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Microplastic contamination in endemic species: a case study on ginger prawn, *Metapenaeus kutchensis*†

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Plastic pollution has increased globally in recent decades and is considered an imminent risk to human health and marine life. This study was carried out to assess microplastic (MP) contamination in the gastrointestinal tract (GIT) of the commercial marine prawn *Metapenaeus kutchensis* sampled from three foremost fishing centers in Gujarat. The samples were dissected in the laboratory, and the GIT was digested with 10% KOH. The MPs were floated using $ZnCl_2$ in accordance with the density gradient technique. Subsequently, filtration was carried out, followed by the observation of the obtained residue using a stereo microscope. Subsequently, MPs underwent chemical and physical characterization (total count, shape, size, and color). From 135 individuals, a total of 173 MPs were identified, with 100% contamination in all the studied individuals. It was demonstrated that the average MP abundance in the prawn's GIT was 3.94 ± 2.40 MPs per g (ranging from 1.68 ± 0.87 to 5.40 ± 1.90 MPs per g). Higher MP contamination was recorded in the post-monsoon period, followed by monsoon and pre-monsoon periods. MP contamination varied significantly between study sites. The abundance of MP contamination in sediment and water was recorded as 11.25 ± 12.23 MPs per kg and 1.38 ± 0.78 MPs per L, respectively. The findings of regression analysis between the body length and the abundance of MPs revealed no significant correlation. PCA showed varied environmental factors influencing prawn MP contamination. Fibers with blue and black colours were reported as the most commonly accounted MPs. Size-wise, the 1–2 mm size class was recorded to be pre-dominated in all study sites. The extracted MPs were found to contain polyethylene, polyethylene terephthalate, and polypropylene in their chemical compositions. The study of MP contamination in endemic species revealed the impact of pollution on sensitive, unique organisms, aiding biodiversity conservation and raising awareness of local ecosystem health. The current study can offer important background information for future investigations as well as provide data for management and conservation of marine eco-systems in Gujarat for safeguarding their health.

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Environmental significance

This study provides critical insights into microplastic (MP) contamination in endemic marine species, specifically examining the ginger prawn *Metapenaeus kutchensis* along Gujarat's coastline. This research reveals 100% MP contamination across the sampled prawns, with an average of 3.94 MPs per g in their gastrointestinal tracts, demonstrating widespread plastic pollution in marine ecosystems. This study uniquely contributes to understanding how MPs affect endemic species, which may be particularly vulnerable to synthetic pollutants. The findings of this study have immediate implications for marine ecosystem health, food web dynamics, and human health through seafood consumption. By examining MP contamination patterns across different sites and seasons, this research provides crucial data for developing targeted conservation strategies and pollution management policies in coastal regions.

1. Introduction

Plastic is widely used and is an important part of daily human life owing to its characteristics such as easy applicability, durability, transparency, light weight, and extremely low price.[1] The global plastic production has increased drastically by approximately 30 Mt over the last five years: 370.5 Mt in 2018 and 400.3 Mt in 2022.[2] Out of the 400.3 Mt plastic produced in

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the year 2022, only 35.5 Mt was recycled globally.[2] According to a previous study,[3] the use and mismanagement of plastic can result in a threefold increase in plastic waste by the year 2060. These discarded waste plastics remain in nature over the years and cause a misbalance in the life cycle of eco-systems.[4,5] The trash from fishing industries, waste water runoff, tourism, beach discards, rivers, and numerous other sources forms a major part of the trash that enters the marine environment.[6,7] According to a previous study,[8] rivers carry 2.40 million metric tons of plastic waste into the marine environment yearly. This plastic gets accumulated in marine environments and undergo physical, mechanical, chemical, and biological degradation processes, resulting in its breakdown into minor plastic particles.[9,10]

Plastic particles with 1 μm to 5 mm size are called microplastics (MPs).[10,11] MPs are primarily divided into primary and secondary MPs according to their way of formation. In sectors including cosmetics, textiles, and medicine, primary MPs are created on purpose,[12] while secondary MPs form as a result of environmental fragmentation. MPs possess various types of shapes including microbeads, fibers, films, fragments, and foams. MP pollution has emerged as a significant threat to the oceanic environment and has been reported in sediments, water, and different faunal groups.[12–16] The MP contamination has been documented in all the phyla of animal kingdom such as Porifera,[17] Coelenterata,[18] Ctenophora,[19] Platyhelminthes,[20] Aschelminthes,[21] Annelida,[22] Arthropoda,[23] Mollusca,[24] Echinodermata,[25] and Chordata (fishes,[12,26] amphibians,[27] reptiles,[28] as well as mammals[29] including humans).[30] Microplastics have also been found to carry hazardous substances on their surface, including pigments, dyes, persistent organic pollutants, heavy metals, and pathogens. Furthermore, as reported by,[31] organisms that ingest MPs have experienced effects such as stunted growth, pseudo-satiation, oxidative stress, maiming, choking, and cellular damage.[32] These species are also vulnerable to additional pollutants in the marine environment that are transported along with MPs.[33–35]

Gujarat state covers around 2340 km-long coastline, which is around 1/3 of the Indian coastline. The biodiversity and ecological aspects of crustaceans, such as prawns[36] and crabs,[1,36–39] have been extensively studied along the marine environment of Gujarat. A total of 30 prawn species have been reported from the Gujarat coast,[36] among which the species *Metapenaeus kutchensis* is endemic to the northwest coast of India. The ginger prawn, *Metapenaeus kutchensis*, is a commercially important penaeid shrimp endemic to the northwest coast of India. The life cycle of this species begins with planktonic larvae hatching from eggs in offshore waters. The larvae undergo several developmental stages, including nauplius, zoea, and *Mysis*, before settling in coastal environments as juveniles. Adults migrate back to marine habitats for reproduction, completing their life cycle.[40] The adult shrimps are pink or red in colour, achieve 103.1 mm and 135.5 mm of average body length in male and female, respectively.

Gujarat state produces 7.80 lakh tonnes of fishery resources annually,[41] accounting for 45% (3.10 lakh tonnes) of India's total prawn production in 2022.[42] Prawns are known for their delicate muscles and high nutritional value. The seasonal fishery of ginger prawn serves as a vital livelihood source for socioeconomically disadvantaged part-time fishermen in the Gulf of Kutch region, India. A study carried out during 1991 to 2002 (ref. 40) indicated the annual catch of 605 t in the north-west coast of India. A sampling study conducted at three selected sites, namely, Surajbari, Madherkhi, and Tikar of Gujarat revealed an annual turnover of approximately ₹200 million during the brief two-month fishing season of August–September 2010.

