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Identification of Microplastics in Three Fish Species in Tondano Lake, Minahasa, Indonesia

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Abstract. Microplastic pollution is a significant threat to aquatic ecosystems and human health, particularly in Indonesia, a major contributor to plastic waste. This study investigated the presence and characteristics of microplastics in three commonly consumed fish species from Tondano Lake, North Sulawesi: *mujair* (*Oreochromis mossambicus*), *payangka baru* (*Oxyeleotris marmorata*), and *payangka lama* (*Ophiocara poropechala*). Analysis of gills and gastrointestinal tracts (GIT) from 11 fish samples revealed microplastic contamination in all species. Mujair exhibited the highest microplastic abundance, predominantly fragments in both gills and GIT. *Payangka baru* showed more fibers in the GIT and fragments in the gills, while *payangka lama* had more fibers in the GIT and fragments in the gills. A positive correlation was observed between fish body weight and microplastic accumulation in the GIT, but not the gills. The findings confirm microplastic contamination in Tondano Lake fish, highlighting the need for stricter waste management and further research on human health implications.

Keywords: microplastics; Ophiocara; *Oreochromis mossambicus*; Tondano Lake.

I. INTRODUCTION

Microplastics, defined as plastic particles smaller than 5 mm in its largest dimension [1], have emerged as a significant pollutant threatening aquatic ecosystems and human health through food chains [2]. These can be categorized based on their physical shapes (namely fibers, foams, fragments, beads, or films) and chemical composition based on their polymer type and additive chemicals [3]. Based on their origins, microplastics are classified into primary and secondary types. Primary microplastics originate from products like cleansers and industrial pellets, while secondary microplastics result from the breakdown of larger plastic debris [4]. Secondary microplastics, in particular, are closely linked to human activities, as they often arise from improper waste disposal and high population density [5]. This connection underscores the urgency of studying microplastic contamination in water bodies near densely populated areas, such as Tondano Lake in North Sulawesi, Indonesia.

Indonesia, as the world's second-largest producer of plastic waste [6], faces a growing microplastic crisis. Recent studies have identified Indonesia and Malaysia as having the highest rates of microplastic ingestion globally [7]. In human, biomass accummulation can occur due to the consumption of seafood contaminated with microplastics [8]. Research by Yona et al. (2020) [9] confirmed microplastic contamination in fish from Indonesia's outer islands, suggesting that water sources near human habitation are even more vulnerable. Despite this, studies on microplastic contamination in Indonesian freshwater systems remain limited and unevenly distributed. While some lakes and coastal areas have been repeatedly investigated, others, including Tondano Lake, have received little to no attention [10, 11]. Systematic research is critical to fill these gaps and provide data necessary for developing effective mitigation strategies and policies [12, 13].

Tondano Lake, a vital water source in North Sulawesi, supports extensive fishing activities and provides fish species such as *mujair* (*Oreochromis mossambicus*, tilapia), *payangka lama* (*Ophiocara poropechala*), and *payangka baru* (*betutu*, *Oxyeleotris marmorata*, marble goby, or *payangka kodok*), which are consumed daily by local communities and even sold to the surrounding cities [14]. *O. mossambicus* and *O. poropechala* have been well characterized previously [15, 16, 17]. *O. poropechala* and *O. mossambicus* were introduced to Tondano lake in 1902 and 1951, respectively, while *O. marmorata* has been found relatively newer than the previous two [14]. Since 2015, *O. marmorata* population has increased in Tondano lake for unclear reasons and was increasingly consumed by the surrounding locals [18].

These fishes are primarily caught using nets or cultured in floating quarantine nets (*karamba*) within the lake [19]. Despite their importance as a food source, no published research has yet assessed microplastic contamination in these fish or the lake itself. Given the high levels of human activity around Tondano Lake and the potential for plastic waste to degrade into microplastics, we hypothesize that these fish species are already contaminated. This study aims to identify and quantify microplastic contamination in these three fish species, providing critical data to address this emerging environmental and public health issue.

