Bioaccumulation of microplastic in intertidal gastropods from Southern Java, Indonesia: abundance in relation feeding guild

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Abstract. Microplastic pollution has become pervasive in marine ecosystems, with the potential to bioaccumulate in marine organisms, including intertidal gastropods. Feeding behaviour may significantly influence microplastic accumulation, as different feeding strategies determine exposure pathways to microplastic particles. This study characterized microplastics and determined their abundance in intertidal gastropods while analysing the relationship between feeding guilds and microplastic accumulation. Three gastropod species representing different feeding guilds were studied: herbivores (*Nerita maxima*), carnivores (*Tylothais aculeata*), and detritivores (*Rhinoclavis sinensis*). Samples were collected from Balekambang Beach, southern Java, during low tide periods. Microplastics were extracted through tissue digestion and filtration, then characterized morphologically and polymer composition was analyzed using ATR-FTIR. Results revealed microplastics in all specimens, dominated by fragments (94.51%), followed by fibres (4.68%), with predominant particle size of 20–40 µm (41.53%) and black coloration (64.80%). Polymer analysis identified polystyrene and nylon. Microplastic abundance exhibited a clear gradient across feeding guilds: highest in detritivores (148.21 particles/g), intermediate in carnivores (143.82 particles/g), and lowest in herbivores (56.19 particles/g). These findings demonstrate that feeding ecology significantly influences microplastic bioaccumulation patterns in intertidal gastropods, with sediment-feeding detritivores exhibiting highest vulnerability to microplastic contamination.

1 Introduction

Microplastics are plastic particles smaller than 5 mm that come from the breakdown of plastic waste through physical, chemical, or biological processes [1]. Microplastic contamination can enter the environment, including intertidal marine zones. These contaminants are increasingly infiltrating marine environments, including intertidal zones, where they pose

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significant risks to marine organisms through physiological harm, disruption of organ functions, and transportation of hazardous substances [1,2]. Gastropods, abundant in intertidal ecosystems, serve crucial ecological roles as consumers and prey for higher trophic levels. The accumulation of microplastics in gastropods not only serves as an indicator of environmental pollution but also has ecological consequences due to the possibility of trophic transfer [2].

Microplastic morphology reflects origin and degradation history, with common forms including fragments, fibres, films, pellets, beads, and foam. Fragments typically derive from rigid plastics like bottles, fibres from synthetic textiles, and films from plastic bags. These morphological characteristics influence environmental distribution and biological availability [3]. Colour variations indicate source and degradation stage, with darker particles often representing aged plastics. Such characteristics affect ingestion risks, as organisms may mistake coloured particles for natural food items [4].

Feeding guild represents a critical factor determining microplastic exposure in gastropods. Herbivorous species like *Nerita maxima* graze on algae and biofilms adhering to rock surfaces, where microplastics may accumulate [5]. Carnivorous gastropods such as *Tylothais aculeata* may ingest microplastics indirectly through contaminated prey [6]. Detritivores such as *Rhinoclavis sinensis* consume organic detritus and sediments, which typically harbour high levels of microplastics [7]. Comparative analysis of microplastic accumulation across feeding guilds can therefore elucidate how trophic behaviour influences bioaccumulation patterns.

Balekambang Beach, situated along Java's southern coast, provides an ideal study site due to significant tourism activity and rich molluscan diversity within its intertidal zone [8]. This research aims to determine microplastic abundance and characteristics in intertidal gastropods and evaluate relationships between feeding guild and microplastic bioaccumulation. The findings should enhance understanding of microplastic contamination dynamics in tropical intertidal ecosystems.

2 Materials and Methods

2.1 Study Area and Sampling Period

This research was conducted at Balekambang Beach (8°24'S, 112°29'E), Bantur District, Malang Regency, East Java, Indonesia, from January to June 2025. Sample preparation and microplastic analysis were performed at the Ecology Laboratory, Department of Biology, Institut Teknologi Sepuluh Nopember (ITS). Polymer identification was conducted at the Applied Chemistry Laboratory, Department of Industrial Chemical Engineering, ITS.