Along with rich biodiversity and its aesthetic values, Gujarat is known for valuable fishing resources, development of tourist attractive places, beachside recreational activities, and pilgrimage places. They also receive industrial and chemical effluents into the oceanic environment *via* rivers.[43] The findings of the recent literature revealed the abundance of MPs in sandy-muddy beaches,[44,45] crabs,[7,46] fish,[26] and oysters[47] of Gujarat. A detailed understanding of microplastic uptake in endemic prawn species from various study sites could provide valuable insights into microplastic variation and reveal the unique vulnerabilities of these species, which may not be adapted to synthetic pollutants.[48] Hence, the current study uniquely focused on an endemic prawn *Metapenaeus kutchensis* across three distinct sites in Gujarat, providing a detailed spatial analysis of MP contamination. The findings will reveal site-specific contamination patterns, informing localized management strategies. This approach fills a gap in understanding regional variations in MP pollution and contributes valuable data to global MP research.

The presence of MPs in prawns has significant ecological and health implications.[49] In marine ecosystems, prawns are an essential component of the food web, and the ingestion of MPs can lead to bioaccumulation, potentially affecting higher trophic levels, including fish and other marine organisms that prey on them.[50] Furthermore, given the potential for humans to consume prawns, the contamination of these organisms with MPs raises concerns about the transfer of pollutants to human consumers, which could have adverse health effects.[51,52] This study highlights the importance of assessing MP contamination in commercially significant species like prawns, particularly in regions like Gujarat, where marine resources are vital to both local ecosystems and human livelihoods. Understanding the impact of MPs on these species is crucial for informing conservation strategies and public health policies.

2. Materials and methods

2.1 Study area and sampling

Among the coastal states of India, Gujarat has the lengthiest coastline, covering more than ∼2340 km, or 21% of the total coastline in the nation. Numerous marine settings such as rocky mangroves, sandy beaches, estuaries, coral reefs, mudflats, and deep-sea habitats are found along Gujarat's coastline.[36] Three distinct fishing harbors in the state of Gujarat were the subject of the current investigation. Sartanpur (21° 18′12.5″N 72°05′43.5″E) (n = 35) is situated in the Bhavnagar district. The other study sites were Mithapur (22°25′19.1″N, 68°

59′37.6″E) ($n = 50$) and Okha (22°28′35.7″N, 69°04′11.6″E) ($n = 50$). Sartanpur and Mithapur are well-known fishing harbors in Gujarat state, where extensive fishing activities are conducted, potentially contributing to plastic pollution in the study area. The study site Okha is a fishing harbor situated in the Devbhumi Dwarka district of Gujarat state and one of the most popular pilgrimages in India, drawing a large number of visitors and pilgrims. Specimens of prawn species were sampled from the fishing centers from January to June 2023 (Fig. 1 and 2). At each sampling station, five samples were collected using a transect method, with each transect placed 100 meters apart from each other. A stainless-steel sampler with an inner diameter of 19 cm and a depth of 5 cm was used while ensuring that the sediment packed it to the top. To ensure consistency, a stainless-steel sheath was inserted under the sampler at each time of collection. A total of 15 L surface water sample was collected using a stainless-steel bucket from 20 cm depth. The samples were collected in triplicate from each site, with each sample taken at 100-meter intervals from one point to the next. The collected surface water was sieved through a 25 μm mesh, and the filtrate was transferred to a glass container. Additionally, to check the correlation between MP contamination in prawn and the environmental matrix, temperature, pH and salinity were measured using a digital instrument at each sampling location. For the seasonal analysis, a total of 50 prawns were collected from the study site Mithapur in each season. The seasons were selected as April to May (pre-monsoon), August to November (monsoon), December to March (post-monsoon), and June and July (fishing ban period).[53] Based on the occurrence of prawn species throughout the year, Mithapur was selected as the only single site for seasonal work. Later, the collected samples of zoanthids,

Fig. 2 Prawn species *M. kutchensis* used in this study (scale bar = 1 cm).

