

Estimation of Microplastic Pollution in Commercial Pelagic Finfish, *Sardinella longiceps* (Valenciennes 1847) Collected from Thoothukudi District, Gulf of Mannar, Southeast India

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ABSTRACT

The revolutionary product of the 20th century is severely impacting global health. While macroplastics can be easily collected when visible, their transformation into microplastics (MPs) poses a significant challenge. MPs have been detected in various human organs, but their ability to bypass stomach acid and reach these organs remains unclear. Our study found that water samples from landing sites, such as Mullakadu (6.64 particles L⁻¹) and Punnakayal (8.44 particles L⁻¹), were contaminated with MPs.

Furthermore, the fish species *Sardinella longiceps* (Indian oil sardine) from these sites showed MPs accumulation, with 17.1 particles per gram of fish gut from Mullakadu and 13.7 particles per gram of fish gut from Punnakayal. Various colors of MPs and shapes were identified in both water and fish gut samples, with fragments dominating. Fourier-transform infrared (FTIR) spectroscopy analysis revealed the presence of polymers like polyamide, polyethylene, and polystyrene. The contamination of commercially significant fish species with MPs poses a serious threat to both environmental and human health, necessitating urgent measures to prevent plastic waste disposal into marine ecosystems.

Keywords Marine pollution, *Sardinella longiceps*, Microplastics, Gulf of Mannar, FTIR analysis.

INTRODUCTION

Sardinella longiceps or the Indian oil sardine is considered one of the most important commercial finfishes that is served as a delicacy and used for oil extraction (Rohit *et al.* 2018). This pelagic fish is suspected of becoming contaminated with microplastics and with heavy metals. Microplastics have become a major problem of the 21st century in marine biota, and their presence is ubiquitous. The size of these microplastics ranges from <2.5 mm to 0.9 nm (Palermo *et al.* 2020). The major source of these microplastics ending up in the ocean comes from anthropogenic

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activities (Palermo *et al.* 2020).

The Gulf of Mannar (GoM), recognized as one of India's most significant marine biodiversity hotspots (Kumaraguru *et al.* 2006), faces increasing pressure from these anthropogenic activities (Akash *et al.* 2025). On average, 400 metric tons of plastics were produced by the year 2020, and it is proven and believed by ecologists that an average of 4.8–12.7 million tons of plastics have accumulated in the marine ecosystem each year. By the end of 2025, it is believed that the ocean will be filled with around 100–250 million tons of plastics (Jambeck *et al.* 2015). These microplastics are formed from marine litter that is discarded on beaches by tourists, the failure of fishermen to retrieve damaged fishing gear, and sailors disposing of plastic debris into the marine environment (Daniel *et al.* 2020).

In this study, we limit our microplastic pollution assessment to a single pelagic finfish, *Sardinella longiceps*. Fishes were collected from different landing sites of GoM such as Mullakadu and Punnakayal, and surface water samples (Pavithran 2021) from those areas were assessed for microplastic pollution.

MATERIALS AND METHODS

Study area and sample collection

The Gulf of Mannar (8°28'N 79°01'E), a marine biosphere reserve in Tamil Nadu, faces significant pollution despite its rich marine resources. Water and fish samples were collected from Mullakadu (8°72'N 78°11'E) and Punnakayal (8°63'N 78°12'E) along the Thoothukudi coast, which are impacted by various pollutants, including plastics and harbor waste.

Morphometry of *Sardinella longiceps*

The morphometric study of *Sardinella longiceps* is necessary to understand contamination by microplastics because it provides valuable information on the species physical characteristics, growth patterns, feeding habits. The morphometric characters considered were TL- Total Length, BL- Body Length, SL- Snout Length, OL- Orbital Length, DFL- Dorsal

Fin Length, POL- Pectoral Fin Length, PVL- Pelvic Fin Length, AFL- Anal Fin Length, CFL- Caudal Fin Length, FL- Fork Length & BW- Body Width.

GSI analysis

Through Gastro Somatic Index (GSI) studies, the feeding habit and the ratio of gut weight to the total body weight of the fish can be calculated using the formula followed by Sangma *et al.* (2019).

Gastro Somatic Index (GSI) = (Weight of gut / Weight of fish) * 100

Microplastic extraction from water samples

25 liters of marine water samples from coastal sites using Whatman filter paper and then examined the filter papers under a stereomicroscope (40X) and observed microplastic debris in various shapes (film, filament, beads and fragments) and colors (blue, red, orange, white, yellow and green) (Hariharan *et al.* 2022).

