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Microplastics Contamination in Commercial Fish Landed at Tasikagung Rembang Coastal Fishing Port, Central Java, Indonesia

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ABSTRACT

Microplastics are synthetic polymers measuring 5 mm or less. Biota may deliberately or inadvertently consume microplastics that pollute aquatic environments. This study aimed to investigate the distribution of microplastics in the gills, digestive tracts, and flesh of the commercial fish species *Decapterus* sp., *Priacanthus tayenus*, and *Nemipterus* sp. captured in PPP Tasikagung, Rembang. The objective of this study was to identify and study the features of microplastics in commercial fish, specifically *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp., at PPP Tasikagung, focusing on their shape, color, size, and polymer type. In July and September 2024, 30 individual fish specimens were gathered. We quantified the length and mass of each fish specimen, performed dissections, and procured the gills, digestive tract, and tissue for examination and microplastic analysis. Each gill, digestive tract, and tissue was processed with a 20% potassium hydroxide (KOH) solution to decompose all organic matter. Whatman No. 41 paper was used to filter the digestion findings, and the prevalence of microplastic morphologies and colors were examined with a binocular microscope (CX21, Olympus, Japan) at a maximum magnification of 400x. The data were examined utilizing Microsoft Excel and SPSS 25.0 software. The analysis indicates that the average microplastic detection rates are 40.8% for *Decapterus* sp., 25.7% for *P. tayenus*, and 33.5% for *Nemipterus* sp. Microplastic forms were predominantly characterized by fiber shapes and a black color with range in size from 50 to 500µm. The types of polymers found are high density polyethylene (HDPE) and polyethylene terephthalate (PET). This study reveals emphasizing the urgent necessity to tackle microplastic pollution in aquatic environments to protect the health of organisms and to ensure human food safety.

INTRODUCTION

The substantial escalation in plastic manufacturing and consumption may lead to an increase in environmental plastic waste. According to **UNEP (2021)**, currently, the amount of plastic reaches approximately 400 million tons per year. However, only around 9% of the plastic produced has been recycled and 12% is burned. If there is no further management action, the flow of plastic waste into the waters is predicted to increase by approximately 11 million tons in 2016 to around 29 million tons in 2040. **Dhali *et al.* (2024)** state that plastic waste is hard to degrade under natural conditions. Plastic debris dispersed along the coastline, surface, and seabed constitutes 95% of the total garbage accumulated in the ocean **(Galgani, 2015)**. Plastic debris in aquatic environments may degrade and fragment due ultraviolet light exposure, which leads to the formation of microplastics **(Ng *et al.*, 2021)**.

Microplastics are plastic particles that are less than 5mm in size **(Kılıç & Yücel, 2023)**. They can enter water bodies in both primary and secondary forms. According to **Zhang *et al.* (2017)**, primary microplastics are plastics intentionally produced in micro sizes, such as microbeads found in cosmetic products, which can then enter water channels. Secondary microplastics are microplastics that originate from the fragmentation of macro-sized plastics. The presence of microplastics in water bodies can cause various problems, particularly regarding their potential contamination of aquatic biota and the risks they pose to human health. Fish, as an important part of the food chain, can easily be contaminated by microplastics if they intentionally or unintentionally consume these particles.

Microplastics that accumulate in the bodies of fish in large quantities can disrupt the fish's digestive process because plastic is difficult to break down **(Browne *et al.*, 2013)**. Microplastics that accumulate in the digestive systems of fish can cause various problems, such as malnutrition, starvation, and even death in fish **(Boerger *et al.*, 2010)**. Microplastics also have the potential to negatively impact humans. **Piyawardhana *et al.* (2022)** assert that if microplastics contaminate fish meat, humans cannot avoid consuming them. The small size of microplastics has the potential to bypass biological barriers, allowing them to penetrate tissues and to accumulate in organs **(Von Moos *et al.*, 2012)**. Continuous exposure to microplastics can cause changes in chromosomes and can increase the potential for various diseases, including lung, prostate, and breast cancer **(Prins, 2008)**. Given the potential for microplastics to contaminate human-consumed fish, the sustainability and safety of fish consumption has become crucial and requires attention.

Several previous studies have discussed the presence of microplastics in fish bodies. **Sawalman *et al.* (2021)** found up to 931 microplastic particles in the gill organs, flesh, and digestive tracts of *Hemiramphus far*, *Lethrinus lentjan*, and *Siganus virgatus* fish from the waters of Barranglompo Island, Makassar. **Utomo and Muzaki (2022)** conducted research and found 510 particles in 2- month-old *Oreochromis niloticus* and 330 particles in 4-month-old *Oreochromis niloticus* from the Floating Net Cage of Ranu Grati, Pasuruan, East Java.

Decapterus sp., *P. tayenus*, and *Nemipterus* sp. are some important commercial fish species landed at the Tasikagung Coastal Fishing Port (PPP), Rembang. The total fish production at PPP Tasikagung reached more than 78 million kilograms with a production value of over Rp 623 billion. The production of *Decapterus* sp. at PPP Tasikagung reached more than 399 thousand kilograms with a production value of more than Rp 3 billion **(PPP Tasikagung, 2023)**. The fish smoking industry in Tasikagung uses *Decapterus* sp. as its main raw material, making it a flagship product in fish processing **(Lubis *et al.*, 2019)**. *Nemipterus* sp. is also classified as a commercial fish species. The production of *Nemipterus* sp. at PPP Tasikagung reached more than 9 million kilograms with a production value of over Rp 87 million. Initially not a target fish in fishing, *Priacanthus tayenus* is now a more frequently landed fish with a commercial value as an export product **(Sivakami *et al.*, 2001)**. The production of *P. tayenus* at PPP Tasikagung contributed a volume of more than 16 million kilograms with a production value of more than Rp 109 billion **(PPP Tasikagung, 2023)**. *Nemipterus* sp. and *P. tayenus* have become important raw materials for fishery products made by the local residents. These three types of fish play an important role in the local economy and have become leading commodities in various processed products in Tasikagung, Rembang.

Until now, research into the identification of microplastics in commercial fish at coastal fishing ports, especially PPP Tasikagung, is still limited. Apart from that, research on fish identification in non-digestive parts, especially meat, is also rarely carried out. *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp. were chosen in this study because these three types of fish are used as the main raw material in the fish processing industry so further information is needed regarding the presence of microplastics in their bodies. The Tasikagung PPP was chosen because it is located in the Rembang region, which is strategically connected to Indonesia's main ocean currents. The region is influenced by the Indonesian Throughflow (Arlindo) **(Mahie, 2005)**, which passes through the Makassar Strait as a major conduit for water mass movement between the Pacific and Indian Oceans **(Soedjono *et al.*, 2016)**. This current movement could potentially carry microplastics into the waters north of Java Island. Based on this, research on microplastics on commercial fish landed at PPP Tasikagung, Rembang was carried out to determine the extent to which microplastics can have an influence on the ecosystem in these waters. The results of this research can be used as a basis for further studies in maintaining the sustainability of aquatic ecosystems and increasing public awareness of the potential risks of fish consumption due to the presence of microplastics that can be found in waters. The aim of this research was to determine the distribution of microplastic contamination in the gills, digestive tract and flesh of commercial fish, namely *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp. at PPP Tasikagung, Rembang and knowing the characteristics of microplastics found in commercial fish, namely *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp. at PPP Tasikagung based on form, color, size and type of polymer.