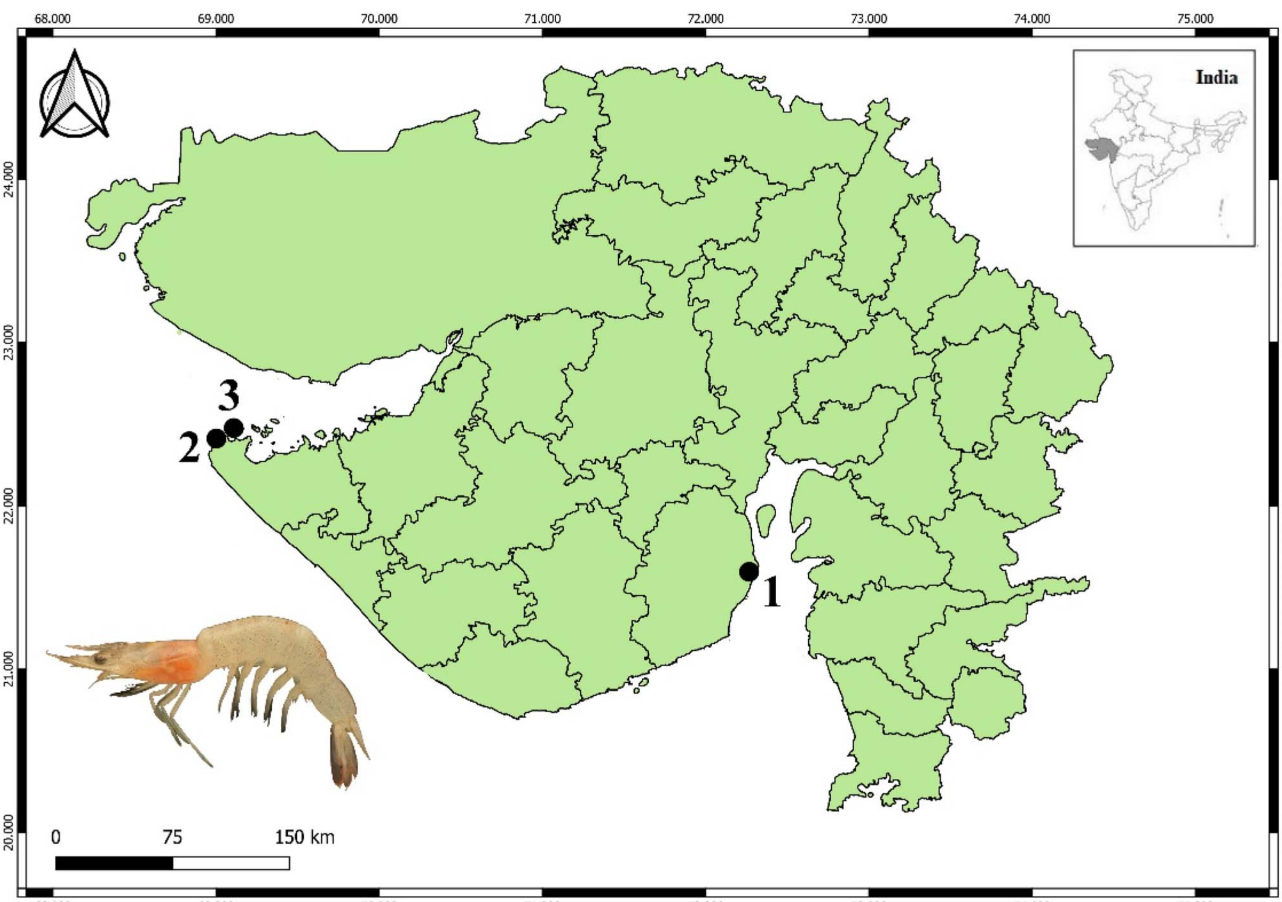

Fig. 1 Geographical locations of the study sites: 1 – Sartanpur, 2 – Mithapur, and 3 – Okha.

sediment and surface water were placed in separate glass containers and brought to the laboratory. The frozen environment was provided using ice packs to avoid the tissue degradation of prawns.

2.2 Processing and analysis of sample

Measurements of morphometric characteristics such as body weight and length were recorded in the laboratory. Specimens were first cleaned with double-distilled water to avoid introducing bodily residues onto their surface. Subsequently, the gastrointestinal tract (GIT) was separated using a stainless-steel forceps and a scalpel in a separate beaker after each specimen was dissected. A layer of aluminum foil was placed on the concave surface of the beakers. In the laboratory, the sediment was dried in an oven and weighed before further analysis. For thorough organic tissue digestion of prawn and sediment, each beaker was filled with a 10% KOH solution and kept in a hot-air oven that was heated to 60 °C.[54] The water sample was filtered using a sieve and the retained organic materials containing MPs were placed in a beaker with a 10% KOH solution. A hypersaline $ZnCl_2$ solution was subsequently used to aid in the MP floating, as they ascend with the supernatant due to their low density. After the supernatant was filtered through filter paper (grade no. 41; pore size: 20 μm), it was left at room temperature to dry inside a laminar flow to avoid external contamination. MPs were characterized according to their sizes, shapes, and colours, from which 10% representative MPs were selected for chemical identification.[55] Photographs of different shapes of MPs were taken using an attached microscopic camera (MATLAB PST-901), and the size of the MPs was measured using the inbuilt camera software Capture pro. Polymer identification was conducted using an ATR-FTIR spectroscope (Bruker-Alpha). The obtained spectra were compared against a comprehensive library of known primary and secondary MP spectra (FLOPP and FLOPP-e; n = 762 spectra), as described previously.[56] For the analysis, a spectral range of 500 to 4000 cm^{-1} was utilized with 64 scans to ensure accurate measurement.

2.3 Quality control and eliminating contamination

To prevent possible contamination, strict safety measurements were implemented during the field collection and analysis procedures. Before dissection, the samples were pre-washed and wrapped in aluminum foil to assure their purity. Before use, stainless-steel utensils were sterilized and cleaned with MilliQ water. As reported in previous studies,[46,57] to minimize external contamination, the sample processing and MP extraction were carried out in an area with less human activities. Three blank samples were analyzed simultaneously as a preventative measure to address possible MP contamination caused by sample processing, and no MPs were found in blanks.

2.4 Statistical analysis

MPs per g and MPs per individual were used as the units of measurement for the calculation of abundance and standard deviation. The data normality was checked using the Shapiro–Wilk test. As the data did not show normal distribution, (W = 0.86, (Fig. S1), see "ESI†", $p < 0.05$), a non-parametric Kruskal–Wallis test was used to assess the variation in MP contamination between the study sites of prawns, sediment and water as well as between seasons. In addition, Dunn's post hoc test was performed in order to understand the variations in MPs between groups. The relationship between the length of prawn bodies and MP abundance was further analyzed by linear regression analysis to determine if the prawn size has an influence on MP ingestion. The coefficient of determination, R^2, and the significance level, p-value, from the regression model determined the strength and statistical significance of the relationship. All data analyses were performed using Origin Pro 2024b and Microsoft Excel.

3. Results and discussion

3.1 Abundance of microplastics

The present study evaluated the presence of MPs in the gut tissue of commercially important prawn *M. kutchensis* collected from the principal fishing harbours of Gujarat. Out of 135 examined individuals, all show the presence of MPs in the GIT. Similarly, MP contamination was discovered to be 100% in three prawn species (*M. monoceros*, *Penaeus indicus*, and *Parapeneopsis stylifera*) that were collected from the North-East Arabian Sea.[58] Similarly, 100% MP contamination was reported in the 10 epipelagic species of prawns collected from the North-West Arabian Sea,[46] whereas some other studies[59,60] reported less contamination in the *Aristeus antennatus* (67%) and *Crangon crangon* (63%) specimens that were collected from the Mediterranean Sea and the Southern North Sea Channel area, respectively. The higher rate of MP contamination in endemic species may induce physiological stress to the organism, including blockage of the gastrointestinal tract and a reduction in feeding efficiency.[61] Over a longer time, this can cause failure in reproductive success and diminish population stability and survival rates.[62] Additionally, endemic species play a unique role in the health of an eco-system. Hence, the higher rate of MP contamination in this species affects the nutrient cycling and food web dynamics. A total of 173 MPs were recorded from the three sampling sites, namely, Okha ($n = 83$), Mithapur ($n = 50$), and Sartanpur ($n = 40$). The average abundance of MPs was recorded as 3.94 ± 2.40 MPs per g (ranging from 1.68 ± 0.87 MPs per g to 5.40 ± 1.90 MPs per g) in *M. kutchensis* collected from three study sites. In the current investigation, it was found that MP contamination in *M. kutchensis* was recorded to be higher than that of *M. monoceros* (3.87 ± 1.05 MPs per g) collected from Northern Bay of Bengal,[63] *M. affinis* (1.02 MPs per g) collected from North-West Persian Gulf,[64] *M. affinis* (4.1 ± 1.22 MPs per g) collected from Iran,[65] *M. ensis* (2.26 ± 1.26 MPs per g) collected from Hoai Nhon district, Binh Dinh province,[66] *M. ensis* (2.1 ± 0.3 MPs per g) from Cau Hai Lagoon, Central Vietnam,[67] *M. kutchensis* (1.68 ± 0.86 MPs per g) and *M. dobsoni* (1.31 ± 1.26 MPs per g) collected from North-West Arabian Sea,[46] *M. brevicornis* (3.78 ± 1.12 MPs per individual) collected from Songkhla Lake, Thailand[68] and *M. moyebi* (4.12 ± 0.69 MPs per individual) collected from Khlong U-Taphao, Southern Thailand. While less contamination was reported than *M.*