Microplastic extraction from fish gut

Gut sample from *S. longiceps* was digested with 15 ml of wet 30% H₂O₂ to retain only the microplastic and inorganic debris (Löder and Gerdtts 2015). Remnants were diluted with double distilled water and filtered with Whatman filter paper. The paper is allowed to wet-dry for the microscopic observation to have a magnified look for microplastic accumulation in the gut (James *et al.* 2020).

Identification of microplastic

The images captured in an inverted microscope were subjected to visual evaluation (maximum length, color and shape). Their size ranges from < 1 µm to < 20 µm to < 50 µm to > 200 µm (Atamanalp *et al.* 2021). The samples were then assessed for the polymer constituents of the microplastics pollutants to understand the source of their origin using FTIR (Fourier Transform Infrared Spectroscopy) (Atamanalp *et al.* 2021, Hariharan *et al.* 2022). The concentration of microplastic accumulation per liter of water was estimated using the formula:

Concentration of microplastic (C) = Total number of microplastics counted (N)/Volume of water filtered (V)

Concentration of microplastic (C) = Total number of microplastics counted (N)/ Weight of gut (W)

FTIR analysis

Fourier Transform Infrared spectroscopy (FTIR) analysis was conducted on the filtered water samples and the gut samples of fish, following the procedures outlined by Hari Krishnan *et al.* (2023) and Alomar *et al.* (2024). A SHIMADZU IR spectrometer was used to collect the infrared spectra. Each sample was scanned forty-five times at a resolution of 4 cm^{-1} within the wave number range of $400\text{--}4000\text{ cm}^{-1}$ using SHIMADZU Lab-Solutions IR software. The resulting average spectrum was recorded.

Statistical analysis

Used MS Excel for data visualization and SPSS tool-pack for one-way ANOVA to find out the significant difference between the samples.

RESULTS

Morphometry

Figure 1 shows the dissected image of *Sardinella*



Fig. 1. Dissection of *Sardinella longiceps* gut for the microplastic analysis.

longiceps with its gut displayed. About 10 individuals of *S. longiceps* were examined for the morphometric analysis. Some of the morphometric data were correlated with the total length of the fish (Table 1). The morphometric measurements were illustrated in Table 2, which showed the strongest correlation between total length and pectoral fin followed by caudal fin. While lowest correlation was observed in body width and fork length in *S. longiceps*.

Gastro-somatic index (GSI)

Gastro-somatic index for *S. longiceps* was obtained as 2.32%, which is the percentage of the ratio of the weight of the gut to the weight of the fish, calculated

Table 1. Correlation between total length of *Sardinella longiceps* with other morphometric characters. *TL- Total Length, BL- Body Length, SL- Snout Length, OL- Orbital Length, DFL- Dorsal Fin Length, POL- Pectoral Fin Length, PVL- Pelvic Fin Length, AFL- Anal Fin Length, CFL- Caudal Fin Length, FL- Fork Length & BW- Body Width.

Sl. No.	Morphometric characters	Individuals									
		1	2	3	4	5	6	7	8	9	10
1	Total Length	14	13.5	13	14.2	13.7	13	14.2	13.9	13	13.7
2	Body Length	11.7	11.5	11.1	12	11.6	11.1	12	12	11.2	11.7
3	Snout Length	0.7	0.6	0.5	0.8	0.6	0.6	0.7	0.7	0.4	0.6
4	Orbital Length	0.9	0.7	0.7	1	0.8	0.7	0.9	0.9	0.7	0.8
5	Dorsal Fin Length	1.8	1.6	1.5	1.9	1.7	1.5	2	1.8	1.6	1.7
6	Pectoral Fin Length	0.9	0.7	0.6	1	0.8	0.6	1	0.9	0.6	0.8
7	Pelvic Fin Length	0.5	0.4	0.3	0.5	0.4	0.3	0.5	0.5	0.4	0.4
8	Anal Fin Length	0.5	0.4	0.3	0.5	0.4	0.3	0.5	0.5	0.4	0.4
9	Caudal Fin Length	3	2.3	2.1	3	2.5	2.1	3	2.8	2.1	2.5
10	Fork Length	3.2	2.5	2.8	3.3	2.7	2.7	3.4	3.1	2.8	2.8
11	Body Width	3.5	3.1	3	3.4	3.5	2.8	3.1	3.3	3	3.2
12	Body Weight	28.4	26.6	25	28.3	27.8	25.3	28.5	27	25.4	27.5

Table 2. Morphometric measurements of *Sardinella longiceps*.

