recorded. The clams were then carefully opened, and the soft tissues were pooled into 500 mL beakers based on transect lines. A 10% potassium hydroxide (KOH) solution was added to each sample in a 3:1 volume ratio (KOH: sample), and the beakers were incubated at 60°C for 48 h to facilitate tissue digestion. Following digestion, samples underwent vacuum filtration using

a millipore filtration system equipped with Whatmann GF/C glass microfiber filters (47 mm, 1.2 µm pore size). Each filter was rinsed with distilled water and dried in an oven at 60°C for 24 h. The filters were then placed in sterile petri dishes for analysis under a compound optical microscope at 40× magnification. Suspected microplastic particles were isolated, mounted on glass slides, and categorized into three types based on their morphology: fragments, films, and fibers.

To identify the polymer composition, selected particles were analyzed using Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR) (PerkinElmer Inc., Waltham, MA, USA). Spectra obtained were compared with a polymer reference library for accurate classification based on characteristic absorbance peaks, following methods from Veerasingam et al. (2021). No specific size range was used for microplastic particles in this study due to limited laboratory resources and the absence of a particle size analyzer. Identification relied on visual observation of suspected microplastics under 40× magnification using a compound microscope, which limited detection to particles large enough to be morphologically distinguishable. Future studies should employ standardized size fractionation and imaging techniques to better capture the full spectrum of plastic pollution.

2.4 Quality control measures

To ensure analytical accuracy and prevent contamination, procedural blanks were prepared using ultrapure water alongside each batch of mud clam samples (five individuals per control). During sample processing and analysis, laboratory personnel wore medical-grade masks, disposable gloves, and lab coats. For the microscopy and microplastic mounting procedures, full personal protective equipment (PPE) was utilized instead of regular lab gowns to reduce the risk of synthetic fiber contamination from clothing.

Density and composition of microplastics

Microplastic density was calculated by dividing the total number of microplastic particles observed by the number of individuals analyzed per sample, adapted from Baechler et al. (2020). The formula used is as follows:

$$\text{Density} = \frac{\text{Number of microplastics}}{\text{Number of individuals}}$$

The composition of microplastics was evaluated based on color, shape, and polymer type as observed under microscopy and confirmed through FTIR analysis.

2.5 Statistical analysis

To determine differences in microplastic concentrations between the sampling sites, we first assessed data normality using the Shapiro-Wilk test. The results indicated that both datasets were not normally distributed, justifying the use of Kruskal-Wallis test to determine significant differences between sampling sites.

3. Results and Discussion

Microplastic contamination in *Polymesoda erosa*, a species of mud clam native to mangrove ecosystems in Butuan Bay (Elvira & Jumawan, 2017), Philippines, was

assessed in this study. A total of 162 suspected microplastic particles were isolated from 135 *P. erosa* individuals collected from three sites: Buenavista, Cabadbaran, and Nasipit. After confirmation, 30 particles were identified as microplastics, yielding a prevalence of microplastic ingestion of approximately 18.5%. Among the three sampling areas, the highest concentration of microplastics was recorded in Buenavista, with 11 microplastic particles found in the clams, followed by Cabadbaran (10 particles) and Nasipit (9 particles) (Table 1). Statistical analysis using the Kruskal-Wallis test revealed no significant differences in microplastic abundance among the three locations ($p = 0.787$), suggesting a relatively uniform distribution of MP contamination within this mangrove-dominated zone. These findings suggest spatial variation in the degree of microplastic contamination within Butuan Bay, which is influenced by environmental conditions, local human activities, and pollution sources (Talbot & Chang, 2022).

Table 1. Coordinates of sampling sites and density of ingested microplastics in *P. erosa* from different across different locations

Study Area	Coordinates	Transect No.	Total no. of <i>P. erosa</i>	No. of MPs	Mean density (no. of MPs/ <i>P. erosa</i> /site)
Cabadbaran	9°4'19"N, 125°32'29" E	1	15	4	0.22±0.04
	8°4'20"N, 125°32'26" E	2	15	3	
	8°4'23"N, 125°32'24" E	3	15	3	
Buenavista	8°58'16"N, 125°26'37" E	1	15	2	0.24±0.10
	8°58'13"N, 126°26'41" E	2	15	4	
	8°58'16"N, 125°26'37" E	3	15	5	
Nasipit	8°58'19"N, 125°20'12" E	1	15	7	0.20±0.24
	8°58'20"N, 125°20'11" E	2	15	0	
	8°58'26"N, 125°20'8" E	3	15	2	
	9°4'19"N, 125°32'29" E	1	15	4	0.22±0.04

