Microplastic Abundance in The Flesh, Gills, and Stomachs of Pelagic Fish in Muncar Water, Banyuwangi, East Java

Sonia Putri Maulidya[1], Syarifah Hikmah Julinda Sari[2,3], Mochamad Arif Zainul Fuad[2,3], Feni Iranawati[2,3] , Sabine Matallana-Surget[4], Aida Sartimbul[2,3]*

[1]Magister of Aquaculture, Faculty of Fisheries and Marine Science, Universitas Brawijaya
[2]Faculty of Fisheries and Marine Science, Universitas Brawijaya
[3]Marine Resource Exploration and Management (MEXMA) Research Group, Universitas Brawijaya
Jl. Veteran 10-11, 65145 Malang, East Java, Indonesia
[4]Division of Biological and Environmental Sciences, Faculty of Natural Sciences, University of Stirling
Stirling FK9 4LA, United Kingdom
Email: aida@ub.ac.id

Abstract

The accumulation of microplastics in fish has become a significant concern in Muncar Waters, East Java, particularly in Bali sardinella (Sardinella lemuru) and scad (Decapterus sp.), which are two of the main catch commodities. Fish samples were collected from local fishermen and analyzed in the laboratory using microscopic techniques to identify and classify microplastic particles based on type and color. A total of 1,322 microplastic particles were detected across all samples, with the highest abundance in the flesh (39.86%), followed by gills (31.01%) and stomachs (29.12%). Fragments were the dominant microplastic type (76.70%), while fibers (15.58%) and films (6.73%) occurred in lower proportions.Purple-colored particles were the most abundant (57.75%), followed by red (11.72%) and transparent (9.00%) microplastics., indicating it is the most contaminated species. This condition is likely due to the degradation of plastic materials, which enter the marine environment through various anthropogenic activities, including improper waste disposal, fishing gear degradation, and industrial runoff. This study highlights the need for improved waste management, stricter regulations, and community awareness to mitigate marine plastic pollution, contributing to the achievement of Sustainable Development Goals (SDGs) 2, 12, 14, and 15. The findings emphasize the urgent need for enhanced waste management practices, stricter regulations on plastic pollution, and increased public awareness regarding the risks of microplastic contamination. The research underscores the significance of consuming safe and nutritious food, promoting ocean conservation, encouraging responsible plastic consumption, and preserving marine biodiversity. Further investigation is necessary to understand the long-term effects of microplastic accumulation in fish and the related risks to the food chain, particularly in human health implications and ecological sustainability.

Keywords: *microplastic, Muncar, pollution, sardinella, scad*

Introduction

Plastic, a versatile synthetic polymer, has become an integral part a (Hofmann *et al*., 2023; Anjeli *et al*., 2024) of daily life in various industries (Zimmermann *et al*., 2019) such as packaging (Bhuyan, 2022), household appliances (Abida *et al*., 2023), medicine (Czuba, 2014; Cirino *et al*., 2023), automotive, and electronic. However, the increasing use of single-use plastics (Winton *et al*., 2022) has led to the accumulation of plastic waste in the environment (Kibria *et al*., 2023; Pilapitiya and Ratnayake, 2024), particularly in the oceans (Thushari and Senevirathna, 2020). The low production costs (Pilapitiya and Ratnayake, 2024) have driven global production (Ritchie *et al*., 2023) and consumption of plastic, resulting in up to 250,000 tonnes of plastic waste floating in the ocean and can cause various negative effects (Amato-Lourenço *et al*., 2020; Kruse *et al*., 2023).

Plastic waste that ends up floating in the ocean degrades into smaller fragments (Dodson *et al*., 2020; Dimassi *et al*., 2022), known as microplastics (Liu *et al*., 2021; Fraissinet *et al*., 2024). These microplastics can come from primary sources like personal care products (Ziani *et al*., 2023; Song, Wang and Li, 2024) (microbeads in scrubs and toothpaste) (Ashrafy *et al*., 2023), cosmetics (Guerranti *et al*., 2019; Wang *et al*., 2019), industry and agriculture (An *et al*., 2020), while secondary microplastics come from the physical, chemical, and biological degradation of larger plastics (Song *et al*., 2024). The main sources of secondary microplastics are carelessly discarded plastic waste, plastic bottles and bags (An *et al*., 2020), and synthetic fibers in

*) Corresponding author

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clothing (Henry *et al*., 2019; Periyasamy and Tehrani-Bagha, 2022).

The Bali sardinella (*Sardinella lemuru*) is a small pelagic fish prevalent in the Indo-Pacific region, especially in the coastal waters of East Java, Bali, and the Bali Strait (Aprianti *et al.*, 2022). Particularly in areas with upwelling currents (Sambah *et al*., 2021), these fish form large schools (Sartimbul *et al*., 2023) and commonly inhabit sheltered bays and lagoons. The term "scad" refers to fish from the genus *Decapterus*, also known as mackerel scads or round scads (Xu *et al*., 2023; Priatna *et al*., 2024). Bali sardinella and scads play a crucial role in Indonesia's small pelagic fisheries, significantly impacting the livelihoods of coastal communities and the national economy (Ramos and Roque, 2023; Sartimbul *et al.*, 2023).

Microplastics floating in the ocean can be accidentally eaten by marine biota, especially pelagic fish like *Sardinella lemuru,* subsequently called Bali sardinella, and *Decapterus* sp., subsequently called scad (Pertami *et al*., 2018). These fish play an important role in the marine food chain as food for larger fish (skipjack and tuna) (Baechler *et al*., 2020; Walkinshaw *et al*., 2020). As filter-feeder fish species (Sartimbul *et al*., 2023), Bali sardinella and scad are highly likely to be exposed to microplastics due to their habit of eating plankton (Ajub *et al*., 2023; Lubis *et al*., 2019; Ziani *et al*., 2023).

