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Microplastics in the Digestive Tract of Eels (*Anguilla* sp.) from Lake Poso, Central Sulawesi, and Their Use as Educational Media

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Abstract: This study aimed to analyze the occurrence and abundance of microplastics in the digestive tract of eels (*Anguilla* sp.) from Lake Poso and to implement the findings as an educational poster-based learning medium. A quantitative descriptive method was employed using six eel samples collected from the Pamona area. Microplastic analysis was conducted through organic matter digestion using 10% KOH solution, filtration with Whatman No. 42 filter paper, and microscopic particle identification. The results showed that all samples (100%) were contaminated with microplastics, with a total of 221 particles and an average abundance of 36.8 particles per individual. The identified microplastic types consisted of fibers (56.56%), fragments (23.53%), and films (19.91%), while pellets were not detected. The dominance of fibers suggests that the main sources of contamination were likely domestic and fishing activities around Lake Poso. The research findings were subsequently developed into an educational poster, which obtained an average feasibility score of 84% and was categorized as highly feasible. These findings contribute to scientific knowledge on microplastic contamination in freshwater eels and demonstrate the potential of local research findings to serve as contextual learning resources for improving students' environmental literacy and awareness.
Keywords: *Anguilla* sp.; Lake Poso; learning media; microplastics; *Waya Masapi*

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INTRODUCTION

Plastic waste pollution has become one of the most pressing environmental challenges worldwide. This problem is largely driven by the extensive use of plastic in daily human activities and the inadequate management of plastic waste (Jambeck et al., 2015). In aquatic environments, plastic debris can undergo physical degradation into particles smaller than 5 mm, commonly known as microplastics (Azizah et al., 2020). Due to their small size, microplastics can disperse widely in aquatic ecosystems and may be ingested by various aquatic organisms when they are mistaken for food or natural prey. Once ingested, these particles may cause physical damage to tissues and expose organisms to hazardous chemical substances associated with the particles (Egbeocha et al., 2018). Microplastics may also pose potential risks to human health because particles accumulated in aquatic organisms can be transferred through the food chain. Several studies have reported that microplastic exposure may affect the digestive, circulatory, reproductive, and respiratory systems (Aulia et al., 2023).

Microplastics have been detected in freshwater bodies, sediments, and aquatic biota in various regions. Their occurrence in aquatic ecosystems has become a global concern because these particles can accumulate in organisms through direct ingestion and trophic transfer within food chains (Li et al., 2020; Egbeocha et al., 2018). Freshwater ecosystems are particularly vulnerable because they receive plastic inputs from domestic waste, agriculture, fisheries, tourism, and other human activities occurring around water bodies.

Eels (*Anguilla* sp.) are among the important biota of Lake Poso and have high ecological and economic value. Local communities refer to them as *masapi* or *sogili*, and they are widely valued for their taste and nutritional quality. As carnivorous predators, eels may accumulate microplastics through trophic transfer, in which particles move from organisms at lower trophic levels to predators at higher trophic levels (Arai & Kadir, 2017). However, studies on microplastic contamination in eels from freshwater ecosystems remain limited compared with studies on fish from marine environments. This gap is important to address because eels occupy multiple habitats during their life cycle and may be exposed to microplastics from different environmental sources.

Previous research in Indonesian freshwater ecosystems has shown that microplastics are present in fish digestive organs. Puspita et al. (2022) reported that consumed fish from Rawa Pening contained microplastics in the form of fragments, fibers, films, and foams, with transparent particles being dominant. Other studies in Indonesian waters have also indicated that fiber-shaped microplastics are frequently the dominant type found in aquatic organisms. This dominance is commonly associated with the widespread use of synthetic textiles and fishing activities that release plastic fibers into aquatic environments (Yudhantari et al., 2019; Hartini & Dewi, 2021). These findings suggest that microplastic pollution in freshwater environments is closely linked to anthropogenic activities and may affect aquatic organisms that are consumed by local communities.