Interestingly, the microplastic density in *P. erosa* differed from the microplastic concentrations found in the sediment at the same sites. According to Navarro et al. (2022), sediment samples from Butuan Bay showed higher microplastic densities in Nasipit (71.1 microplastics/kg), followed by Buenavista (48.9 microplastics/kg), and Cabadbaran (40.0 microplastics/kg). In contrast, the present study revealed that Buenavista exhibited the highest density of microplastics per individual clam, with a mean of 0.24 microplastics per clam (Table 1). This discrepancy between sediment microplastic concentrations and those found in *P. erosa* can be explained by several factors. The increased microplastic density in Buenavista could be attributed to the longer lifespan of the clams in this region, as they are not as frequently harvested for consumption as those in Cabadbaran and Nasipit. Consequently, clams in Buenavista may have had more time to accumulate microplastics. Additionally, the type and frequency of human activities in each area, such as aquaculture and waste disposal practices, could also influence the levels of microplastic pollution in the local environment and subsequently affect the amount ingested by the bivalves. Although sampling was conducted at a single time point, this snapshot provides a clear foundation for identifying temporal patterns in future studies.

Although no published hydrodynamic models are currently available for Butuan Bay, the physical characteristics of estuarine mangrove systems including low-energy wave action, tidal flushing, and fine sediment deposition are likely to promote the accumulation and retention of microplastics within these environments. The consistent presence of microplastics across sampling sites, regardless of their proximity to specific pollution sources, suggests that these hydrological and sedimentary processes play a role in shaping contamination patterns. Understanding local water circulation and sediment transport mechanisms would greatly improve the ability to identify potential microplastic sinks, predict at-risk areas, and guide targeted monitoring and management strategies. We recommend future research to focus on developing site-specific hydrodynamic models that can inform plastic pollution mitigation in mangrove-dominated estuaries like Butuan Bay. Integrating such circulation models with plastic monitoring data could help identify hotspot zones in other mangrove areas with similar hydrological features. This would also enhance the predictive capacity of microplastic surveillance efforts, especially in regions where field sampling is limited.

Polymesoda erosa specimens from three sites in Butuan Bay, Philippines—Cabadbaran (0.22 MP/individual), Buenavista (0.24 MP/individual), and Nasipit (0.20 MP/individual)—have consistently low microplastic densities compared to bivalves studied in other parts of the world (Table 2). This trend may be attributed to several factors, including lower microplastic pollution loads in the area (Magesh & Ajith, 2024), the feeding behavior of *P. erosa* (Ward et al., 2019), or possibly the filtering characteristics of mangrove sediments (Liu et al., 2022) that may trap or sequester microplastics before they reach benthic organisms. In contrast, *Crassostrea virginica* from Florida, USA, recorded a strikingly high MP density of 16.5 particles per individual (Waite et al., 2018), while Pacific razor clams (*Siliqua patula*) and Pacific oysters (*Crassostrea gigas*) from Oregon showed ingestion rates of 8.84 and 10.95 particles/individual, respectively (Baechler et al., 2020). These values are substantially higher by nearly 40 to 80 times than those observed in *P. erosa* from Butuan Bay. The elevated microplastic levels in these U.S. samples likely reflect both the higher urban and industrial activity near their sampling locations and the more intensive filter-feeding behavior of the species studied. Meanwhile, *Mytilus edulis* and *Crassostrea gigas* from France showed intermediate MP densities of 0.36 and 0.47, respectively (Van Cauwenberghe & Janssen, 2014), while bivalves from Hong Kong and Korea registered 0.98 and 0.33, respectively (Cho et al., 2021; Lam et al., 2023). These findings indicate regional variability in microplastic exposure, which may be influenced by local waste management practices, coastal development, hydrodynamic conditions, and species-specific filtration efficiency. The relatively low MP levels in *P. erosa* do not negate the presence of pollution, but rather reflect the complex interplay between environment, species, and pollution sources, reinforcing the value of *P. erosa* as a sentinel species for future microplastic monitoring in mangrove ecosystems.

