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RESEARCH ARTICLE

THE ABUNDANCE OF MICROPLASTICS IN THE DIGESTIVE SYSTEM OF SILVER BARB (*Barbonymus gonionotus*) FROM THE WATERS OF THE KARANG MUMUS RIVER, SAMARINDA CITY, INDONESIA

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ABSTRACT

The intensive use of plastic materials worldwide has raised concerns about microplastic pollution which is ubiquitous in aquatic environments around the world and can negatively impact aquatic biota. There are, however, many unknowns about pollutant quantities and interactions with biota, especially in developing regions of the globe. The purpose of this study was to investigate the abundance and types of microplastics consumed by fish and to determine the relationship between fish size and microplastic consumption. In this study, we examined silver barb (*Barbonymus gonionotus*) (*n=20*) sampled from Karang Mumus River, Samarinda City, East Kalimantan, Indonesia. Samples were obtained from a fisherman who were fishing with passive fishing gears along the Karang Mumus River. The length and weight of the fish were measured, and then the separated organs of the digestive system were then processed for microplastic content analysis: dissolving organic matter (digestive process) using *potassium hydroxide* (KOH) solution, leaving only non-organic material, including microplastics, then observed under a stereo microscope. We enumerated and identified types of microplastics encountered. Microplastic particles were found in all silver barb samples. The results of this investigation found an average microplastic abundance of 22.40 (SE: 2.5) per fish. Fiber microplastic particles were the most prevalent, comprising 70% of the total, with film microplastics accounting for 26%, and fragment microplastics making up the remaining 4%. The results of a linear model showed that there was a positive relationship between total length (*p-value* <0.06) and wet weight (*p-value* <0.07) of silver barb on the abundance of microplastic particles per individual fish, but both relationships were not significant. This study provides the first evidence of microplastic consumption by fish in the Karang Mumus River, which also indicates the potential for microplastic content in the water column, sediment, and interactions to and impacts on aquatic biota.

KEYWORDS

Water pollution monitoring, Borneo, Kalimantan, fish, lentic, tawes, Karang Mumus

1. INTRODUCTION

Inadequate waste management has and continues to represent a threat to global environmental sustainability. Among the myriad types of waste plaguing our ecosystems, plastic waste stands out due to its ubiquitous and persistent nature. In the year 2017 alone, there was a staggering production of approximately 8,300 million metric tons of plastic worldwide (Geyer et al., 2017; Worm et al., 2017). Much of this plastic eventually ends up in aquatic ecosystems, both marine and freshwater (Laskar and Kumar, 2019). Aquatic ecosystems suffer disproportionately to terrestrial ecosystems, as they typically serve as a sink for these pollutants with plastic constituting a staggering 70% of the total waste composition in water bodies (Galgani et al., 2015).

Primary sources of microplastics in aquatic environments come from intentionally produced plastic particles that fall into the microplastic category. Examples include plastic pellets used as raw materials in the production of plastic products or plastic microbeads commonly added to personal care products (Karlsson et al., 2018; Miraj et al., 2021). Although plastic materials are durable and not easily degradable, over time weathering and oxidation processes can cause plastic waste to fragment into smaller sizes, forming secondary plastic debris. When plastic particles are smaller than <5 mm, they are classified as microplastics (Agamuthu et al., 2019). Urban runoff and sewage are responsible for transporting both macro and microplastics into water bodies, where these materials further degrade through a combination of physical, biological, and chemical processes (Wu et al., 2017).

Microplastic particles have the potential to be ingested or consumed by aquatic organisms, including fish (Horton et al., 2018; Park et al., 2020; Chen et al., 2022). The shape and size of microplastics often mimic natural prey increasing the chances for consumption by aquatic biota. Concerns arise because microplastics in aquatic environments have been shown to serve as vectors for the transfer of various harmful chemicals and pathogenic organisms (Issac and Kandasubramanian, 2021). Furthermore, during digestion, additives in these plastic polymers can be released and can have negative effects on aquatic organisms including disruptions to feeding patterns and to reproduction (Sussarellu et al., 2016; Wang et al., 2020). Aquatic biota, especially fish, also for a large percentage of human diets worldwide (Belton et al., 2018), and there is concern that plastics transferred and accumulated through such trophic interactions can result in human health impacts (Makhdoumi et al., 2023).

