

# Distribution and Types of Microplastics in Coastal Sediments of Sepanjang Beach

Risda Putri Indriani\*, Reza Dino Mahardika, Feni Oetari, Rusdi, Hanum Isfaeni

Master of Biology Education, Faculty of Mathematics and Science, Jakarta State University, Jakarta, Indonesia

\*Corresponding Author: [risda17putri@gmail.com](mailto:risda17putri@gmail.com)

## Article history

Received	Received in revised form	Accepted	Available online
31 January 2025	18 December 2025	18 February 2026	18 February 2026

**Abstract:** Sepanjang Beach, a popular tourist site, experiences significant plastic pollution, including microplastics, primarily introduced by visitors. This study investigates the presence and characteristics of microplastics in the digestive systems of gastropods and bivalves harvested for food and in the surrounding seawater. Sampling was conducted using purposive sampling and quadratic transects. The transect length was 50 meters, set perpendicular to the beach, with quadrant plots measuring 1x1 meters. In each plot, one individual from each species found was collected. Samples were prepared using 15 ml of 10% KOH solution and incubated overnight. Microplastics were analyzed optically using a stereo microscope at 40x magnification. The highest number of microplastics was found in the *Turbo setosus* species with 701 particles. Fibers were the most common form of microplastic found in both gastropods and bivalves, totaling 2,204 particles. Microplastics were also detected in seawater from the beach, with fibers again being the most prevalent at 553 particles.

**Keywords:** gastropods, marine environment, microplastics, plastics debris, pollution

## 1. Introduction

Plastic waste production is increasing alongside the growing use of plastic in daily life. Plastic is a material that is cheap, lightweight, durable, and resistant to corrosion. It is made from long chains of polymer molecules derived from raw materials such as carbon, silicon, hydrogen, oxygen, and chlorine [1]. Due to its durability, plastic is difficult to degrade in the environment.

According to data from the National Waste Management Information System (SIPSN) of the Ministry of Environment and Forestry (KLHK) in 2021, Indonesia generated 25,899 tons of waste per year. Of this amount, 33% was unmanageable. Plastic waste accounts for 15.4% of the total waste generated. Plastic waste has different buoyancy depending on its type. Plastic waste made from polyethylene (PE) and polypropylene (PP) floats well on water because of its good buoyancy. On the other hand, polyvinyl chloride (PVC) plastic tends to sink and settle at the bottom. It can also be carried along by water currents. Microbial activity also affects plastics by changing their physicochemical properties. This process causes the plastics to break down into smaller pieces [1]. These pieces, which measure less than 5 mm, are called microplastics [2], [3].

Microplastics are divided into two types based on their sources: primary and secondary microplastics. Primary microplastics are plastics manufactured in small sizes and are commonly found in facial cleansers, cosmetics, and toothpaste, which are generally made from polyethylene, polystyrene, and polypropylene. Secondary microplastics result from the fragmentation

of larger plastics [4]–[6]. Generally, the types of microplastics found in the ocean primarily originate from secondary microplastics [6].

Research on microplastic pollution in Indonesian waters has already been extensively conducted, particularly focusing on coastal ecosystems [7]–[9]. In the Sei Sikambing River, Medan, microplastics were found in types of polyethylene, polypropylene, and polystyrene in forms of films, fragments, granules, foams, and fibers [10]. Meanwhile, in the Progo River, Yogyakarta, up to 1173.25 microplastic particles per kilogram were discovered, while in the Opak River, there were 3729.67 particles per kilogram. The high number of microplastic particles is attributed to the confluence of Rivers Code, Gadjahwong, Oyo, and wastewater discharge from the TPA Piyungan landfill in the Opak River [11]. Additionally, another study mentioned that in Barón Beach, Yogyakarta, 53.14% of the microplastics were fibers, 36.97% were films, and 9.89% were fragments [12].

Plastic waste carried by water currents poses a threat to aquatic animals. Larger plastic debris, measuring over 5mm, can be ingested by fish, turtles, birds, and cetaceans [13]. In contrast, microplastics can be swallowed by smaller animals. When animals ingest microplastics, these particles may become lodged in their digestive tracts, be expelled in feces, or absorbed into the intestinal epithelial layers through phagocytosis. Absorbed microplastics have the potential to enter other tissues within the body [14]. Research on rodents indicates that solid polystyrene can easily transfer from the intestines to the lymphatic system, which can then enter the bloodstream and spread to other tissues [15].