The types of microplastics identified in *P. erosa* samples included fibers, fragments, and films. Fibers were by far the most dominant type, comprising 93% of the microplastics observed (Figure 2). This is consistent with findings from other studies (Waite et al., 2018; Baechler et al., 2020), which found that fibers were the most abundant type of microplastic in marine organisms. In the context of Butuan Bay, fishing and aquaculture activities are widespread, particularly in Buenavista and Nasipit, where synthetic ropes, nets, and cage linings typically made from nylon, polyethylene, or polypropylene are commonly used. Continuous exposure to sun, wave action, and abrasion can cause these materials to degrade into microfibrils that enter the water column and sediments. The prevalence of fibers in *P. erosa* can be attributed to the widespread presence of synthetic

Table 2. Comparative microplastic densities reported in various bivalve species from different countries

Study area	Species	MP Particle/Individual	Reference
Cabadbaran, Butuan Bay, Philippines	<i>Polymesoda erosa</i>	0.22	This study
Buenavista, Butuan Bay, Philippines	<i>Polymesoda erosa</i>	0.24	This study
Nasipit, Butuan Bay, Philippines	<i>Polymesoda erosa</i>	0.20	This study
Florida, USA	<i>Crassostrea virginica</i>	16.5	(Waite et al., 2018)
Oregon, USA	Pacific razor clams (<i>Siliqua patula</i>)	8.84	(Baechler et al., 2020)
	Pacific oysters (<i>Crassostrea gigas</i>)	10.95	
France	<i>Mytilus edulis</i>	0.36	(Van Cauwenberghe & Janssen, 2014)
	<i>Crassostrea gigas</i>	0.47	
Hong Kong	Not specified	0.98	(Lam et al., 2023)
Korea	Not specified	0.33	(Cho et al., 2021)

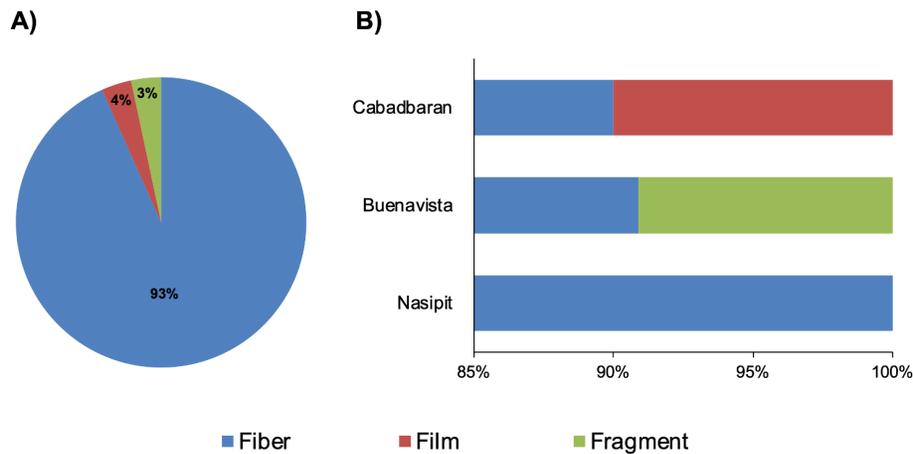


Figure 2. Mean relative abundance of ingested microplastics (MPs) by shape (A) and their and their distribution across different sampling sites (B)

textiles and plastic waste in marine environments. These fibers often originate from the breakdown of clothing, fishing nets, and other plastic materials, which enter the aquatic environment through domestic wastewater discharge, stormwater runoff, and direct littering (Browne et al., 2011). Households in the vicinity of the sampling sites often lack advanced filtration systems, and greywater from laundry, which can release thousands of synthetic microfibers per wash (Browne et al., 2011)—may enter estuarine systems untreated. The proximity of informal settlements and agricultural runoff zones in Cabadbaran may further explain the presence of plastic films and diverse fiber types observed in this site. Though there is no known textile industry in Butuan City, indirect fiber input from imported clothing, fishing gear, and urban runoff remains a probable source pathway. Furthermore, the ingestion of these fibers by *P. erosa* poses potential risks, as sharp-edged fibers may cause internal injuries to the organisms, impair their feeding mechanisms, and affect overall health (Nor & Obbard, 2014). Furthermore, fibers have been shown to carry persistent organic pollutants (POPs), which could be transferred to the clams, introducing additional chemical exposure and toxicity risks (Engler, 2012).