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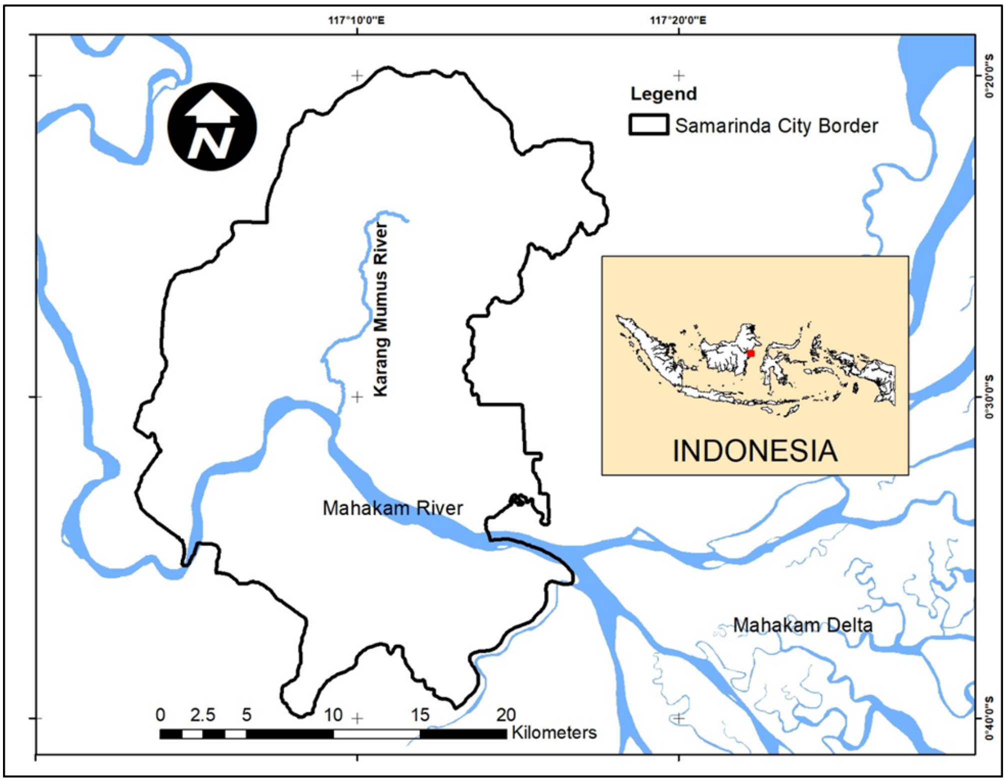

Figure 1: Map of Karang Mumus River in the Samarinda City, East Kalimantan, Indonesia

The Karang Mumus River, as an urban river in the city of Samarinda (Figure 1), faces similar challenges to many other urban rivers worldwide, including plastic pollution (Suharko & Kusumadewi, 2019). The deposition of plastic waste that occurs in the Karang Mumus River raises concerns about the potential presence of microplastic pollution in this ecosystem. However, to date, there have been no published studies that have observed the presence of microplastics in aquatic biota from the Karang Mumus River.

Figure 2: A silver barb of the Karang Mumus River

Fish are an important component of Indonesian human diets, and fishing and aquaculture provide large economic value (Sari and Muslimah, 2020). One of the fish species commonly found in parts of Indonesia is the silver barb (*Barbonymus gonionotus*) (Figure 2) locally known as "tawes" in Indonesian Language. This fish, a member of the Cyprinidae family, is often cultivated due to its relative ease of production and relatively high market value. Silver Barb are generally known as an omnivorous fish but are reported to have a preference for aquatic plants and plankton (Das et al., 2018). Recent research findings have documented the role of aquatic plants and algae in the accumulation and dispersion of microplastics in aquatic environments (Ceschin et al., 2023; Huang et al., 2023). As a result of this pathway, there is potential for microplastic consumption and accumulation in silver barb.

There have been no previously published studies on microplastic consumption by silver barb anywhere in Indonesia. Therefore, we addressed this knowledge gap with this analysis from silver barb in the Karang Mumus River in East Kalimantan Province, Indonesia. Specifically, the objective of this study was 1) to identify the types and abundance of microplastics in the digestive system of silver barb living in the Karang Mumus River and 2) determine if there was a relationship between the size of silver barb and microplastic consumption. This research serves as an initial reference point regarding microplastic consumption by silver barb in Indonesia.