Several studies have investigated the presence of microplastics in organisms. For example, 77% of anchovy samples from Tokyo Bay, Japan, contained microplastics. Among these, 52% were polyethylene and 43.3% were polypropylene [6]. In the UK, microplastics were detected in 63% of shrimp samples. This research also found that microplastics larger than 20  $\mu\text{m}$  cannot move into tissues [16]. Meanwhile, on Pramuka Island, Thousand Islands, Indonesia, microplastics in various forms (fibers, films, fragments, and granules) were present in 66.89% of snail samples and 68.72% of crab samples [4].

Given the ecological and commercial importance of mollusks and the potential human health risks posed by microplastic contamination, assessing microplastics in these organisms is critical, particularly in key areas such as Pantai Sepanjang. Mollusks contribute to nutrient cycling [17], [18] and serve ecological roles as detritivores, while also providing commercial value [19] and serving as food sources [20]. Microplastic contamination in their digestive systems poses risks to higher-level consumers through the food chain. This importance motivated research on microplastic content in mollusks at Pantai Sepanjang Yogyakarta, an area with identified microplastic pollution related to tourism and plastic waste. Studies in similar coastal areas highlight the presence and diversity of microplastics in mollusk populations and emphasize the need for continued monitoring and mitigation strategies to protect both ecosystem health and human consumers.

## 2. Materials and Methods

### 2.1. Materials

The research aims to analyze the microplastic content in the digestive system of mollusks at Sepanjang Beach, Yogyakarta, Indonesia. This study was conducted using an exploratory descriptive method. Data collection techniques involved purposive sampling and quadrant transect methods. The tools used for data collection included a measuring tape, stakes, rope, camera, and swimming equipment. After collecting the mollusks, they were identified based on morphological characteristics using field guides from various articles. Environmental parameters were measured using universal pH indicator paper, a thermometer, and a DO meter.

### 2.2. Methods

#### 2.2.1. Sample collection and preparation

Sample collection was conducted at 4 stations, each station having 4 transects, and each transect containing 5 plots. The determination of stations was based on the locations where gastropods were found on Sepanjang Beach. At each station, transects were drawn that extended 50 meters perpendicular to the shoreline.

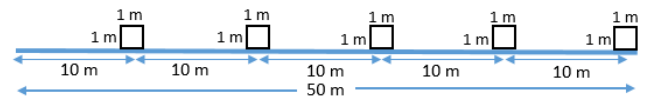


Figure 1. Plot Layout Sketch

The plot used measures 1x1 meters. The distance between plots is 10 meters. Replication is done three times. In each plot, one individual from each species found is collected and stored in a specimen bottle. The layout sketch of the plots can be seen in Figure 1.



Figure 2. Location of Each Data Collection Station

### 2.3. Experimental variable and analytical procedures

The researchers analyzed the mollusks obtained for microplastic content using protocol 1b, modified from Dehaut et al. (2016). First, they measured the length and weight of the mollusk samples. Then, they removed the mollusks from their shells and stored them in beakers. Next, they immersed the samples in 10M NaOH and incubated them at 40°C for up to 7 days at room temperature. After incubation, they added a NaCl solution to the mixture and incubated it for 24 hours to allow microplastic particles to float to the surface. They collected 20 ml of the surface solution containing the most microplastics. From this solution, the researchers performed three replicates by dripping 1 ml into each Sedgewick Rafter chamber. They observed the solutions under a light microscope at 100x magnification. They repeated this treatment with a control variable 20 ml of solution left open in the laboratory to ensure that the visible microplastics did not come from ambient air. Finally, they categorized the identified microplastics into fragments, fibers, films, and granules.

Seawater samples were collected from four different stations. Researchers filtered the samples using a 350-mesh plankton net to remove sand, plankton, and salt, preparing the seawater for testing. Each station's water was divided into two 200 ml samples. Then, 218 g of NaCl was added, followed by a 24-hour sedimentation period at 40°C. After this, researchers took 20 ml of solution from the surface and repeated observations three times. For each observation, 1 ml of solution was randomly placed in a Sedgewick Rafter chamber. Finally, the solutions were

examined under a light microscope at 100x magnification.

#### 2.4. Data Analysis

The data was analyzed using descriptive analysis by calculating the total, average, and percentage of the types of microplastics present in each species. The types of microplastics are categorized into fragments, fibers, films, and granules. This calculation is also compared with the body mass of each species.