In addition to fibers, plastic fragments and films were also present in the samples, though they accounted for a smaller proportion of the total microplastics (Figure 2). These particles likely originated from the degradation of larger plastic debris, such as food packaging and plastic bags, which are frequently discarded into the environment and break down into smaller, more easily ingested pieces (Li et al., 2016). The fragmentation of plastics over time is a significant contributor to the increasing prevalence of microplastics in marine environments, as these particles can persist for hundreds of years, continuously polluting ecosystems (Chubarenko et al., 2016).

Although fibers were the dominant microplastic type across all sites (93% overall), subtle variations were observed in the relative abundance of fragments and films among the locations (Figure 2B). Buenavista had a slightly higher proportion of fragments, while Cabadbaran showed a more balanced presence of films and fragments compared to Nasipit. These differences may reflect varying site-specific human activities. For instance, Buenavista, known for its dense aquaculture operations, likely contributes to fragment-type plastics due to wear and breakage of equipment such as nets, ropes, and feed packaging. In contrast, Cabadbaran's proximity to residential areas and agricultural zones may account for the presence of film-like plastics, often associated with household waste, agricultural mulch, or food packaging. Meanwhile, Nasipit, a port area with shipping and transport activity, may be influenced by fishing gear and maritime debris, explaining the fiber dominance there.

In addition to human activities, environmental factors such as water circulation and sedimentation patterns could also shape these microplastic profiles. Mangrove areas with slower tidal flushing may allow more deposition of heavier film and fragment particles, while areas with greater turbulence may favor the suspension or redistribution of lightweight fibers. These distinctions reinforce the need to contextualize microplastic types not only by morphology but also by source, activity, and physical setting.

The colors of the microplastics found in *P. erosa* samples varied, with blue being the most predominant (56%), followed by black and transparent (17% each), brown (7%), and white (3%) (Figure 3A). The high proportion of blue microplastics is consistent with findings from other studies, including Baechler et al. (2020), which found that blue is a common color in marine plastic pollution. Blue microplastics are typically associated with fibers from nylon or polypropylene ropes, which are commonly used in boating and fishing activities (Chubarenko et al., 2016). The presence of black microplastics, found exclusively in the Cabadbaran and Buenavista sites (Figure 3B), may be linked to the use of black-colored fishing nets in local aquaculture. Black microplastics are often derived from the

degradation of polyethylene, a polymer commonly used in fishing gear and other industrial applications (Olam, 2023). Transparent microplastics, which are typically associated with products like plastic bags and food wrappers, were also commonly found, indicating that these materials contribute to plastic pollution in Butuan Bay. While the number of confirmed microplastics per site limits statistical extrapolation, the diversity in color and form supports the interpretation that multiple sources contribute to microplastic contamination in these mangrove systems.

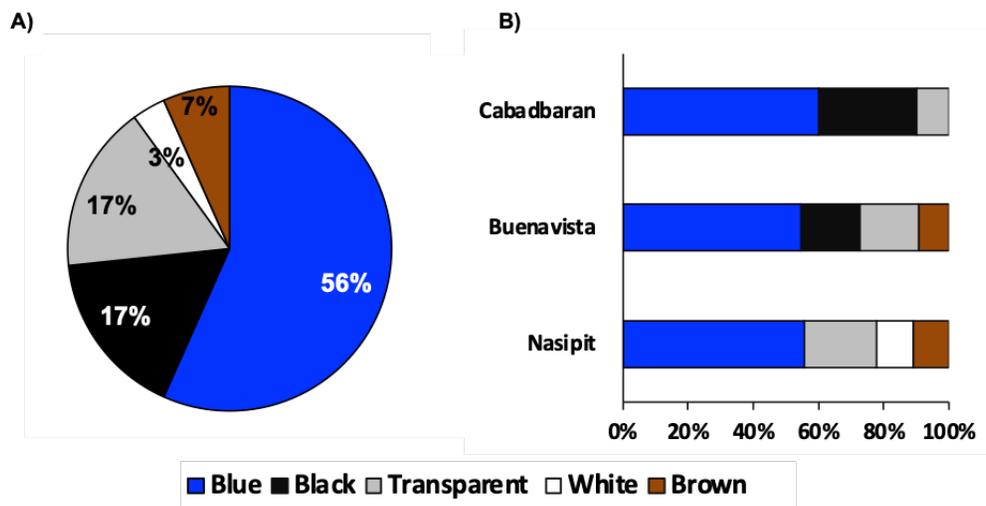


Figure 3. Mean relative abundance of ingested microplastics (MPs) categorized by color (A) and variation in color distribution across the different sampling sites.