2. METHODOLOGY

2.1 Study Location Description

The Karang Mumus River flows through Samarinda City, which serves as the capital of East Kalimantan Province, Indonesia. The total catchment area of this river is estimated to be approximately 32,196.3 hectares (Pujowati et al., 2010). The upper part of the river includes the reservoir of Waduk Benanga, which the water is supplied by small rivers in its vicinity. The lower section of the river is where it converges with the Mahakam River before ultimately reaching the ocean. The length is estimated to be approximately 18 kilometers (calculated using ArcGIS). The Karang Mumus River flows through densely populated areas, including the campus of Mulawarman University and the largest traditional central market in Samarinda City. The density of Samarinda City population in the year of 2020 has reached of 1,163 people /km^2 (Central Agency of Statistics, 2021). Samarinda City is heavily urbanized along the river corridor (Figure 3), likely increasing plastic pollution in these downstream reaches.

Figure 3: Karang Mumus River at urban stretch

2.2 Sampling

Silver barb were obtained by procuring fish caught by one local fisherman, who was actively fishing along the Karang Mumus River in Samarinda City. A total of 20 individual of silver barb were collected on the October 2nd

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2022. This fisherman used a passive gear type known locally as "tampirai" to catch the fish. Traditionally, tampirai is constructed from either bamboo or rattan and functions similarly to hoop nets with an opening that allows fish to enter but is difficult for fish to exit (Mardhiyah et al., 2022). Subsequently, the collected fish samples were packed in a cooler for transport to the Water Quality Laboratory-Mulawarman University.

2.3 Sample Analyses

In the laboratory, the collected silver barbs were measured for their total length (cm) and wet weight (g). Subsequently, each fish sample was dissected to retrieve their digestive organs, from the esophagus to the intestine near the anus. These digestive organs were then stored in a freezer for 1 week before subsequent lab analyses. Each sample of the digestive system was further processed to remove organic matter, leaving behind non-organic materials, including microplastics. This process was carried out using a 10% KOH (potassium hydroxide) solution and H_2O_2 (hydrogen peroxide), following the protocol detailed by (Stock et al., 2019; Filgueiras et al., 2020). The samples were oven-heated to 60°C for 24 hours to accelerate decomposition. Subsequently, the solution resulting from the organic matter decomposition process was filtered using filter paper (Whatman brand; pore size 20-25 µm) using a liquid vacuum pump. Particles retained on the filter paper were then observed using a stereo dissecting microscope with magnifications ranging from 10-45×. The identification of microplastic types in this study followed the protocols from (Eppehimer et al., 2021; Hidalgo-Ruiz et al., 2012), and observed microplastics were categorized into four major types: fiber, fragment, film, and bead (Helm, 2017). As part of quality control efforts, we took measures to minimize the contamination of samples from airborne microplastic deposition. All equipment used was cleaned with distilled water pre and post analysis. During preparation and observation, glass beakers and aluminum cups (used as containers for filter paper) were always covered with aluminum foil when not in use, and all investigators wore white 100% cotton clothing. All of these processes were conducted inside a closed building to minimize external contamination.

We analyzed the data using a linear model in STATA Version 15.1 (StataCorp, College Station, TX, USA) with alpha of 0.05 as threshold for significance to determine the relationship between total length, wet weight, and microplastic consumption.

3. Results and Discussion

3.1 Abundance and Types of Microplastic

We observed microplastics in 100% of silver barb sampled (N=20), representing a combined 448 microplastic particles total. Regarding occurrence of different microplastic types in silver barb, fibers were observed in100% of fish, fragments in 50%, film in 25%, and no microplastic beads were observed. Microplastic counts ranged from 7 to 43 microplastic particles per individual fish with an average abundance of 22.40 ± 2.50 SE. The average total length of silver barb was 15.20 cm ± 0.40 SE ranging from 12 cm to 18.5 cm. The average wet weight was 54.25 g ± 3.80 SE ranging from 25 g to 88 g (Table 1).

Table 1: Observed microplastic consumption by silver barb from the Karang Mumus River

No.	Fish Length (cm)	Fish Weight (gram)	Microplastic Consumption (No.)			
			Fiber	Film	Fragment	Total Microplastic
1.	18	77	11	5	1	17
2.	18.5	88	12	12	3	27
3.	16.5	71	19	16	1	36
4.	17.5	75	28	11	0	39
5.	15	56	36	7	0	43
6.	16	56	15	10	3	28
7.	15	46	23	7	1	31
8.	14.5	50	10	9	0	19
9.	16	68	12	18	1	31
10.	15.5	55	21	9	0	30
11.	14.4	48	5	4	0	9
12.	14	40	8	0	1	9
13.	13	30	10	3	4	17
14.	12	29	6	0	1	7
15.	12.5	25	15	4	0	19
16.	16	65	6	1	0	7
17.	15	49	32	2	0	34
18.	17	68	17	0	0	17
19.	13.5	43	10	0	1	11
20.	14	46	17	0	0	17
Average						
	15.20	54.25	15.65	5.90	0.85	22.40
Standard Error						
	0.40	3.80	1.94	1.24	0.26	2.50
Total						
			313	118	17	448