II. METHODS

This study is a descriptive and exploratory investigation aimed at identifying the abundance of microplastics in fish samples collected from Tondano Lake. Fish samples were obtained directly from the proximal outlet area of the lake (Fig. 1) using nets operated by local fishermen. Three species commonly consumed by the local population were selected for analysis: *mujair* (*Oreochromis mossambicus*, n=5), *payangka baru* (*Oxyeleotris marmorata*, n=3), and *payangka lama* (*Ophiocara poropechala,* n=3). To examine the potential correlation between microplastic abundance and body weight, samples of varying sizes were included in the study. Each specimen was weighed (in grams) and measured for length (in centimeters).

The gills and gastrointestinal tracts (GIT), including the liver and bile, were surgically dissected from each fish. These samples were then digested in concentrated (65%) nitric acid for a minimum of 72 hours in glass containers. Following digestion, a concentrated NaCl solution was used to float the microplastics (1:3 ratio), which were then filtered using Whatman #65 filter paper. Microplastics were identified and categorized as fibers, fragments, or films using a dissecting microscope (Leica EZ4) at 30x magnification.

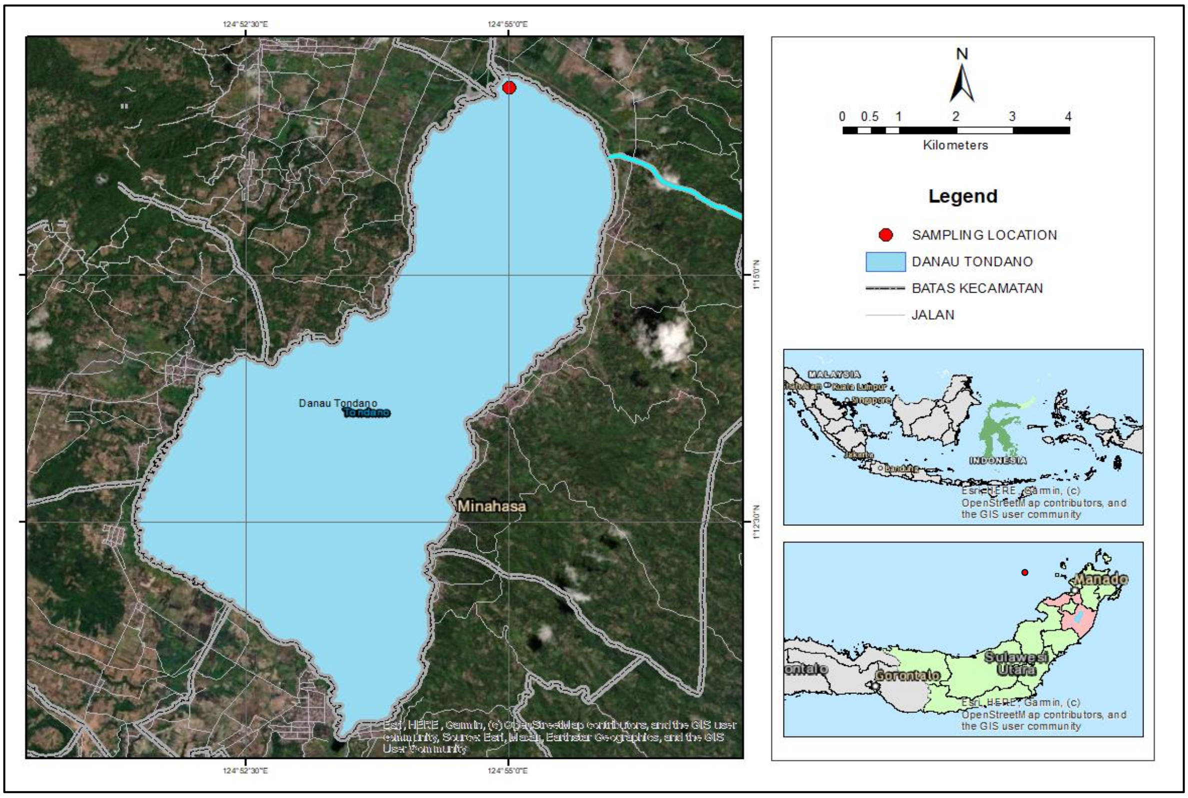

Fig. 1. The sampling locations in Tondano lake (red circle).