Research on microplastics in the genus *Anguilla* remains relatively scarce. Existing studies have mainly focused on other aspects of eel biology or plastic degradation. For example, Senjaya et al. (2021) examined the potential of bacteria from the digestive tract of eels to degrade plastic waste but did not report the level of microplastic contamination in the eel digestive tract itself. Therefore, information on the occurrence, types, and abundance of microplastics in eels from Indonesian freshwater ecosystems remains insufficient, particularly in lake ecosystems such as Lake Poso.

Microplastic pollution is not only an environmental issue but also an important topic for science education. Low public awareness of the impacts of plastic waste highlights the need to strengthen environmental literacy through contextual learning. Research findings on microplastic contamination in eels can provide scientific information about the condition of aquatic environments and can also be developed into poster-based learning media. By presenting local research findings in a visual and contextual format, such media can help students understand environmental pollution, its impacts on aquatic organisms, and the importance of conserving freshwater resources. Thus, integrating environmental research into learning media represents a strategic effort to connect scientific findings with education and to promote students' ecological awareness.

Based on observations around Lake Poso, plastic pollution is presumed to be associated with human activities along the lakeshore, including settlements, tourism, and fishing activities. This study was conducted in the Pamona area of Lake Poso, with sampling focused on *waya masapi*, a traditional fishing device used by local fishers along the natural migration route of eels toward the sea. Although studies on microplastics in freshwater fish have been conducted in Indonesia, to the best of the authors' knowledge, scientific information on microplastic contamination in the digestive tract of eels (*Anguilla* sp.) from Lake Poso, Central Sulawesi, remains unavailable. Lake Poso is an important habitat for eels and is increasingly exposed to anthropogenic pressures that may generate plastic waste. Therefore, eels may serve as a potential bioindicator for assessing microplastic pollution in this freshwater ecosystem. In addition, because eels are economically valuable and commonly consumed by local communities, microplastic contamination in this organism may also have implications for food safety.

Based on this background, this study aimed to identify the presence of microplastics in the digestive tract of eels, determine the types of microplastics found, and develop learning media based on research findings on microplastic contamination in eels (*Anguilla* sp.) from Lake Poso. The novelty of this study lies in providing baseline data on microplastic contamination in eels from Lake Poso while also translating local environmental research into educational poster media to support students' environmental literacy. The findings are expected to contribute to environmental science, fisheries studies, and biology education, as well as to support efforts to improve public awareness and management of plastic waste in the Lake Poso area.

METHOD

Study Design and Sampling

This study employed a laboratory observational method with a quantitative descriptive approach to identify and characterize the occurrence of microplastics in the digestive tract of eels (*Anguilla* sp.). The study population consisted of eels (*Anguilla* sp.) inhabiting the waters of Lake Poso, with six individuals selected as samples using purposive sampling (Sugiyono, 2016).

The study was conducted from January to March 2026. Eel samples (*Anguilla* sp.) were collected from Lake Poso, Pamona District, Poso Regency, Central Sulawesi, Indonesia, located at approximately 1°54'–2°04' S and 120°32'–120°43' E, particularly in the Pamona area. This location was selected because of its strategic position as a natural migration route for endemic aquatic biota. Therefore, sampling was carried out directly at the *waya masapi* fishing site used by local fishers. All specimens collected from the lake ecosystem were subsequently analyzed at the Biology Laboratory, Faculty of Teacher Training and Education, Tadulako University. The sampling location is shown in Figure 1.