When compared to research conducted on several fish species, namely carp (*Cyrinus carpio*), crucian carp (*Carassius cuvieri*), bluegill (*Lepomis macrochirus*), bass (*Micropterus salmoides*), catfish (*Silurus asotus*), and snakehead (*Channa argus*) found in the Han River, South Korea, the average abundance value is similar. In that study, an average of 20 microplastic particles per fish was found, with a range of findings ranging from 4 to 48 particles per fish (Park et al., 2020). However, our observed average was much higher than in roach (*Rutilus rutilus*) found in the Thames River, England, where the average was only 0.69 microplastic particles per fish, with only 32.8% of fish containing microplastics (Horton et al., 2018). Furthermore, research on 27 freshwater fish species in the Nandu River, southern China, also showed a lower average consumption of only 3.2 microplastic particles per individual (Chen et al., 2022). Differences in microplastic pollution, both type and abundance, as well as fish life stage, trophic level, and foraging techniques will likely influence microplastic consumption rates, so care should be taken with direct comparisons to our silver barb samples.

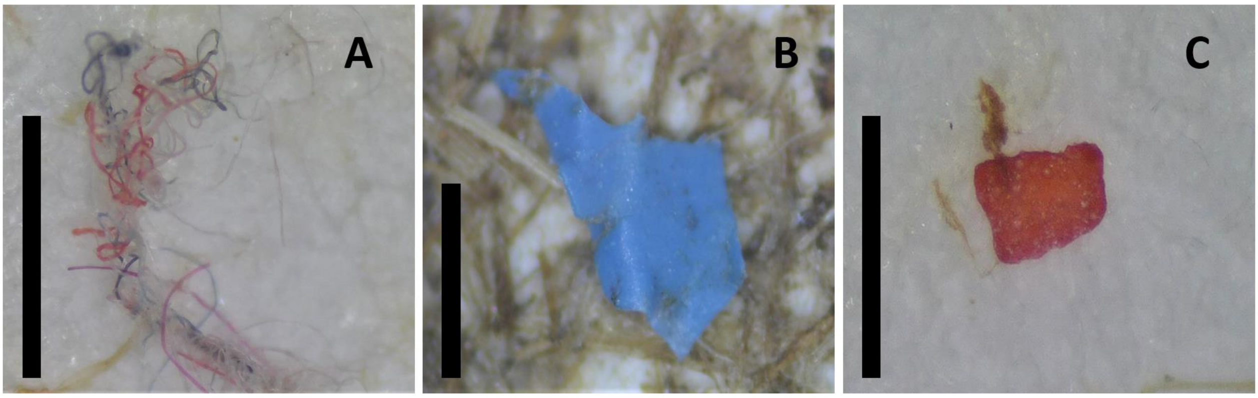

Figure 4: Illustrative photo of the types of microplastics found in the digestive system of silver barb from the Karang Mumus River: A. Fiber, B. Film, and C. Fragment. Horizontal black bar ≈ 0.5 mm.

In terms of microplastic types observed in the digestive system of silver barb, combined we found fibers were the most dominant type (representing 70% of all microplastics observed), followed by film (26%) and fragments (4%) (Figure 4 and 5). The dominance of fibers was also reported by (Horton et al., 2018). Who found that 75% of microplastics observed in roach from the Thames River were fibers. However, contrary to our findings, Park et al. (2020) reported that microplastic fragments accounted for 73% of the microplastics detected in multiple fish species from a river in South Korea, surpassing other microplastic types. Other studies have reported consumption of microplastic beads by fish (Grigorakis et al., 2017). But we did not detect any microbeads, suggesting that their usage in personal care products might be limited or uncommon in our study area.

In aquatic environments, numerous studies have found that fibers represent the most commonly encountered type of microplastic (Neves et al., 2015; Nadal et al., 2016; Jabeen et al., 2017; Nematollahi et al., 2021). These fibers primarily originate from textile products, particularly synthetic clothing (Rebelein et al., 2021). The increased prevalence of microplastic fibers in our environment is largely attributed to the degradation of synthetic fabrics (Henry et al., 2019; Rebelein et al., 2021). Over the course of a fabric's lifespan, these fibers are released through wear and abrasion from routine use and laundering. In fact, a single piece of clothing can release more than 1,900 fibers, each measuring less than 1mm in length, during a single washing cycle (Browne et al., 2011). Once washed, these synthetic fibers from laundry water often make their way into municipal water systems. Although some of these fibers are removed during wastewater treatment, a significant portion are released into the environment through effluent discharge (Browne et al., 2011). In our study area, the urban regions situated along the Karang Mumus River lack municipal wastewater treatment facilities. As a result, untreated wastewater is directly discharged into this river, potentially resulting in increased microplastic concentrations relative to treated effluent.