### 3. Results and Discussion

Mollusks were found distributed across four stations at Sepanjang Beach, Yogyakarta. The types of mollusks discovered include six species, consisting of four gastropods and two bivalves. All samples were tested to determine the levels of microplastics present in the bodies of the mollusks.

Table 1. Microplastic Recapitulation in Mollusks Samples

Species	Massa (gr)	Total	Particle / gr
1. <i>Conus emaciatus</i>	54.31*	594	10.94
2. <i>Cypraea moneta</i>	6.79	575	84.68
3. <i>Cypraea lynx</i>	9.01	570	63.23
4. <i>Turbo setosus</i>	23.35	701	30.02
5. <i>Periglypta reticulata</i>	11.61	520	44.79
6. <i>Modiolus micropterus</i>	4.04	618	152.97
Total		3578	
Average		596.33	

\* Body mass with shell

Based on Table 1, it is known that the species with the highest number of microplastic particles is *Modiolus micropterus*, with 152.97 particles per gram, while the species with the lowest is *Periglypta reticulata*, with 30.02 particles per gram. The highest microplastic abundance in *Modiolus micropterus* is presumed to be due to its bodily resilience, which allows it to inhabit diverse habitats and tolerate foreign contamination, thereby causing the contaminants to accumulate and be retained within its body [21]. Furthermore, four forms of microplastic pollution were identified: fragments, fibers, and granules.

Microplastics found in mollusk samples can be categorized based on their particle shapes, which include fragments, fibers, granules, and films. Fragments are characterized as irregular pieces of plastic, while fibers are long and thin, resembling strands. Films are defined as thin and flexible microplastics that can easily conform to various shapes. In contrast, granules are small plastic beads that often originate from the breakdown of larger plastic items. This classification helps in understanding the diverse forms of microplastics present in marine ecosystems and their potential impact on mollusks health and the

broader environment.

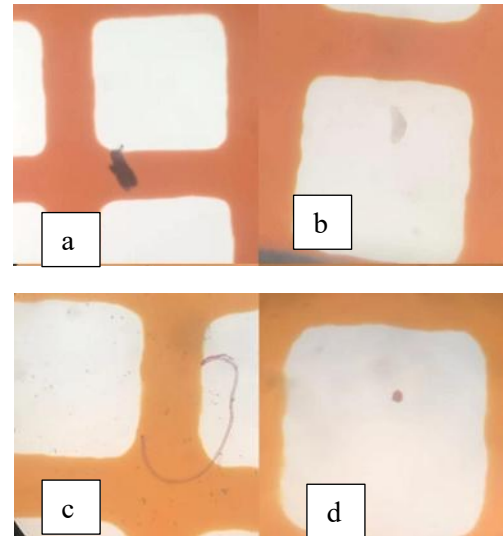


Figure 1. Various forms of microplastics. a. Fragment form, b. Film form, c. Fiber form, d. Granule form

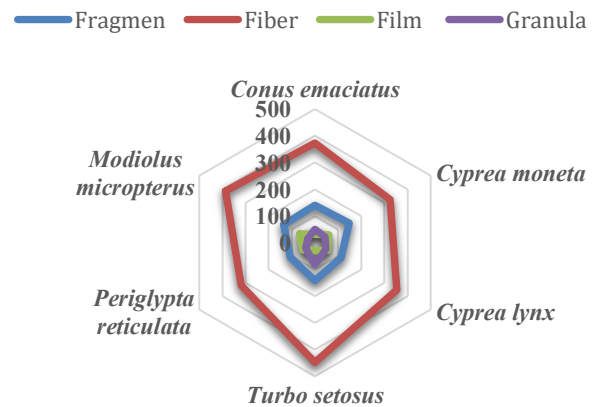


Figure 2. Graph of the number and shape of microplastic samples in mollusks.

Based on Figure 2, the most commonly found shape of microplastic particles in the mollusk samples is the fiber shape, with a total of 2,204 particles, while the least common shape is granules, with only 293 particles. The fiber-shaped microplastics were most frequently found in *Turbo setosus*, totaling 448 particles. Fibrous microplastics easily attach themselves to algae, which are a food source for *Turbo setosus* [22]. and can thus accumulate in the snail's body.