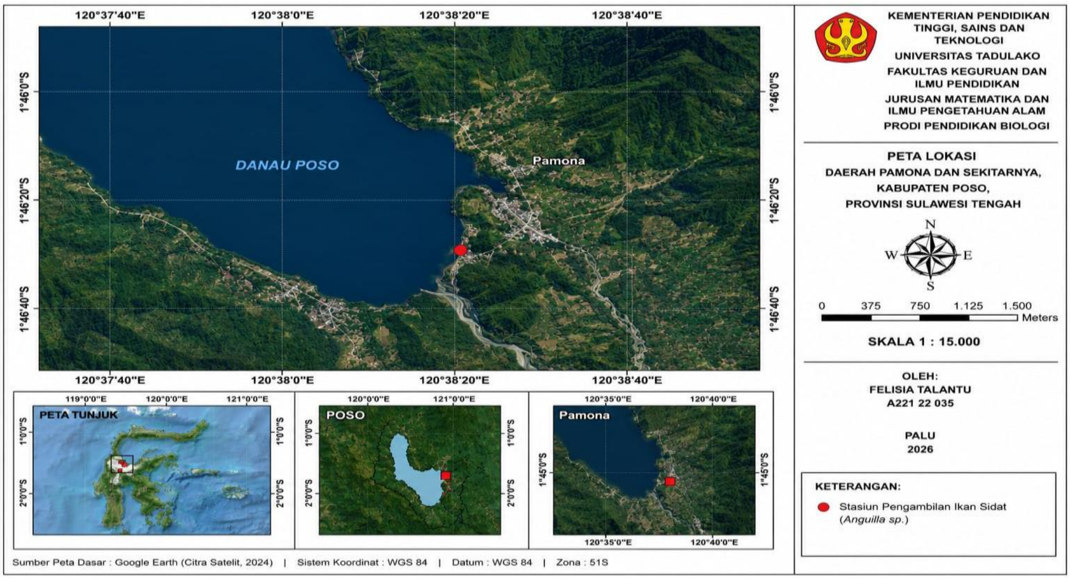


Figure 1. Map of the research location in Lake Poso, Pamona District, Poso Regency, Central Sulawesi (The red point indicates the eel (*Anguilla* sp.) sampling site in the *Waya Masapi* area)

Samples were collected purposively from sites influenced by residential and fisheries activities. The collected fish specimens were placed in storage containers and preserved in 70% ethanol to maintain the integrity of the digestive organs prior to laboratory analysis. The instruments used in this study included a microscope, Erlenmeyer flasks, an incubator, an oven, filter paper, and a set of dissection tools. The materials used consisted of 10% KOH solution, distilled water, and aluminum foil.

Microplastic Extraction and Identification

The analytical procedure began with the dissection of the digestive tract. The isolated digestive tract was immersed in 10% KOH solution and incubated at 60°C for 48 h until the organic matter was degraded. The digested solution was then filtered using Whatman No. 42 filter paper with an approximate pore size of 2.5 μm. Particles retained on the filter paper were dried and observed under a light microscope at 100× to 400× magnification.

Microplastics were identified based on their morphological characteristics and classified into four categories: fibers, fragments, films, and pellets. Based on particle size, microplastics were categorized as small (<1 mm), medium (1–3 mm), and large (3–5 mm). Final identification was performed visually using a binocular microscope at 40× to 100× magnification to verify the accuracy of the number and morphology of the detected microplastic particles.

Data Analysis

The data obtained, consisting of the number and types of microplastics found in the digestive tract of eels, were analyzed using a quantitative descriptive approach. Microplastic abundance was calculated for each sample to determine the mean value. Microplastic density was calculated using the following formula:

$$\mathrm{KR} = \frac{\mathrm{ni}}{\mathrm{N}}$$

Note:
KR = microplastic density (particles/individual)
ni = number of microplastic particles detected
N = total number of fish samples (individuals)

The identified microplastic particles were then classified according to their morphology, namely fibers, fragments, films, and pellets, to determine the dominant microplastic type. The results were presented in tabular form to facilitate interpretation and were further related to the environmental conditions of Lake Poso and anthropogenic activities that may contribute to microplastic contamination.

Development and Validation of Learning Media

The development of the learning media was conducted using a Research and Development (R&D) model adapted from the stages proposed by Borg and Gall (Borg & Gall, 2003). The stages implemented in this study included planning, development of the initial product, expert validation, product revision, and limited-scale testing.

The validation instrument consisted of an assessment questionnaire using a Likert scale, covering the aspects of content feasibility, language, presentation, and media appearance. The validation data were analyzed using the feasibility percentage technique with the following formula:

$$\text{Mean percentage} = \frac{\text{Total percentage score}}{\text{Number of assessment aspects}} x100$$

The feasibility categories for the learning media are presented in Table 1.