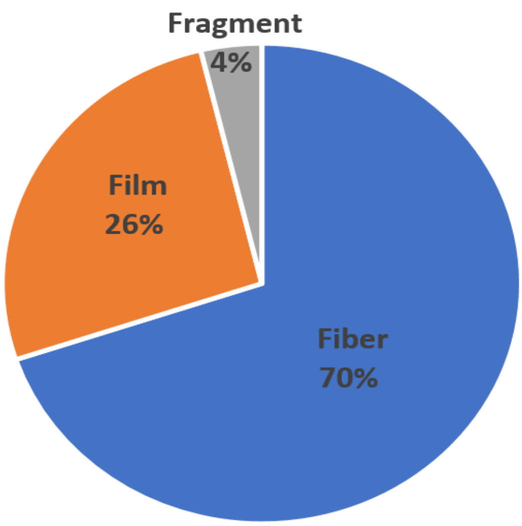

Figure 5: The composition of microplastic types in silver barb from the Karang Mumus River.

The abundance of microplastic particles found in the digestive system of fish can be influenced by several factors, including the concentration of microplastic particles in their habitat (water column and riverbed sediments), the position of the fish from upstream to downstream, the proximity to human settlements, the fish's feeding patterns, fish size, and the fish's life stage (Horton et al., 2018). Silver barb is classified as omnivorous fish, and juvenile of silver barbs are known to feed on various types of phytoplankton, primarily Cyanophyceae, Dinophyceae, and Zygnematophyceae (Ain et al., 2021). This species prefers bottom to midwater in slow flowing or standing waters of lakes, rivers, streams and reservoirs (Suryaningsih et al., 2020). Depending on size and shape of the particle, slow waters typically result in greater deposition rates of microplastics into the benthos (Ballent et al., 2016; Hoellein et al., 2019). It is highly likely that microplastic particles present in the waters and river bed of the Karang Mumus River may attach to phytoplankton and periphyton and be ingested by silver barb. Further research is needed to understand the dynamics of microplastic quantities in the digestive system of silver barb, including observations of microplastic particle concentrations in water and sediment, as well as their accumulation in or overlap with the fish's foodbase in Karang Mumus River.

3.2 The Relationship Between Fish Size and Microplastic Consumption

There was a positive relationship between both fish total length (Figure 6A) and wet weight (Figure 6B) with the abundance of microplastic particles observed in the digestive system of silver barb. However, these relationships were not statistically significant: total length ($p = 0.06$), wet weight ($p = 0.07$) (Table 2).

Table 2: Summary of linear regression results explaining the coefficient, standard error and p-value of observed fish length and fish weight

Fish length			
	Coefficients	*Standard Error*	*P-value*
Intercept	-19.08	20.39	0.36
Fish length	2.73	1.33	0.06
Regression Statistics			
Multiple R	0.43		
R Square	0.19		
Adjusted R Square	0.14		
Standard Error	10.36		
Observations	20		
Fish wet weight			
	Coefficients	*Standard Error*	*P-value*
Intercept	7.76	8.02	0.35
Fish weight	0.27	0.14	0.07
Regression Statistics			
Multiple R	0.41		
R Square	0.17		
Adjusted R Square	0.12		
Standard Error	10.49		
Observations	20		