Sl. No.	Morphometric characters	<i>Sardinella longiceps</i> Correlation r
1	TL vs BL	0.964
2	TL vs SL	0.868
3	TL vs OL	0.920
4	TL vs DFL	0.943
5	TL vs POL	0.989
6	TL vs PVL	0.897
7	TL vs AFL	0.897
8	TL vs CFL	0.971
9	TL vs FL	0.747
10	TL vs BW	0.726

in grams.

Microplastic observation

Four different morpho-types of MPs were observed namely Fragments, Beads, Film and Filament with fragments and beads being the most abundant morphotypes in all the samples and the film and filament types being less counted (Tables 3 – 4). Six different colors of these MPs were also seen as red, blue, orange, white or transparent, yellow & green (Fig. 2). Under 40X magnification and 20 μm size the microplastic images were observed. The size ranges from 0.25 μm to 0.5 μm . The filament length was measured to be 200 μm and it may go higher but its thinness could be 0.01 μm to 0.3 μm (Fig. 2).

Table 3. Estimated concentration of MP in the water samples from Mullakadu and Punnakayal landing site - Thoothukudi-GoM.

Sl. No.	Water sample	Type of MP	Number of MP counted	Volume of water filtered (L)	Total count of MP (N)	Concentration of MP (conc. perlt)
1	Mullakadu landing site	Fragment	66	25	166	6.64
		Film	30			
		Bead	64			
		Filament	6			
2	Punnakayal landing site	Fragment	137	25	211	8.44
		Film	25			
		Bead	46			
		Filament	3			

Table 4. Estimated concentration of MP in the fish gut samples of *Sardinella longiceps* from Mullakadu and Punnakayal landing site - Thoothukudi - GoM.

Sl. No.	Gut sample	Type of MP	Number of MP counted	Weight of gut of 25 fishes(g)	Total count of MP	Concentration of MP (conc per gram.)
1	Punnakayal landing site	Fragment	208	27.1	372	13.7
		Film	74			
		Bead	80			
		Filament	10			
2	Mullakadu landing site	Fragment	363	29.6	506	17.1
		Film	51			
		Bead	86			
		Filament	6			