MATERIALS AND METHODS

1. Time and location of research

Samples were collected using simple random sampling from the fishermen's catch in July and September 2024 and were bought at the Tasikagung Fish Landing Site (TPI) Rembang, Central Java (Fig. 1). This study used samples of *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp.

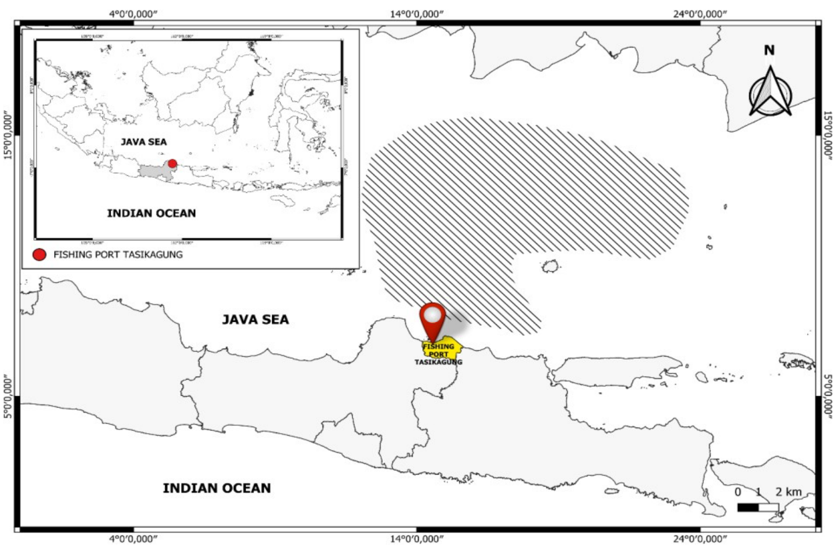

Fig. 1. Commercial fish landing location at PPP Tasikagung Rembang, Central Java, Indonesia

2. Research tools and materials

The tools used in this research include a ruler (precision 0.1cm) for measuring length, a digital scale (precision 0.1 grams) for weighing fish, stationery for recording, a freezer for storing samples in frozen condition, a section kit as a fish dissection tool, Whatman No. 41 filter paper for filtering samples, a vacuum pump set (Rocker 300) to assist in sample filtration, specimen containers as sample containers, a 100ml measuring cup, an oven (Memmert), a binocular microscope (CX21, Olympus, Japan) for observing microplastics, an OptiLab device (OptiLab Viewer 2.2, Miconos, Indonesia) for visualizing found microplastics, Image Raster software (Image Raster 3, Miconos, Indonesia) for measuring microplastics, aluminum foil, object glass (Sail brand, China) as a place for microplastic particles, and cover glass (Sail brand, China) to cover samples on the object glass. The materials used in this study include fish catches such as *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp. as observation samples, 20% KOH as a substance to break down organic materials, and distilled water for sterilization.

3. Research procedure

3.1. Sample measurement and extraction

A total of 30 individuals of *Decapterus* sp., *Nemipterus* sp., and *P. tayenus* were collected (Fig. 2). The sample size used was the same as that of **Arisanti *et al.* (2023)**, who collected 30 *Rastrelliger* spp. from three different fishing grounds in the same fishing area at PPS Belawan. The total body length and mouth opening of each fish were measured. The mouth opening was measured from the top to the bottom when the fish's mouth is wide open **(Ridwan *et al.*, 2020)**. The samples were labeled and placed in the freezer at -20°C and analyzed the following day. *Decapterus* sp., *Nemipterus* sp., and *P. tayenus* were dissected to obtain the gills, digestive tract, and flesh. The fish flesh was obtained by making a longitudinal incision from behind the head to the area near the tail **(Dehaut *et al.*, 2019)**. The gills, digestive tract, and flesh removed were each placed into prepared sample containers, then treated with a 20% potassium hydroxide (KOH) solution with a minimum volume of three times the sample volume. The digestion technique was used to separate and identify microplastics, destroying organic material with an oxidative base solution (20% KOH). The KOH concentration was increased to 20% to enhance the effectiveness of the digestion process. This increase in concentration does not affect or damage the microplastics present in the sample **(Munno *et al.*, 2018)**. Subsequently, incubation was carried out using the method of **Rochman *et al.* (2015)** at a temperature of 60ºC for 24 hours, followed by soaking the samples for 14 days. This method was modified from **Foekema *et al.* (2013)** and then developed by **Munno *et al.* (2018)** in a more efficient method when used to dissolve biological material in tissue. The samples successfully dissolved were then filtered using Whatman No. 41 filter paper with a vacuum pump.

3.2. Contamination control

All equipments utilized in this investigation were disinfected via rinsing with distilled water. During the treatment, the researchers employed cotton laboratory coats, gloves, and masks to reduce contamination. Throughout the laboratory study procedure, the samples were situated in a sterile environment, and measures to prevent cross-contamination, such as the use of air conditioning, were implemented **(Sawalman *et al.*, 2021)**. The workspace and laboratory coats were cleaned using a dust roller to eliminate dust. Three control petri dishes devoid of samples were constructed to confirm the absence of contamination during visual observation **(Nanlohy *et al.*, 2024)**. The control petri dishes were opened during air exposure of the samples and were closed during their absence of air exposure **(Vojnović *et al.*, 2024)**.

4. Observation and data collection

4.1. Microplastic identification

The samples screened were then visually observed using a binocular microscope connected to an OptiLab camera device, then the shape, color, and number of microplastics were recorded and documented. For the characteristics of microplastics observed, they have a size less than 5mm, with no organic structure; microplastics in the form of fibers have the same thickness in all parts, and have a homogeneous particle color **(Hidalgo-Ruz *et al.*, 2012)**. Furthermore, the objects in the image were measured using Image Raster 3 software by applying the measure function.

4.2. FTIR (Fourier Transform Infrared) analysis

FTIR (Fourier Transform Infrared) is a technique for analyzing plastic polymers based on the type of plastic bonds. FTIR operates by identifying functional groups in a compound through the production of infrared absorbance. Each compound exhibits a unique absorbance pattern, facilitating its differentiation and quantification **(Sankari, 2010)**. The results of the FTIR analysis consist of wavelengths originating from the plastic polymers present in the sample. The FTIR ATR spectrum data generated from the tested samples is then entered into the OpenSpecy database.

5. Data analysis

The observational data encompasses the morphology, dimensions, color, and quantity of microplastics, which were assessed for their prevalence. The data were subsequently evaluated descriptively and were presented as graphs or tables. A Spearman Rank correlation test was used to assess the association between the quantity of microplastics in each individual and mouth opening, as well as evaluating the correlation of microplastic abundance in the gills, digestive tract, and flesh of each fish species. The assessment of microplastic prevalence in the gills, digestive system, and tissue is derived from the study conducted by **Boerger *et al.* (2010)** as outlined below.

$$\text{Abundance} = \frac{\textit{The number of microplastics found (MP)}}{\textit{The number of fish (individu)}}$$

The comparison of microplastic abundance was conducted at a significance level of 5%. The normality test revealed that the microplastic abundance among fish species in each organ did not follow a normal distribution. Consequently, the next analysis employed the non-parametric Kruskal-Wallis test to compare the microplastic abundance among different fish species in each organ. The Post Hoc Dunn test will follow if the analysis results indicate a significant value.