III. RESULTS AND DISCUSSION

Results

The morphometric characteristics (body and organ weight- length) of the samples are described in Table 1, while the representative pictures of the specimens are displayed in Fig. 2. As expected, *O. mossambicus* have larger body size than *O. porocephala* and *O. marmorata*.

The microplastics found in each fish species were categorized into fibers, fragments, and films (Fig. 3). The abundance of microplastics in each species is illustrated in Fig. 4. Among the species examined, *O. mossambicus* fish exhibited the highest microplastic abundance per sample, particularly in their gastrointestinal tract (GIT). The most prevalent type of microplastic in *O. mossambicus* was fragments, which were found in both the gills and GIT. In *O. marmorata*, fibers were the most common type in the GIT, while fragments dominated in the gills. Similarly, in *O. poropechala*, fibers were the most abundant in the GIT, and fragments were predominant in the gills. This suggests a positive correlation between the size/weight of the fish and the amount of microplastic contamination accumulated in their bodies, as shown in Fig. 5. Larger or heavier fish tend to accumulate more microplastics in their GIT, but not gills, highlighting the impact of body size on microplastic ingestion and retention. We found varying colors of microplastic, ranging from black, blue, red, and transparent, sugggesting that these microplastics are the resudials of the plastics being used by the societies around Tondano lake.

TABLE 1
THE MORPHOMETRIC CHARACTERISTICS OF THE FISH SAMPLES

Species	Body weight (g)	Body length (cm)	GIT weight (g)	Gill weight (g)
O. mossambicus (n=5)	152.82±20.76	20.56±1.08	11.06±0.94	7.34±1.07
O. marmorata (n=3)	40.00±12.53	15.50±1.50	1.60±0.42	1.23±0.19
O. porocephala (n=3)	32.20±7.43	13.90±0.80	2.20±0.30	0.80±0.23