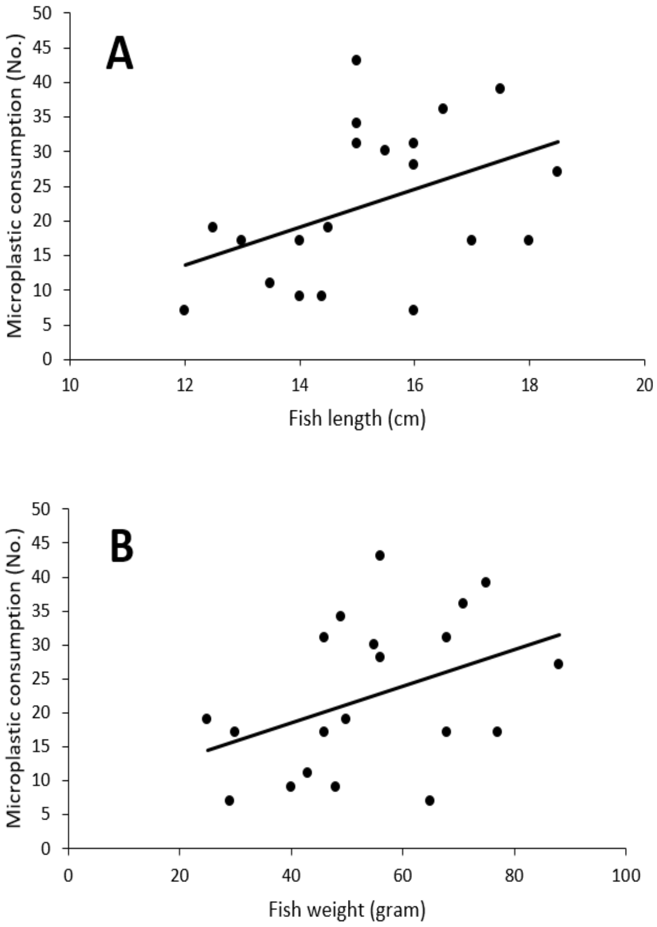

Figure 6: Scatter plot of the linear regression relationship between fish length (A) and fish weight (B) with the quantity of consumed microplastic particles (*n=20*)

The linear model analysis (Table 2) showed relatively low explanatory power for microplastic consumption rate: total length (r^2=0.19), wet weight (r^2=0.17). This suggests that microplastic consumption by silver barb is attributed to other factors not documented in this study.

Unlike our results, reported a highly significant, positive relationship (p = 0.001) between the fish length and the abundance of microplastic particles in 46 fish species found in the Amazon River in Brazil. However, similar to our findings, fish weight was not statistically significant (Pegado et al., 2018). The size of fish based on their maturity level influences the amount of food they consume. Larger fish have greater metabolic requirements resulting in higher rates of feeding, which can increase the chances of microplastic consumption compared to smaller fish (Hölker & Breckling, 2001). However, this intuitive relationship remains equivocal in the literature with large variations in fish size and microplastic consumption rates (Peters & Bratton, 2016; Horton et al., 2018).

4. Conclusion

Our research confirms that microplastic particles have been ingested by silver barb in the Karang Mumus River in East Kalimantan, Indonesia, and this is the first study of its kind. Microplastic consumption by silver barb likely serves as an indication that other fish species living in the Karang Mumus River also consume microplastic particles. The average abundance of microplastic particles found in the digestive organs of silver barb was 22.40 (SE: 2.5): 70% fibers, 26% film, 4% fragments, and 0% beads.

The relationship between the length and weight of silver barb and microplastic consumption showed a positive correlation, but these relationships were not statistically significant. The findings of this research are expected to serve as an initial reference regarding the threat of microplastic particle contamination to fish in the Karang Mumus River. Fish are an important economic resource and source of protein in human diet in Indonesia and across Southeast Asia, raising concerns about tropic transfer of microplastics and their associated contaminants to people.

Further investigation is necessary to gain a better understanding of microplastic abundance in the water column and river benthos as well as their consumption by other fish species. This entails examining microplastic concentrations in both water and sediment and the association of microplastics with the foodbase including the phytoplankton and periphyton typically consumed by silver barb. This also includes identifying point and nonpoint sources of microplastics, seasonal differences in abundances, as well as densities and attenuation rates of microplastics along the river network.

References

Agamuthu, P., Mehran, S. B., Norkhairah, A., & Norkhairiyah, A. 2019. Marine debris: A review of impacts and global initiatives. Waste Management & Research, 37(10), 987-1002.

Ain, C., Rudiyanti, S., & Isroliyah, A. 2021. Food Habits and Ecological Niche of Silver Barp Fish (Barbonymus gonionotus) in Jatibarang Reservoir, Semarang. In IOP Conference Series: Earth and Environmental Science (Vol. 750, No. 1, p. 012028). IOP Publishing.

Ballent, A., Corcoran, P. L., Madden, O., Helm, P. A., & Longstaffe, F. J. 2016. Sources and sinks of microplastics in Canadian Lake Ontario nearshore, tributary and beach sediments. Marine pollution bulletin, 110(1), 383-395.

Belton, B., Bush, S. R., & Little, D. C. 2018. Not just for the wealthy: Rethinking farmed fish consumption in the Global South. Global Food Security, 16, 85-92.

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. 2011. Accumulation of microplastic on shorelines woldwide: sources and sinks. Environmental science & technology, 45(21), 9175-9179.