The Spearman Rank correlation test is a statistical test applied to determine the correlation between data variables. This test was chosen because the data were not normally distributed. The basis for making this test decision is:

a. If the *P-value* < 0.05, then there is a correlation.
b. If the *P-value* > 0.05, there is no correlation.

According to **Hinkle *et al.* (2003)**, the level of correlation strength was as follows:

a. 0.00 – 0.30 is in the very weak category.
b. 0.30 – 0.50 is in the weak category.
c. 0.50 – 0.70 belongs to the medium category.
d. 0.70 – 0.90 belongs to the strong category.
e. 0.90 – 1.00 belongs to the very strong category.

RESULTS

1. Abundance of microplastics

The research results show that the percentage of fish contaminated with microplastics was calculated based on the number of individuals containing microplastics compared to the total samples analyzed. The percentage of contamination was 100% for *Decapterus* sp., 86.67% for *P. tayenus*, and 93.3% for *Nemipterus* sp. In detail, the microplastic contamination in the organs of *Decapterus* sp. is 37% in the gills, 57% in the digestive tract, and 6% in the flesh. In *P. tayenus*, the percentages are 43% in the gills, 48% in the digestive tract, and 9% in the flesh. In *Nemipterus* sp., the percentages are 41% in the gills, 48% in the digestive tract, and 10% in the flesh.

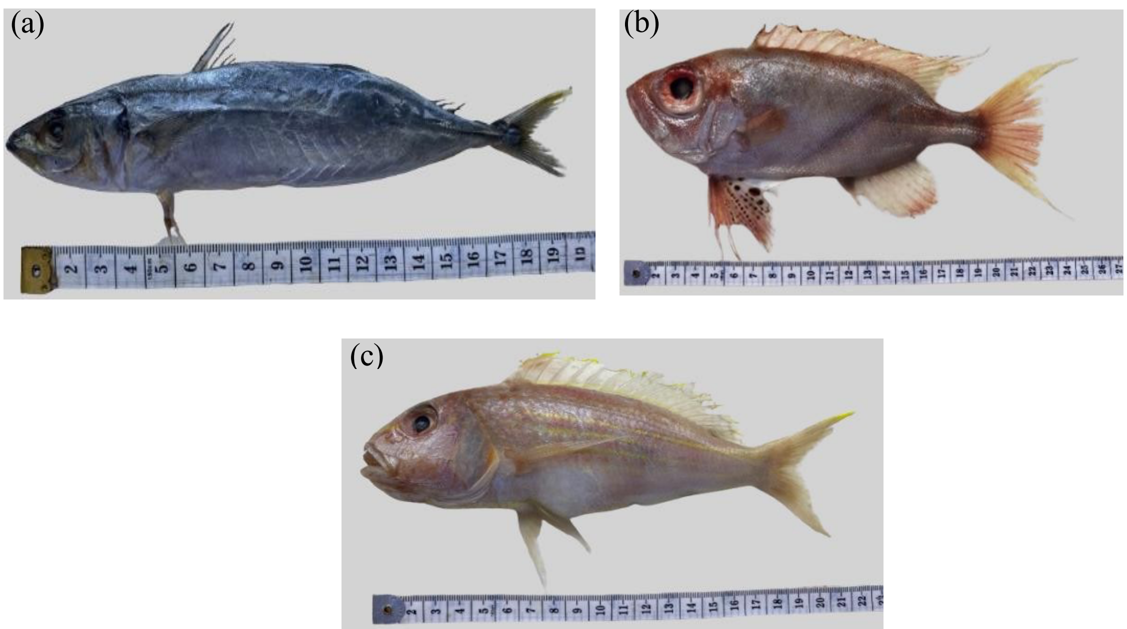

Fig. 2. Research sample **(a)** *Decapterus* sp., **(b)** *P. tayenus*, and **(c)** *Nemipterus* sp.

The abundance of microplastics in each species of commercial fish varied. The abundance was presented based on the gills, digestive tract, and flesh. Fig. (3) presents the abundance of microplastics in each organ of commercial fish species.

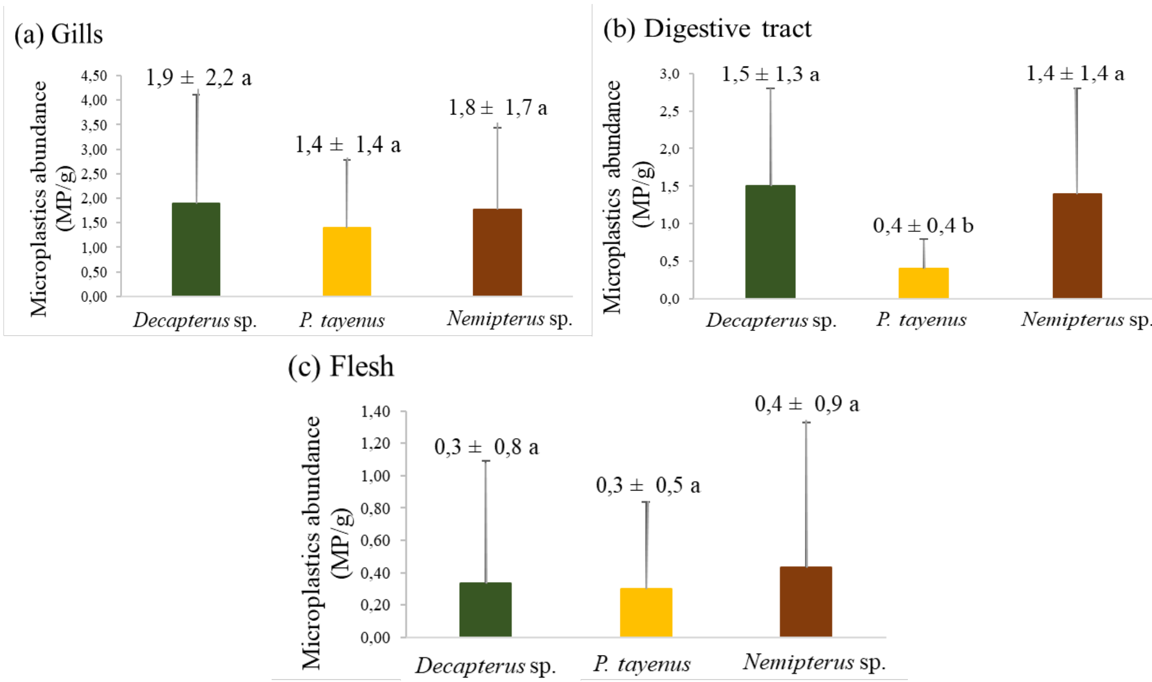

Fig. 3. Abundance of microplastics in each organ in commercial fish species (different letters indicate significant differences *P*-value < 0.05

Based on Fig. (3), the average abundance of microplastics in the gills of *Decapterus* sp. is 1.9 ± 2.2 MP/g, *P. tayenus* is 1.4 ± 1.4 MP/g, and *Nemipterus* sp. is 1.8 ± 1.7 MP/g. The average abundance of microplastics in the digestive tract of the three fish species was at 1.5 ± 1.3 MP/g for *Decapterus* sp., 0.4 ± 0.4 MP/g for *P. tayenus*, and 1.4 ± 1.4 MP/g for *Nemipterus* sp. The average abundance of microplastics in the flesh of *Decapterus* sp. was 0.3 ± 0.8 MP/g, *P. tayenus* was 0.3 ± 0.5 MP/g, and *Nemipterus* sp. was 0.4 ± 0.9 MP/g. The abundance of microplastics in the gills of *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp. was not significantly different (*P*-value = 0.723 > 0.05). This is the same as the abundance of microplastics in the flesh of the three types of fish which also showed no significant difference (*P*-value = 0.907 > 0.05). Meanwhile, in the digestive tract there were significant differences in the abundance of microplastics (*P*-value = 0.000 < 0.05), which was shown by *P. tayenus* being significantly different from *Decapterus* sp. and *Nemipterus* sp.