Microplastics can penetrate food systems, causing bioaccumulation and biomagnification (Parolini *et al*., 2023; Tang, 2021). They can also absorb organic substances, especially persistent organic pollutants (POPs), intensifying environmental contamination. Persistent organic pollutants (POPs), included in pesticides, solvents, and pharmaceuticals, can bioaccumulate and exacerbate environmental contamination (Tang, 2020). Microplastics are detected in the gastrointestinal tracts and bivalve tissues of fish and crustaceans, and human consumption of polluted seafood may cause health problems (Kristanti *et al*., 2022; Oza *et al*., 2024).

This study has not been extensively performed because it looks at the fish's gills and flesh in addition to its digestive tract. Microplastics in fish gills may affect humans if the fish is eaten whole or if extremely tiny particles and chemicals are transported to edible muscle tissue. Microplastics predominantly accumulate in the gills and stomach, where they are eliminated before to cooking; however, they remain hazardous (Su *et al*., 2019). Small fish like Bali sardinella and scad are consumed whole, encompassing the gills and intestines. Human exposure to microplastics concentrated in these organs is direct. Smaller microplastics can migrate from the gills and intestines to the liver and muscle tissue, which humans consume (Onaji *et al*., 2025). Furthermore, studies on the presence of microplastics in Bali sardinella and scad (*Decapterus* sp.) from Muncar water are still extremely rare. This research is crucial for ensuring food chain safety, given that Muncar serves as a supply of fish for canning companies. Research conducted by Yudhantari *et al*. (2019) investigated the presence of microplastics in the digestive tract of Bali sardinella caught in the Bali Strait, a region with significant potential for catching pelagic fish.

This This study aims to characterize microplastic types and quantify their abundance in fish organs to inform future conservation and public health initiatives. This study is expected to strengthen regulations and law enforcement regarding restrictions on single-use plastic use and better management of plastic waste, contributing to the achievement of several Sustainable Development Goals (SDGs) 2, 12, 14, and 15 such as safe and nutritious food security, ocean conservation, responsible consumption and production of plastics, and maintaining marine biodiversity and ecosystems.

Materials and Methods

The study collected 25 pelagic Bali sardinella and scad samples in March, April, and May 2023 from the catch of PPP Muncar fishermen in the pelagic fishing zone of Muncar Waters (-8.405169° 114.417222º) shown in Figure 1. The fish were measured for length and weight using a fish ruler and a digital scale, preserved in a cooler, and weighed separately. The samples were analyzed at the Marine and Fisheries Resources Exploration Laboratory (ESPK), Faculty of Fisheries and Marine Sciences, Brawijaya University.

Before microplastic extraction begins, the fish specimens undergo a careful dissection process to separate and prepare specific tissues (flesh, gill, abd stomach) for analysis. The goal is to isolate the parts of the fish most likely to contain microplastics and to ensure clean, uncontaminated samples. Each fish is measured for total leght and body weight. Fish are dissected to separate flesh, gill, and stomatch. Each organ type is weighed to record initial data. The samples were dried at 50°C, treated with 30% H_2O_2 (Li *et al*., 2015) at a 1:10 weight-to-volume ratio for 24 hours at 40°C (Li *et al*., 2015; Yu *et al*., 2019), and then immersed in 10% KOH for 48-72 hours (Karami *et al*., 2018) at 40°C (Yu *et al*., 2019) until the organs were degraded. A 10% KOH solution at a 1:20 weight-to-volume ratio was used to avoid compromising the integrity of the fish organs. The samples were purified from KOH using ethanol, followed by a 3-hour density separation using $ZnCl_2$ (Crutchett and Bornt, 2024) to isolate the organic materials from the floating microplastics. Then 0,025 L^{-3} of $ZnCl_2$ was taken and filtered using Whatman filter paper no. 42. The filter paper was then placed in a petri dish, dried, and examined under a trinocular microscope to assess the quantity, morphology, and coloration of the microplastics.

Data collection and analysis

Microplastics were identified using a Leica DM500 equipped with a Leica ICC50 E camera at 10X magnification. Each particle observed on the filter paper was calssified bassed on morphological characteristics, including shape and color. The microplastic types were determined visually and categorized into fragments, fibers, films, pellets, and foams, following morphological descriptions established in previous studies (Boettcher *et al*., 2023; Tanaka and Takada, 2016). Identification criteria included angularity and rigidity for fragments, filamentous, appearance of fibers, this flrxible sheets of films, spherical shape fo pellets, and porous texture for foams. Color identification was conducted visually under the microscope to distinguish between various pigmentation patterns. The amount of microplastics in the fish organs (gill, flesh, and stomatch) was calculated using a formula provided by Boeger *et al*. (2010), as followers:

$$Total\ Abundance = \frac{Total\ Microplastic\ Particles}{Sample\ Weight}$$

The abundance of microplastics in each organ (gill, flesh, and stomatch) was determined by dividing the total number of microplastics particles found in that organ by the number of fish analyzed, expressed as a particles per individual. When normalized by wheight, the result were expressed as particles per gram tissue. The percentage (%) of microplastics in each organ was then calculated to determine their proportional distribution using the following formula:

$$Pi = \frac{Ni}{Nt} x100$$

Where Pi is the percentage of microplastic abundance in organ i, Ni is the number of microplastic particles found in that organ, and Nt is the total number of microplastic particles detected accross all samples. These calculated values were used to generate the distribution graph presented in Figure 2, which illustrated the total and proportional abundance of microplastics in the fish organ analyzed.

Data on abundance, type, and color of microplastics were analyzed using Microsoft Excel in the form of tables or graphs. Statistical tests were performed using SPSS software to determine the distribution and variation of microplastic abundance in different fish organs. The Kolmogorov-Smirnov normality test was applied to evaluate wether the data followed a normal distribution, expressed by the probability density function:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}}$$

Where μ is the mean and σ is the standard deviation. If the test indicated that the data were not normally distributed (P< 0.05), it was assumed that the data deviated from a normal form and might follow poisson or nonparametric (uniform) distribution, depending in the observed frequency characteristic. In such cases, the Kruskal-Wallis test, a nonparametric alternative to one-way ANOVA, was employed to compare the median abundance of microplastics among the gill, flesh, and stomatch.

