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Physicochemical Analysis of Porong River Water and Gonadal Maturity of Silver Barb (*Barbonymus gonionotus*) under Microplastic Exposure

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Abstract

Microplastics are a form of contaminant found in waters, including coastal and river waters. Many rivers were under anthropogenic pressures that influence the water ecosystem. This study aimed to evaluate water quality, the microplastics abundance, and analyze their relationship to gonadal maturity of silver barb (Barbonymus gonionotus). Methods included sample collection at three stations in the Porong River, Sidoarjo, East Java. The sample was observed for water quality, microplastics abundance, and the gonadosomatic index of Silver Barb (Barbonymus gonionotus). The analysis was a descriptive-analytical approach. Results indicate that the quality of the Porong River water was within standard thresholds. The samples are characterized by elevated organic matter (9.84–12.82 mg/L). Nutrient levels, including nitrate (1.09–1.23 mg/L), ammonia (0.05–0.10 mg/L), and orthophosphate (0.18–0.20 mg/L) indicate enrichment. Microplastics were detected at all stations with abundance from 7,467 to 11,200 particles/m³, and were dominated by fragments, fibers, films, and pellets. Descriptive analysis indicates that the water quality of the Porong River still supports fish reproduction, but microplastics have the potential to reduce future reproduction and silver barb populations, so a pollution management strategy is needed. Future management strategies are needed to control pollution and maintain the sustainability of fish populations in the Porong River.

Keywords: *water quality; microplastics; gonadal maturity; Barbonymus gonionotus; Porong River*

1. Introduction

River natural pathways that trace the movement of water and other material across the physical landscape, supporting ecosystems and sustaining human communities [1,2]. However, Human activities degrade water quality, disrupt ecosystems, and affect food chains and fisheries [3]. One contaminant currently receiving attention is microplastic pollution. Microplastics are plastic particles with a size smaller than 5 mm. It rose from the breakdown of larger plastic debris through physical, chemical, and biological processes [4,5]. In freshwater systems, these particles may also carry toxic substances and transfer them to aquatic organisms [2,5]. The rivers act as pathways in spreading microplastics toward coastal and marine environments. In Indonesia, plastic waste is estimated to be about 0.48–1.29 million tons that enter the ocean each year through rivers, with microplastic concentrations ranging 30–960 particles per liter [6]. The densely populated regions in South and Southeast Asia were causing plastic pollution, with the rivers serving as major routes [4,7,8].

The Porong River is located in Sidoarjo, East Java, which flows into the Java Sea. River water carries many materials that influence both the delta and coastal environments [1]. Especially the mud volcano (Lapindo) eruption in 2006 made the Porong River deliver large volumes of sediment into this river system. This condition led to significant changes in the river's physical characteristics, including increased suspended solids and sediment deposition. In parallel, plastic mismanagement is widely identified as a key driver of pollution, especially on Java rivers. Rivers act as efficient pathways transporting plastics from densely populated basins toward the sea [2,4]. Environmental plastics progressively fragment via abiotic and biotic weathering into microplastics [5,7]. Microplastics are also frequently detected in inland waters with ecologically significant abundances [8]. Microplastics have also been detected in abundance in inland waters, with ecologically significant abundances [8]. Microplastics are readily absorbed by freshwater biota and can act as vectors for absorbed toxic substances. This raises ecological and seafood safety concerns in river-connected fisheries [9,10].

Water quality affects fish physiology and reproduction through changes in metabolism, hormones, and gonad development [11,12]. Environmental conditions and microplastics can affect the gonadal maturity of fish through accumulation in the body, causing oxidative stress, inflammation, and hormonal disruption [13,14]. Also, Microplastics can bind to harmful pollutants, increasing their toxicity to aquatic organisms [15–17]. Microplastic studies still largely discuss its presence, distribution, and impacts separately, especially in the marine environment [11,18,19]. There are still a few studies examining the relationship between microplastics, water quality, and their impact on fish reproduction in freshwater [20]. Environmental conditions and pollution patterns in tropical areas differ from those in temperate areas, so exposure and biological responses may also differ [21]. Therefore, Different environmental conditions cause differences in exposure and response of organisms to pollution [22,23]. This study aims to evaluate the water quality of the Porong River using physical and chemical parameters, identify the abundance and types of microplastics present, and assess their relationship with the gonadal maturity of silver barb (*Barbonymus gonionotus*).

2. Materials and Methods

2.1. Research Design

Field research was conducted in the Porong River, East Java, Indonesia, to analyze the relationship between water quality, microplastics, and fish gonad maturity from December 2022 to January 2023. The location was chosen because it is close to human activity, and samples were analyzed to assess water quality, microplastics, and aspects of fish reproduction at the Freshwater Fisheries Laboratory Unit (UPT) in Sumberpasir, Malang.