2.2 Sample Collection

Gastropod samples were collected manually during spring low tides across three representative zones of the intertidal area. Samples were immediately preserved in 70% alcohol and transported to the laboratory in cooled containers. Species identification utilized shell morphological characteristics with reference to standard taxonomic guides [5,6]. Morphometric parameters, including shell length, diameter, thickness, and wet weight, were recorded for each specimen.

2.3 Microplastic Extraction and Analysis

Gastropod soft tissues were separated from shells, blotted dry, and weighed. Tissue digestion employed a 30% H_2O_2 solution (1 mL per gram tissue wet weight) with heating at 60°C until

complete digestion. The resulting solution was vacuum filtered through Whatman No. 42 filter paper (2.5 µm pore size). Microplastic particles on filters were examined under a stereo microscope (4.5× magnification) connected to an Optilab image analysis system for morphological characterization (shape, size, colour). Polymer identification of representative particles utilized ATR-FTIR spectroscopy, with spectra compared against standard polymer libraries.

2.4 Data Analysis

Microplastic abundance was calculated as particles per gram of tissue wet weight. Data were analysed descriptively and compared across species and feeding guilds to identify accumulation patterns. Statistical analysis employed one-way ANOVA to test for significant differences in microplastic abundance among feeding guilds.

3 Result and Discussion

3.1 Microplastics Characteristics

Microplastics were detected in all gastropod specimens, with fragments particles being the most prevalent morphology (94.51%). Fibers constituted 4.68% and films 0.81% of the detected microplastics, a distribution consistent with those observed in Indian Ocean surface waters [9]. These forms predominantly originate from food packaging, plastic bags, and fishing gear commonly used in coastal areas [10]. The predominant size class was 20–40 µm (41.53%), likely reflecting both environmental prevalence and gastropod ingestion selectivity, as smaller particles remain suspended longer in water columns [11]. Black particles predominated (64.80%), indicating secondary microplastics from degraded consumer products and fishing equipment [12]. ATR-FTIR analysis revealed that polystyrene and nylon were the predominant polymers. This finding aligns with findings from land-based sources, such as food containers and fishing nets [13].

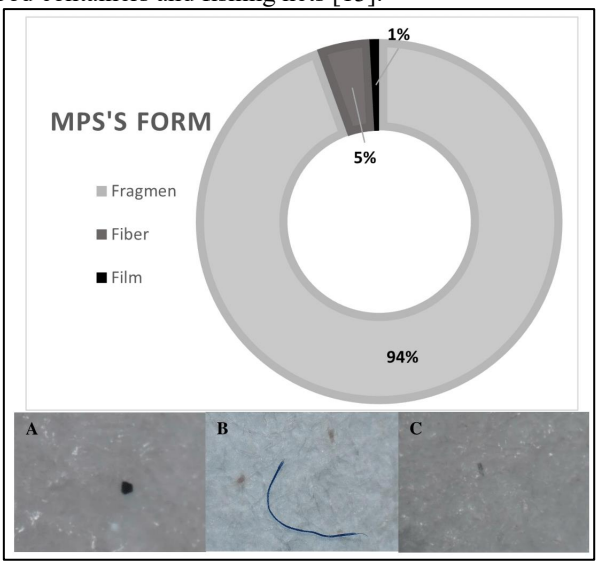

Fig. 1. Diagram of Microplastic Abundance by Shape in Three Gastropod Species from Balekambang Beach, Malang (A. Fragmen ; B. Fiber ; C. Film).

