JEB®

Journal of Environmental Biology

p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

Journal website : www.jeb.co.in ★ **E-mail :** editor@jeb.co.in

Triveni Enterprises (Educational Services Set-up)

Original Research

DOI : http://doi.org/10.22438/jeb/44/3/MRN-5078

Abundance and distribution of subsurface microfibres and seabed macrolitter in Thoothukudi, Gulf of Mannar, South-east coast of India

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Received: 20.07.2022 *Revised*: 08.10.2022 *Accepted*: 19.11.2022

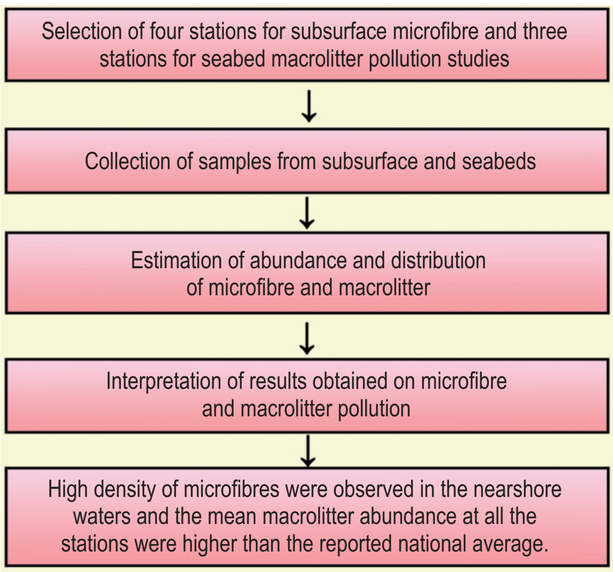
Abstract

Aim: Considering the potential harm caused by plastic pollution to the marine ecosystem, the present study was conducted to elucidate the status of microfiber and macrolitter in the selected areas of Thoothukudi on the South-east coast of India.

Methodology: The abundance and distribution of subsurface microfibers in four locations of Tuticorin inshore waters were estimated by filtering subsurface waters using a 250µm mesh epineuston net. The non-biodegradable macrolitter on the seabed at three locations of Thoothukudi was estimated by swept area method.

Results: Among the four selected stations, a higher quantity of microfibres was observed in the subsurface waters at 5m depth close to nearshore areas, with the highest mean numerical abundance of 3.13±0.3 nos.m l^{-1}. The annual difference in the subsurface microfibre abundance varied significantly between stations ($p<0.05$). Plastics were the most dominant litter constituents on the sea beds among three stations. A significant seasonal variation ($p<0.05$) with maximum mean total macrolitter abundance was noticed on the seabed at Kayalpattinam (45.81± 9.3 kg km^{-2}). The estimated mean macrolitter abundance at all the stations was higher than the reported national average of 10.95±3.05 kg km^{-2}.

Interpretation: This study revealed variations in the abundance and distribution of microfibers and macrolitters in the selected areas of Tuticorin. The study emphasises the role of land and marine-based anthropogenic activities in the plastic pollution of this region.



Key words: Abundance, Gulf of mannar, Microfibres, Macrolitter, Subsurface waters, Seabed

How to cite : Asha, P.S., K. Diwakar, H. Sivanesh and P. Kaladharan: Abundance and distribution of subsurface microfibres and seabed macrolitter in Thoothukudi, Gulf of Mannar, South-east coast of India. *J. Environ. Biol.*, **44**, 401-408 (2023).

Introduction

Marine litter has become a pervasive problem globally due to its ubiquity and potential harm to marine organisms and ecosystems (UNEP, 2016). Litter enters the marine environment from various sources such as ships, beachgoers, rivers and municipal drainage systems (Williams and Simmons, 1997). Plastic constitutes a significant share of the world's litter; 80% originates from land and 20% from fishing nets and ropes (Gündoğdu and Çevik, 2017). Macroplastics entering the ocean are readily transported long distances from source areas and accumulate in sinks (Ryan *et al.,* 2009). Jambeck *et al.* (2015) established that over 8 million tonnes of plastic enter the marine environment annually. In addition, it has been reported globally that marine litter causes substantial loss to fishers due to the repair cost of damaged gears and the opportunity cost of lost fishing time when cleaning the entangled nets (Katsanevakis, 2011). In the marine ecosystem, large plastic items degrade into smaller fragments by weathering, photodegradation, and biodegradation becoming "microplastics" (<5 mm) (Li *et al.,* 2018). Microplastics have been found in surface and sub-surface waters, within the water column, in sediments, on deep-sea floor and even in Polar Regions (Kanhai *et al.,* 2018). It has been estimated that there is a global marine surface load of 4.85×10^{12} pieces of microplastics within 0.33–4.75mm size (Eriksen *et al.,* 2014).