2. Form, color, and size of microplastics

2.1. Microplastic's forms

The forms of microplastics found are fibers and fragments. A visual representation of the forms of the microplastics found is presented in Fig. (4).

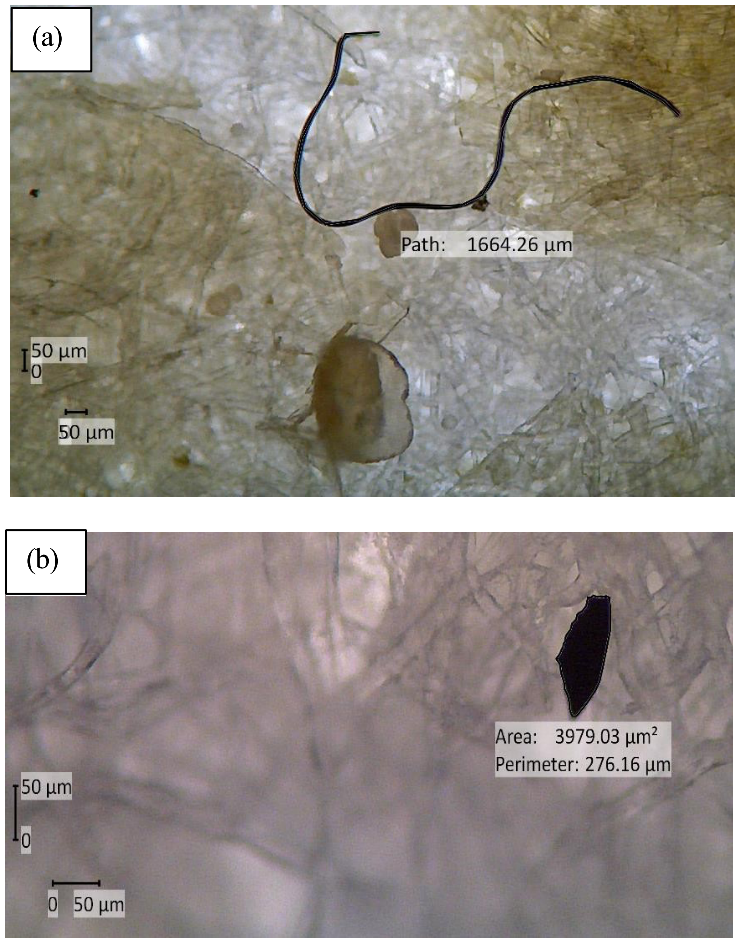

Fig. 4. Microplastic forms **(a)** fiber and **(b)** fragments

Microplastic fibers were measured based on their line length (path). Microplastics in the form of films and fragments were measured by their area and perimeter. The scale used for measuring microplastics was 50µm.

This figure shows the percentage of microplastic forms found in various organs of commercial fish. This data can provide knowledge about the extent to which microplastic contamination affects the fish body. These results are important for understanding the potential risk of microplastics that can enter the human body through fish consumption.

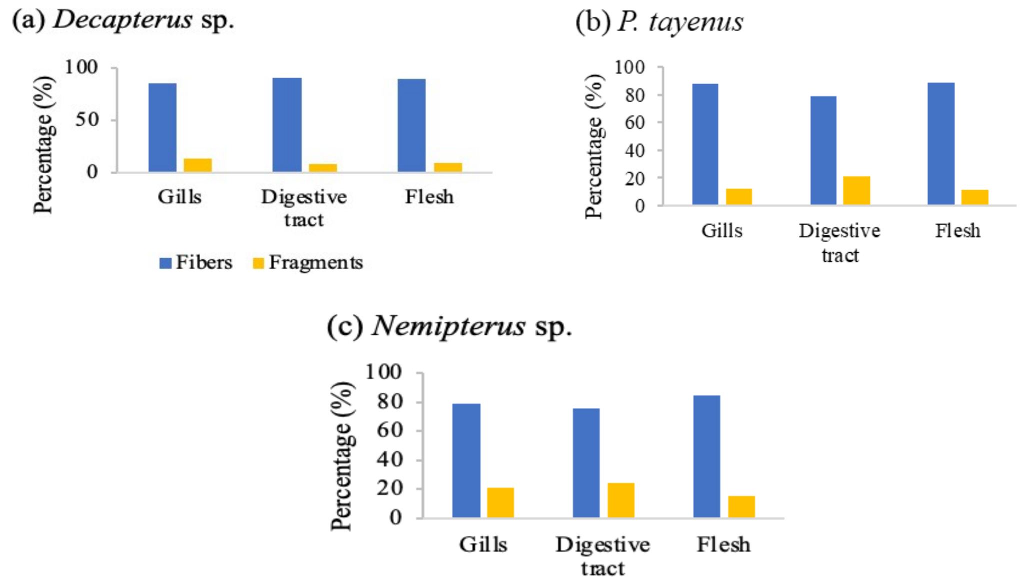

Fig. 5. Percentage of microplastic forms in each organ of commercial fish species

The characteristics of the microplastic shapes found in the organs of *Decapterus* sp., *P. tayenus,* and *Nemipterus* sp. include fibers and fragments (Fig. 5). In this study, fiber microplastics were frequently observed. The percentage of fiber microplastics in *Decapterus* sp. is 86% in the gills, 91% in the digestive tract, and 90% in the flesh. In *P. tayenus*, it is 89% in the gills, 79% in the digestive tract, and 90% in the flesh. In *Nemipterus* sp., it is 79% in the gills, 76% in the digestive tract, and 85% in the flesh.

2.2. Color

Various colors of microplastics were found in this study. Black microplastics were often found in this study. The following was the proportion of microplastic colors found in *Decapterus* sp. (Fig. 6), *P. tayenus* (Fig. 7), and *Nemipterus* sp. (Fig. 8).