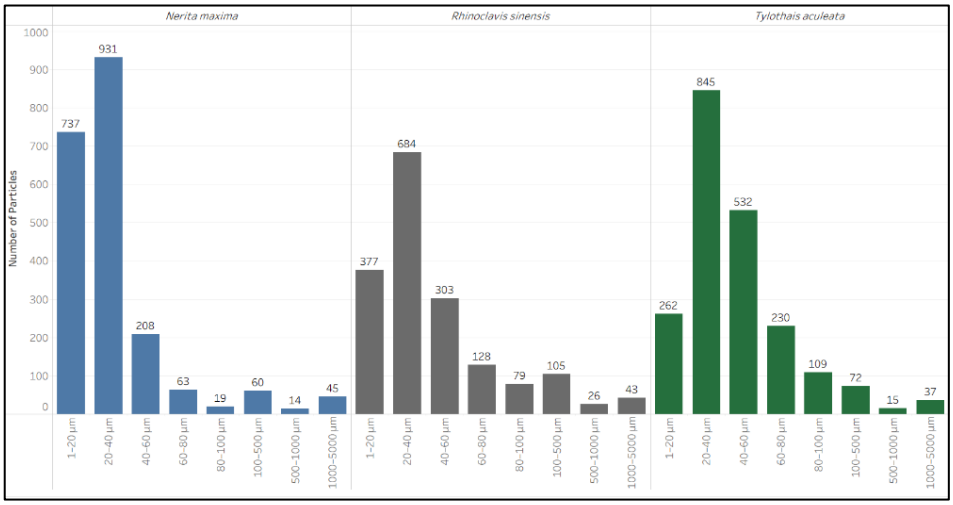

Fig. 2. Diagram of microplastic abundance by shape in three gastropod species from Balekambang Beach, Malang.

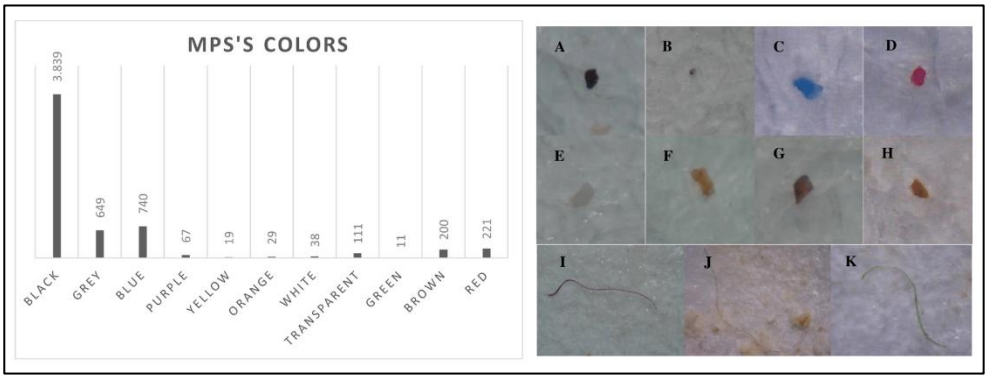

Fig. 3. Diagram of microplastic abundance by shape in three gastropod species from Balekambang Beach, Malang (A. Black; B. Grey; C. Blue; D. Red; E. White; F. Yellow; G. Brown; H. Orange; I. Purple; J. Transparent; K. Green).

3.2 Microplastics Abundance Across Feeding Guilds

Microplastic abundance demonstrated significant variation among species (one-way ANOVA, $p < 0.05$), revealing a clear gradient aligned with feeding ecology: detritivores *R. sinensis* exhibited the highest accumulation (148.21 ± 15.43 particles/g), followed by carnivorous *T. aculeata* (143.82 ± 12.67 particles/g), with herbivorous *N. maxima* showing the lowest accumulation (56.19 ± 8.24 particles/g).

3.3 Feeding Ecology as Determinant of Microplastic Accumulation

The observed abundance gradient directly reflects the feeding mechanisms and habitat utilization of each guild. Detritivores, including *R. sinensis*, feed extensively on organic matter within sediments, where microplastics preferentially accumulate due to similar particle sizes and densities [7,12]. This intimate sediment contact during feeding explains their significantly higher microplastic burdens. Carnivorous gastropods like *T. aculeata* experience dual exposure pathways: direct ingestion during substrate exploration and indirect

consumption through microplastic-contaminated prey [6,13]. This trophic transfer mechanism contributes to their intermediate accumulation levels. Herbivorous gastropods such as *N. maxima* primarily graze on epilithic biofilms, which typically contain lower microplastic concentrations than sediments [5,14]. Their more selective feeding behaviour and reduced sediment interaction result in substantially lower microplastic ingestion.