Based on Figure 3, all forms of microplastics were found in the seawater samples. The most commonly found form was fiber, with a total of 553 particles, while the least common was granule, with only 42 particles. Fiber microplastics were most abundant at Station II, with 193 particles, and least abundant at Station IV, with 83 particles. Granule microplastics were most frequently found at Station IV, with 22 particles, and were not detected at Station I.

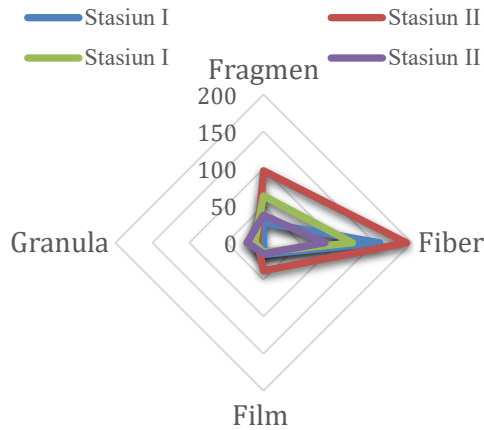


Figure 3. Graph of the number and shape of microplastics at each station.

Based on images 2 and 3, the type of microplastic most commonly found in mollusk samples and seawater samples is fiber. Fibers resemble threads or fishing nets [23]. Fiber-type microplastics have thin shapes and sizes, which often lead to their presence floating on the surface [24]. These fiber microplastics originate from washing clothes, fishing nets, industrial raw materials, household items, plastic bags designed to degrade in the environment, or from the degradation of fishing products [23]. Unlike fibre, microplastics in the form of fragments and films originate from pieces of plastic containing strong synthetic polymers, such as those found in beverage bottles and plastic food packaging that are degraded by factors such as ultraviolet radiation, mechanical forces from ocean waves, oxidative agents from plastics, and the hydrolytic properties of seawater [25]. Meanwhile, granular microplastics generally originate from factories that use plastic in beauty and hygiene products, known as microbeads [26]. Granules are microplastics in the form of fine, transparent, round particles, similar to the microbeads found in hygiene and cosmetic products [24].

The presence of microplastics in seawater may be attributed to the accumulation of plastic waste from rivers in Yogyakarta that flow into Sepanjang beach. Reports have indicated contamination in Yogyakarta's rivers, with the Progo River showing up to 1,173.25 microplastic particles/kg and the Opak River containing 3,729.67 microplastic particles/kg [11]. One of the causes of this river pollution is the incomplete waste management at the landfill site. Research has reported no significant difference in microplastic abundance in leachate water before and after treatment [27]. This indicates that water from landfill waste processing can carry microplastic particles into the rivers, subsequently leading to the pollution of seawater.

Microplastics can also spread due to currents and tides [28]. Coastal currents and wind transport can contribute to a higher distribution of microplastics near

the coast. The lack of proper plastic management (incomplete burning, unplanned incineration, dumping, etc.) can be a major cause of the transportation of microplastics and their relatively high abundance on beaches [29]. Additionally, the larger the biota, the more microplastics are found within that biota [23].

Mollusks, particularly shellfish, are filter feeders, meaning they absorb food found in seawater. Initially, microplastics enter through the gills and are transported by cilia to the labial palps for selection. The results of this selection are then passed to the digestive organs. If microplastics are found in the digestive organs, their size is typically less than 1500  $\mu\text{m}$  [30]. If the microplastics are larger than this, they are likely only attached to the gills [31]. Once microplastics are in the digestive organs, they can be excreted in feces or absorbed into the intestinal epithelial layer through phagocytosis. One study on the mussel *M. edulis* showed that polystyrene microplastics could move from the intestine to the hemolymph within three days [32]. Additionally, microplastics can carry heavy metals such as Pb, Cr, Cu, Cd, Ni, and Co. Large accumulations of microplastics in the digestive tract can hinder nutrient absorption [32].

Microplastics in gastropods enter through the food consumed, such as contaminated microalgae and zooplankton [4]. The small size of microplastics makes them difficult to distinguish from their food sources, allowing gastropods to ingest these particles [33]. In fact, *L. stagnalis* can swallow microplastics up to 90  $\mu\text{m}$  in size [34]. High accumulation of microplastics in gastropods poses risks to their health, including carcinogenic effects and hormonal imbalances [32]. However, some gastropods can adapt to the presence of microplastics. For instance, *L. stagnalis* has the ability to select digestible food, enabling it to expel microplastics along with its feces [34]. This mechanism helps reduce microplastic accumulation in the digestive system of *L. stagnalis*.