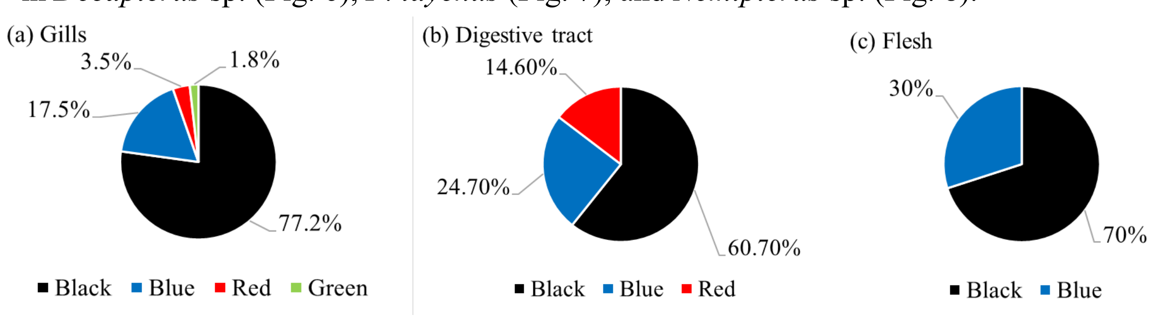

Fig. 6. Percentage of microplastic color in each organ of *Decapterus* sp.

The colors of microplastics found in the gills of *Decapterus* sp. were black, blue, red, and green, with respective percentages of 77.2, 17.5, 3.5, and 1.80%. The colors of microplastics found in the digestive tract include black, blue, and red, with percentages of 60.70, 24.70, and 14.60%, respectively. In the flesh section, the colors of the microplastics found were black and blue, with percentages of 70 and 30%, respectively.

A variety of microplastic colors were found in *P. tayenus*. The color black dominated all the colors of microplastics found in this fish. Fig. (7) shows the various colors of microplastics found in *P. tayenus*.

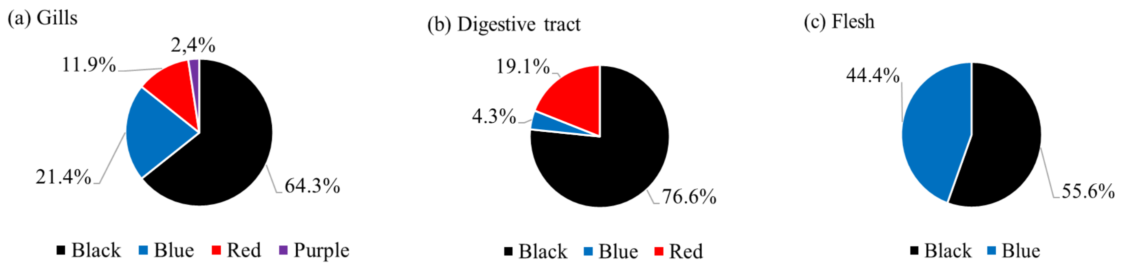

Fig. 7. The percentage of microplastic color in each organ of *P. tayenus*

The colors of microplastics found in the gill passages of *P. tayenus* were black, blue, red, and purple, with respective percentages of 64.3, 21.4, 11.9, and 2.4%. The colors of microplastics found in the digestive tract include black, blue, and red, with percentages of 76.6, 4.3, and 19.1%, respectively. In the flesh section, the colors of the microplastics found were black and blue, with percentages of 55.6 and 44.4%, respectively.

Various colors of microplastics were found in *Nemipterus* sp. Black microplastics dominated all the colors of microplastics found in this fish. Fig. (8) presents the variation in microplastic colors.

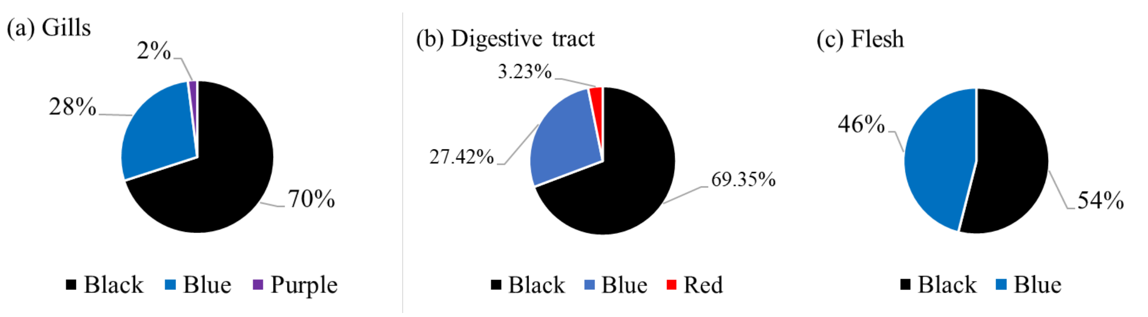

Fig. 8. Percentage of microplastic color in each organ of *Nemipterus* sp.

The colors of microplastics found in the gills of *Nemipterus* sp. were black, blue, and purple, with percentages of 70, 28, and 2%, respectively. The colors of microplastics found in the digestive tract include black, blue, and red, with percentages of 69.35, 27.42, and 3.23%, respectively. In the flesh section, the colors of the microplastics found were black and blue, with percentages of 54 and 46%, respectively.

2.3. Size

The size of the microplastics detected in the three types of fish in this study consisted of very small, small, and large particle sizes. The classification into three size categories was based on the outlines of **Imhof *et al.* (2016)**. Fig. (9) presents the distribution of various sizes of microplastics detected in the samples.

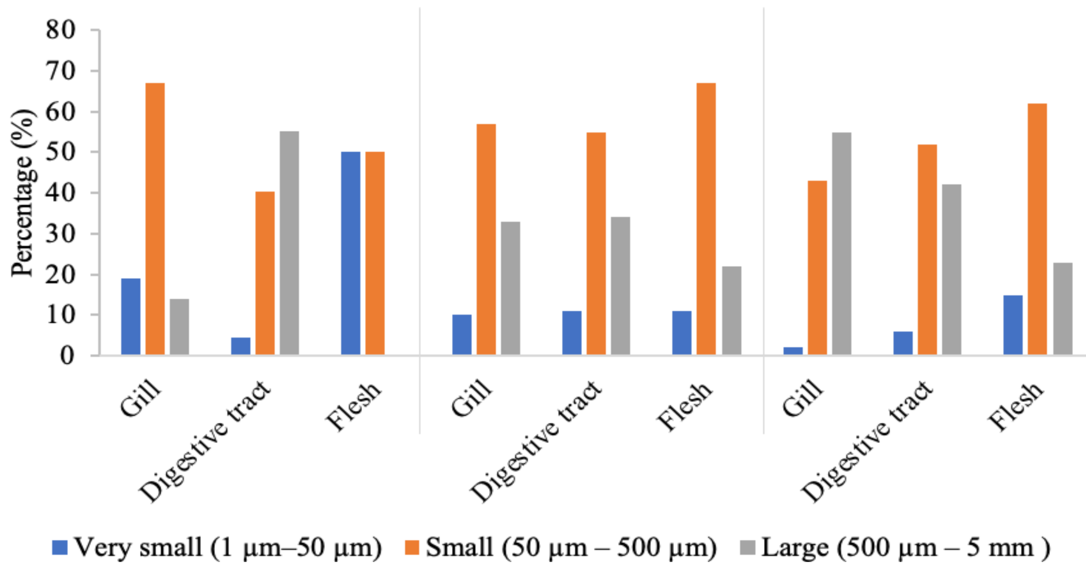

Fig. 9. Percentage of microplastic sizes in each organ of commercial fish species including gills, digestive tract and flesh according to three size groups

Based on Fig. (9), the size of microplastics from the three dominant commercial fish species is small (50–500µm). This suggests that the fish frequently accumulates small-sized microplastic particles in every organ. Also, very small microplastic particles were detected, although their quantity tends to be lower than that of larger or smaller particles.