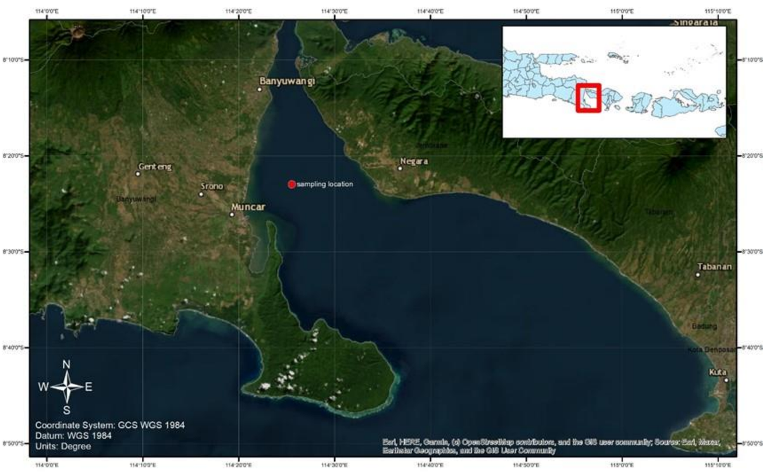

Figure 1. Research location and sampling of pelagic fish (*Sardinella lemuru* and *Decapterus* sp.)

Result and Discussion

Microplastics abundance in fish organs

The results of the microplastic abundance detected in the gills, flesh, and stomach of a total of twenty-five pelagic fish were acquired, along with the kind and color of each microplastic particle. A total of 1322 microplastic particles were obtained, spread across the gills, flesh, and stomach organs. The distribution of the contamination is explained in Figure 2.

From the results of microplastic research on all fish, the abundance value of microplastics was obtained in each fish organs located in the gills, flesh, and stomach. The abundance of microplastics in each organ was shown in Table 1.

Table 1. Abundance of Microplastics in Fish Organs

Microplastic Abundance	Sum (mean±SD)
Microplastic abundance in gills	30,38 ± 46,56
Microplastic abundance in stomach	14,75 ± 15,94
Microplastic abundance in flesh	10,53 ± 13,58

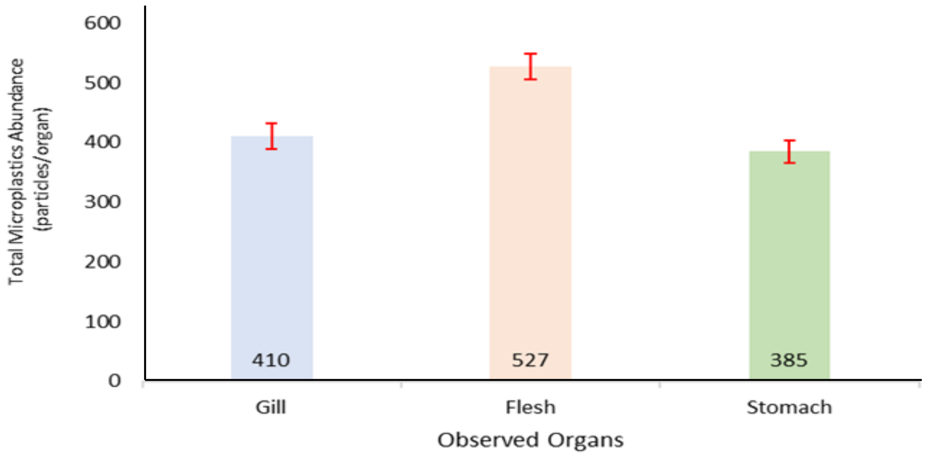

Figure 2. Total abundance of observed microplastic particles (n=1322) detected in the gills, flesh, and stomach of pelagic fish samples.

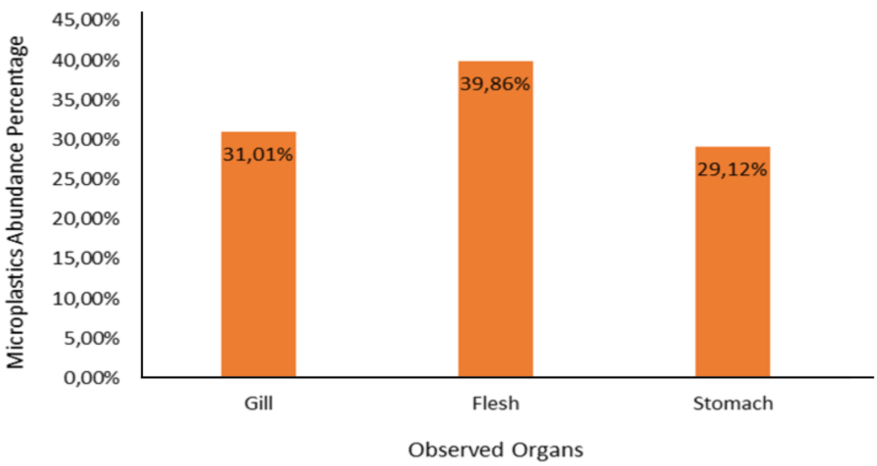

Figure 3. Percentage distribution of microplastic abundance in the gill, flesh, and stomach of pelagic fish. The proportion of each organ's contribution to the total microplastic load (n=1322) was calculated using, where is the number of microplastic particles in organ i and is the total number of particles observed across all samples.