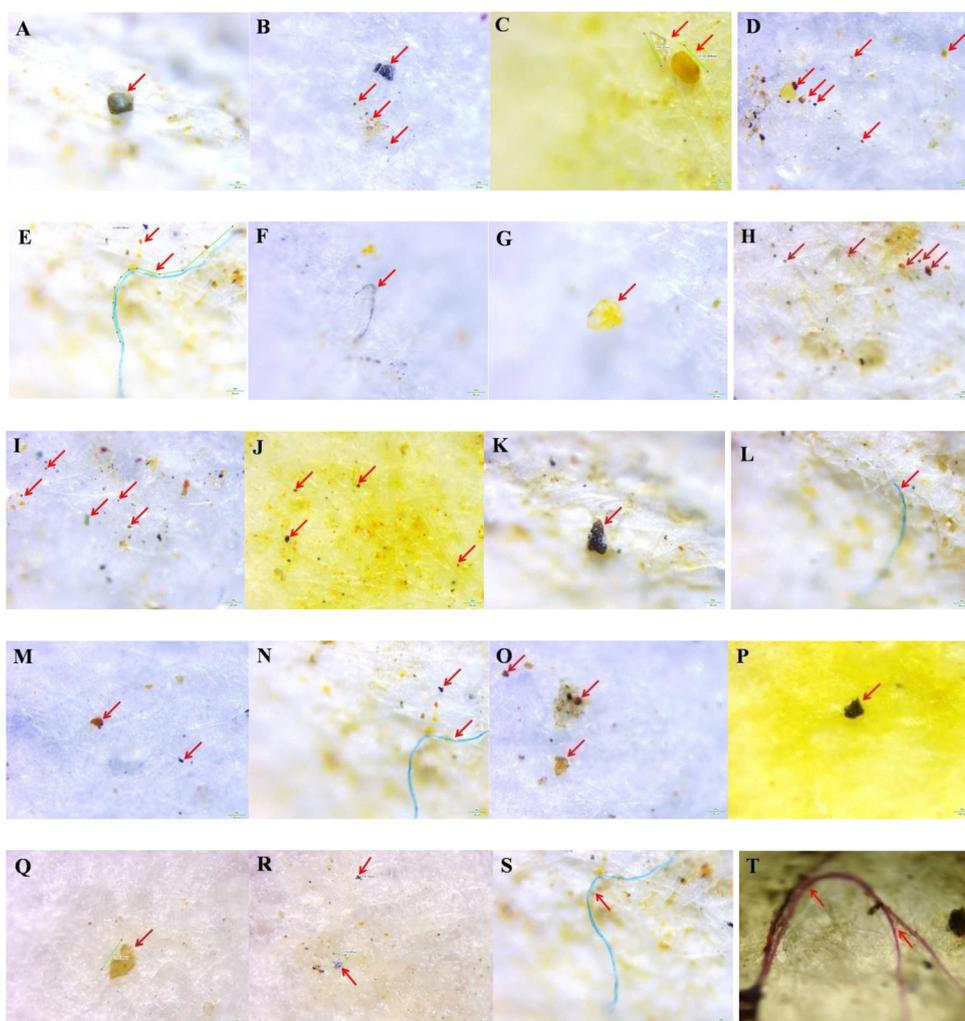


Fig. 2. Types of MP observed under stereoscopic microscope from the water and fish gut samples of the Punnakayal & Mullakadu landing sites. A, C & P– Beads, B,C,D,H,I, J, M & R - Fragments, C,G,K,O & Q - Film, B,E,F,L,N,S & T – Filament.

Estimation of microplastic (MPs)

The study found varying concentrations of microplastics (MPs) in water and fish gut samples from two landing sites. Water samples from Punnakayal had a higher MPs concentration (8.44 individuals/L) compared to Mullakadu (6.64 individuals/L). However, fish gut samples from Mullakadu showed higher MPs contamination (17.1 particles/g) than Punnakayal (13.7 particles/g) (Tables 3–4).

In Fig. 3 type of MPs distributed in the fish gut and the water samples were shown with fragments

being the most common MPs in both samples followed by beads. The order thus follows Fragments > Beads > Film > Filament. From Fig. 3 MPs in water samples S1 and S2 shows the order of distribution as Fragments > Beads > Film > Filament. Fragments in S1 shows 64% and that of S2 shows 38%. Beads and Filaments in S2 exceeds S1 by 5% & 6% respectively. Similarly, the gut samples also follow the same trend as Fragments > Beads > Film > Filament. Film in S2 is 4% more than S1 fish gut samples. All these four types of MPs were seen in all the four samples but in different concentrations.

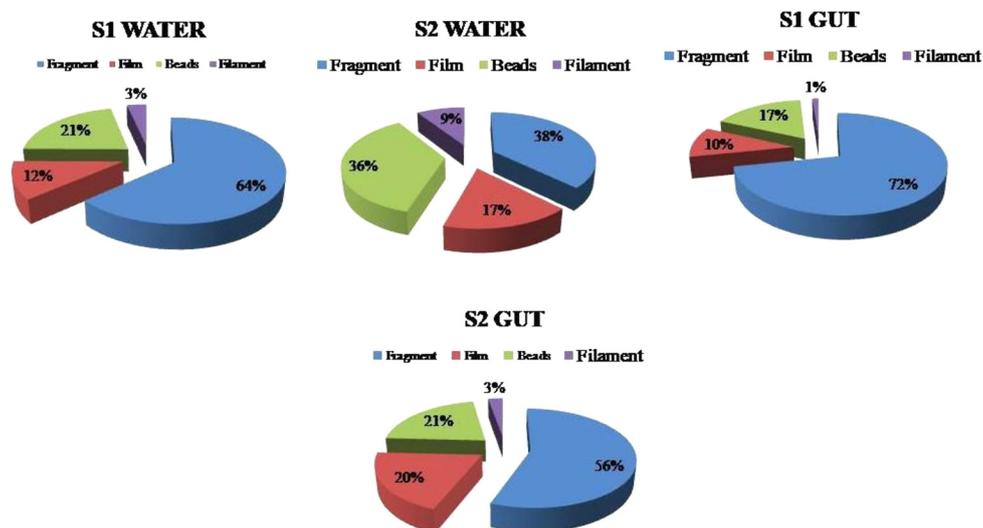


Fig. 3. Proportion of MP distributed in various water samples and fish gut. S1 & S2 – Water sample from Punnakayal & Mullakadu landing sites, S3 & S4 – Fish gut sample of *Sardinella longiceps* from Punnakayal & Mullakadu landing sites respectively.