Central Agency of Statistics 2021. Population Statistic Report of East Kalimantan 2020. https://kaltim.bps.go.id/indicator/12/572/1/-sp2020-jumlah-penduduk-hasil-sensus-penduduk-menurut-wilayah-dan-jenis-kelamin-di-provinsi-kalimantan-timur-2020.html

Ceschin, S., Mariani, F., Di Lernia, D., Venditti, I., Pelella, E., & Iannelli, M. A. 2023. Effects of Microplastic Contamination on the Aquatic Plant Lemna minuta (Least Duckweed). Plants, 12(1), 207.

Chen, Y., Shen, Z., Li, G., Wang, K., Cai, X., Xiong, X., & Wu, C. 2022. Factors affecting microplastic accumulation by wild fish: A case study in the Nandu River, South China. Science of the Total Environment, 847, 157486.

Das, M., Rahim, F. I., & Hossain, M. A. 2018. Evaluation of fresh Azolla pinnata as a low-cost supplemental feed for Thai Silver Barb Barbonymus gonionotus. Fishes, 3(1), 15.

Eppehimer, D. E., Hamdhani, H., Hollien, K. D., Nemec, Z. C., Lee, L. N., Quanrud, D. M., & Bogan, M. T. 2021. Impacts of baseflow and flooding on microplastic pollution in an effluent-dependent arid land river in the USA. Environmental Science and Pollution Research, 28, 45375-45389.

Filgueiras, A. V., Preciado, I., Cartón, A., & Gago, J. 2020. Microplastic ingestion by pelagic and benthic fish and diet composition: A case study in the NW Iberian shelf. Marine Pollution Bulletin, 160, 111623.

Galgani, F., Hanke, G., & Maes, T. 2015. Global distribution, composition and abundance of marine litter. Marine anthropogenic litter, 29-56.

Geyer, R., Jambeck, J. R., & Law, K. L. 2017. Production, use, and fate of all plastics ever made. Science advances, 3(7), e1700782.

Grigorakis, S., Mason, S. A., & Drouillard, K. G. 2017. Determination of the gut retention of plastic microbeads and microfibers in goldfish (Carassius auratus). Chemosphere, 169, 233-238.

Helm, P. A. 2017. Improving microplastics source apportionment: a role for microplastic morphology and taxonomy?. Analytical Methods, 9(9), 1328-1331.

Henry, B., Laitala, K., & Klepp, I. G. 2019. Microfibres from apparel and home textiles: Prospects for including microplastics in environmental sustainability assessment. Science of the total environment, 652, 483-494.

Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M 2012 Microplastics in the marine environment: a review of the methods used for identification and quantification. Environmental Science & Technology 46(6): 3060–3075.

Hoellein, T. J., Shogren, A. J., Tank, J. L., Risteca, P., & Kelly, J. J. 2019. Microplastic deposition velocity in streams follows patterns for naturally occurring allochthonous particles. Scientific Reports, 9(1), 3740.

Hölker, F., & Breckling, B. 2001. An individual-based approach to depict the influence of the feeding strategy on the population structure of roach (Rutilus rutilus L.). Limnologica, 31(1), 69-78.

Horton, A. A., Jürgens, M. D., Lahive, E., van Bodegom, P. M., & Vijver, M. G. 2018. The influence of exposure and physiology on microplastic ingestion by the freshwater fish Rutilus rutilus (roach) in the River Thames, UK. Environmental Pollution, 236, 188-194.

Huang, S., Jiang, R., Craig, N. J., Deng, H., He, W., Li, J. Y., & Su, L. 2023. Accumulation and re-distribution of microplastics via aquatic plants and macroalgae-A review of field studies. Marine Environmental Research, 105951.

Issac, M. N., & Kandasubramanian, B. 2021. Effect of microplastics in water and aquatic systems. Environmental Science and Pollution Research, 28, 19544-19562.

Jabeen, K., Su, L., Li, J., Yang, D., Tong, C., Mu, J., & Shi, H. 2017. Microplastics and mesoplastics in fish from coastal and fresh waters of China. Environmental Pollution, 221, 141-149.

Karlsson, T. M., Arneborg, L., Broström, G., Almroth, B. C., Gipperth, L., & Hassellöv, M. 2018. The unaccountability case of plastic pellet pollution. Marine pollution bulletin, 129(1), 52-60.

Laskar, N., & Kumar, U. 2019. Plastics and microplastics: A threat to environment. Environmental technology & innovation, 14, 100352.

Makhdoumi, P., Hossini, H., & Pirsaheb, M. 2023. A review of microplastic pollution in commercial fish for human consumption. Reviews on environmental health, 38(1), 97-109.