Fibres are the most abundant type of microplastics found in the environment. Because of their large surface ratio/volume, these microplastics can transport various chemicals like heavy metals and persistent organic pollutants. In addition, they can also interact with a variety of smaller marine animals (Ziajahromi *et al.,* 2017). Kaladharan *et al.* (2020) summarise the macroplastic pollution in the trawl grounds of Visakhapatnam along India's east coast. Substantial information is available on the beach litter pollution of various coastal ecosystems in Tamil Nadu, India. Thoothukudi district, along the east coast of India, borders the southern part of Tamil Nadu and is of commercial and economic importance for marine fisheries. Jeyasanta *et al.* (2020) found that the beaches of Thoothukudi are under substantial pressure due to increased plastic littering. Plastics have been found in the stomachs of economically important fishes like pompano dolphinfish, *Coryphaena equiselis*, and sharp nose sardine, *Amblygaster clupeoids*, caught off Thoothukudi (Sivadas *et al.,* 2016). Similarly, high levels of microplastic contamination in the seawater and epipelagic fish have been described (Kumar *et al.,* 2018). However, no information is available on the variation in abundance and distribution of microfibres in the subsurface waters and macrolitter in the sea beds of the Thoothukudi region. To address this knowledge gap, the present study was conducted to assess the levels of microfibres and macrolitter in the selected areas of Thoothukudi on the South-east coast of India.

Materials and Methods

The abundance and distribution of microfibres in the subsurface waters of Thoothukudi inshore areas were assessed for 28 months, from June 2013 to December 2015. Four stations were selected for monthly sampling. Station 1: was at 5m depth, 3.34NM away from the busy Tuticorin fishing harbour, where the sea was relatively shallow and turbid due to the influence of effluents from the fishing harbour and sewage discharge. Station 2: was at 10m depth, 1.18NM away from the St.1. Station 3: was at 15m depth, 2.82NM away from St.2. Station 4: was the deepest (20m depth) among all the stations and 4.76NM from St.3.

By engaging the research vessel *Cadalmin-IV*, samples for microfibres were collected every month from the subsurface waters of four stations by a 10 min surface horizontal haul using a 250-µm mesh epineuston net. The sample collected in the cod-end of the net consisted of microfibres and the plankton of the area. The entire volume was fixed with 4% formalin on board the vessel and brought to laboratory. The sample was fractioned using a Folsom Plankton Splitter, and the microfibre items were enumerated using a Sedgwick-Rafter Counting Cell under a microscope during the sampling month in triplicates. The average of three samples for each station was computed as the abundance. Measurements concerning the length and breadth of the microfibres were taken using a phase-contrast microscope with a stage and ocular micrometre. All the procedures followed the contamination protocol (Masura *et al.,* 2015). Utmost care was taken to avoid airborne contamination by covering the samples with aluminium foil and excluding textile fibres during sample sorting. We also conducted air and water blanks during sample processing to determine whether there was any contamination during laboratory analyses.

The non-biodegradable macrolitter on the seabed at Thoothukudi was estimated for 25 months based on a monthly sampling from August 2014 to September 2016. Sampling stations were fixed based on the opinion of fishers on the probability of litters caught in their nets. Consequently, the macrolitter caught in the bottom-set gill nets operated by a single fisher from two fish landing centres (*i.e.,* Kayalpattinam and Tuticorin Bay) and a modified country trawler (*Thallumadi*) from Mottaigopuram were selected for the study. At Kayalpattinam, the fishers operated their gill nets approximately 7.6NM away from shore at a depth of 30 m. In contrast, at Tuticorin Bay, they performed their gill nets at 15 m depth, about 7.02 km from shore. At Mottaigopuram, the operation of the Thallumadi trawler gear took place 5.39NM away from the shore at 13 m depth. The non-biodegradable macrolitter caught by the same fisher was analysed for the entire study period from each station. The litter items collected from each fishing gear were brought to the laboratory, cleaned of adhering sand particles, dried under shade, and weighed using a top-pan balance.