Average count of MPs in different samples was observed to be 45.66 ± 5.03 for fragments in Punnakayal waters and 22 ± 4.58 for Mullakadu waters in

case of fragments being the most. Filament gives the least contributions with Punnakayal waters has 2.52 ± 0.56 and Mullakadu waters show 5.33 ± 1.59 as a whole. Same pattern was observed in the fish gut samples too. The study highlights the presence of MPs in different concentrations across samples (Table 5).

Table 5. Type of MP accumulated in the water and fish gut samples collected from the Punnakayal & Mullakadu landing sites.

Types of MP	Mean \pm Standard deviation			
	S1 Water	S1 GUT	S2 Water	S2 GUT
Fragment	45.66 ± 5.03	121 ± 8.54	22 ± 4.58	69.33 ± 9.01
Beads	8.33 ± 2.51	17 ± 3.61	10 ± 2.64	24.66 ± 3.51
Film	15.33 ± 3.05	28.66 ± 5.03	21 ± 8.08	26.66 ± 7.63
Filament	2.52 ± 0.56	2 ± 1	5.33 ± 1.59	3.33 ± 0.57

FTIR analysis

From the graph obtained from FTIR Fig. 4 possible chemical bonds of the polymers were deduced

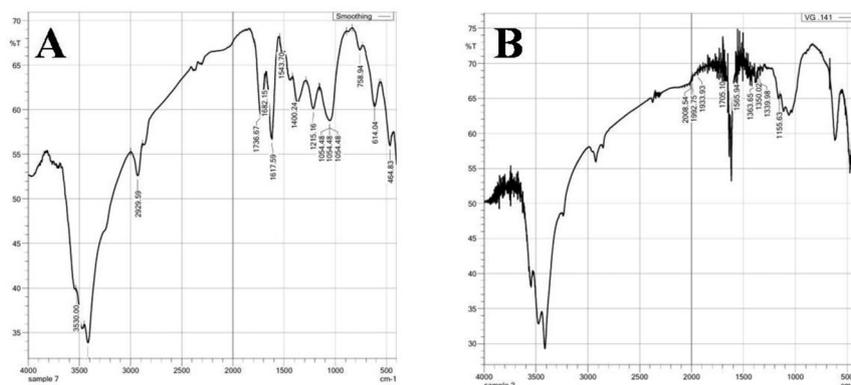


Fig. 4. FTIR image of the MP polymer for the water samples of Punnakayal & Mullakadu landing sites.

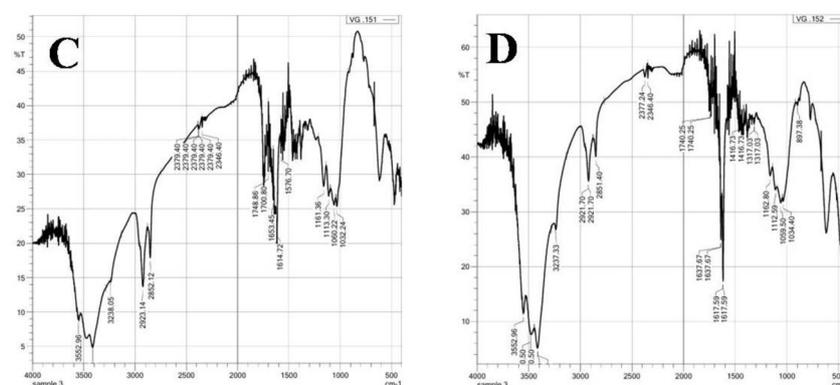


Fig. 5. FTIR image of the MP polymer for the fish gut samples of Punnakayal & Mullakadu landing sites.

through the wavenumbers for the water samples like phenols, nitro compounds, alkene, ketone, aldehydes. Similarly from the Fig. 5 we can predict the following chemical bonds of MPs in the fish gut samples like aromatic cyano compounds, amino compounds, alkenes, halogen based polymers.