3. Types of plastic polymers detected in samples

Polymer identification can provide an overview of the type of plastic found in waters and its potential impact on exposed biota. Polymer detection can map the source of contamination. The microplastics tested were 8 particles, which were selected according to different characteristics based on shape and color. The following are the types of polymers found in this research.

Table 1. Types of plastic polymers detected in samples

No	Polymer	Percentage
1	High density polyethylene (HDPE)	25%
2	Polyethylene terephthalate (PET)	75%

The captured microplastic particles represent a variety of different shapes and colors. From the identification results, two types of polymer were obtained, namely high-density polyethylene (HDPE) and polyethylene terphthalate (PET). The results of FTIR analysis showed that the polymer found was 25% HDPE and 75% PET.

4. Correlation test

The Spearman Rank correlation test was applied to determine the presence or absence of a correlation or relationship between the amount of microplastics in each individual and the mouth opening. This test can be applied to determine the level of correlation between the two variables. Fig. (11) displays the results of the Spearman Rank correlation test between the amount of microplastics per individual and mouth opening.

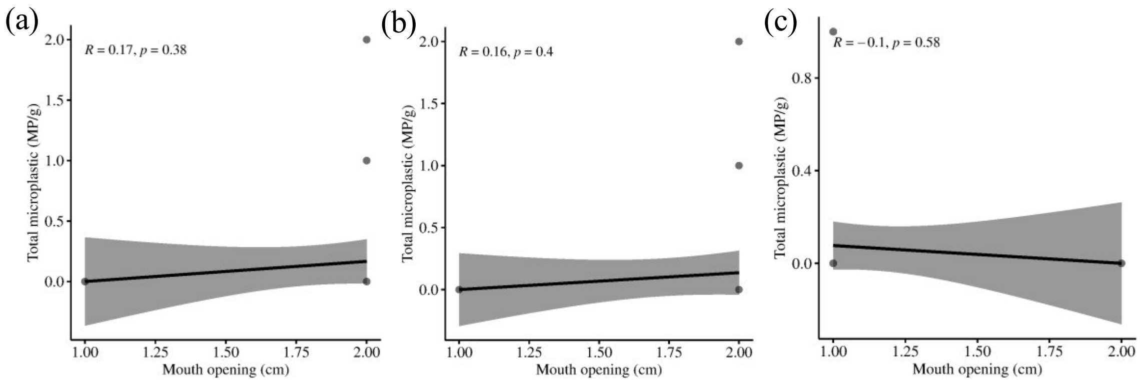

Fig. 11. Correlation between the number of microplastics in each individual and the mouth openings of each fish species **(a)** *Decapterus* sp., **(b)** *P. tayenus,* and **(c)** *Nemipterus* sp.

Based on the results of the Spearman Rank correlation test analysis in Fig. (11), the correlation values between the amount of microplastics per individual and the mouth opening of each species, *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp., were obtained. The correlation coefficient values for *Decapterus* sp. (0.17), *P. tayenus* (0.16), and *Nemipterus* sp. (0.1) indicate that the relationship between the amount of microplastics per individual and the mouth opening of these three species is very weak. The -value for *Decapterus* sp. is 0.38, *P. tayenus* is 0.4, and *Nemipterus* sp. is 0.58. These values show that there is no correlation between the amount of microplastics per individual and the mouth opening of each fish species.

To find out how microplastics were distributed in the bodies of *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp., researchers are looking at how microplastics are linked between their organs. This allows us to determine the correlation of microplastic exposure between the organs of each fish species. Fig. (12) illustrates the correlation of microplastic particles between the organs of *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp.

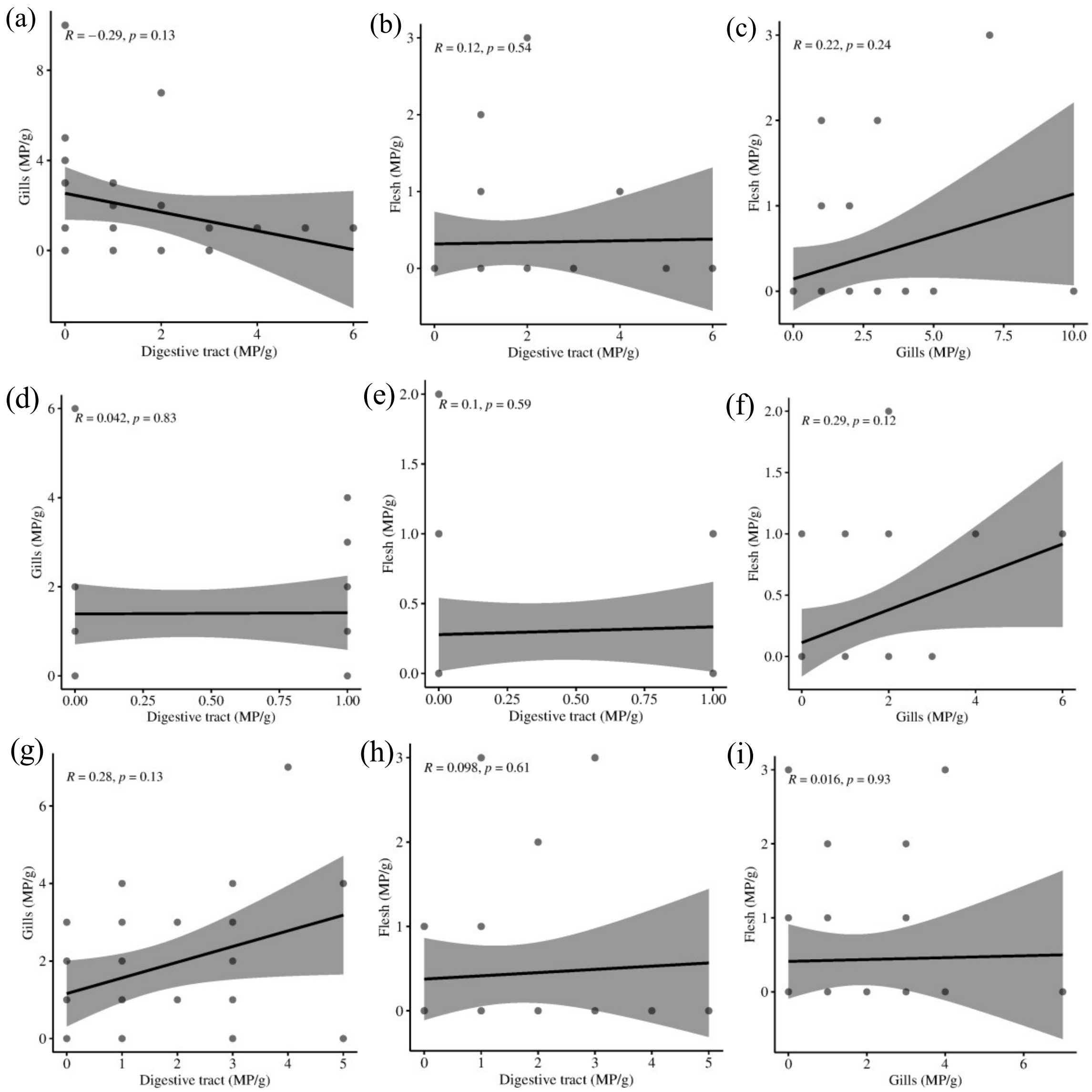

Fig. 12. Correlation of microplastic particles between organs in *Decapterus* sp. (a-c), *P. tayenus* (d-f), and *Nemipterus* sp. (g-i)

Based on the results of the Spearman rank correlation test analysis in Fig. (12), the correlation value between microplastic particles between organs in *Decapterus* sp., *P. tayenus* and *Nemipterus* sp. was obtained. These results show that there is no correlation between the organs of *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp. This is indicated by a *P*-value of more than 0.05.