Table 1. Feasibility percentage categories for learning media

Percentage	Media Feasibility Category
81%–100%	Highly feasible
61%–80%	Feasible
41%–60%	Moderately feasible
21%–40%	Not feasible
<21%	Highly not feasible

Source: Arikunto (2014)

RESULTS AND DISCUSSION

The results of this study showed that all eel (*Anguilla* sp.) samples collected from Lake Poso were contaminated with microplastics. This finding indicates that microplastics have entered the freshwater ecological system of Lake Poso and may accumulate in predatory organisms such as eels. This condition is consistent with Horton et al. (2017), who reported that freshwater ecosystems, including lakes and rivers, are vulnerable to microplastic accumulation because they receive plastic waste inputs from human activities on land. The microplastics identified in the digestive tract of eel consisted of three morphological types: films, fragments, and fibers. The number of microplastic particles detected in each sample is presented in Table 2.

Table 2. Microplastic content in the digestive tract of eel (*Anguilla* sp.)

Sample	Length (cm)	Body weight (kg)	Number of samples	Film	Fragment	Fiber	Total particles
Anguilla sp. 1	115	6.0	1	11	30	34	75
Anguilla sp. 2	105	5.5	1	5	7	27	39
Anguilla sp. 3	95	5.0	1	15	1	21	37
Anguilla sp. 4	65	1.1	1	7	6	18	31
Anguilla sp. 5	55	0.9	1	1	5	17	23
Anguilla sp. 6	45	0.7	1	5	3	8	16
Total							**221**
Microplastic density							**36.8**

As shown in Table 2, a total of 221 microplastic particles were found in the six eel samples, with an average density of 36.8 particles/individual. The highest number of particles was recorded in the first sample, with 75 particles, whereas the lowest number was found in the sixth sample, with 16 particles. In general, larger individuals tended to contain more microplastic particles than smaller individuals. However, this pattern should be interpreted cautiously because of the limited number of samples. The observed tendency may indicate that body size, individual age, foraging range, and food intake volume could influence the likelihood of microplastic accumulation in the digestive tract.

Eels are benthic predators that actively forage near the bottom substrate. This feeding behavior may increase their exposure to microplastics through two main pathways: direct ingestion from water and sediment, and indirect ingestion through contaminated prey organisms. This mechanism is related to trophic transfer, in which particles or contaminants move from organisms at lower trophic levels to predators at higher trophic levels. Egbeocha et al. (2018) explained that microplastics can be ingested by aquatic organisms and may cause both physical and chemical effects. Wright et al. (2013) also emphasized that ingested microplastic particles can cause mechanical disturbances in the digestive tract, interfere with feeding activity, and affect the physiological condition of aquatic organisms.

The percentage distribution of each microplastic type is presented in Table 3.

Table 3. Distribution of total particles by microplastic type

Microplastic Type	Total particles	Percentage (%)
Fiber	125	56.56
Fragment	52	23.53
Film	44	19.91
Pellet	0	0
Total	**221**	**100**

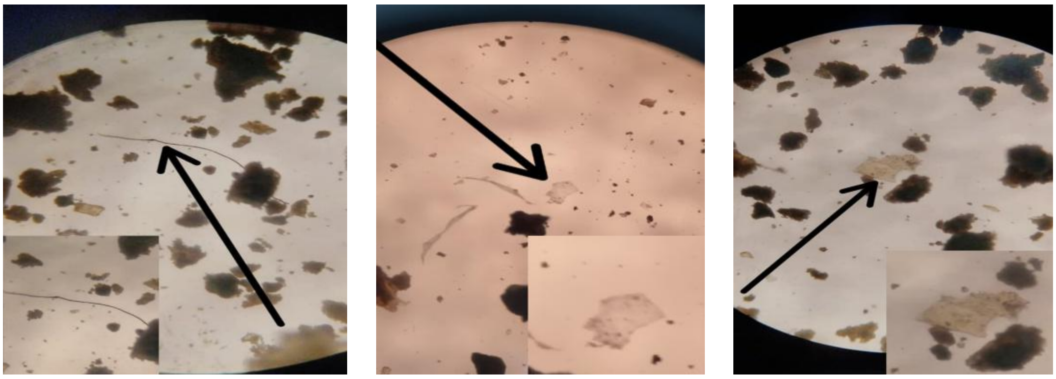
Table 3 shows that fibers were the most dominant microplastic type, with 125 particles or 56.56% of the total particles. Fragments were the second most abundant type, with 52 particles or 23.53%, followed by films, with 44 particles or 19.91%. No pellet-type microplastics were detected in any of the samples analyzed. The dominance of fibers in this study supports the assumption that the main sources of microplastic contamination in Lake Poso are domestic and fisheries-related activities, particularly wastewater from synthetic textile washing, plastic ropes, fishing nets, and degraded nylon-based fishing gear.