Figure 2 showed microplastic abundance is mostly found in flesh with 527 microplastic particles. Microplastics in flesh from fish contaminated with microplastics enter the digestive tract and cause oxidative stress and cytotoxicity, which spreads microplastics to other organs, including consumable muscles (Alberghini *et al*., 2023; Subaramaniyam *et al*., 2023; Unuofin and Igwaran, 2023; Utomo and Muzaki, 2023). A prominent finding of microplastics in flesh can occur when meat is eaten with the skin, which may be an entry point (Daniel *et al*., 2020). Karami *et al*. (2018) found the greatest microplastics in fish organs, purportedly because fish were contaminated during handling on board and translocation. Fish swallow microplastics, which cannot be processed and accumulate in muscle and flesh (Subaramaniyam *et al*., 2023). 410 microplastics polluted gills. Due to characteristics such as gill morphology, gill filtration apparatus effectiveness, and microplastic size, microplastics get retained in the gill organs during breathing (Barboza *et al*., 2018). Gills are one of the first organs to be exposed to microplastic-containing water (Chen *et al*., 2023) due to their frontal location. 385 microplastics pollute the stomach. Due to digestion, fish-eating microplastics, or food chain transmission, microplastics can end up in the stomach (Roch *et al*., 2020). Lemuru and cad fish are filter feeders that eat plankton (Sartimbul *et al*., 2018) or very small food particles. Microplastics may have been eaten by prey due to their small size (Alberghini *et al*., 2023; Dawson *et al*., 2018). Thus, when larger predators like humans eat these pelagic fish, their microplastics travel up the food chain (Mahu *et al*., 2023).

Figure 3 present the percentage distribution of microplastic abundance across the gill, flesh and stomach of pelagic fish collected from Muncar waters. The percentage values were calculated using the formula, where *Ni* represent the total number of microplastic particles found in each organ and *Nt* is the total number of microplastic particles detected across all fish samples (n=1322). The result indicate that microplastic abundance was highest in the flesh (39.86%) with 10.53 ± 13.58 abundance, followed by the gill (31.01%) with 30.38 ± 46.56T abundance, and stomach (29.12%) with 14.75 ± 15.94 abundance. The predominance of microplastics in the flesh suggest that smaller particles may have translocated from the digestive tract or gills into edible muscle tissues, posing potential health risk to consumers. Variation in organ-specific microplastic concentrations may also reflect differences in organ function, such as filtration efficiency in the gills or digestive processing in the stomach, as well as particle sie and morphology. Studies conducted by Basri K. *et al*. (2024), have shown that microplastics can adhere to the gills and skin of fish, with the flesh sometimes containing higher concentrations than other organs. This accumulation in organs is concerning because it suggests that microplastics can penetrate edible parts of the fish, posing potential health risks to consumers. Research conducted in Indonesia by Yona *et al*. (2022), has found varying concentrations of microplastics in different fish species and organs. For instance, in Sendang Biru, the gills of *Sardinella lemuru* (Bali sardinella) had the highest microplastic particles, followed by the GIT and muscles. In contrast, for other species like *Decapterus tabl* (scad), higher concentrations were observed in the muscles than in the gills and GITs. Fish can ingest these particles directly by mistaking them for food or indirectly through their prey. Once ingested, microplastics can translocate from the gastrointestinal tract (GIT) to other organs, including flesh. This translocation indicates that microplastics can potentially enter the food chain, raising concerns about their impact on both aquatic ecosystems and human health. As fish are consumed by larger predators, including humans, the accumulation of microplastics could have far-reaching ecological and health implications.

Microplastics contamination and abundance based on the type

Pelagic fish, such as Bali sardinella and scad, that live near the surface or sea surface (Sambah *et al*., 2021) are very susceptible to microplastic exposure. This is because these fish are included in the low food chain category that consumes plankton (Pertami *et al*., 2019; Sartimbul. *et al*., 2023) and other small organisms, which may have been exposed to microplastics first. Furthermore, their habitat on the sea's surface frequently serves as a gathering place for plastics, including microplastics (Li *et al*., 2020; Osorio *et al*., 2021; Akdogan *et al*., 2023) . In addition, pelagic fish have gills that function as filters to filter food and water. Unfortunately, this filter cannot distinguish between plankton and microplastics, so these particles are still caught. Microplastics themselves often have a shape that is similar to the fish's natural food (Foo *et al*., 2022), so they can easily be swallowed by fish. As a result, the ingestion of microplastics poses a significant threat to the health of marine ecosystems. This not only affects the fish themselves but can also have cascading effects throughout the food chain (Omeyer *et al*., 2022), ultimately impacting human health through seafood consumption.

The study found the microplastic varieties depicted in Figure 4, including fragments, fibers, films, pellets, and foams. According to Tanaka and Takada (2016), the fragments recovered in this investigation are characterized by their angularity and durability. Fragments, a form of secondary microplastic, are diminutive plastic fragments that are the result of the degradation of larger synthetic plastic products (Boettcher, Kukulka and Cohen, 2023; Ziani *et al.*, 2023). They develop strength as a result of friction with the water surface, exposure to sunlight (UV) (Na *et al.*, 2024), and sea waves (Bergfreund *et al.*, 2024). Synthetic fibers were identified in this investigation. The fibers exhibit characteristics such as long filaments (Yang, Gao and Nowack, 2023; Gliaudelytė, Persson and Daukantienė, 2024) or short filaments with variable colors and thicknesses. Fiber also known as Synthetic textiles frequently shed thin, threadlike structures during the laundry process. Clothing (European Environment Agency, 2022), fish nets (Gliaudelytė *et al.*, 2024), and a variety of other textile products can all be sources of fibers. The film particles discovered in this investigation were transparent and slender. Films is flexible, a form of secondary microplastic, are made up of thin sheets that are derived from shattered plastic bags or other plastic packaging (Marrone *et al.*, 2021). They exhibit transparency, flexibility, and a slender shape (Singh *et al.*, 2022). The study also identified the pellet variety, which was characterized by its small size and round shape. This variety of microplastic is a small plastic granule that is frequently employed as a raw material in the production of larger plastic products (FFI & FIDRA, 2017). Thin foam or styrofoam-shaped foam particles were identified in this investigation. Styrofoam is an example of a porous plastic granule (Kuroda *et al.*, 2024; Wei *et al.*, 2022), that is employed in product packaging in the form of microplastic foam.