The identification of various polymer types in the microplastic samples revealed a diverse range of plastic materials present in the environment. Seven different polymers were identified, with ethylene-vinyl acetate (EVA) being the most prevalent, comprising 34% of the microplastics (Figure 4). EVA is commonly used in products like foam slippers, plastic wrappers, and boat coatings (Molino et al., 2019). The high occurrence of EVA in the present study suggests that discarded consumer products, including footwear and plastic packaging, are significant contributors to the microplastic pollution in Butuan Bay. High-density polyethylene (HDPE), which accounted for 23% of the microplastics, is another commonly used polymer found in products such as storage containers, bottles, and food packaging (Olam, 2023). The identification of polyethylene terephthalate (PET) in the samples further highlights the widespread use of plastic packaging in local communities, as PET is commonly used in beverage bottles and food containers (Olam, 2023). Further, PET is the primary material used in polyester fabrics, which are known to shed significant quantities of microfibers during washing (Browne et al., 2011). These fibers often bypass conventional wastewater treatment systems and may enter aquatic ecosystems via untreated greywater discharge, especially in areas lacking centralized sewage infrastructure. In the case of Butuan Bay, many surrounding communities discharge domestic wastewater directly into estuarine and mangrove systems, which likely contributes to the prevalence of PET-based fibers.

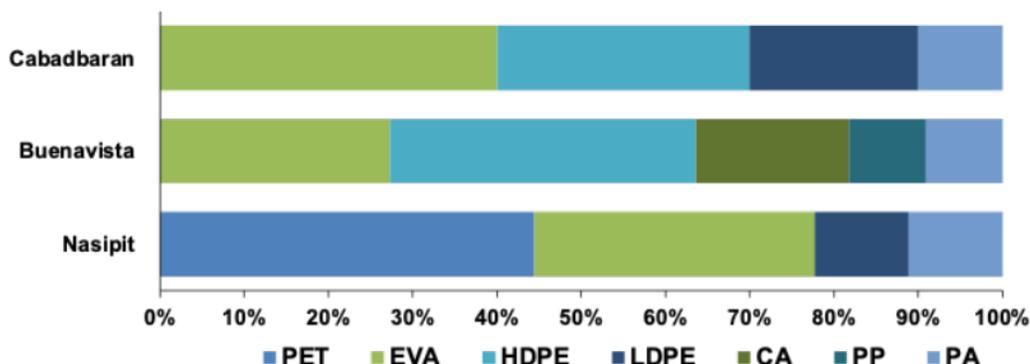


Figure 4. Polymer composition of microplastics detected in *Polymesoda erosa*: PET-polyethylene terephthalate, EVA-ethylene-vinyl acetate, HDPE-high-density polyethylene, LDPE-low-density polyethylene, CA-cellulose acetate, PP-polypropylene and PA-polyamide

This interpretation is consistent with the observed dominance of fibrous microplastics and aligns with prior studies showing that PET is frequently detected in aquatic organisms exposed to human settlements (Browne et al., 2011; Engler, 2012; Arcadio et al., 2025). Although PET is also used in food and beverage packaging, its high detection rate in this study, alongside its fibrous morphology, supports the conclusion that textile-related sources, particularly household laundry, are a significant contributor to microplastic pollution in the area. Other polymers, including low-density polyethylene, polyamide, cellulose acetate, and polypropylene, were present in smaller amounts but still contributed to the overall microplastic load found in *P. erosa* (Table 3). The use of FTIR enhanced the precision of polymer identification, though particles smaller than 20 μm , such as nanoplastics, may fall below detection thresholds. This study also highlights the importance of continued methodological advancements to explore the full spectrum of plastic pollution.