The sorted constituents were graded into four major groups, as shown in Table 1, according to the UNEP Guidelines (2009), and the abundance was estimated using the swept area calculation method. The distance travelled by each fishing net was calculated by the formula D = V * t, where 'V' is the boat's velocity, and 't' is the time taken to reach the spot. The swept area 'a' was estimated as a = D * hr *X_2, where 'D' is the distance covered, 'hr' is the length of the head-rope, 'X_2' is the fraction of the head-rope length hr, which is equal to the width of the path swept by the trawler. The value of X_2 = 0.5, as suggested by Pauly (1980), was used in the present study. The annual, seasonal, and station-wise variations in the litter constituents in the subsurface and seabed were analysed using One-way ANOVA. The analyses were performed at significance level of 0.05 and 0.01, respectively. All statistical tests, including Pearson's Correlation between all possible combinations were determined using SPSS software (version 20; Chicago, USA).

Results and Discussion

The microfibres observed at all the sampling stations appeared transparent or whitish under microscope. Fig. 1 (a,b,c) shows the station-wise variations in microfiber's numerical abundance, length, and width in the subsurface water of Tuticorin. The numerical abundance was comparatively higher in the subsurface waters of (5 m depth) Station 1 (St.1) and ranged between 0.5 and 7nos. ml^{-1} at St.1., 1 and 6 nos. m l^{-1} at St. 2 (10m depth)., 0.5 and 7nos. ml^{-1} at St.3 (15 m depth), and 1.5 and 5.5 nos. ml^{-1} at St.4 (20 m depth). At St. 4, sampling could only be conducted for a limited period due to rough weather conditions at sea. The annual and monthly differences in the microfiber abundance varied significantly between stations ($p<0.05$). The mean abundance of microfibres was lowest (2.09±0.35 nos. ml^{-1}) at St.3 and highest (3.71±0.69 nos. ml^{-1}) at St.1 (Fig. 1a). In this study, a proportionate decrease in the numerical abundance of microfibres with distance from the shore was observed. A comparatively higher abundance of microfibres was observed at 5m depth St.1, which may be due to the influence of anthropogenic activities in the harbour and untreated sewage discharge. Caldwell *et al.* (2019) also observed a higher magnitude of microplastics at stations closer to the busy harbour due to its proximity.

In the present study, the abundance of microfibres in Thoothukudi subsurface water ranged between 0.5 and 7nos. ml^{-1}. The estimated values in the present study were higher than 0.0031 to 0.0237 nos. ml^{-1} reported by Sathish *et al.* (2020) in the epipelagic, mesopelagic, and trawl habitats in the sea of Thoothukudi. The difference may be due to their limited sampling period from a higher distance level within the sea. In their studies, Barrows *et al.* (2018) reported an average of 0.0118 nos. ml^{-1} from the world ocean surface. Sathish *et al.* (2020) also reported the dominance of fibres among their microplastic collections in different parts of the Thoothukudi Sea. The same trend of a higher concentration of transparent microfibres has been observed in the surface waters of the Indian Ocean (Barrows *et al.,* 2018).

The microfibres observed in the subsurface waters of Thoothukudi are secondary in nature. They might have originated from fishing gear since textiles and fishing gear are reported to be a vital source of microfibres in the marine environment (Mu *et al.,* 2019). Apart from the intensive fishing activity, untreated sewage effluent discharge through the Buckle Canal is a significant source of plastic entry into the Thoothukudi subsurface waters (Sugumar *et al.,* 2008). Naidu *et al.* (2022) also highlighted that land-based human activities influence the microplastic abundance in Indian coastal areas. It was difficult to segregate the microfibres observed in this study for their micron size; hence, the chemical nature could not be assessed. Sathish *et al.* (2020) reported that polyethylene was the most commonly detected microplastic in their studies in Thoothukudi and also ascertained the role of domestic sewage and intensive fishing activities in polluting the surrounding seas. The light-coloured microfibres indicate discolouration of plastic polymers, which has undergone weathering and degradation (Pan *et al.*, 2019).