Table 1 Comparison of the abundance of MPs in different *Metapenaeus* species across the world

Country	Location	Species	Number of individuals	Mean body length (cm)	Mean body weight (g)	Total MPs	MPs per g	MPs per individual	Reference
Bangladesh	Northern Bay of Bengal	*M. monoceros*	100	—	4.72 ± 0.76	39	3.87 ± 1.05	7.80 ± 2	69
India	Kerala	*M. dobsoni*	50	10.6 ± 0.8	10.42 ± 1.6	0	0	0	70
Maharashtra	North eastern Arabian Sea	*M. monoceros*	60	11.1–16.4	9.65–30.29	434	78.48 ± 48.37	7.23 ± 2.63	58
Khuzestan province, Iran	Musa Bay	*M. affinis*	—	—	—	—	1.02	—	64
Thailand	Songkhla	*M. brevicornis*	18	7.16 ± 1.15	5.01 ± 0.44	68	—	3.78 ± 1.12	68
Binh Dinh province	Hoai Nhon district	*M. ensis*	24	6.93 ± 0.36	2.35 ± 0.38	—	2.26 ± 1.26	—	71
Iran	Persian Gulf	*M. affinis*	60	11.25 ± 1.2	6.16 ± 1.4	84	4.1 ± 1.22	8.1 ± 3.56	65
Songkhla province, Southern Thailand	Khlong U-Taphao	*M. moyebi*	17	7.94 ± 0.19	4.48 ± 0.29	122	—	4.48 ± 0.29	72
Cau Hai Lagoon	Central Vietnam	*M. ensis*	30	8.2 ± 0.3	3.6 ± 0.6	31	2.1 ± 0.3	0.9 ± 0.2	67
India	Gujarat	*M. Dobsoni*	100	6.14 ± 0.62	8 ± 1.41	106	1.31 ± 1.26	1.06 ± 1	46
India	Gujarat	*M. kutchensis*	50	6.01 ± 1.03	1.32 ± 0.27	50	1.68 ± 0.86	1 ± 0.37	46
India	Gujarat	*M. kutchensis*	135	6.08 ± 0.95	1.32 ± 0.27	173	3.94 ± 2.40	1.28 ± 0.63	Present study

monoceros (78.48 ± 48.37 MPs per g) collected from the north-eastern part of the Arabian Sea[58] (Table 1). The highest abundance of MPs was found at Okha (5.40 ± 1.90 MPs per g), followed by Sartanpur (4.74 ± 4.44 MPs per g) and Mithapur (1.68 ± 0.87 MPs per g) (Fig. 3). The abundance of MP contamination varied significantly between study sites ($H(\chi^2) = 12.96$, df = 26, $p < 0.01$). Moreover, the results of Dunn's post hoc test revealed that the abundance of MP contamination varied significantly between study sites Sartanpur and Mithapur ($p < 0.05$) and between study sites Mithapur and Okha ($p < 0.05$). The global distribution of MPs in different *Metapenaeus* is depicted in Fig. 4.

A total of 39, 111, and 130 MP particles were recorded in the sediment with abundances of 4.48 ± 3.41 MPs per kg, 13.54 ± 9.23 MPs per kg and 15.73 ± 18.38 MPs per kg in study sites Okha, Mithapur, and Sartanpur, respectively (Fig. 5A). The abundance of MP contamination did not vary significantly between study sites ($H(\chi^2) = 3.38$, df = 14, $p = 0.18$). A total of 39, 29, and 75 MP particles were recorded in the sediment with abundances of 1.86 ± 0.28 MPs per L, 0.64 ± 0.65 MPs per L and 1.66 ± 0.81 MPs per L in study sites Okha, Mithapur, and Sartanpur, respectively (Fig. 5B). The abundance of MP contamination did not vary significantly between study sites ($H(\chi^2) = 4.62$, df = 8, $p = 0.09$). PCA shows that MPs in *M. kutchensis* have a strong negative correlation with MPs in sediment ($r = -0.99969$) and significant negative correlations with temperature ($r = -0.83616$), pH ($r = -0.93462$), and salinity ($r = 0.02872$). However, there is a moderate negative correlation with MPs in water ($r = -0.51371$) (Fig. 6A and B). The seasonal analysis reveals higher MP contamination in *M. kutchensis* collected from post-monsoon (1.68 ± 0.87 MPs per g), followed by monsoon (1.34 ± 0.67 MPs per g) and pre-monsoon (0.96 ± 0.61 MPs per g) (Fig. 7). The abundance of MP contamination varied significantly between seasons ($H(\chi^2) = 6.86$, df = 29, $p < 0.05$).

MP contamination is more common in areas where plastic pollution from tourism, industry, urbanization, and fishing is a problem.[47] Additionally, a positive correlation between MP pollution and extensive human activity was found.[73] All the study sites are the major fishing harbors of Gujarat state, representing the rich marine history of the area and acting as a crucial hub for the fishing industry.[46] Moreover, Okha is a highly significant pilgrimage location with deep roots in Hindu mythology that welcomes over a million visitors a year in search of religious serenity and reverence.[46] The study sites Okha and Sartanpur show a higher abundance of MP contamination, perhaps as a result of higher human pressure from surges and intense fishing activities.[1,74] There was no significant correlation observed between the body size and the abundance of MPs ($R^2 = 0.0002$; df = 53; $p = 0.94$) (Fig. 8). Conversely, in oyster collected from the Gujarat coast, a negative connection was found between shell length and MP abundance.[47] Due to their widespread presence in the marine environment, MPs are equally exposed to creatures of varying sizes.