Data are presented as average±standard errors of mean

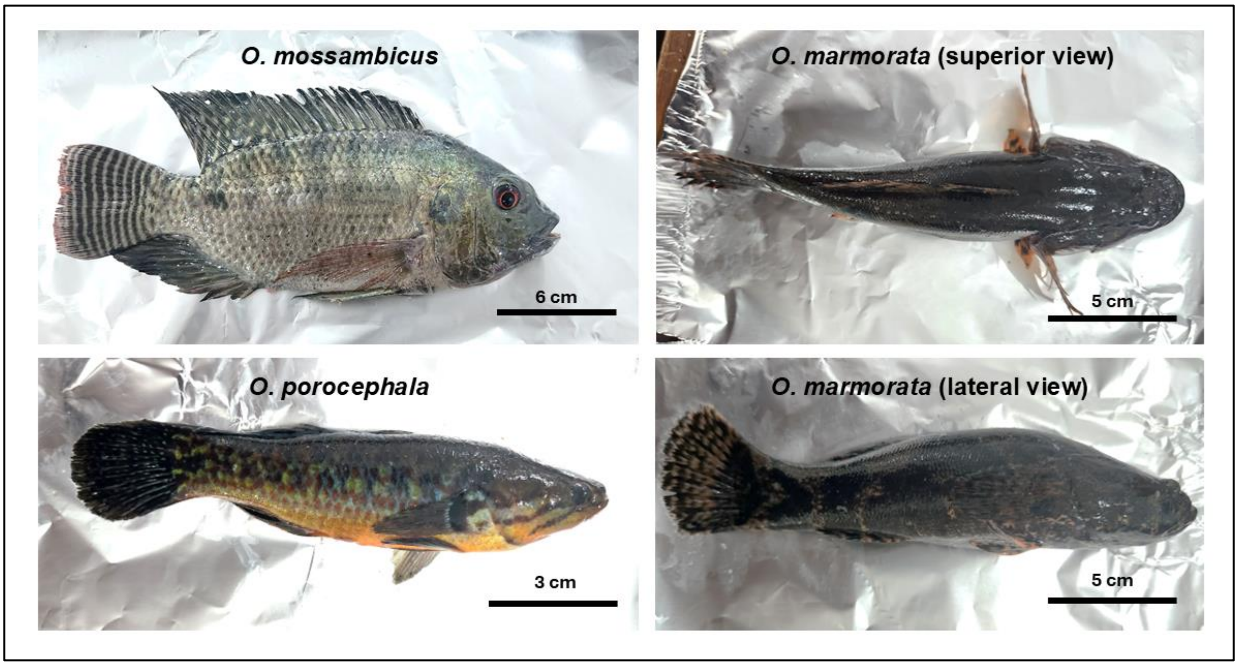

Fig. 2. The specimen of *O. mossambicus, O. porocephala, and O. marmorata* included in this study.

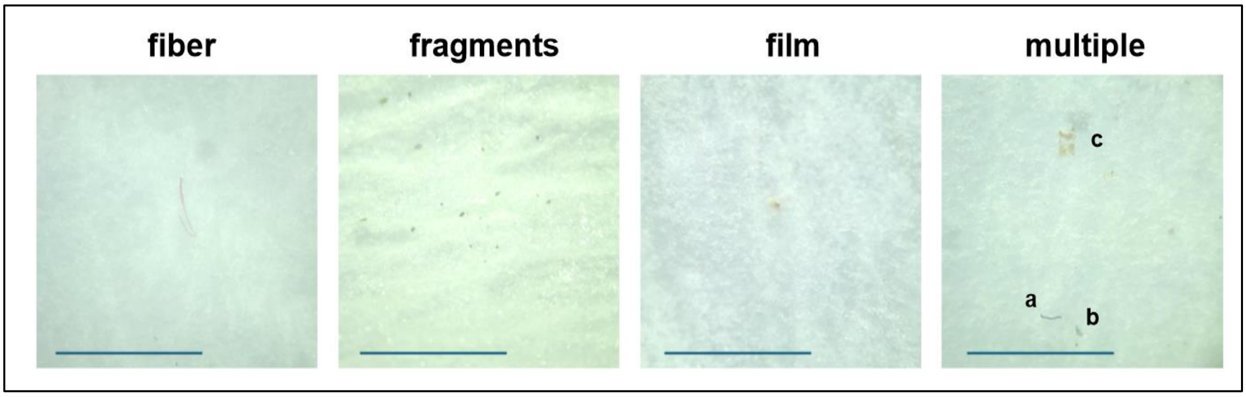

Fig. 3. The types of microplastics found as visually identifiable using Lecia EZ24: fiber, fragments, and film. Far right panel shows all three shapes in one panel (a: fiber; b: fragment; c: film). Scalebars are 5 mm.