Statistical analysis

The study found statistically significant differences across all four variables (water and fish gut samples from Punnakayal and Mullakadu). The results ($p < 0.05$) indicate that these differences are unlikely due to chance. Strong linear trends were observed in fish gut samples from both sites. While significant differences were found in water samples and fish gut samples, a post-hoc analysis (Tukey's test) revealed no significant difference between the two sites due to the small sample size. This suggests that both Punnakayal and Mullakadu landing sites in the Gulf of Mannar are equally polluted with plastics and microplastics.

DISCUSSION

This study discusses the morphological characteristics of *Sardinella longiceps* and its relation to microplastic (MPs) pollution. Morphometric data, useful for species identification, has been previously reported for clupeids by Khatun *et al.* (2021) and in catfishes by Sivanesh *et al.* (2025). Gastro somatic index (GSI) shows the feeding intensity and the seasonal variance in the gut content of the fish. When the fishes are in active breeding season the GSI is found to be very

low conversely, the GSI is high in migration time and growing periods. The Gastro-somatic index and the length-weight relationship was reported in the ornamental fishes like *Chanda nama* and *Trichogaster lalius* by Sangma *et al.* (2019) on a seasonal basis with a variation of 3.97–1.72 in *Chanda nama* and 1.7–5.18 in *Trichogaster lalius* with each species showing a seasonal variation in the gut content. The GSI we have observed in *S. longiceps* 2.32. Karbalaee *et al.* (2019) reported the presence of three basic morphotypes of MPs namely fragment (67.4%), film (16.3%), and fiber (16.3%) from the muscle and gill regions of the commercial fishes captured from the Malaysian coast, but our samples showed the presence of four basic morpho-types of MPs with fragments dominating the most (38–64%) in water samples and (56–72%) in fish gut samples of Indian oil sardines. Conversely, filaments showed a very low count in all the samples. Various shapes of MPs like fragments, beads, filaments, films, transparent and fibers are reported from various aquatic ecosystems around the world likewise Sivanesh *et al.* (2025) has reported the presence of the morpho-types like fragment, fiber and bead of MPs in the gut of freshwater finfishes from the Thamirabarani river.

Harikrishnan *et al.* (2023) reported about the various colors of MPs as red, blue, transparent white, green similar to us. This research identified four different morpho-types of MPs in water samples with fragments dominating the most (34–64%), followed by beads (21–36%), while foam is absent. In the fish gut samples, the predominant form of MPs seen was

fragments (56–72%) followed by beads (17–21%) and these MPs pollutants come in a variety of colors. Among fish species, pelagic fishes are more prone to MPs injection than demersal fishes. The size of these MPs ranges from 0.5 μm – 20 μm in the case of fragments and beads and the length of the filament morphotype is up to 105 μm similar to that of Asadi *et al.* (2019). Harikrishnan *et al.* (2023) mentioned the occurrence of 0.5 mm tiny transparent MPs in the seafood samples collected from the Southeast coast of India.

Studies have analyzed microplastic (MPs) composition using FTIR spectroscopy. Selvam *et al.* (2020) identified polymers like polyethylene in MPs debris from sea salts. Similarly, our study found polyethylene as the predominant MPs form in water and fish gut samples of *Sardinella longiceps* from the Gulf of Mannar. FTIR results confirmed plastic polymer presence in both sample types. These findings align with Harikrishnan *et al.* (2023), who reported polyethylene dominance (53.3–67.4%), highlighting the presence of 1115 MPs particles from over 220 samples of 17 different commercial fish species from India's Southeast coast. Our study detected 506 and 372 MPs particles in *S. longiceps* gut samples from Mullakadu and Punnakayal, respectively. Globally, MPs pollution has been reported in various sardine species, highlighting the widespread issue Palermo *et al.* (2020), Hussien *et al.* (2021) Ranatunga *et al.* (2021) and Zeghdani *et al.* (2023).

Asadi *et al.* (2019) used Tukey's test to analyze the significant difference in MPs distribution in marine biota in Indonesia's Baluran National Park, finding a significant difference ($p < 0.01$). In contrast, our samples showed no significant difference, likely due to the small sample size. However, ANOVA analysis of fish gut samples from the Mullakadu landing site revealed a significant difference in MPs presence compared to other samples.