The presence of microplastics in seawater, Bivalvia, and Gastropoda affects humans. Some Bivalvia and Gastropoda are common foods consumed, allowing microplastics to inadvertently enter the human body [35]. Research indicates the presence of microplastics, specifically polypropylene and polyethylene terephthalate, in human feces. The estimated annual intake of microplastics by humans ranges up to 11,000 particles from shellfish, 1,000 particles from salt, and 5,800 particles from tap water; additionally, microplastics can also originate from food processing, packaging, and airborne microplastics [36]. The accumulation of microplastics in the human body has the potential to cause health disturbances. At the cellular level, microplastics can increase oxidative stress in brain cells and epithelial cells, as well as enhance cytokine and histamine production [35]. The impacts of microplastics at the

tissue and organ levels remain significantly unknown; therefore, further research is needed to understand these effects.

#### 4. Conclusion

The conclusion of this study is that gastropods and bivalves found on Sepanjang Beach, Gunungkidul, Yogyakarta, are contaminated with microplastics. Microplastics found on the bodies of gastropods and molluscs are in the form of fibres, fragments, films, and granules. Microplastics were also detected in the seawater at this beach. Contamination of gastropods, bivalves, and seawater has the potential to harm ecosystems and humans.

#### Acknowledgement

A gratitude to Dr. rer. nat. Mufti Petala Patria, M.Sc and the team from Universitas Indonesia for allowing and assisting the researchers in identifying the types of microplastics found in the specimens. Researches also grateful to Universitas Gadjah Mada for their support during our time at Pantai Sepanjang Yogyakarta.