MPs in *M. kutchensis* show a significant negative correlation with sediment MPs ($r = -0.99969$), suggesting that the species could not ingest meaningful amounts of MPs bound to the

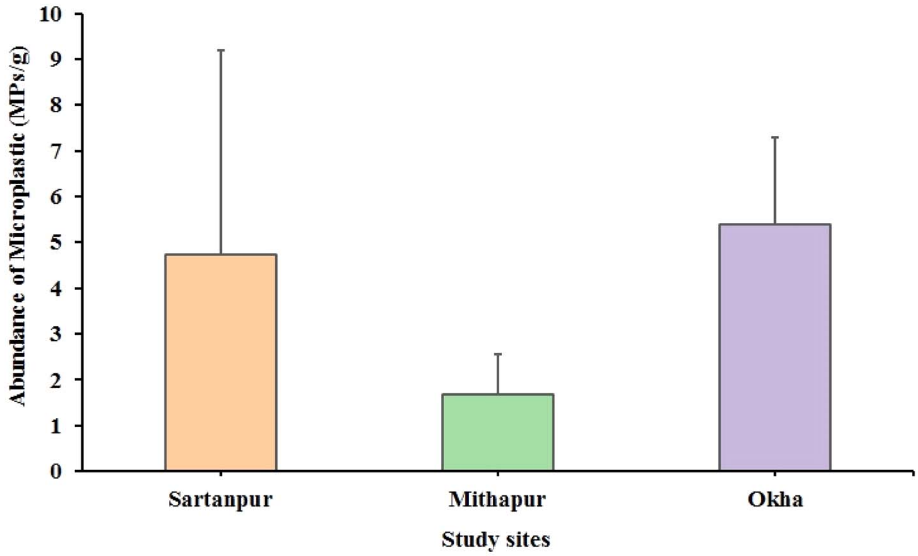

Fig. 3 Average abundance of microplastic contamination in the GIT of *M. kutchensis* at study sites.

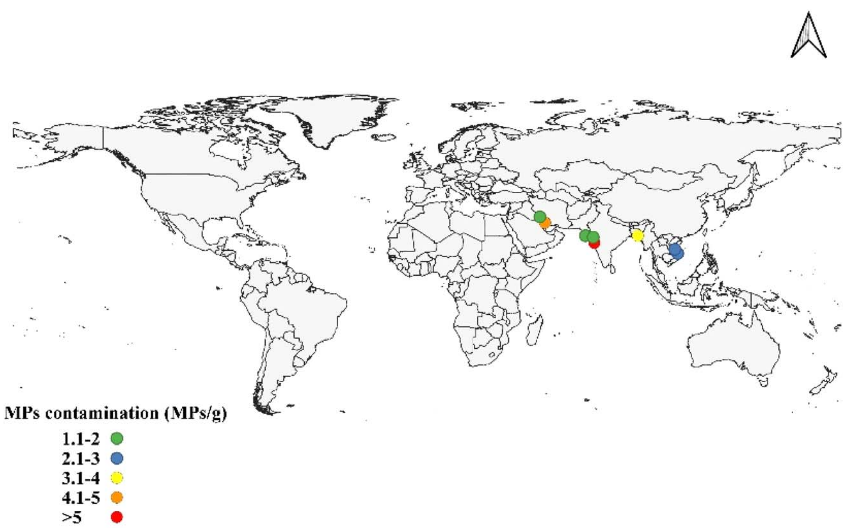

Fig. 4 Global comparative map of microplastic contamination in different species of the genus *Metapenaeus*.

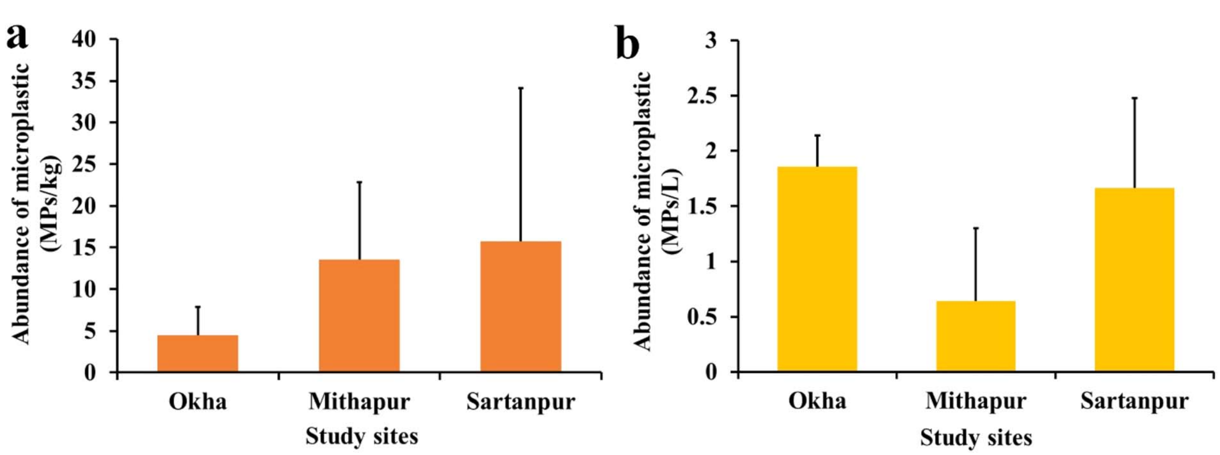

Fig. 5 Average abundance of microplastic contamination: (a) sediment and (b) water.

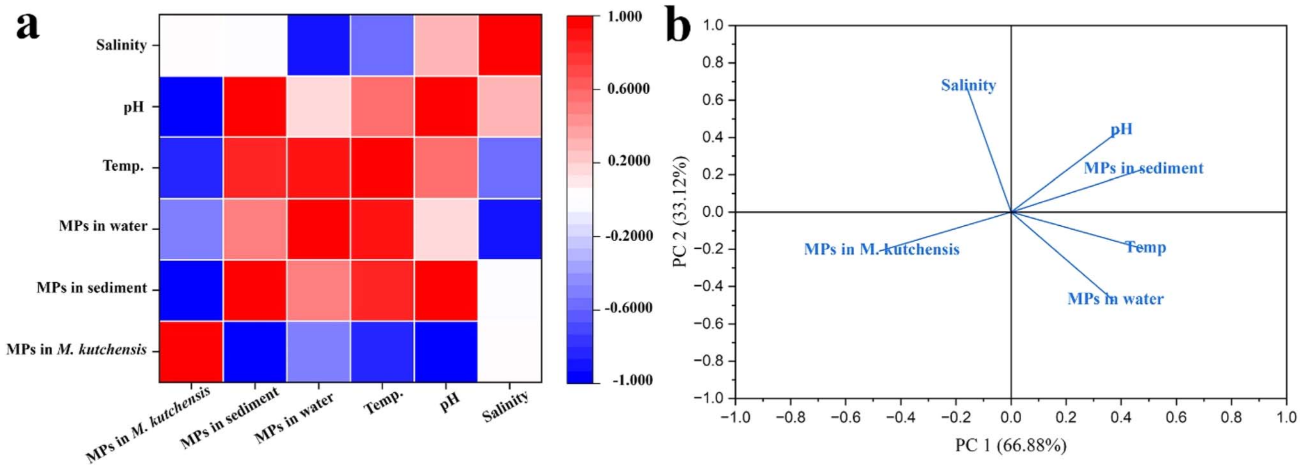

Fig. 6 (a) Pearson's correlation and (b) principal component analysis between microplastic contamination in prawns, sediment, water and environmental matrices (temperature, pH, and salinity).