Figure 5 shows the categories of microplastic abundance according to their classifications. The x-axis delineates the categories of microplastic particles identified. The y-axis displays the total contamination of microplastic particles, measured in particles per type. The predominant types of microplastics identified were fragments, totaling 1,014 particles, followed by fibers with 206 particles, films with 89 particles, pellets with 11 particles, and foam with 2 particles. Observations and computations indicated that the fragment type had the highest overall contamination value. Plastic subjected to sunlight will deteriorate and fragment into smaller pieces (Cai *et al.*, 2023; Shi *et al.*, 2023), referred to as fragments. This process persists until the plastic attains a tiny size. Fragmented microplastics are believed to originate from shattered plastic bottles, caps, or jars (Ariyunita *et al.*, 2021; Kurniawan *et al.*, 2021).

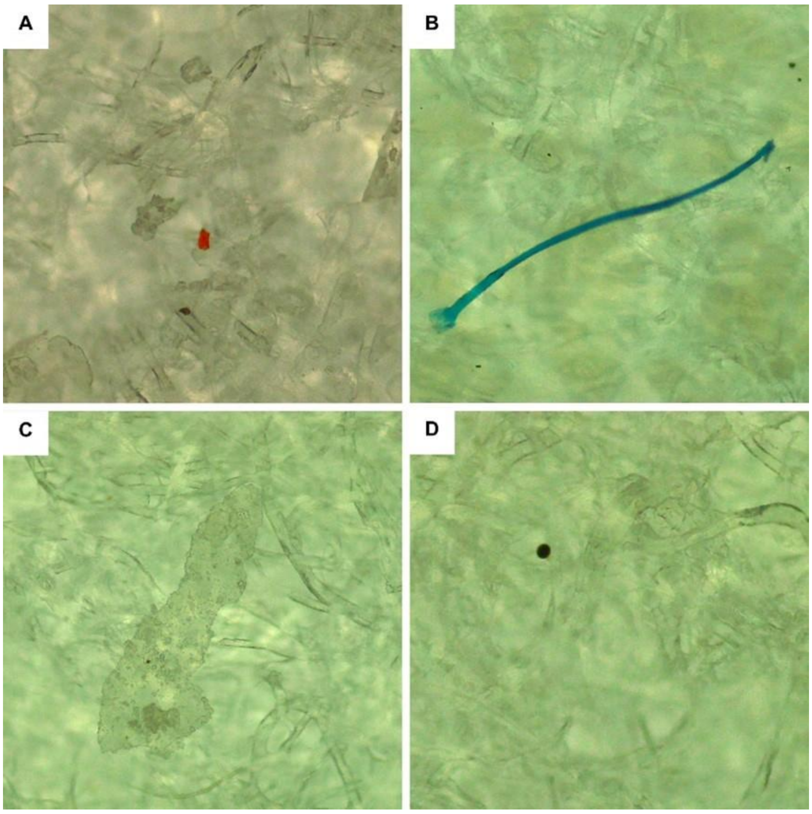

Figure 4. Types of microplastics found in pelagic fish (*Sardinella lemuru* and *Decapterus* sp.) showed fragment (A); fiber (B); film (C); pellet (D)

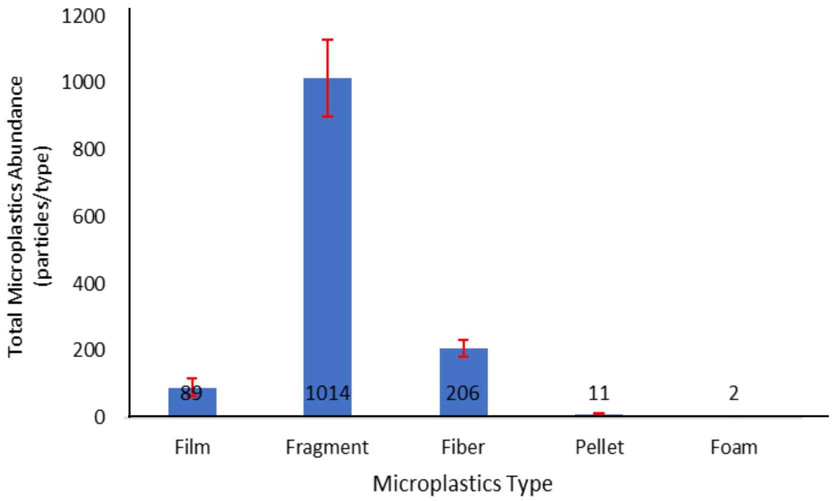

Figure 5. Total microplastic abundance of microplastic particles based on the type of microplastic found in fish pelagis (*Sardinella lemuru* and *Decapterus* sp.)

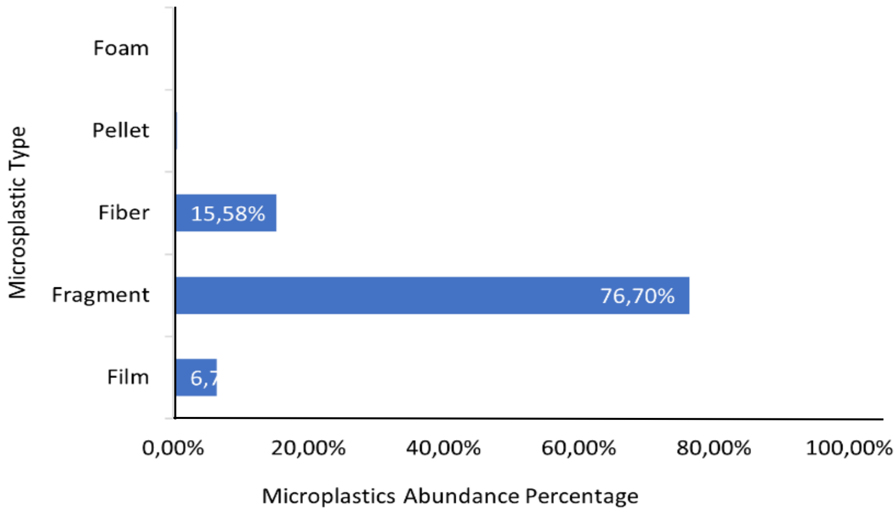

Figure 6. Microplastic abundance by type in pelagic fish *Sardinella lemuru* and *Decapterus* sp.