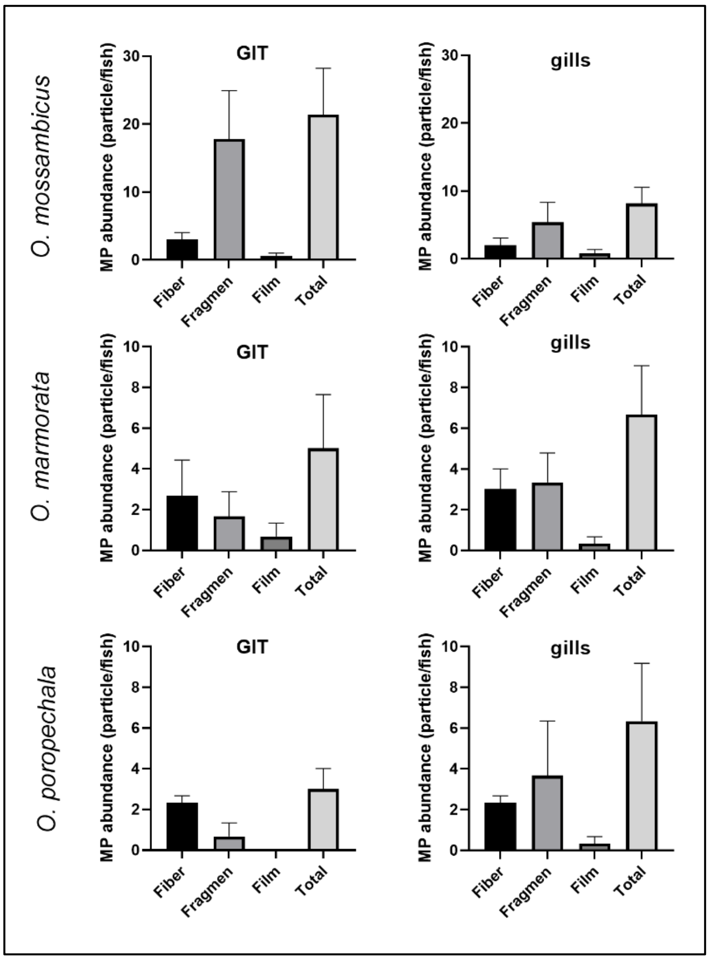

Fig. 4. Microplastics (MP) abundance in *O. mossambicus* (n=5), *O. marmorata* (n=3), and *O. poropechala* (n=3) GIT and gills, expressed in mean particle per fish. Error bars are SEMs.

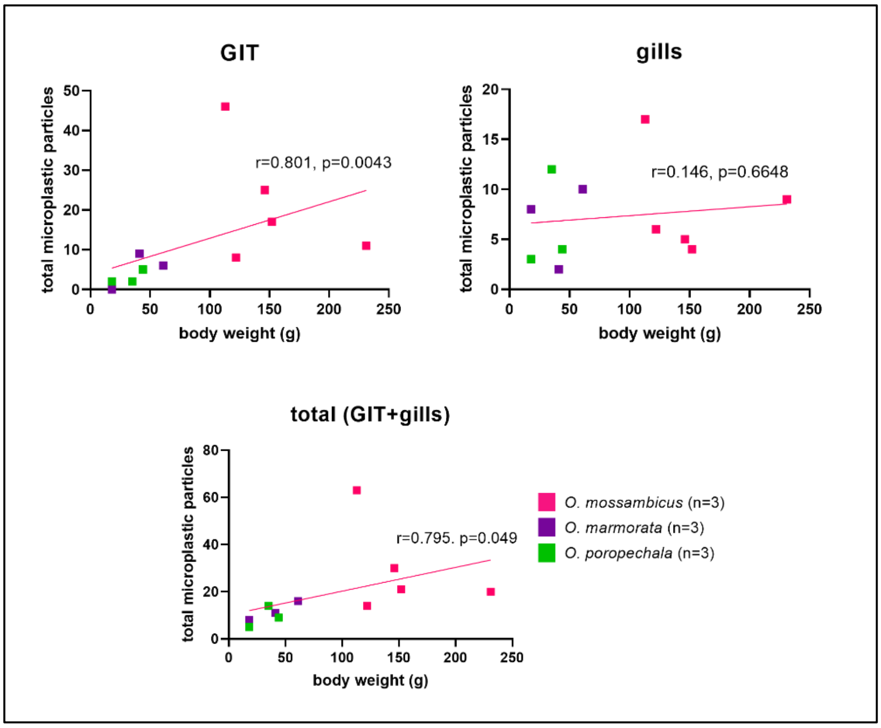

Fig. 5. Correlation between microplastic abundance (in the GIT, gills, and combined) and fish body weight by Spearman's rank test.

Discussions

Hypothesis confirmation

Our findings confirmed the initial hypothesis that the fishes in Tondano lake have been contaminated with microplastics. To our knowledge, this is the first report of microplastic contamination in fishes found in Tondano lake, which should prompt a mitigation action to prevent biomass accumulation in human. These findings align with numerous previous studies indicating that all researched freshwater fish in Indonesian water are exposed to microplastics [20]. The abundance and kind of fragments suggests that primary sources of contamination come from the degradation of plastic waste in the aquatic environment [21].