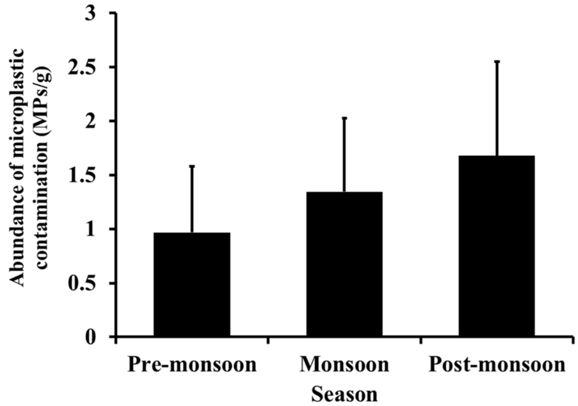

Fig. 7 Average abundance of microplastic contamination in *M. kutchensis* across seasons.

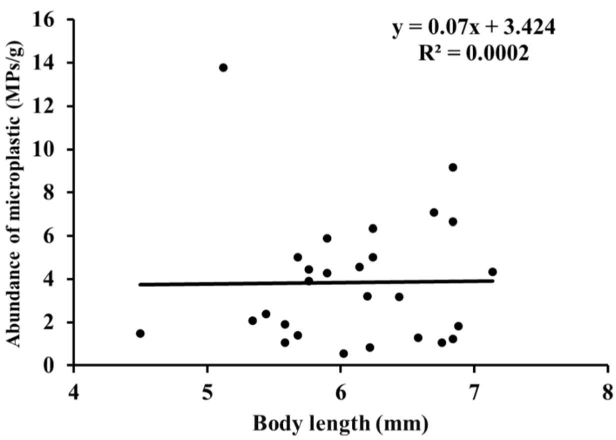

Fig. 8 Regression analysis between the body length of *M. kutchensis* and microplastic contamination ($p = 0.94$).

sediment. The negative correlations seen with temperature ($r = -0.83616$) and pH ($r = -0.93462$) suggest that environmental stressors may possibly limit the bioavailability of the MP. The salinity has less influence on MP uptake, as indicated by the weak positive correlation with the parameter $r = 0.02872$. This also indicates a moderate negative relationship with MPs in water ($r = -0.51371$) and suggests that factors other than the concentration of MP in water may govern uptake in *M. kutchensis*. These relationships show complex interactions between environmental factors and MP contamination. A higher contamination of MPs is recorded in *M. kutchensis* collected from post-monsoon, followed by monsoon, and pre-monsoon. Moreover, higher MP pollution was found in the fish samples collected from the marine environment of Gujarat.[75] The observations of many marine ecosystems depict the seasonal fluctuations of MPs. It has been determined that the more rainfall in some marine ecosystems showed a higher MP concentration with a peak flow of particles occurring during the last part of rainy season due to runoff.[76] In a similar manner, fish MP ingestion varied seasonally in the Alappuzha mudbanks, India, and showed higher incidence rates during the period of the mudbank, implying that MP intake was impacted by the high environmental concentration during the same period.[77,78]

3.2 Physical and chemical characterization of MPs

The extracted MP's shape, colour, and size were all physically characterized. The highest amount of fibres was found at all study sites, followed by fragments, films, and foams (Fig. 9A and B). In case of seasonal analysis, fibres were found dominantly in all the seasons. Similarly, fibres were recorded predominantly in the other studies on prawns.[58,64–66,79] Photo-degradation is the main factor that leads to the creation of different MP shapes.[43,80] The high abundance of fibres in the ocean could be caused by intensive fishing and wastewater discharge.[12]

In terms of MP's colour classification, blue and black MPs predominated throughout all study sites, subsequently red, white, and green MPs (Fig. 10A). In case of seasonal analysis, black- and blue-coloured MPs were found dominantly in all the seasons (Fig. 10B). Similarly,[64] a previous study has also