2.2. Determination of Sampling Stations

Three stations were selected purposively with different conditions, and sampling was done in triplicate for data reliability. The distance between Station 1 and Station 2 was about 7 km, and between Station 2 and Station 3 was approximately 9 km, with samples collected in triplicate at each station to ensure reliable and comparable data.

2.3. Sampling and Analytical Procedures

In each station, a water sample was collected, and its quality parameters were measured both on site (in situ) and in the laboratory (ex situ). On-site measurements included temperature, pH, dissolved oxygen (DO), and salinity. The laboratory analysis included total dissolved solids (TDS), total suspended solids (TSS), carbon dioxide (CO_2), ammonia, nitrate, phosphate, total organic matter (TOM), and microplastic abundance.

Fish samples were dissected to evaluate gonadal maturity. Gonad weight and total body weight were measured to calculate the gonadosomatic index (GSI). The gonads were then examined visually to determine their developmental stage. Fecundity was estimated in female fish by counting the number of eggs under a microscope. In addition, egg diameter was measured to further assess reproductive status

To observe microplastics, water samples from each station were filtered using stainless steel sieves with specific mesh sizes. The retained material was then dried in an oven to remove moisture. To eliminate organic matter, the samples were treated with hydrogen peroxide. The remaining particles were examined and categorized based on their shape, such as fragments, fibers, films, and pellets. The data were analyzed using descriptive statistics with Origin software (version 9).

3. Results and Discussion

3.1. Water Quality Parameters

Observations on the three sampling stations of Porong River show several physical and chemical parameters, which are shown in Table 1. This study assesses the water conditions descriptively and analytically and highlights the role of microplastics in water quality monitoring and its ecological impacts [15,16]. Microplastics are commonly found in freshwater, especially in areas under pressure from human activity [7,17]. Microplastics in Southeast Asia are dominated by fibers and polyethylene, so it is necessary to analyze not only the quantity but also the characteristics and water quality [24]. Rivers distribute microplastics and increase exposure to organisms, necessitating analysis of the environment–biological response relationship [25–27].

Table 1. Average length and weight measurements of Mutiara catfish (*Clarias gariepinus*) cultured with probiotic and non-probiotic treatments

Parameter	Unit	Location 1	Location 2	Location 3
Temperature	°C	27.77 ± 1.22	28.37 ± 2.58	29.03 ± 2.00
TDS	mg/L	249.9 ± 71.56	582.1 ± 167.54	652.1 ± 267.91
TSS	mg/L	4.1 ± 2.05	9.3 ± 6.29	37.9 ± 47.41
pH	-	6.8 ± 0.54	6.7 ± 0.58	6.8 ± 0.62
DO	mg/L	5.4 ± 2.17	5.0 ± 3.20	5.6 ± 2.14
CO_2	mg/L	13.4 ± 6.96	20.3 ± 11.39	16.8 ± 9.03
Nitrate	mg/L	1.09 ± 1.66	1.10 ± 1.71	1.23 ± 1.32
Ammonia	mg/L	0.10 ± 0.07	0.05 ± 0.02	0.10 ± 0.11
Orthophosphate	mg/L	0.18 ± 0.04	0.18 ± 0.06	0.20 ± 0.11
TOM	mg/L	12.22 ± 5.22	9.84 ± 2.40	12.82 ± 6.19
Salinity	g/L	2.06 ± 1.76	4.37 ± 3.12	5.12 ± 2.35

Water temperature in all stations is relatively stable (27.77–29.03 °C) and within the normal range of tropical waters (28–31 °C), so it is not a major limiting factor compared to other stressors [7]. TDS (249.9–652.1 mg/L) and salinity (2.06–5.12 g/L) increased between stations, indicating seawater intrusion [28]. TSS variations (4.1–37.9 mg/L) affect turbidity and can inhibit primary productivity due to a reduction in light penetration [29]. Chemical conditions are quite good (neutral pH (6.7–6.8)), but low DO (5.0 to 5.6 mg/L) and high CO_2 (13.4–20.3 mg/L) indicate intense biological activity [30,31]. High TOM (9.84–12.82 mg/L) indicates a large organic load that increases microbial activity and BOD, which can reduce oxygen and cause stress in fish [32–35]. Environmental stress can divert energy from reproduction to survival, thereby inhibiting gonadal development, with the effects also being influenced by organic matter and microbial activity [36,37]. TOM, BOD, and DO together determine the quality of aquatic habitats and influence the reproductive success of organisms [38–41]. Nutrient levels, including nitrate (1.09–1.23 mg/L), ammonia (0.05–0.10 mg/L), and orthophosphate (0.18–0.20 mg/L) indicate enrichment that could potentially cause eutrophication, and salinity indicates estuarine influence [42–44]. At the time of the study, the Porong River still supported aquatic life, but was experiencing environmental stress due to the accumulation of organic matter and nutrients.