This feeding guild-dependent accumulation pattern aligns with established principles of trophic ecology, in which exposure pathways directly influence contaminant burdens [13]. The high abundance in detritivores underscores their role as ecosystem sentinels for sediment-associated contaminants. At the same time, the carnivore-herbivore differential highlights the importance of both direct and indirect exposure routes in microplastic transfer through intertidal food webs.

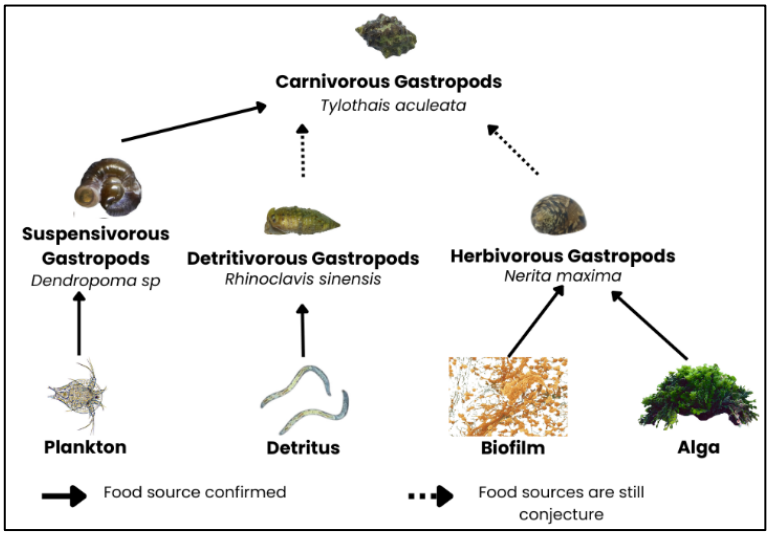

Fig. 4. Visualization of food sources and trophic chain in gastropods

Findings by [15] reinforce the notion that diet is a critical determinant of microplastic accumulation across benthic invertebrates. For example, filter-feeding organisms exhibit significantly higher microplastic loads compared to detritivorous organisms due to passive filtration of suspended particles in the water column, which increases the risk of ingestion. Conversely, detritivores and sediment feeders, despite their constant contact with sediment, exhibit greater selectivity toward organic detritus, reducing the likelihood of ingestion of non-food particles. The positive correlation between soft tissue mass and microplastic abundance also suggests that feeding rate and body size enhance accumulation potential [15].

Collectively, these findings emphasize that trophic strategy not only determines exposure pathways but also regulates the magnitude of bioaccumulation in intertidal ecosystems. Detritivores serve as key indicators of sediment-derived contamination, while differences between herbivores and carnivores reflect the balance between direct and indirect exposure pathways in the movement of microplastics across trophic levels. This supports the broader ecological concept that feeding behaviour and habitat use are major drivers of microplastic distribution in marine food webs.

4 Conclusion

This study confirms extensive microplastic contamination in intertidal gastropods from southern Java. The contaminants were predominantly fragment-shaped, black, and small-

sized (20–40 µm). Polymer analysis identified polystyrene and nylon, indicating predominantly land-based pollution sources. Most significantly, microplastic abundance demonstrated a clear feeding guild-dependent gradient: detritivores > carnivores > herbivores, establishing feeding ecology as a primary determinant of microplastic bioaccumulation. Our findings underscore the critical importance of trophic position and feeding strategies in assessing microplastic impacts in marine ecosystems. Detritivorous gastropods emerge as particularly vulnerable to microplastic contamination, warranting special conservation attention in intertidal habitats affected by plastic pollution.

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