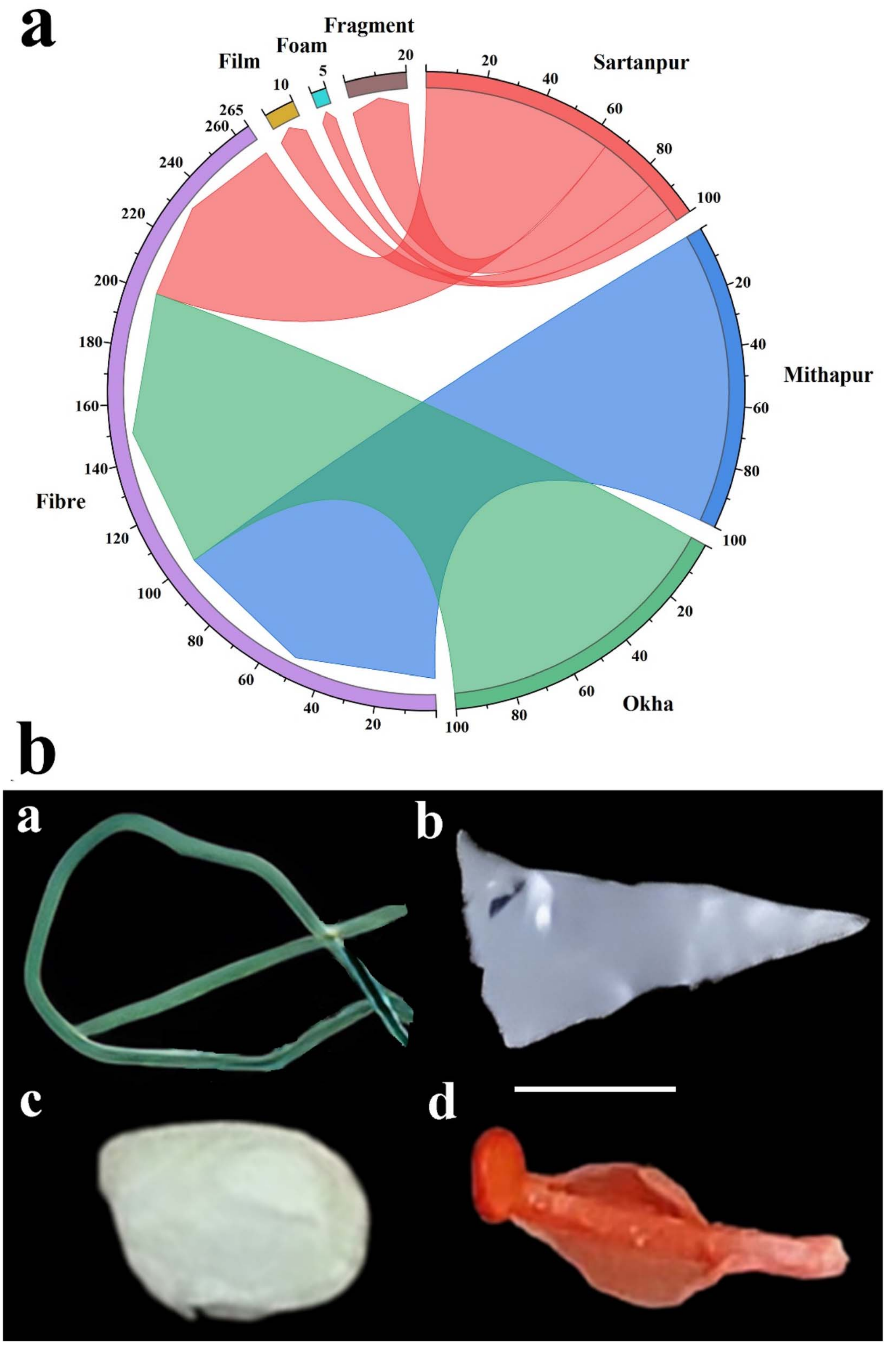

Fig. 9 (a) Percentage composition of the shape of microplastics extracted from the GIT of *M. kutchensis*. (b) Shape of different microplastics: (a) fibres, (b) films, (c) foams, and (d) fragments (scale bar = 1 mm).

observed that the black- and blue-coloured MPs were most abundant in *M. affinis* collected from the Persian Gulf, Iran. Similar findings have been reported in a previous study,[64] in which it was observed that black colour MPs prevailed in prawn. In contrast, white-coloured MPs were predominantly *M. affinis* collected from Musa Bay[64] and *M. ensis* collected from Binh

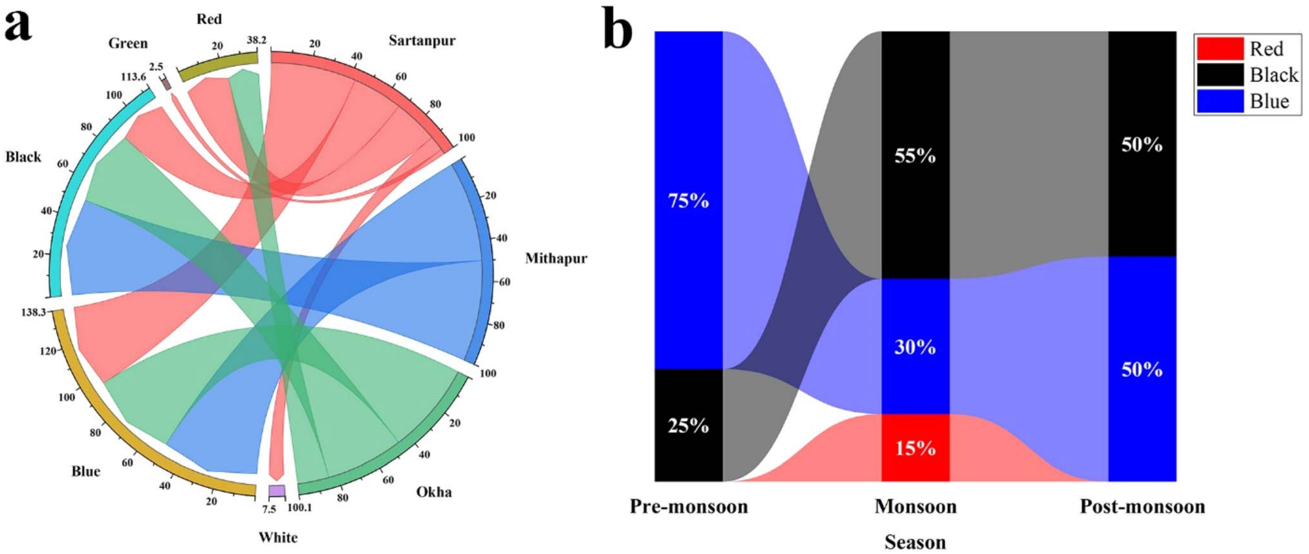

Fig. 10 Percentage composition of the colour of microplastics: (a) extracted from the GIT of *M. kutchensis* from study sites and (b) across seasons.

Dinh province.[66] The uses and inappropriate disposal of blue- and black-coloured fishing nets can be the possible reason for blue- and black-coloured MPs in the marine environment of Gujarat.

The size-wise classification of MPs revealed the predominance of 1–2 mm-sized MPs in all the study sites, followed by <500 μm, <500 μm^{-1} mm, 2–3 mm, 3–4 mm, and 4–5 mm size classes (Fig. 11A). In the case of seasonal analysis, the occurrence of various sized MPs was recorded in all the seasons (Fig. 11B), whereas 500 μm^{-1} mm and 250–500 μm size class MPs were recorded extensively in *M. monoceros* collected from the Northern Bay of Bengal, Bangladesh.[58] Moreover, MPs larger than 500 μm were recorded dominantly in *M. affinis* collected from the North-West Persian Gulf,[64] and 0.5–0.1 mm size range MPs were abundantly recorded[65] from the Persian Gulf, Iran. While three prawn species collected from the North-Eastern Arabian Sea showed a predominance of MPs of 0.1–0.2 mm.[58] The decomposition of larger plastic items may be the cause of the emergence of several size classes of MPs. Additionally, it was shown that the dietary habits of marine organisms can affect the abundance of MPs of different sizes.