The findings of this study indicate that the microplastic abundance in all pelagic fish samples. Figure 6 is predominantly composed of fragments, accounting for 76.70%, followed by fibers at 15.58%, films at 6.73%, pellets at 0.83%, and foam at 0.15%. Consistent with microplastic contamination in all fish samples, which is predominantly of the fragment type (Figure 5), the percentage of microplastic abundance is likewise dominated by the fragment type. Microplastic fragments exhibit diverse sizes, yet are often smaller than other microplastic forms, including fibers or pellets. The diminutive size facilitates the passage of pieces via the gills and into the digestive tract of fish (KILIÇ, 2022; Mahjoub *et al*., 2022).

As shown in Figure 7, the film type is the most prevalent microplastic type in the gill organ, with a percentage of 14.63%. The fragment type is the most prevalent microplastic type in the meat organ, with a percentage of 89.56%. The fiber type is the most prevalent microplastic type in the stomach organ, with a percentage of 23.12%. The pellet type is the most prevalent microplastic type in the stomach organ, with a percentage of 1.04%. The foam type is the most prevalent microplastic type in the gill organ, with a percentage of 0.49%. Overall, the fragment form of microplastic accounts for the highest percentage in nearly all of the fish organs that have been examined. This implies that the environmental degradation of plastic has resulted in a significant quantity of microplastic fragments, which are subsequently consumed by fish. While the fragment type is considered the most prevalent, the percentage of different forms of microplastics in each organ varies significantly. This demonstrates that the distribution of microplastics in the fish body is influenced by factors such as its size (Nitzberg *et al*., 2024), shape, and density, as well as the digestive mechanism of the fish (Uurasjärvi *et al*., 2020).

The majority of microplastics found in these fish are pieces, although there are many other kinds. Microplastic particles are abundant in almost every organ, which means that fish easily consume them and have a tough time getting rid of them. Many factors contribute to the dominance of fragments, one of which is the tendency of fish to consume plastic pieces resulting from the breakdown of larger plastic items (Collard *et al*., 2017), which are commonly found in marine environments. Since microplastic pieces are denser than the more evenly dispersed fibres in the water column, they can be mistaken for prey (Sarasita *et al*., 2020; Yona *et al*., 2023). Depending on factors such as the fish's eating ecology, pollution sources, and local environmental circumstances, the prevalence of pieces in certain species may differ (Yona *et al*., 2022a). Recent investigation conducted by Ory *et al*. (2017), have revealed that microplastic fragments are the primary category of microplastics detected in fish species such as Bali sardinella and scad. Research on the amberstripe scad (*Decapterus muroadsi*) indicated that 80% of the analysed fish had consumed microplastics, predominantly blue polyethylene pieces. These findings raise significant concerns about the potential impact of microplastics on marine ecosystems and the health of predatory species that rely on these fish as a food source. Research by Avisina *et al*. (2024), indicates that microplastic fragments are the predominant type of microplastic found in Bali sardinella from PPP Mayangan Probolinggo. Bali sardinella may mistakenly ingest microplastics, confusing them for prey.

Microplastics contamination and abundance based on the color

Microplastics in the organs of pelagic fish can vary in color distribution based on a number of criteria, such as the type of plastic, the degradation process, the organ type, and the pollution source. Fish eat microplastics that match their natural habitat (color). The colors of different types of plastic also exhibit distinct hues. The initial hue of plastic can change as it degrades (Key *et al*., 2024). As a result, various organs, including the gills, flesh, and stomach, may have a distinct distribution of micoplastic colors.

Figure 8 shows the categories of microplastic contamination categorized by color. The x-axis represents the different colors of the microplastic particles identified. The y-axis represents the total contamination of microplastic particles, measured in particles per color. The predominant color of microplastic particles is purple, comprising 763 particles, followed by red with 155 particles, transparent with 119 particles, green with 94 particles, blue with 90 particles, orange with 49 particles, pink with 20 particles, brown with 18 particles, and yellow with 14 particles. The results indicate that purple exhibits the highest contamination value across all three organs. Plastic frequently incorporates artificial dyes to enhance its