Fish can ingest microplastics through several mechanisms, primarily via active and passive uptake. Active uptake occurs when fish mistake microplastics for food, while passive uptake happens when microplastics are inadvertently consumed along with their actual diet [22], [23]. Once ingested, microplastics can translocate throughout the digestive tract and gills, entering the circulatory system. From there, microplastics can spread to various organs within the fish and subsequently enter the food chain [24]. This aligns with our findings, where microplastics were detected in both the gastrointestinal tracts (GIT) and gills of *O. mossambicus, O. poropechala,* and *O. marmorata*, indicating that these fish are actively and passively ingesting microplastics from their environment.

Microplastic contamination in fish is species-specific [25], [26]. Omnivorous and filter-feeding fish, including species like *O. mossambicus* tend to accumulate higher levels of microplastics compared to carnivorous species [27], [28]. Furthermore, omnivorous fish are less efficient at eliminating microplastics than filter-feeding fish [29]. Our study supports this, as *O. mossambicus*, an omnivorous species, showed the highest microplastic abundance, particularly in the form of fragments, while *O. poropechala* species, which are filter feeders, exhibited higher fiber concentrations. This suggests that feeding behavior plays a critical role in the type and amount of microplastics ingested.

Body size also plays a significant role in microplastic accumulation, with larger fish generally accumulating more microplastics than smaller ones [30]. This is consistent with our observation that larger fish, such as *O. mossambicus*, had higher microplastic loads compared to smaller individuals. The positive correlation between fish weight and microplastic abundance (Fig. 4) further reinforces this relationship, highlighting that larger fish are more likely to accumulate microplastics over time.

These findings suggest that the accumulation of microplastics in species like *O. mossambicus, O. poropechala* and *O. marmorata* makes them potential vectors for transferring microplastics to higher levels of the food chain. Given that these fish are commonly consumed by local communities, this raises concerns about human exposure to microplastics through dietary intake. Environmental factors, such as the concentration of microplastics in the water, feeding behaviors related to fish size, and food availability, also significantly influence the rate of microplastic consumption in fish populations [31]. The high levels of human activity around Tondano Lake likely contribute to the microplastic pollution, emphasizing the need for improved waste management and environmental monitoring to mitigate this issue.

Study limitations and further recommendations

In this current research, microplastic identification was based solely on visual methods. While this method is sensitive to microplastic identification, this can leave a room of false positive. To confirm and identify the plastic polymer, spectroscopy techniques such as Fourier transform infra-red (FTIR) or Raman would provide more precise polymer identification. Moreover, the sampling was conducted in a single period, which may not reflect seasonal variations. Further research using spectroscopy methods is needed for more accurate polymer identification. Since human do not consume the GIT and gills of these fishes, the next step of research would be to identify the availability of microplastics in the meat of these fishes. Parallel public health research about the fish consumption behavior among the people surrounding Tondano Lake is also important in approximating the microplastic comsumption and accumulation in human, in order to formulate intervention strategies.

Ecological and health implications

Consuming fish from Lake Tondano is very likely to introduce microplastics into the human body. The findings of this study, however, need to be interpreted cautiously, as we did not examine the microplastic contents in the fish meat, which people consume. Nevertheless, the presence of microplastics in the GIT and gills of Tondano Lake fishes, especially *mujair (O. mossambicus)*, *payangka baru (O. marmorata)*, and *payangka lama (O. poropechala)*, underscores the risk of microplastic ingestion by humans who consume these fish, potentially leading to health concerns. To address this issue, stricter plastic waste management policies should be enforced around the lake, including regulations on waste disposal and the promotion of biodegradable alternatives. Additionally, community awareness programs and improved waste infrastructure, such as recycling facilities and regular cleanups, are essential to reduce plastic pollution and protect the lake's biodiversity. Further research and monitoring are also needed to assess the long-term effects of microplastics and to guide effective mitigation strategies, ensuring the health of both the ecosystem and the local population.

IV. CONCLUSIONS

In conclusion, our findings highlight the vulnerability of Tondano Lake's fish populations to microplastic contamination, driven by species-specific feeding behaviors, body size, and environmental conditions. This underscores the urgent need for further research and policy interventions to protect both aquatic ecosystems and human health.

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Conflict of interest statement
The authors declare no competing interest.

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