The dominance of fiber-type microplastics observed in this study is consistent with Li et al. (2020), who reported that fibrous microplastics are commonly found in aquatic ecosystems as a result of domestic activities and synthetic textile waste. Napper and Thompson (2016) also reported that the washing of synthetic clothing can release microplastic fibers into wastewater, making it an important pathway through which microplastics enter aquatic environments. Similar findings were reported by Yudhantari et al. (2019) in Bali Strait lemuru fish, where fibers were the dominant microplastic type compared with other particle forms. Hartini and Dewi (2021) also found fiber-dominated microplastics in biota and water samples from the Brantas River. These similar patterns suggest that fibers are among the most common microplastic forms found in Indonesian aquatic ecosystems, both in marine and freshwater environments.

The morphological characteristics of the identified microplastics also provide indications of their possible sources. Fiber microplastics were characterized by elongated, thread-like shapes and are commonly associated with the degradation of synthetic textiles, plastic ropes, fishing nets, or domestic waste. Fragments had irregular shapes and relatively rough surfaces, which are generally derived from broken hard plastics such as bottles, plastic containers, pipes, or other degraded plastic materials. Meanwhile, film microplastics were thin and flexible and are usually derived from plastic bags, food packaging, or other single-use plastics that fragment easily in aquatic environments (Free et al., 2014; Hiwari et al., 2019; Yona et al., 2023). Therefore, the composition of microplastics found in this study indicates that pollution pressure in Lake Poso is closely related to anthropogenic activities around the lake, including settlements, fisheries, and tourism.

The absence of pellet-type microplastics in all samples indicates that microplastic contamination in eels from the Pamona area of Lake Poso was unlikely to be dominated by primary industrial plastic materials. Pellets are commonly associated with plastic resin raw materials or industrial spills. In contrast, the dominance of fibers, fragments, and films suggests that the microplastics contaminating the digestive tract of eel were more likely secondary microplastics, which originate from the fragmentation of larger plastic debris. Such fragmentation may occur through environmental weathering caused by ultraviolet exposure, temperature changes, water movement, and other mechanical processes. Barnes et al. (2009) explained that plastic degradation in the environment can generate smaller particles that are widely dispersed and difficult to control in aquatic ecosystems.

A visual representation of the microplastic types found in the digestive tract of eel is shown in Figure 2.



a **b** **c**

Figure 2. Microplastic types: (a) fiber; (b) fragment; (c) film

The presence of microplastics in all eel samples has important ecological implications. As a species with high ecological and economic value, eel may serve as a bioindicator of microplastic pollution in Lake Poso. Once ingested, microplastics may remain in the digestive tract because they are not easily digested by fish. The accumulation of these particles may interfere with digestion, reduce nutrient absorption efficiency, induce physiological stress, and act as carriers for hazardous chemicals adsorbed onto the plastic surface. Rochman et al. (2015) reported that anthropogenic debris, including plastic fibers, can be found in fish and bivalves intended for human consumption. Therefore, microplastic contamination in aquatic biota should also be considered from a food safety perspective. In this context, the presence of microplastics in eel from Lake Poso is relevant not only ecologically, but also in relation to public health because eels are consumed by local communities.

These findings further support the view that freshwater ecosystems are highly vulnerable to microplastic pollution. Microplastic research has historically focused more on marine ecosystems, although lakes, rivers, and wetlands can also function as important accumulation sites because they receive waste inputs from land-based activities. Horton et al. (2017) emphasized that research on microplastics in freshwater ecosystems needs to be expanded because freshwater systems play an important role in transporting plastic particles from land to the ocean. Thus, the data from Lake Poso provide important baseline information for understanding microplastic contamination in eel from Indonesian freshwater ecosystems.