#### References

- [1] J. A. Ivar do Sul and M. F. Costa, "The present and future of microplastic pollution in the marine environment," *Environ. Pollut.*, vol. 185, pp. 352–364, 2014, doi: 10.1016/j.envpol.2013.10.036.
- [2] V. Griet *et al.*, "A critical view on microplastic quantification in aquatic organisms," *Elsevier Environ. Reseach*, no. 2014, 2015, doi: 10.1016/j.envres.2015.07.016.
- [3] L. Van Cauwenberghe, A. Vanreusel, J. Mees, and C. R. Janssen, "Microplastic pollution in deep-sea sediments," *Environ. Pollut.*, vol. 182, pp. 495–499, 2013, doi: 10.1016/j.envpol.2013.08.013.
- [4] M. P. Patria, C. A. Santoso, and N. Tsubita, "Microplastic Ingestion by Periwinkle Snail *Littoraria scabra* and Mangrove Crab *Metopograpsus quadridentata* in Pramuka Island, Jakarta Bay, Indonesia," *Sains Malaysiana*, vol. 49, no. 9, pp. 2151–2158, 2020.
- [5] W. . Shim, S. . Hong, and S. Eo, "Identifications methods in microplastic analysis: A review," *R. Soc. Chem.*, 2016, doi: 10.1039/C6AY02558G.
- [6] K. Tanaka and H. Takada, "Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters," *Nat. Publ. Gr.*, vol. 6, no. September, pp. 1–8, 2016, doi: 10.1038/srep34351.
- [7] V. Priscilla, A. Sedayu, and M. P. Patria, "Microplastic abundance in the water, seagrass, and sea hare *Dolabella auricularia* in Pramuka Island, Seribu Islands, Jakarta Bay, Indonesia," *J. Phys. Conf. Ser.*, vol. 1402, no. 3, 2019, doi: 10.1088/1742-6596/1402/3/033073.
- [8] N. H. F. Rahmawati and M. P. Patria, "Microplastics Dissemination from Fish *Mugil dussumieri* and Mangrove Water of Muara Teluknaga, Tangerang, Banten," *J. Phys. Conf. Ser.*, vol. 1282, no. 1, 2019, doi: 10.1088/1742-6596/1282/1/012104.
- [9] S. Fitri and M. P. Patria, "Microplastic contamination on *Anadara granosa* Linnaeus 1758 in Pangkal Babu mangrove forest area, Tanjung Jabung Barat district, Jambi," *J. Phys. Conf. Ser.*, vol. 1282, no. 1, 2019, doi: 10.1088/1742-6596/1282/1/012109.
- [10] N. Harpah, I. Suryati, R. Leonardo, A. Risky, P. Angeng, and R. Addauwiyah, "Analisa jenis, bentuk dan kelimpahan mikroplastik di sungai sei sikambang medan," *J. Sains dan Teknol.*, vol. 20, no. 2, 2020, doi: 10.36275/stsp.v20i2.270.
- [11] I. Utami, K. Resdianningsih, and S. Rahmawati, "Temuan Mikroplastik pada Sedimen Sungai Progo dan Sungai Opak Kabupaten Bantul," *J. Ris. Drh.*, vol. XXII, no. 1, 2022.
- [12] N. Suwartiningsih, I. Setyowati, and R. Astuti, "Microplastics in pelagic and demersal fishes of Pantai Baron, Yogyakarta, Indonesia," *J. Biodjati*, vol. 5, no. 1, pp. 33–49, 2020, doi: 10.15575/biodjati.v5i1.7768.
- [13] J. G. . Derraik, "The pollution of the marine environment by plastic debris: a review," *Mar. Pollut. Bull.*, vol. 44, pp. 842–852, 2002.
- [14] N. Hussain, V. Jaitley, and A. T. Florence, "Recent advances in the understanding of uptake of microparticulates across the gastrointestinal lymphatics," *Elsevier Adv. Drug Deliv. Rev.*, vol. 50, pp. 107–142, 2001.
- [15] M. A. Browne, T. Galloway, R. Thompson, and P. M. Chapman, "Microplastic - An emerging contaminant of potential concern," *Integr. Environ. Assesment Manag.*, vol. 3, no. 4, pp. 2004–2006, 2007.
- [16] L. I. Devriese *et al.*, "Microplastic contamination in brown shrimp (*Crangon crangon*, Linnaeus 1758) from coastal waters of the Southern North Sea and Channel area," *Mar. Pollut. Bull.*, vol. 98, no. 1–2, pp. 179–187, 2015, doi: 10.1016/j.marpolbul.2015.06.051.
- [17] M. Persulesy and I. Arini, "Keanekaragaman Jenis Dan Kepadatan Gastropoda Di Berbagai Substrat Berkarang Di Perairan Pantai Tihunitu Kecamatan Pulau Haruku Kabupaten Maluku Tengah," *Biopendix J. Biol. Pendidik. dan Terap.*, vol. 5, no. 1, pp. 45–52, 2019, doi: 10.30598/biopendixvol5issue1page45-52.
- [18] B. Mardika, S. Utami, and J. Widiyanto, "Identifikasi Keanekaragaman Gastropoda Sebagai Bioindikator Kualitas Air Sungai Nogosari Pacitan," in *Prosiding Seminar SIMBIOSIS V*, 2020, pp. 349–357, [Online]. Available: <http://prosiding.unipma.ac.id/index.php/simbios>