Limited variation was observed in the length and width of microfibres at different stations. The microfibres' length ranged from 0.018 to 0.083 mm at St.1; 0.01 to 0.073 mm at St.2; 0.017-0.094 mm at St.3, and 0.038-0.109 mm, with the highest mean of 0.091±0.016 mm at St.4 (Fig. 1b). The width of the microfibres varied between 0.0004 and 0.0125 mm, with the highest mean of 0.0037±0.0012 mm at St.2 (Fig. 1c). The length of the microfibres reported in this study was lower than those reported by Kumar *et al.* (2018) in a study on the microfibres observed in the stomach contents of commercial fish of Thoothukudi. The studies on global coastal marine environments observed the predominance of 0.1-1.5 mm size microplastics (Barrows *et al.,* 2018). The size of microfibres is considered a critical factor influencing their distribution and detrimental effects (Ziajahromi *et al.,* 2017). Organisms may ingest smaller microplastics, including microfibres, more quickly than larger ones, which causes a higher risk to marine life. At St.1, the abundance of microfibre was higher during the summer season (3.78±0.94nos. ml^{-1}).

For the remaining stations, a comparatively higher abundance was observed during the pre-monsoon period. A lower abundance was noticed during the post-monsoon period, yet the difference did not vary significantly. At St.1, the mean length of the microfibres was higher during the post-monsoon season than for the remaining stations (Table 2). This study showed a higher abundance of microfibres during the summer season in the shallow waters at St.1 and for the remaining stations during the pre-monsoon period. This seasonal variation might be due to the influence of wind, surface current and rainfall in bringing the microfibres to the marine environment, as indicated by Gundogdu *et al.* (2018). Pattiaratchi *et al.* (2021) ascertained the unique features of the Indian Ocean, such as reversing wind directions due to monsoon, fronts, upwelling and ocean currents that control plastic distribution in the region.

Plastic wastes, including takeaway food containers and carry bags, were the most dominant non-biodegradable litter constituents at all the stations. At Kayalpattinam seabed, 100% of the litter collected was plastic waste (Fig. 2c). At Tuticorin Bay and Mottaigopuram, 97.19 and 97.23% of the waste collected were also plastics. Fishing-related debris, including nylon/ HDP ropes and fishing net pieces, was the second most abundant item comprising 2.8 and 1.7% of total litter landed at Tuticorin Bay and Mottaigopuram, respectively. At Mottaigopuram, the thermocol