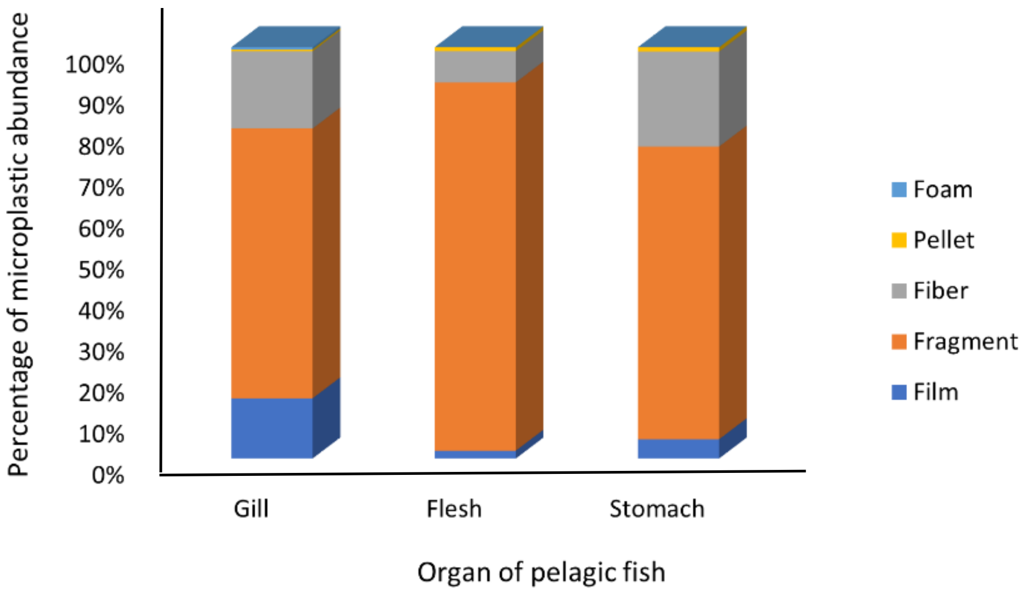

Figure 7. Abundance of microplastic types in each fish organ

visual appeal (Gibbons *et al*., 2019; Micheluz *et al*., 2021; Zhao *et al*., 2022). In the degradation process in marine environments, these dyes may exhibit greater durability compared to other plastic components (Key *et al*., 2024; Zhao *et al*., 2022), resulting in microplastic fragments that often retain their original colors, including purple. Interactions between plastics and the marine environment, including exposure to sunlight, chemicals (Micheluz *et al*., 2021), and waves (Shi *et al*., 2022; Zhao *et al*., 2022) in seawater, can alter the color of plastics. Black and dark colors, including brown, purple, and green, signify the types of PS and PP and are believed to harbor pollutants such as PAHs and PCBs that are absorbed. These darker colors in plastics not only indicate specific types of materials like polystyrene (PS) and polypropylene (PP) but also suggest their potential to accumulate harmful pollutants from the marine environment.

The results of this study showed that the percentage abundance of microplastics in the overall samples of honeybees and kingfish was dominated by purple, which measured 57.72%, followed by red, which measured 11.72%, clear, which measured 9.00%, green, which measured 7.11%, blue, which measured 6.81%, orange, which measured 3.71%, pink, which measured 1.51%, brown, which measured 1.36%, and yellow, which measured 1.06%. Microplastic contamination in the entire fish sample was dominated by purple (Figure 9), and the percentage abundance of microplastics was likewise dominated by purple. According to Zhao *et al*. (2022), certain kinds of plastics have a tendency to get darker in hue during the passage of time. Consumer products such as plastic bags, beverage bottles, and children's toys, which are dark in hue or purple in color, can also serve as sources of microplastics. This change in color over time can indicate degradation, which may lead to the release of microplastics into the environment.

The analysis of microplastic color abundance (Figure 10) across various organs revealed that purple was the predominant color in the stomach, comprising 58.96% of the pollution. In the gills, blue was the most prevalent color at 7.56%. The flesh exhibited a dominance of red at 16%, followed by green at 7.97% and orange at 4.74%. The stomach also showed minor contributions from yellow at 1.82% and pink at 2.08%. Brown accounted for 2.9% in the flesh, while transparent microplastics constituted 17.80% in the gills. Predominant microplastic colors were identified in the gill organs, stomach, and flesh of the studied fish.

Colors such as purple and blue are frequently observed in fish organs. Dark-colored plastics are prevalent in marine habitats because they originate from consumer goods such as black plastic bags and containers (Maulana *et al*., 2023). Prolonged exposure to ultraviolet light, biofouling, and the buildup of pollutants can cause these particles to darken, which in turn increases their environmental prevalence (Sarasita *et al*., 2020). Bali sardinella and scad may swallow more microplastics of a dark hue because they may mistake them for prey owing to similarities in size, shape, or color. A study by Sarasita *et al*. (2020), focusing on various commercial fish species in the Bali Strait, including Bali sardinella,