- is/article/viewFile/1777/1518.
- [19] H. Hartati, N. Azmin, M. Nasir, and M. Yulianti, "Inventarisasi Keanekaragaman Gastropoda Dikawasan Mangrove Desa Wilamaci Kecamatan Monta Kabupaten Bima," *Oryza ( J. Pendidik. Biol. )*, vol. 11, no. 1, pp. 1–6, 2022, doi: 10.33627/oz.v11i1.691.
- [20] A. Andrimida, "Inventarisasi Berilustrasi Siput Laut (Gastropoda: Heterobranchia) Di Selat Sempu, Indonesia," *Biotropika J. Trop. Biol.*, vol. 9, no. 3, pp. 190–202, 2021, doi: 10.21776/ub.biotropika.2021.009.03.03.
- [21] I. B. Wahyono, Muslim, H. Suseno, C. A. Suryono, and A. Pujiyanto, "Bioaccumulation of zinc by *Portunus pelagicus*: Nuclear application techniques that use radiotracer  $^{65}\text{Zn}$  to study influence of concentration of Zn in seawater," *Marit. Technol. Res.*, vol. 6, no. 1, pp. 1–12, 2024, doi: <https://doi.org/10.33175/mtr.2024.266903>.
- [22] R. Romolo and I. Auliya, "Food Preference , Fecundity , Proximate Analysis on Eggs and Meat of *Turbo crassus* (W . Wood 1828) and *Turbo setosus* (Gmelin 1791) in Sepanjang Beach , Gunungkidul , Special Region of Yogyakarta," *J. Trop. Biodivers. Biotechnol.*, vol. 06, no. 02, pp. 1–13, 2021, doi: 10.22146/jtbb.61873.
- [23] S. N. Fitria, V. Anggraeni, I. W. Abida, and A. S. Junaedi, "Identifikasi Mikroplastik pada Gastropoda di Sungai Brantas," *Environ. Pollut. J.*, vol. 1, no. 2, pp. 159–166, 2021.
- [24] D. Purnama *et al.*, "ANALISIS MIKROPLASTIK PADA SALURAN PENCERNAAN IKAN TONGKOL (*Euthynnus affinis*) HASIL TANGKAPAN NELAYAN DI PELABUHAN PERIKANAN PULAU BAAI KOTA BENGKULU," *J. Enggano*, vol. 6, no. 1, pp. 110–124, 2021.
- [25] H. Hiwari, N. P. Purba, Y. N. Ihsan, L. P. S. Yuliadi, and P. G. Mulyani, "Kondisi sampah mikroplastik di permukaan air laut sekitar Kupang dan Rote , Provinsi Nusa Tenggara Timur Condition of microplastic garbage in sea surface water at around Kupang and Rote , East Nusa Tenggara Province," vol. 5, pp. 165–171, 2019, doi: 10.13057/psnmbi/m050204.
- [26] O. Bajt, "From plastics to microplastics and organisms," *FEBS Open Bio*, vol. 11, no. 4, pp. 954–966, 2021, doi: 10.1002/2211-5463.13120.
- [27] I. Utami and Agustina, "Deteksi Pencemaran Mikroplastik pada Air Lindi di TPA Piyungan Yogyakarta Indonesia," *Florea J. Biol. dan Pembelajarannya*, vol. 9(1), no. 22 May 2022, pp. 24–32, 2022, [Online]. Available: <http://e-journal.unipma.ac.id/index.php/JF/article/view/11907>.
- [28] L. Weiss *et al.*, "From source to sink: part 2—seasonal dispersion of microplastics discharged in the NW Mediterranean Sea by the Rhone River in southern France," *Environ. Sci. Pollut. Res.*, 2024, doi: 10.1007/s11356-024-35364-6.
- [29] D. H. Nainggolan, A. Indarjo, and C. A. Suryono, "Mikroplastik yang Ditemukan di Perairan Karangjahe , Rembang , Jawa Tengah," *J. Mar. Res.*, vol. 11, no. 3, pp. 374–382, 2022.
- [30] B. De Witte *et al.*, "Quality assessment of the blue mussel (*Mytilus edulis*): Comparison between commercial and wild types," *Mar. Pollut. Bull.*, vol. 85, no. 1, pp. 146–155, 2014, doi: 10.1016/j.marpolbul.2014.06.006.
- [31] Z. Rahim, N. P. Zamani, and M. S. Ismet, "Kontaminasi Mikroplastik pada *Perna viridis* di Teluk Lampung," *J. Kelaut. Trop.*, vol. 25, no. 1, pp. 48–56, 2022, doi: 10.14710/jkt.v25i1.12722.
- [32] M. A. Browne, S. J. Niven, T. S. Galloway, S. J. Rowland, and R. C. Thompson, "Report Microplastic Moves Pollutants and Additives to Worms , Reducing Functions Linked to Health and Biodiversity," *Curr. Biol.*, vol. 23, no. 23, pp. 2388–2392, 2013, doi: 10.1016/j.cub.2013.10.012.
- [33] M. A. Browne *et al.*, "Accumulation of microplastic on shorelines worldwide: Sources and sinks," *Environ. Sci. Technol.*, vol. 45, no. 21, pp. 9175–9179, 2011, doi: 10.1021/es201811s.
- [34] A. Weber *et al.*, "Ingestion and toxicity of microplastics in the freshwater gastropod *Lymnaea stagnalis*: No microplastic-induced effects alone or in combination with copper," *Chemosphere*, vol. 263, 2021, doi: 10.1016/j.chemosphere.2020.128040.
- [35] K. Blackburn and D. Green, "The potential effects of microplastics on human health: What is known and what is unknown," *Ambio*, vol. 51, no. 3, pp. 518–530, 2022, doi: 10.1007/s13280-021-01589-9.
- [36] P. Schwabl *et al.*, "Detection of various microplastics in human stool: A prospective case series," *Ann. Intern. Med.*, vol. 171, no. 7, pp. 453–457, 2019, doi: 10.7326/M19-0618.