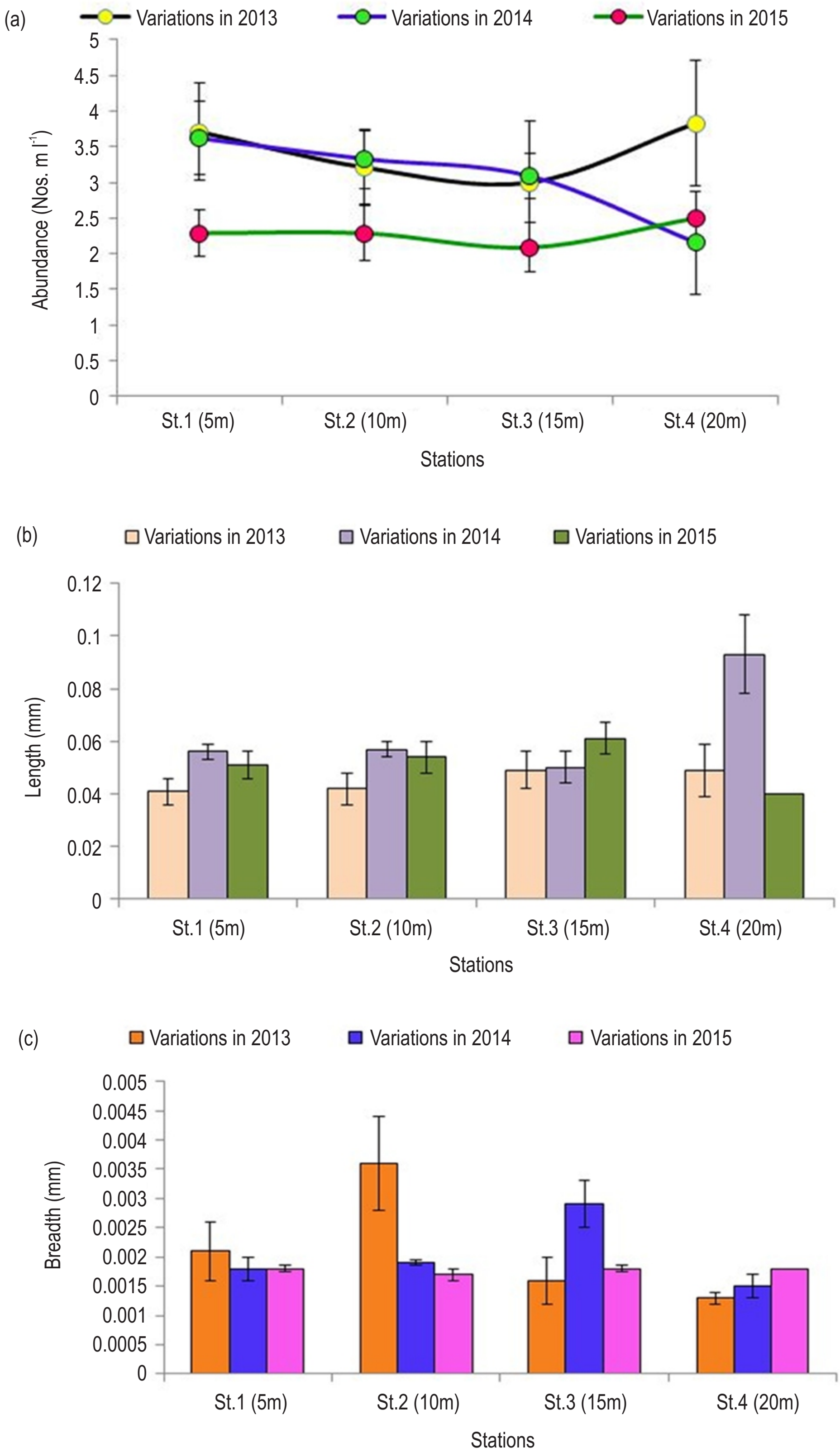


Fig.1: Mean (±SE) values of microfiber's (a) abundance, (b) length and (c) width in the subsurface waters of Thoothukudi at four stations (5m, 10m, 15m and 20m).