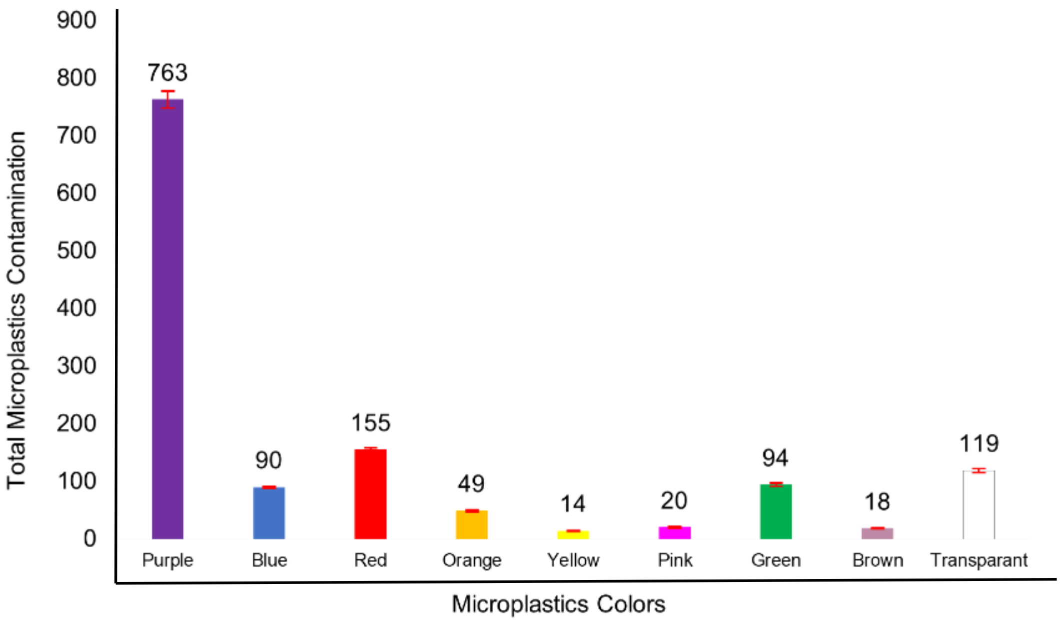

Figure 8. Amount of microplastic contamination based on color

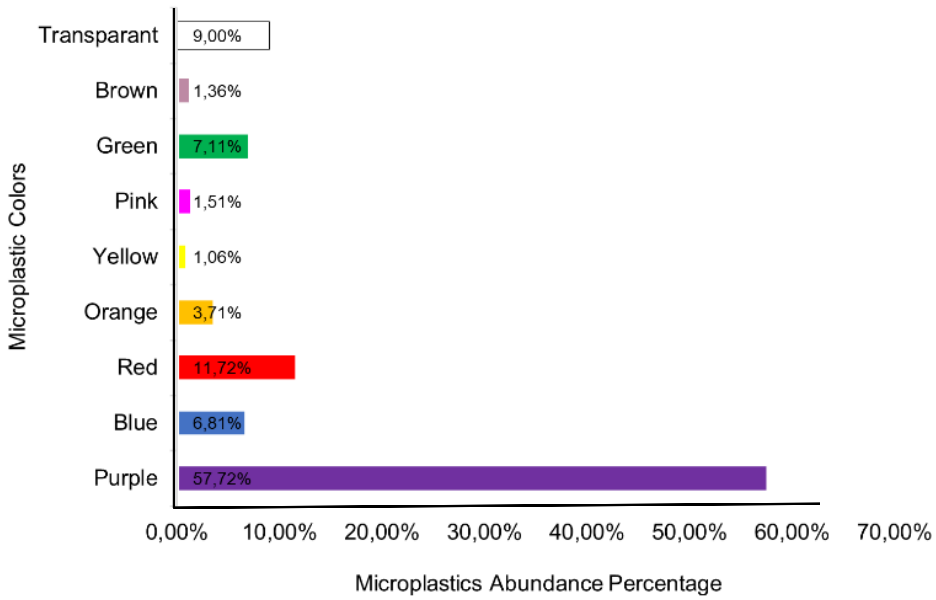

Figure 9. Microplastic abundance based on color in pelagic fish *Sardinella lemuru* and *Decapterus* sp.

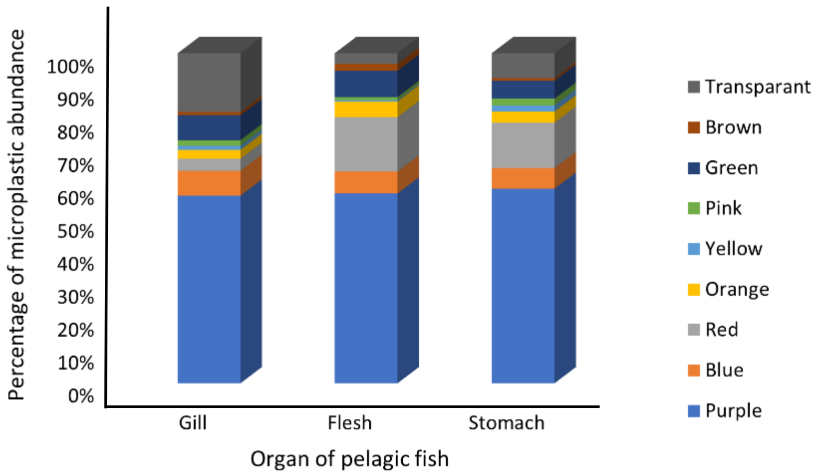

Figure 10. Abundance of microplastic colors in each fish organ

found that blue is the most common microplastic color found in both fish organs, followed by black, red, and other colors with a smaller percentage. However, current research indicates that this pelagic fishes primarily consume dark purple microplastics. The color of microplastics that are ingested can fluctuate as a result of the fish's foraging behaviour and environmental factors. For example, fish may consume microplastics that are similar in colour to their natural prey. Another study conducted by Yona *et al*. (2022) examines the prevalence of microplastics in the gills and gastrointestinal tracts of snakehead gudgeon fish from the Dubibir mangrove ecosystem in Situbondo; the findings indicate that blue is the predominant microplastic colour detected in both organs, followed by black, red, and other colours with fewer particles.

Statistical tests were carried out with the use of SPSS in order to determine the differences in abundance that were present in the three organs. Data that was not usually dispersed was determined by the number of microplastics that were discovered in the gill organs, stomach, and flesh.

The Shapiro-Wilk normality test produced significance values of 0.00, 0.03, and 0.000, indicating that the p-value is less than 0.05. This result confirms that the data were not normally distributed. Therefore, the use of the Kruskal-Wallis nonparametric test was applied to analyze differences among the three examined organs – gills, flesh, and stomach. This test was chosen because it is appropriate for comparing more than two independent groups when the assumption of normality is not satisfied. The result of the Kruskal-Wallis anlysis revealed a statistically signficant difference in microplastic abundance among the theree organs ($p<0.05$), indicating that the distribution of microplastics varied significantly between the gills, flesh, and stomach. This analysis allows for a comprehensive understanding of how microplastics accumulate in different organs of the organism. By comparing the median ranks of the groups, researchers can identify significant differences in microplastic concentrations across the examined organs, providing valuable insights into the ecological impact of pollution on aquatic life. This method not only highlights the specific organs affected but also sheds light on the broader implications for the health of the aquatic ecosystems. Ultimately, the findings can inform conservation efforts and regulatory policies aimed at mitigating microplastic pollution.

The Kruskal-Wallis test applied to compare the abudance of microplastics particles (particles per individual) among the three fish organs: gills, flesh, and stomach. This nonparametric test was selected because the data did not follow a normal distribution according to the Kolmogorov-Smirnov test results ($p<0.05$). The null hypptesis (H_0) stated that there is no significant difference in microplastic abundance among the organs, while the alternative hypothesis (H_1) proposed that at least one organ contains a significantly difference abundance level. The Kruskal–Wallis test yielded a p-value of 0.579 ($p > 0.05$), indicating that no statistically significant difference was found in microplastic abundance between the gills, flesh, and stomach of Bali sardinella and scad. Conversely, some researchers argue that the variability in microplastic concentrations across different organs may not be as pronounced as suggested, indicating that environmental factors could play a more substantial role in uniform distribution. Additionally, they propose that the methodology used to assess microplastic levels might introduce biases, potentially leading to an overestimation of differences among organ samples.

Conclusion

Research on microplastics is a rigorous field of study and an emerging scientific trend that is extensively investigated. This research entails an extensive process and can enhance awareness regarding the effects of the plastic waste we utilise daily. The investigation identified five categories of microplastics: fragments, fibres, films, pellets, and foams, exhibiting a range of colours including purple, red, blue, and green. The observational results indicated that microplastics were predominantly concentrated in beef, accounting for 39.86%. This study aims to promote judicious use of disposable plastic products to mitigate microplastic pollution in nature, particularly concerning fish consumption.

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