The variation in polymer types across sampling sites may be indicative of site-specific waste sources or localized discharges. Cabadbaran and Buenavista exhibited higher proportions of ethylene-vinyl acetate (EVA) and high-density polyethylene (HDPE), which are materials commonly used in aquaculture infrastructure such as floaters, netting, ropes, and foam products (Molino et al., 2019; Sharma et al., 2024). These sites host extensive fish cage operations and local aquaculture, which could be contributing EVA and HDPE into the surrounding sediments through mechanical wear, UV degradation, or discarded gear. In contrast, Nasipit, home to a major port and transport hub, was dominated by polyethylene terephthalate (PET). PET is widely used in single-use beverage bottles and packaging materials, and its prevalence in Nasipit may reflect port-related activities, cargo handling waste, or commercial urban runoff. The dominance of PET particularly in fiber form could also indicate influence from residential water discharge, as discussed earlier. The clustering of PET in this site is consistent with observations from Arcadio et al. (2025) and Browne et al. (2011), who found PET fibers to be abundant near densely populated or industrialized areas lacking advanced wastewater treatment. These spatial differences in polymer composition highlight the importance of linking microplastic pollution to land-use types, infrastructure, and human behavior. Incorporating source

tracking and polymer fingerprinting in future studies may help further clarify the relationships between plastic use patterns and environmental contamination profiles.

Ecological implications: Mangrove filters or microplastic traps?

The results of this study reinforce the paradoxical role of mangroves as both ecological filters and traps for microplastics. The consistent presence of microplastics in all *Polymesoda erosa* samples, although in low concentrations across three different sampling sites, despite no significant differences in abundance ($p = 0.787$), implies that these areas are uniformly impacted by microplastic pollution. This uniformity could indicate a widespread environmental contamination potentially influenced by tidal action, local human activities, or hydrological connectivity within the mangrove zone. As filter feeders, *P. erosa* continuously siphon large volumes of water to extract food making them highly susceptible to incidental ingestion of suspended microplastics (Fraissinet et al., 2024). The findings demonstrate that the mangrove sediment and water column in Butuan Bay are not free from plastic pollution. Though the densities were relatively low (ranging from 0.20–0.24 MP/individual), their presence in all samples across the three sites implies a widespread, if subtle, contamination. Notably, Buenavista showed slightly higher microplastic ingestion compared to Nasipit and Cabadbaran. This could be indicative of either greater retention or lower flushing capacity of that particular mangrove site, suggesting that some mangrove areas may act as microplastic sinks due to their sediment-trapping ability and limited hydrodynamic exchange (Qiao & Wang, 2024). From an ecological standpoint, this trapping function is double-edged. On one hand, mangroves may intercept and localize plastic pollutants, preventing their spread into adjacent marine environments. On the other hand, this same function increases localized exposure for benthic organisms, particularly sedentary species like *P. erosa*. Prolonged and repeated exposure to low concentrations of microplastics may accumulate over time, potentially leading to chronic effects on physiological functions such as feeding efficiency, digestive health, and reproductive success (Yin et al., 2021; Chartres et al., 2024). Furthermore, the dominance of fibers (93%)—primarily blue in color and composed mainly of EVA and HDPE—aligns with the likely sources from domestic wastewater, fishing gear, and degraded packaging materials (Sharma et al., 2024). These polymers are not only persistent but are also capable of adsorbing hazardous pollutants, including heavy metals and hydrophobic organic compounds (Zhu et al., 2023). This raises concerns about compound toxicity in *P. erosa*, where ingested microplastics could act as vectors for transferring harmful substances into their tissues. If *P. erosa* forms part of the local human diet, this introduces a potential pathway for microplastic-associated contaminants to enter the food chain. The fact that microplastics were present in all clams across all sites, despite their small quantities, suggests that mangrove areas, even in relatively undeveloped regions like Butuan, are not immune to plastic contamination. This reinforces the idea that mangrove systems serve as ecological barometers, capable of revealing early warning signs of anthropogenic impact. The relatively lower density of microplastics found in *P. erosa* compared to other bivalves in urban or industrialized areas could reflect the semi-enclosed nature of the study area or the limited plastic input due to less intense coastal development. However, even low-density pollution may become problematic over time, particularly if plastic accumulation outpaces degradation or flushing. Furthermore, the lower MP ingestion rates recorded in *P. erosa* in the current study could support the idea that mangrove habitats function as microplastic filters, at least to some extent. The dense root networks and high sedimentation rates in mangroves may help immobilize plastics before they reach bivalve habitats (Guo et al., 2025; Kesavan et al., 2025). However, this also raises concerns that

sediments may act as long-term microplastic sinks, potentially releasing these particles over time or under changing environmental conditions. It is also important to recognize that species-specific differences in feeding strategy, physiology, and habitat preferences may explain the wide variation in MP ingestion rates. For instance, mussels and oysters are known for their high filtration capacity and longer water exposure, making them more prone to ingesting suspended microplastics compared to burrowing clams like *P. erosa* that filter sediment pore water.