3.2. Microplastic Abundance and Identification

Microplastic contamination was assessed by analyzing water samples from each station, focusing on both abundance and particle types shown in Table 2 and Fig. 1.

Table 2. Type and abundance of microplastics in Porong River

Location	Type of Microplastics				Total	Average (particle/m^3)
	Film	Fragment	Fiber	Pellets		
Location 1	6	18	5	9	37	7467
Location 2	8	16	4	14	42	8467
Location 3	14	19	5	17	56	11200

Microplastics were found at all sampling points, with average abundances ranging from 7,467 to 11,200 particles m^{-3} (highest at Station 3), indicating a relatively higher level of contamination in that area. These values fall within the range reported for other impacted freshwater systems and reinforce the idea that microplastics are now widespread in rivers and lakes [45,46] . The increasing trend across stations likely reflects differences in human activity along the river. Areas with higher population density or more intensive land use often show higher microplastic levels, mainly due to domestic waste and wastewater inputs [47,48].

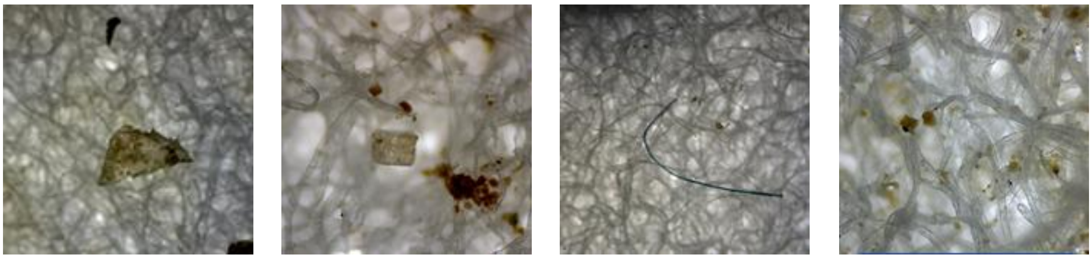
(a) (b) (c) (d)

Fig. 1. Types of microplastics obtained in Porong River: (a) Fragment, (b) Film, (c) Fiber, and (d) Pellets.

Morphological classes (fragments, fibers, films, pellets) align with categories repeatedly documented in freshwater monitoring, where fragments are often dominant [49]. Their origins can also be inferred: fragments and films usually come from the breakdown of larger plastic items, fibers are often linked to textile sources and wastewater, and pellets may be associated with industrial raw materials [50]. The presence of multiple types suggests that microplastics in the river come from a variety of sources and pathways. Given their persistence and ability to interact with other pollutants, continued monitoring remains important [3,51].

3.3. Gonadosomatic Index and Fecundity

The reproductive condition of the silver barb was evaluated based on gonadal maturity stages and gonadosomatic index (GSI), as presented in Table 3. The presence of fish at different maturity stages suggests that reproduction may occur over an extended period rather than in a single season, which is common in many riverine species [2,52]. Differences in GSI values among individuals and stations likely reflect variations in environmental conditions [53]. Temperature, for example, plays a key role in regulating reproductive cycles, while oxygen availability influences how energy is allocated for growth and reproduction [54,55]. In general, higher GSI values were observed in areas with relatively better environmental conditions. This is in line with previous studies showing that pollution, particularly chemical contaminants with endocrine-disrupting effects, can reduce GSI and interfere with normal gonadal development [48]. Similar patterns have been reported in other freshwater systems, where exposure to pollutants is associated with lower reproductive performance [56]. Fecundity also varied among individuals, which is expected. Differences in body size and condition are known to influence egg production, with larger and healthier individuals typically producing more eggs. However, environmental stress can increase variability and weaken this relationship [57,58].