Mardhiyah, B., Abbas, E. W., Mutiani, M., Syaharuddin, S., & Subiyakto, B. 2022. Traditional Fishing Tools for Banjar People. The Kalimantan Social Studies Journal, 4(1), 1-8.

Miraj, S. S., Parveen, N., & Zedan, H. S. 2021. Plastic microbeads: small yet mighty concerning. International Journal of Environmental Health Research, 31(7), 788-804.

Nadal, M. A., Alomar, C., & Deudero, S. 2016. High levels of microplastic ingestion by the semipelagic fish bogue Boops boops (L.) around the Balearic Islands. Environmental Pollution, 214, 517-523.

Nematollahi, M. J., Keshavarzi, B., Moore, F., Esmaeili, H. R., Saravi, H. N., & Sorooshian, A. 2021. Microplastic fibers in the gut of highly consumed fish species from the southern Caspian Sea. Marine Pollution Bulletin, 168, 112461.

Neves, D., Sobral, P., Ferreira, J. L., & Pereira, T. 2015. Ingestion of microplastics by commercial fish off the Portuguese coast. Marine pollution bulletin, 101(1), 119-126.

Park, T. J., Lee, S. H., Lee, M. S., Lee, J. K., Lee, S. H., & Zoh, K. D. 2020. Occurrence of microplastics in the Han River and riverine fish in South Korea. Science of the Total Environment, 708, 134535.

Pegado, T.d.S.e.S., Schmid, K., Winemiller, K. O., Chelazzi, D., Cincinelli, A., Dei, L., & Giarrizzo, T. 2018. First evidence of microplastic ingestion by fishes from the Amazon River estuary. Marine Pollution Bulletin, 133, 814-821.

Peters, C. A., & Bratton, S. P. 2016. Urbanization is a major influence on microplastic ingestion by sunfish in the Brazos River Basin, Central Texas, USA. Environmental pollution, 210, 380-387.

Pujowati, P., Arifin, A. S., & Mugnisjah, W. Q. 2010. Analisis sosial ekonomi masyarakat di Daerah Aliran Sungai Karang Mumus dalam rencana pengelolaan lanskap Agroforesty. Jurnal Agro Ekonomi Kehutanan EPP, 7(1), 8-13.

Rebelein, A., Int-Veen, I., Kammann, U., & Scharsack, J. P. 2021. Microplastic fibers—underestimated threat to aquatic organisms?. Science of the Total Environment, 777, 146045

Sari, D. A. A., & Muslimah, S. 2020. Blue economy policy for sustainable fisheries in Indonesia. In IOP Conference Series: Earth and Environmental Science (Vol. 423, No. 1, p. 012051). IOP Publishing.

Stata Statistical Software 2017. Release 15, StataCorp LLC, College Station, TX, USA.

Stock, F., Kochleus, C., Bänsch-Baltruschat, B., Brennholt, N., & Reifferscheid, G. 2019. Sampling techniques and preparation methods for microplastic analyses in the aquatic environment–A review. TrAC Trends in Analytical Chemistry, 113, 84-92.

Suharko, S., & Kusumadewi, C. D. 2019. Organisasi Masyarakat Sipil dan Restorasi Sungai: Studi pada Gerakan Memungut Sehelai Sampah di Sungai Karang Mumus di Kota Samarinda. Jurnal Sosiologi Reflektif, 14(1), 81-104.

Suryaningsih, S., Bhagawati, D., Sukmaningrum, S., & Puspitasari, I. A. R. 2020. The Morphometrical Character of Silver Barb Fish Barbonymus gonionotus (Bleeker, 1849). In IOP Conference Series: Earth and Environmental Science (Vol. 593, No. 1, p. 012027). IOP Publishing.

Sussarellu, R., Suquet, M., Thomas, Y., Lambert, C., Fabioux, C., Pernet, M. E. J., ... & Huvet, A. 2016. Oyster reproduction is affected by exposure to polystyrene microplastics. Proceedings of the national academy of sciences, 113(9), 2430-2435.

Wang, W., Ge, J., & Yu, X. 2020. Bioavailability and toxicity of microplastics to fish species: A review. Ecotoxicology and environmental safety, 189, 109913.

Worm, B., Lotze, H. K., Jubinville, I., Wilcox, C., & Jambeck, J. 2017. Plastic as a persistent marine pollutant. Annual Review of Environment and Resources, 42, 1-26.

Wu, W. M., Yang, J., & Criddle, C. S. 2017. Microplastics pollution and reduction strategies. Frontiers of Environmental Science & Engineering, 11, 1-4.