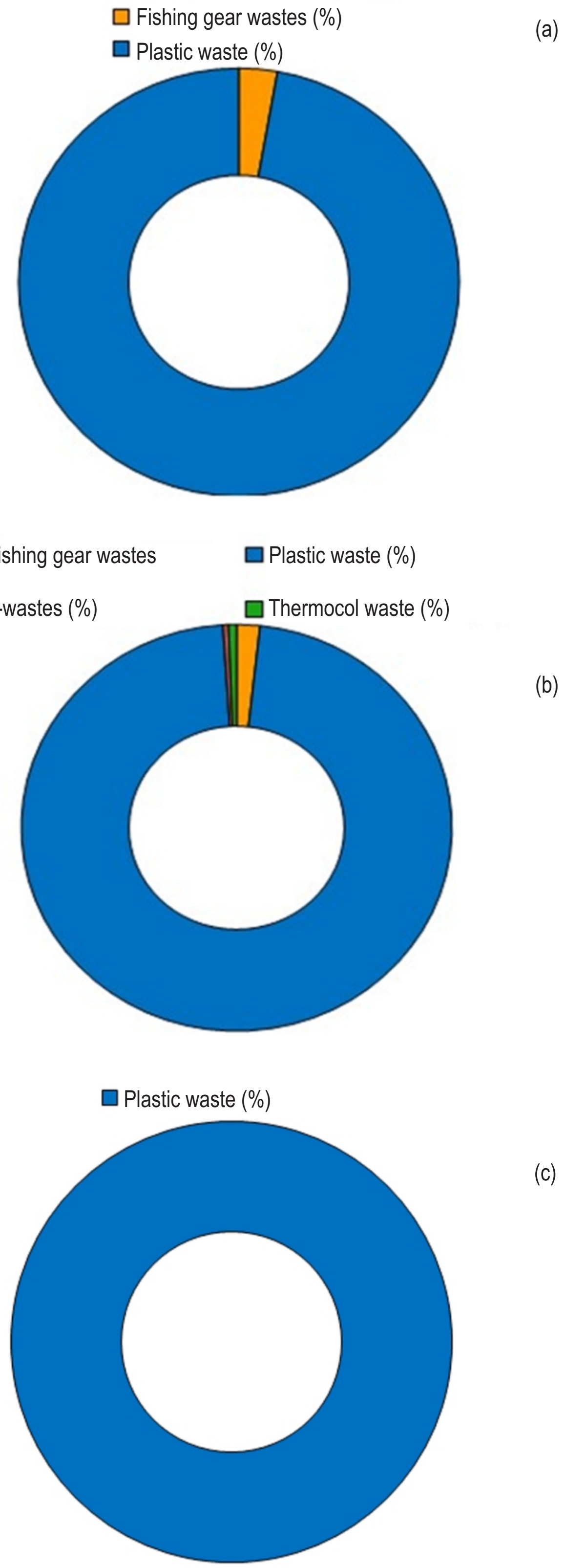


Fig. 2: Percentage composition of macrolitter constituents on the seabed of Thoothukudi at three stations (a) Tuticorin Bay, (b) Mottaigopuram and (c) Kayalpattinam.

Table 1: Classification of collected macrolitter constituents on the seabed's of Thoothukudi, South-east coast of India as per UNEP (2009) guidelines

Category	Materials
Fishing gear waste	Nylon/HDP ropes/fishing-net pieces/long lines
Plastic waste	Covers, carry bags, sachets, PET bottles, milk containers, creams, oil, ointments, toothpaste
Electronic waste	TV/computer hardware, mobile-phone handsets or parts, chargers, battery-operated toys, CDs
Thermocol waste	PUF insulation for ACs and fridges, Styrofoam

Table 2: Seasonal variation in the mean (±SE) abundance (nos ml^{-1}), length (mm) and width (mm) of the microfibers in the subsurface water of Thoothukudi, South-east coast of India

Stations	Parameters	Seasons			
		Postmonsoon	Summer	Premonsoon	Monsoon
	Abundance	2.5±0.547	3.78±0.937	3.66±0.533	2.5±0.300
1 (5m)	Length	0.055±0.006	0.046±0.005	0.053±0.005	0.050±0.006
	Width	0.001±0.0001	0.002±0.0005	0.001±0.0001	0.001±0.00003
	Abundance	2.666±0.51	2.928±0.621	3.22±0.553	2.72±0.449
2 (10m)	Length	0.053±0.005	0.047±0.009	0.058±0.004	0.064±0.008
	Width	0.001±0.0001	0.001±0.0002	0.002±0.0006	0.011±0.003
	Abundance	1.9±0.187	2.571±0.602	3.166±0.583	2.75±0.527
3 (15m)	Length	0.051±0.014	0.047±0.007	0.058±0.004	0.060±0.007
	Width	0.001±0.00005	0.003±0.001	0.002±0.001	0.001±0.00004
	Abundance	2.5	2.75±0.750	4.5±0.0001	1.75±0.750
4 (20m)	Length	0.040	0.050±0.012	0.09±0.018	0.074±0.034
	Width	0.0015	0.001±0.00002	0.001±0.0001	0.001±0.0001

Table 3: Mean (±SE) abundance (kg km^{-2}) of macrolitter constituents on the seabed at three stations of Thoothukudi, South-east coast of India

Constituents	Stations		
	Karapad Bay	Mottaigopuram	Kayalpattinam
Fish gear waste	0.632±0.380	0.705±0.674	0
House hold plastic	21.89±7.94	39.32±8.951	45.81±9.28
Electronic waste	0	0.168±0	0
Thermocol waste	0	0.243±0.181	0
Total litter	22.52±7.95	40.43±8.804	45.81±9.28