Table 3. Gonadosomatic index (GSI) measurement results of fish

Location	Maturity Stages	Fish Weight (g)	Total Gonad Weight (g)	GSI (%)	Fecundity(eggs)
1	V	66	0.09	0.14	26
2	V	104	0.1	0.10	119
	III	197	2.71	1.38	352
	IV	196	2.88	1.47	3514
	IV	689	132.72	19.26	24155
3	IV	163	1.58	0.97	1169
	III	36	0.63	1.75	Male
	IV	124	1.97	1.59	Male
	V	88	0.07	0.08	Male
	V	148	0.05	0.03	Male

As shown in Fig. 2, egg diameter measurements showed considerable variation, with average values of 677.50 ± 122.39 µm at Location 1, 715.63 ± 143.76 µm at Location 2, and 613.75 ± 108.74 µm at Location 3, with values broadly comparable to reported cyprinid eggs in closely related *Barbonymus gonionotus* crosses (mean egg diameter ≈0.72 mm) measured via microscopy-based morphometrics [59]. Such variation is consistent with differences in reproductive condition and egg quality, because egg morphology (including diameter) is widely treated as a reproduction-relevant trait that can respond to maternal energetic status (notably lipid allocation) and is discussed alongside fertilization and hatching performance in freshwater finfish [60]. The between-location differences are also plausibly mediated by environmental conditions, as fish embryonic development rates and hatching timing are documented to vary with external water parameters (e.g., temperature, DO, and pH), and prior cyprinid developmental work explicitly notes that egg-size and developmental differences can be influenced by incubation temperature and water quality [57,60].

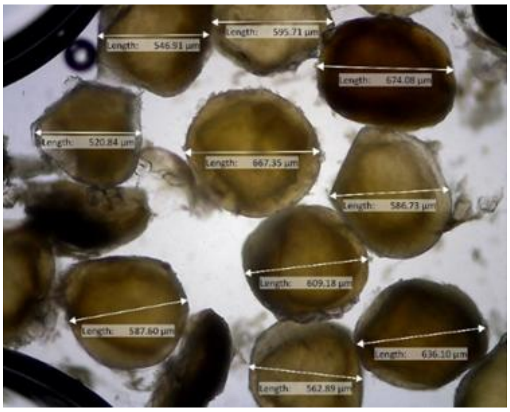

Fig. 2. Eggs of Silver Barb (*Barbonymus gonionotus*)

3.4. Relationship of Microplastics with Gonadal Maturity

Observed co-variation between degraded water quality (e.g., elevated organic matter and microbial activity) and higher microplastic abundance is plausible because microplastics in inland waters participate in coupled transport–transformation processes that are strongly mediated by hydrodynamics and biogeochemistry [45]. In particular, polymer degradation and fragmentation into smaller particles can occur via interacting physical, chemical, and biological mechanisms, which may be facilitated under environmentally reactive conditions (e.g., biofilm-mediated processes) [39]. Nevertheless, microplastic abundance cannot be attributed to "water quality" alone, because watershed inputs and in-river transport/retention (including effects of organic matter, ionic strength, and flow conditions) can dominate spatial patterns [29].

Microplastics may impair gonadal development through physiological stress and endocrine-related pathways, and reviews synthesize evidence for reproductive disturbance in fish following microplastic exposure [31,61]. Risk may be amplified because plastics can contain additives and sorb co-occurring pollutants, potentially increasing organism exposure to endocrine-active/toxic chemicals, although the magnitude of this vector effect is context-dependent and remains an active uncertainty [62].

4. Conclusions

The results of this study indicate that the overall water quality of the Porong River still falls within the Class III standards defined by Government Regulation No. 22 of 2021. Measured parameters showed temperature values between 27.8–29°C, TDS 249.9–652.1 mg/L, TSS 4.1–37.9 mg/L, pH 6.7–6.8, 282 DO 5.0–5.6 mg/L, CO_2 13.4–20.3 mg/L, nitrate 1.09–1.23 mg/L, ammonia 0.05–0.10 mg/L, 283 phosphate 0.18–0.20 mg/L, TOM 9.84–12.82 mg/L, and salinity 2.06–5.12 g/L. Even so, these values also suggest that the river is not entirely free from environmental pressure. Signs of moderate stress are evident, particularly from the accumulation of organic matter and the presence of microplastics. Microplastic abundance, which ranged from 7,467 to 11,200 particles/m^3 across the sampling stations, points to ongoing inputs from human activities. Plastic pollution is likely to increase, and although Porong Rivers still support fish reproduction, the impact of environmental stress can slowly reduce reproductive performance over the long term. From a management perspective, these findings suggest that integrated river management is needed to reduce plastic pollution, as well as strengthening the waste management system and public education to maintain the sustainability of ecosystems and fisheries.

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Author Declaration

Data availability statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement: NPW: Conceptualization, Investigation, Formal Analysis, Data Curation, Visualization, Writing Original Draft. MFHM: Methodology, validation. NSN: Investigation, Data Curation, Formal Analysis. MHNP: Investigation, Resources, Data Collection. RGM: Formal Analysis, Software, Visualization.

Declaration of Competing Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Artificial Intelligence Statement: The authors declare that generative AI tools were used solely to assist with language editing and grammar improvement. All scientific content, data analysis, interpretation, and conclusions presented in this manuscript were developed entirely by the authors.

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