Beyond physical harm, microplastics can also act as vectors for hazardous contaminants. Several studies have demonstrated that plastic particles can adsorb heavy metals, persistent organic pollutants (POPs), and pathogenic bacteria from the surrounding environment (Engler, 2012; Zhu et al., 2023). The polymers detected in this study particularly EVA, HDPE, and PET are known to bind hydrophobic compounds and may serve as carriers of such contaminants into the tissues of filter-feeding organisms like *P. erosa*. This raises serious food safety concerns, especially since *P. erosa* is harvested and consumed locally, often with minimal processing. The combined ingestion of microplastics and associated toxicants may increase the risk of chemical exposure or bacterial infection for both aquatic life and human consumers. This underlines the importance of integrating microbial and chemical contaminant testing in future microplastic monitoring programs involving edible bivalves.

4. Conclusions

This study has shed light on the occurrence of microplastic ingestion in *Polymesoda erosa* collected from mangrove sediments in Butuan Bay, Philippines. The consistent presence of microplastics across all samples, despite relatively low ingestion rates, suggests that even semi-enclosed and vegetated habitats like mangroves are not insulated from plastic pollution. This finding underscores the complexity of mangrove ecosystems, which may act not only as natural filters that trap sediments and pollutants but also as inadvertent sinks for microplastics that accumulate in the benthic environment and transfer to local fauna. The detection of polymers such as EVA and HDPE in ingested particles and the predominance of fibrous forms suggest persistent contamination likely tied to household, urban, and fishing-related sources. These materials, often light and resistant to degradation, may settle in the sediment-rich mangrove beds where filter-feeding organisms like *P. erosa* reside. However, the implications of this research must be interpreted within the context of its limitations. The study employed a relatively small sample size, confined to a single sampling period, and did not include concurrent analysis of surrounding sediments or water for microplastic abundance. These constraints limit the ability to draw broader ecological conclusions or to fully capture seasonal and spatial variability in microplastic exposure. Nonetheless, the study provides valuable baseline data that can serve as a foundation for future, more comprehensive investigations. Given these findings, several actions are recommended. First, future research should expand sampling to include multiple seasons and additional bioindicator species to better understand temporal trends and the extent of microplastic contamination in mangrove ecosystems. Incorporating sediment and water analyses will also be critical in linking environmental conditions with bioaccumulation in organisms. At the local governance level, efforts should be made to strengthen community-based solid waste management in coastal areas, particularly near mangrove habitats. Public awareness campaigns that emphasize the connection between land-based waste and marine pollution could help reduce plastic leakage into aquatic systems. Finally, national conservation programs focused on blue carbon and mangrove

restoration should integrate pollution monitoring strategies to ensure that rehabilitated areas are not only ecologically productive but also resilient against emerging threats like microplastics.

This study highlights the dual role of mangroves as both ecological sanctuaries and potential pollution sinks. The findings call for a more nuanced approach to mangrove conservation, one that considers not only the ecosystem services they provide but also their capacity to accumulate and redistribute anthropogenic contaminants like microplastics. Finally, this study suggests a critical food safety dimension, that microplastics may not only affect bivalve health through ingestion but also serve as carriers of harmful substances, such as heavy metals or pathogenic bacteria. Given the local consumption of *P. erosa*, this raises potential human health risks. Integrating microbial and chemical risk assessments into future microplastic monitoring efforts is essential to evaluate the full scope of ecological and public health impacts in mangrove-associated communities. Moreover, through targeted research, community engagement, and policy integration, it is possible to protect both the integrity of mangrove ecosystems and the health of the species and people that depend on them.

5. Acknowledgements

The authors would like to thank the Department of Science and Technology—Accelerated Science and Technology Human Resource Development Program (DOST-ASTHDRP) for the financial assistance in the conduct of this study, to Caraga State University, Dr. Rey Y. Capangpangan of Research on Environment and Nanotechnology, MSU at Naawan and Mindanao State University—Iligan Institute of Technology for allowing us to conduct laboratory experiments especially in analyzing the samples polymer type.

6. Authors' Contributions

Carl Kenneth P. Navarro – performed the research, wrote the paper, designed research, analyzed data; Cris Gel Loui A. Arcadio – performed the research, wrote the paper, designed research, analyzed data; Hernando P. Bacosa – designed research, supervision, edited the paper, analyzed data.

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7. Conflicts of Interest

Authors declare no conflict of interest.

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