DISCUSSION

We suspect that *Decapterus* sp.'s omnivorous nature is the cause of the high accumulation of microplastics in its digestive tract. According to **Mizraji *et al.* (2017)**, omnivorous organisms consume a wide variety of foods, so it is not surprising that they ingest more microplastic particles compared to carnivorous or herbivorous fish. Another factor is caused by pelagic fish species including filter feeders, namely fish that obtain their food by filtering the water with gill filters which are large in number and have a fine structure **(Amrullah, 2021)**. The abundance of microplastics in the digestive tracts of *P. tayenus* shows significant difference with that of *Decapterus* sp. and *Nemipterus* sp. This is thought to be caused by several factors. *P. tayenus* are included in the demersal fish group, which tend to eat benthic organisms and sediments that may have lower levels of exposure to microplastics. Demersal fish whose habitat is on the seabed or its surroundings are thought to have less exposure to microplastics than fish that live in open waters **(Amin *et al.*, 2023)**. According to **Rivera-Garibay *et al.* (2024)**, the amount of microplastics ingested by fish caught, for example using conventional fishing methods, is influenced by the movement of the species and the type of fishing gear used. On the other hand, *Decapterus* sp. are pelagic fish that like to migrate **(Setya & Susiloningtyas, 2022)**. Pelagic fish naturally migrate based on their life cycle, feeding needs, and to adapt to their environment **(Barnuevo *et al.*, 2022)**, thereby increasing their exposure to microplastics. Exposure to microplastics in *Decapterus* sp. is higher because *Decapterus* sp. are pelagic fish which more easily swallow microplastics, considering that microplastics have a shape, size and color similar to plankton **(Keerthika *et al.*, 2023)**. Meanwhile, *Nemipterus* sp. may be exposed to microplastics because it is thought that their habitat is influenced by currents around coral reefs, considering that these fish tend not to migrate and live in association with coral reefs **(Jumiati *et al.*, 2021)**. Currents around coral reef areas have a role in distributing nutrients, oxygen, larvae and sediment as well as contributing to cleaning up dirt and sediment buildup around them **(Ekayogiharso *et al.*, 2014)**. The distribution of microplastics is influenced by various factors such as wind, water currents, the size of the water body, and the density of the particles **(Peña *et al.*, 2023)**, thus providing the opportunity for microplastics to move between different locations. Meanwhile, fish can accidentally ingest plastic while searching for their natural food **(Roman *et al.*, 2022)**.

The abundance of microplastics in the gill organs of *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp. shows no significant difference. We suspect this to be due to the abundance of microplastics in the surrounding environment and the respiratory mechanism that dynamically enters and exits the gills. Various areas such as marine waters, sediments, seabeds, beaches, and shorelines can disperse microplastics **(Gallagher *et al.*, 2016)**. The fish's respiration process tends to easily release microplastics found in the gills back into the environment **(Zhang *et al.*, 2021)**. The abundance of microplastics in the flesh among the three fish shows no significant difference. This is suspected because microplastics from the external environment do not significantly contaminate fish flesh. However, under certain conditions, microplastics can adhere to body organs and interact with them without passing through the digestive tract first **(Abbasi *et al.*, 2018)**.

Microplastics can be found in the gills, presumably through accidental exposure during the seawater filtration process and direct contact with the surrounding environment, making them likely to be trapped in the gills **(Collard *et al.*, 2017)**. Microplastics were also detected in the digestive tracts of all three fish samples. According to **Buwono *et al.* (2021)**, the digestive tract is the main site for the accumulation of both food and non-food items, which fish obtain through the process of hunting and swallowing with their mouths. The digestive tract and gills frequently accumulate more microplastics than other organs, such as muscles, due to their stronger defenses against the entry of foreign substances **(Abbasi *et al.*, 2018)**. Microplastics were also found in the flesh of *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp. This study aligns with the findings of **Barboza *et al.* (2020)**, who discovered microplastics in the dorsal muscles of fish such *as Dicentrarchus labrax*, *Trachurus trachurus*, and *Scomber colias*. Although the exact mechanism by which microplastics enter muscle tissue remains unclear, **Zeytin *et al.* (2020)** suspect that they escape from the digestive tract through the intestinal lining. Microplastics can also adhere to body organs and associate with them without having to pass through the digestive system first **(Abbasi *et al.*, 2018)**. Therefore, we need to conduct further research on the process of microplastics absorbing from the digestive tract into the flesh. The form of microplastics that are often found is fiber. This study aligns with the findings of **Rummel *et al.* (2016)**, who found that fish inhabiting pelagic and demersal areas frequently harbor fiber-type microplastics. *Decapterus* sp. accumulates a significant amount of microplastics due to its habitat at the surface. Microplastics, whether intentionally or unintentionally, are more likely to contaminate pelagic fish that inhabit the water's surface **(Lopes *et al.*, 2020)**.

Meanwhile, fibers can also reach the demersal zone, which is a habitat for *P. tayenus*, and *Nemipterus* sp. Fiber found in the demersal area can originate from wastewater pipes in wastewater treatment plants, then enter the surface and accumulate in the sediment **(Wen *et al.*, 2018)**. According to **Kane and Clare (2019)**, the transportation of microplastics in water bodies can occur when microplastics sink or move due to the activities of living organisms, are carried by deep ocean currents, causing previously settled microplastics to move or relocate, and are transported by gravity in sediment-laden water flow. Fiber microplastics are the most commonly found type in the environment **(Acharya *et al.*, 2021)**. We suspect that fishing gear is the source of fiber-shaped microplastics. This is due to the degradation process that fishing gear, typically made from fiber-type ropes, can undergo **(Nor & Obbard, 2014)**. According to **Hasanah *et al.* (2023)**, fish from capture fisheries are vulnerable to microplastic contamination. This is because fishermen's use of gill nets and other fishing gear, which can break down into microplastic fibers, increases their exposure to microplastics **(Zhu *et al.*, 2018)**. According to **Browne *et al.* (2011)**, one of the main contributors to fiber microplastics is suspected to originate from domestic waste contaminated with fibers from washing clothes made of synthetic fibers. Conventional washing will release a significant amount of fiber from synthetic textiles. Meanwhile, microplastic fragments can originate from larger plastic materials, such as bags, bottles, food containers, and plastic from food products **(Suprayogi *et al.*, 2024)**.