(0.418%) and electronic waste (0.603%) were the least abundant constituent (Fig. 2a,b). In the present study, plastics from anthropogenic sources like food containers and carry bags were the most dominant litter constituent at all stations, indicating their essential role in marine pollution. A positive correlation was also observed between the total litter abundance and plastics at different stations ($p<0.01$). Worldwide, the dominance of land-based plastic has been reported in seabed litter (Kaladharan *et al.,* 2020; Strafella *et al.,* 2019). The abundance and composition of litter observed in the sea beds of the study stations indicated the influence of local marine-based anthropogenic sources in polluting the marine environment. This finding conforms with the global proportion of land-based sources to sea-based sources in the marine litter (80/20%) as reported by Tubau *et al.* (2015). Anthropogenic factors such as the proximity of sources (Gerigny *et al.,* 2019) and natural elements play significant roles in transporting litter to areas distant from their sources (Alvito *et al.,* 2018).

The gill net collections at Kayalpattinam constituted only plastics and reported the highest total litter abundance of 45.81±9.3 kg km^{-2}, followed by 40.43±8.8 kg km^{-2} in the *Thallumadi* catches of the Mottaigopuram. The gillnet collection at Tuticorin Bay reported the lowest value of 22.52±7.96 kg km^{-2}. The annual difference in the total litter abundance varied significantly only at Kayalpattinam ($p<0.05$). At Mottaigopuram, the plastic abundance was 39.32±8.95 kg km^{-2}, while the fishing-related litter had a mean abundance of 0.706±0.7 kg km^{-2} as much as 3.378 kg km^{-2} of electronic waste was observed here in September 2015. The thermocol polystyrene was twice recorded to have a mean abundance of 0.24±0.18 kg km^{-2}. At Tuticorin Bay, the dominant plastic litter abundance was 21.9±7.94 kg km^{-2} followed by a fishing-related litter of 0.63±0.38 kg km^{-2} (Table 3).

The maximum mean abundance of total litter from Thoothukudi was 45.81±9.3 kg km^{-2}, which was slightly lower than the highest record of 55.24±16.52 kg km^{-2} reported from the Veraval coast (North-west coast of India) and substantially higher than the 2.11±0.53 kg km^{-2} from the Visakhapatnam coast (East coast of India). All three stations from Thoothukudi recorded mean litter abundances higher than that reported for the national average of 10.95±3.05 kg km^{-2} (Kaladharan *et al.,* 2020).

Variation between the three stations of Thoothukudi might be due to the difference in depth and mode of operation of specific fishing gear in the sampling stations. The present study reported a similar macrolitter abundance of 30.6 to 109.8 kg km^{-2} to that reported by Lee *et al.* (2006) on the seabed of the East China Sea and the South Sea of Korea. The abundance was lower than the range (0.02-3264.6 kg km^{-2}) reported in the Mediterranean Sea (Ramirez-Llodra *et al.,* 2013). However, it is higher than 0–11.6 kg km^{-2} for artificial polymers reported in the Gulf of Alicante seafloor (Garcia-Rivera *et al.,* 2017). The dominance of plastic litter on the sea bottom in the Thoothukudi region may be due to the preferential submersion facilitated by epiphytic growth in their large cavities, as indicated by Cozar *et al.* (2014). Similarly , Kink *et al.* (2022) ascertained that size has a substantial impact on the distribution of plastic object at the sea. This study reveals variations in the abundance and distribution of microfibres and macrolitter in the subsurface and seabeds of selected waters of Thoothukudi, Gulf of Mannar, on the South-east coast of India. This research also emphasises the role of land or marine-based anthropogenic activity in causing the litter problem in the Thoothukudi coastal marine environment and would also serve as a baseline for future research on marine litter in the Gulf of Mannar.

Acknowledgments

We wish to express our gratitude to the Director, ICAR-CMFRI, Kochi and the Scientists–in-Charge of Tuticorin Research Centre of ICAR-CMFRI for the sup¬port and encouragements given during the execution of this work.

Add-on Information

Authors' contribution:P.S. Asha: Conceptialization, writing the draft and editing; **K. Diwakar, H. Sivanesh:** Investigation and formal analysis and **P. Kaladharan:** Review and editing.

Funding: The funding support for the research work was by the Indian Council of Agricultural Research, Department of Agricultural Research and Education, Ministry of Agriculture and Farmers welfare, Government of India.

Research content: The research content of the manuscript is original and has not been published elsewhere.

Ethical approval: Not applicable.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability: Not applicable.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology*.

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