In addition to generating ecological data, this study also developed the research findings into an educational poster as a biology learning medium. The poster was validated by content experts, design experts, media experts, and students as users. This validation aimed to assess the feasibility of the content, visual appearance, readability, and effectiveness of the poster in communicating information about microplastic pollution in eel. The validation results are presented in Table 4.

Table 4. Validation results of the learning medium

Validator	Percentage (%)	Feasibility category
Content expert	85	Highly feasible
Design expert	82	Highly feasible
Media expert	81	Highly feasible
Students	88	Highly feasible
Average	**84**	**Highly feasible**

As shown in Table 4, the educational poster obtained an average validation score of 84%, placing it in the highly feasible category. This result indicates that the developed medium was able to present information clearly, systematically, communicatively, and visually attractively. The combination of colors, images, layout, and research-based data presentation was considered helpful in supporting students' understanding of microplastic pollution in a more concrete manner. Ariyanto et al. (2018) stated that appropriate learning media can help improve students' understanding of biological concepts. In this study, the use of local data from Lake Poso makes the poster more contextual because it connects environmental pollution material with real ecological phenomena in students' surrounding environment.

The use of research findings as a learning medium has important value for strengthening environmental literacy. Data on fiber dominance, the presence of fragments and films, and the absence of pellets can be used to explain pollution sources, plastic degradation processes, pathways of microplastic entry into organisms, and their impacts on aquatic ecosystems. Through an educational poster, complex scientific information can be simplified into visual material that is easier to understand while maintaining its scientific substance. This approach can help bridge the gap between classroom theory and ecological realities in students' local environment.

Overall, this study provides important baseline data on the presence of microplastics in the digestive tract of eel (*Anguilla* sp.) from Lake Poso. The finding that all samples were contaminated with microplastics highlights the need for serious attention to plastic waste management around the lake, particularly waste originating from settlements, fisheries, and tourism activities. From a conservation perspective, microplastic contamination in eel requires attention because this species has ecological, economic, and social value for communities around Lake Poso. Therefore, controlling plastic waste sources, conducting regular water quality monitoring, and educating communities through research-based learning media are important steps to support the sustainability of the Lake Poso ecosystem.

CONCLUSION

Based on the findings of this study, all eel (*Anguilla* sp.) samples collected from the *waya masapi* area of Lake Poso were contaminated with microplastics, with a prevalence of 100%. A total of 221 microplastic particles were detected, with an average abundance of 36.8 particles per individual. The microplastic types identified in the digestive tract consisted of fibers (56.56%), fragments (23.53%), and films (19.91%), whereas pellets were not detected. The absence of pellets suggests that microplastic contamination in the Pamona area is likely associated with domestic waste and local anthropogenic activities rather than primary industrial plastic sources. The findings of this study were subsequently developed into an educational poster, which received an average validation score of 84% and was categorized as highly feasible. Therefore, the poster can be used as a contextual learning medium to improve students' environmental literacy and awareness of the risks of microplastic pollution in Lake Poso.

RECOMMENDATION

Based on these findings, strategic measures are needed, particularly the implementation of integrated waste management policies by local authorities, to reduce sources of secondary microplastics originating from domestic and fisheries-related activities around Lake Poso. The conservation of endemic aquatic biota should also be integrated into educational practices through the use of locally based scientific learning media, such as research-based educational posters. Such media can serve as visual educational tools to strengthen ecological awareness and encourage active community participation in mitigating plastic pollution.

Further research is also strongly recommended by increasing the number of samples and expanding the sampling locations to obtain more representative data on the level of microplastic contamination in Lake Poso. Future studies should also apply advanced instrumental analyses, such as Fourier Transform Infrared Spectroscopy (FTIR), and investigate biomagnification in the muscle tissue of eels. These approaches would provide a more comprehensive scientific basis for assessing environmental toxicity risks and ensuring food safety for local communities in the future.

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