The colors of microplastics found overall in the gills, digestive tract, and flesh of *Decapterus* sp., *P. tayenus,* and *Nemipterus s*p. are black, blue, red, purple, and green. The duration of exposure to sunlight can cause the microplastics to change in color **(Browne, 2015)**. The dominant microplastic found in this study is black in color. These results are in line with the research conducted by **Surwatiningsih *et al.* (2020)**, which found that black was the dominant color of microplastics in pelagic and demersal fish at Baron Beach, Yogyakarta, Indonesia. Each fish species has a different sensitivity to the color of its food **(Zhang *et al.*, 2015)**.

According to **Surwatiningsih *et al.* (2020)**, fish have conical-shaped retinas, which function to detect colors in their prey. When the color of microplastics closely resembles that of natural prey, it can enhance the likelihood of ingestion **(Hastuti *et al.*, 2019)**. The color of microplastics that are often found is black. This is because biota that see particles from below tend to consume particles that have a dark color **(Ugwu *et al.*, 2021)**. One of the main contributors of black microplastics comes from vehicle tires **(Deswati *et al.*, 2025)**. Car tires produce wear particles due to the mechanical abrasion process **(Kole *et al.*, 2017)**. Black-colored microplastics are estimated to originate from textile fibers or plastic bags **(Johan *et al.*, 2021)**. Fish that forage more often consume microplastics that are similar in color to their natural food rather than those that do not resemble their food **(Roch *et al.*, 2020)**. For instance, carotenoid pigments in certain parts of their bodies give copepods their red-orange or bright blue colors **(Vilgrain *et al.*, 2022)**. The difference in the amount of microplastics in certain colors is suspected to be due to exposure to sunlight over a certain period, resulting in color changes in the microplastics **(Browne *et al.*, 2015)**.

This study finds a higher frequency of small-sized microplastics. According to **Setala *et al.* (2014)**, different biota ingest different microplastics depending on the size, particle abundance, and the presence of their natural prey. Therefore, we suspect that small-sized microplastics tend to be abundant in the waters, closely resembling the natural food particles of fish. We suspect that the similarity in microplastic sizes from the observed fish stems from their dietary selectivity in the environment and the process of microplastic accumulation in the fish **(Sawalman *et al.*, 2021)**.

The organs of the studied fish contained microplastics with sizes ranging from 1 to 5mm. The size range of microplastics found in this study is similar to the size of plankton **(Hastuti *et al.*, 2019)**. For example, copepods have a body size of 400µm - 1mm **(Figuerido & Vianna, 2018)**. Microplastics have also been found in fish flesh. This is similar to the research conducted by **Barboza *et al.* (2020)**, which found fiber and fragment microplastics measuring up to 490 µm and 2363 µm in their study results. Microplastics may infiltrate the fish's body and penetrate its internal tissues. However, the mechanism of microplastic translocation is still unknown **(Jovanović *et al.*, 2018)**. According to **Barboza *et al.* (2020)**, microplastics can enter through lesions on fish skin, even if the lesions are not visible during physical visual observation of the fish. **Jabeen *et al.* (2017)** suggested that prolonged contact with microplastics, particularly those with uneven and sharp edges, can damage the stomach wall and cause lesions, potentially leading to the transfer of microplastics.

Microplastic samples from *Decapterus* sp., *P. tayenus* and *Nemipterus* sp. fish were tested using Fourier Transform Infrared (FTIR). The identified polymers are high density polyethylene (HDPE) and polyethylene terephthalate (PET). PET microplastics are one of the most frequently found microplastics. This is because PET is widely used in food and beverage packaging, making audio and video cassettes, making polyester fiber, and making photographic films **(Yulia & Dewata, 2023)**. Research conducted by **Hossain *et al.* (2023)** also found polyethylene and polyethylene terephthalate polymers in *Scomberomorus guttatus* fish. Polyethylene and polyethylene terephthalate, along with nylon, polyamide, and polypropylene, are the primary materials used in fish nets **(Lima *et al.*, 2023)**. HDPE is a type of polyethylene **(Clarinsa & Sutoyo, 2021)** and is also the main material often used as plastic food bags **(Sabri *et al.*, 2021)**. Plastic pipes and domestic waste, which can enter water systems through river flow and surface runoff, are potential sources of PET **(Wu *et al.*, 2021)**. **Nanlohy *et al.* (2024)** report that bottles and food packaging frequently use PET as a material. PET polymers can also originate from industrial and fishery wastes that lack proper waste management practices, leading to their disposal into water bodies **(Lin *et al.*, 2021)**. Both the surface and the bottom of water bodies frequently contain PET polymer **(Issac & Kandasubramanian, 2021)**.

The results of the correlation test between the number of microplastics per individual and the mouth opening of each species, *Decapterus* sp., *P. tayenus*, and *Nemipterus* sp., show that there is no correlation between the two variables. The mouth size does not always determine the amount of microplastics that fish can ingest. Other factors, such as feeding mechanisms and environmental characteristics, also influence the amount of microplastics ingested by fish. According to **Roch *et al.* (2020)**, the absorption of microplastics by fish is difficult to avoid due to their similarity to the fish's natural food, unintentional consumption when fish drink water and breathe, and bioaccumulation from the food chain. Fish with large or small mouths have the same chance of consuming microplastics in equal amounts. This is due to the behavior of fish, which more often consume microplastics that are similar in color to their natural food **(Roch *et al.*, 2020)**.

The correlation results of the amount of microplastics between the digestive tract organs, gills, and flesh in *Decapterus* sp., *P. tayenus* and *Nemipterus* sp. show that there is no correlation between organs in these three types of fish. This difference can be caused by differences in the function of each organ and the mechanism by which microplastics enter the water into these organs **(Yona *et al.*, 2020)**. According to **Zhang *et al.* (2021)**, the fish in this case likely ingested the microplastics present in their gills from the surrounding environment. According to **Chen *et al.* (2022)**, the passive consumption of microplastics through the water surrounding fish can be considered the main mechanism by which fish ingest these particles. According to **Roch *et al.* (2020)**, an increase in the amount of microplastics, both similar and dissimilar to fish's natural food, can occur in tandem with an increase in microplastic concentration in the water. Microplastics accumulated in various types of fish do not exhibit a clear pattern, whether viewed through biological factors (body size) or ecologically (habitat). This is because fish tend to accidentally consume microplastics from their environment, and some microplastics may be more difficult to expel from their bodies **(Chen *et al.*, 2022)**.

CONCLUSION

The waters north of Rembang have been contaminated with microplastics, which is proven by the discovery of microplastics in *Decapterus* sp., *P. tayenus* and *Nemipterus* sp. landed at PPP Tasikagung Rembang. This research found microplastic contamination in the gills, digestive tract and flesh of the three types of fish. The microplastics found were predominantly fiber shaped, black in color, and 50 – 500 µm in size. The types of polymers found in this research are high density polyethylene (HDPE) and polyethylene terephthalate (PET). The detection of microplastics in commercial fish means it is necessary to increase awareness of food safety for people who consume it. Microplastic consumption by fish can disrupt marine food webs, affect fish health, and potentially carry harmful contaminants to humans through seafood consumption, thereby compromising environmental and public health.

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