This study confirms the presence of microplastics (MPs) in both study areas along the Southeast coast of India, as well as in the fish samples (*Sardinella longiceps*) collected from these regions. Despite the designation of the Gulf of Mannar as a Biosphere Reserve (1989) and a Marine National Park (1986),

there is a pressing need to raise awareness among local communities about the dangers of disposing plastics and other waste into these marine ecosystems and on the beaches near pilgrimage sites. Educating and creating awareness among both locals and tourists is the most effective mitigation strategy to protect and preserve these beautiful marine habitats.

CONCLUSION

Plastic pollution poses a significant threat to marine ecosystems, particularly in coastal areas. This study investigated microplastics (MPs) pollution at Punnakayal and Mullakadu landing sites in the Gulf of Mannar, India, where fishing, tourism, and pilgrimage activities exacerbate the issue. Using FTIR spectroscopy, we identified plastic polymers in the environment. Our findings provide baseline values for MPs accumulation in fish gut (13.7–17.1 particles per gram), highlighting the need for further research on MPs presence in edible fish parts and potential toxin bioaccumulation. This study underscores the urgent need to address plastic pollution's impact on marine ecosystems and human health.

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REFERENCES

- Akash, A., Kaviarasan, T., Dhineka, K., Sambandam, M., Mishra, P., & Anand, M. (2025). Quantification of Plastic Pollution in Gulf of Mannar Marine Biosphere Reserve: Risk Assessment and Management Strategies. *Regional Studies in Marine Science*, 83, 104051. <https://doi.org/10.1016/j.rsma.2025.104051>
- Alomar, C., Rios-Fuster, B., Cefali, M. E., Fagiano, V., & Deudero, S. (2024). Monitoring microplastics in coastal waters of a biosphere reserve: A case study in Menorca (Spain). *Environmental Science and Pollution Research*, 31(1), 882–894. <https://doi.org/10.1007/s11356-023-31061-y>
- Asadi, M. A., Ritonga, Y. A., Yona, D., & Hertika, A. M. (2019). Vertical distribution of microplastics in coastal sediments of Bama Resort, Baluran National Park, Indonesia. *Nature*

- Environment and Pollution Technology*, 18 (4), 1169—1176.
<https://www.researchgate.net/publication/350735499>
- Atamanalp, M., Köktürk, M., Uçar, A., Duyar, H. A., Öz demir, S., Parlak, V., & Alak, G. (2021). Microplastics in tissues (brain, gill, muscle and gastrointestinal) of *Mullus barbatus* and *Alosa immaculata*. *Archives of Environmental Contamination and Toxicology*, 81, 460—469.
<https://doi.org/10.1007/s00244-021-00885-5>
- Daniel, D. B., Thomas, S. N., & Thomson, K. T. (2020). Assessment of fishing-related plastic debris along the beaches in Kerala Coast, India. *Marine Pollution Bulletin*, 150, 110—696.
<https://doi.org/10.1016/j.marpolbul.2019.110696>
- Hariharan, G., Purvaja, R., Anandavelu, I., Robin, R. S., & Ramesh, R. (2022). Ingestion and toxic impacts of weathered polyethylene (wPE) microplastics and stress defensive responses in whiteleg shrimp (*Penaeus vannamei*). *Chemosphere*, 300, 134—487.
<https://doi.org/10.1016/j.chemosphere.2022.134487>
- Harikrishnan, T., Janardhanam, M., Sivakumar, P., Sivakumar, R., Rajamanickam, K., Raman, T., & Singaram, G. (2023). Microplastic contamination in commercial fish species in Southern coastal region of India. *Chemosphere*, 313, 137—486.
<https://doi.org/10.1016/j.chemosphere.2022.137486>
- Hussien, N. A., Mohammadein, A., Tantawy, E. M., Khattab, Y., & Al Malki, J. S. (2021). Investigating microplastics and potentially toxic elements contamination in canned Tuna, Salmon and Sardine fishes from Taif markets, KSA. *Open Life Sciences*, 16 (1), 827—837.
<https://doi.org/10.1515/biol-2021-0086>
- Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science*, 347 (6223), 768—771.
<https://www.science.org/doi/10.1126/science.1260352>
- James, K., Vasant, K., Padua, S., Gopinath, V. K. S. A., Babu, A., & John, S. (2020). An assessment of microplastics in the ecosystem and selected commercially important fishes off Kochi, South-eastern Arabian Sea, India. *Marine Pollution Bulletin*, 154, 111027.
<https://doi.org/10.1016/j.marpolbul.2020.111027>
- Karbalaei, S., Golieskardi, A., Hamzah, H. B., Abdulwahid, S., Hanachi, P., Walker, T. R., & Karami, A. (2019). Abundance and characteristics of microplastics in commercial marine fish from Malaysia. *Mar Pollut Bull*, 148, 515.
<https://doi.org/10.1016/j.marpolbul.2019.07.072>
- Khatun, D., Hossain, M. Y., Hossain, M. F., Mawa, Z., Rahman, M. A., Hasan, M. R., & Sikha, S. N. (2021). Population parameters of a freshwater clupeid, *Corica soborna* (Hamilton 1822) from the Ganges River, North-western Bangladesh. *Pakistan Journal of Zoology*, 53 (4), 1279—1290.
<https://doi.org/10.17582/journal.pjz/20191208161233>
- Kumaraguru, A. K., Joseph, V. E., Marimuthu, N., & Wilson, J. J. (2006). Scientific information on Gulf of Mannar Marine Biosphere Reserve Trust, Ramanathapuram—A bibliography. <http://eprints.cmfri.org.in/id/eprint/6766>
- Löder, M. G., & Gerdts, G. (2015). Methodology used for the detection and identification of microplastics—a critical appraisal. *Marine Anthropogenic Litter*, pp 201—227.
https://doi.org/10.1007/978-3-319-16510-3_8
- Palermo, J. D. H., Labrador, K. L., Follante, J. D., Agmata, A. B., Pante, M. J. R., Rollon, R. N., & David, L. T. (2020). Susceptibility of *Sardinella lemuru* to emerging marine microplastic pollution. *Global Journal of Environmental Science and Management*, 6 (3), 373—384.
<https://www.gjesm.net/>
- Pavithran, V. A. (2021). Study on microplastic pollution in the coastal seawaters of selected regions along the Northern coast of Kerala, Southwest coast of India. *Journal of Sea Research*, 173, 102060.
<https://doi.org/10.1016/j.seares.2021.102060>
- Ranatunga, R. R. M. K. P., Wijetunge, D. S., & Karunarathna, K. P. R. (2021). Microplastics in beach sand and potential contamination of planktivorous fish *Sardinella gibbosa* inhabiting in coastal waters of Negombo, Sri Lanka. *Sri Lanka Journal of Aquatic Sciences*, 26 (1), In press.
<https://doi.org/10.4038/sljas.v26i1.7587>
- Rohit, P., Sivadas, M., Abdussamad, E. M., Margaret Muthu Rathinam, A., Koya, K. P., Ganga, U., & Supraba, V. (2018). Enigmatic Indian Oil Sardine: An insight (No. 130). ICAR-Central Marine Fisheries Research Institute. <http://eprints.cmfri.org.in/id/eprint/13281>
- Sangma, S. K., Bhattacharjee, P., & Pal, P. (2019). Length-weight relationship, Relative length of gut and Gastro-somatic index of *Chanda nama* (Hamilton 1822) and *Trichogaster lalius* (Hamilton 1822) from Tripura, India. *Journal of Entomology and Zoology Studies*, 7 (3), 737—742.
- Selvam, S., Manisha, A., Venkatramanan, S., Chung, S. Y., Paramasivam, C. R., & Singaraja, C. (2020). Microplastic presence in commercial marine sea salts: A baseline study along Tuticorin Coastal salt pan stations, Gulf of Mannar, South India. *Mar Pollut Bull*, 150, 110675.
<https://doi.org/10.1016/j.marpolbul.2019.110675>
- Sivanesh, H., Viveke, A. A., & Raj, R. A. (2025). Microplastic Analysis in Catfish *Mystus gulio* (Hamilton 1822) and Tilapia *Oreochromis niloticus* (Linnaeus 1758) from Tirunelveli District, Tamil Nadu, India. *Environment and Ecology*, 43 (1A), 264—274.
<https://doi.org/10.60151/envec/IVNR7948>
- Zeghdani, Z., Aissa, Z. A., Kherfallah, L., Bouchemma, N., Gherbi, R., & Ramdane, Z. (2023). Microplastic ingestion in *Sardinella aurita* Valenciennes, 1847 and *Lithognathus mormyrus* (Linnaeus 1758) along the Gulf of Bejaia, Algeria. *Indian Journal of Fisheries*, 70 (2), 95—100.
[doi:10.21077/ijf.2023.70.2.132270-12](https://doi.org/10.21077/ijf.2023.70.2.132270-12)