ATR-FTIR spectroscopy was used to determine the polymer composition of the isolated MPs. The recovered MP polymer composition was found to be polyethylene (PE) (40%), polyethylene terephthalate (PET) (40%), and polypropylene (PP) (20%) upon comparing the observed spectra with known plastic libraries (Fig. 12). Similarly, the detected polymers of MPs retrieved from sediments have been identified to be PE, PET,

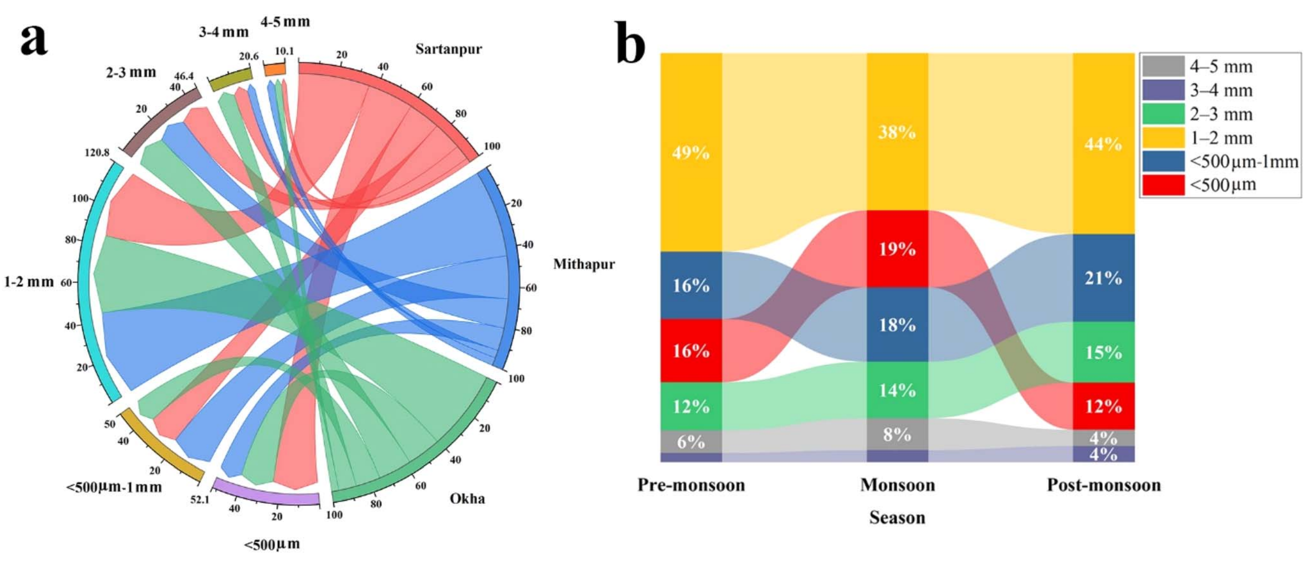

Fig. 11 Percentage composition of the size of microplastics: (a) extracted from the GIT of *M. kutchensis* from study sites and (b) across seasons.

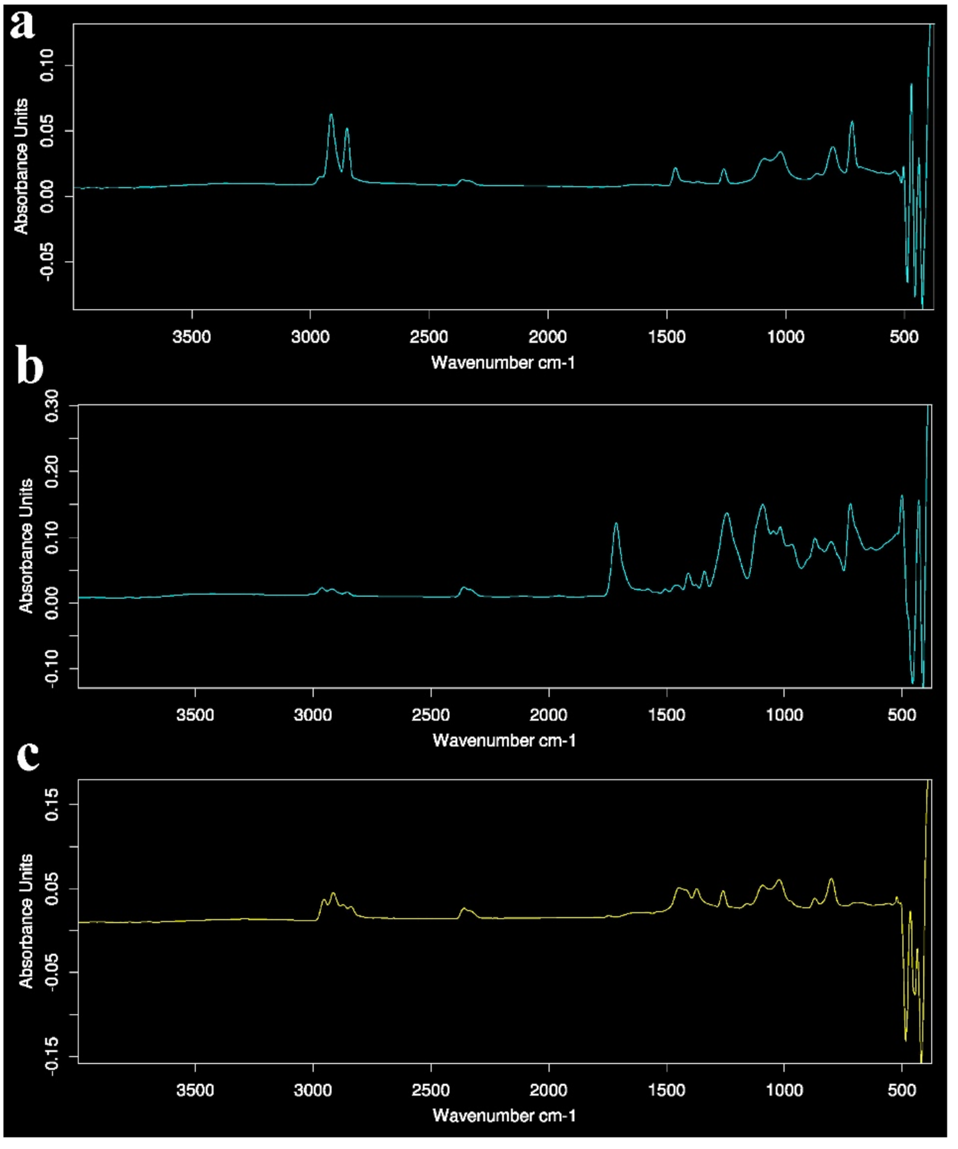

Fig. 12 ATR-FTIR spectra of extracted microplastics: (a) PE, (b) PET, and (c) PP.

and PP,[44,46] in crabs[7], oysters,[47] and fish[26] of the marine environment of Gujarat. The possible sources of PE can be grocery bags, squeeze bottles, toys, cable insulation, housewares, and packaging films.[26] PET is used in bottles, jars, clothing, carpets, sleeping bags, industrial strapping, automotive parts, packaging, and fiberfill for winter jackets. The possible sources of PP can be furnishings, medical components, sportswear, fishing nets and mats, plastic containers, feed, and fertilizer sacks.[1]

MP contamination poses significant ecological and health risks to prawns and marine ecosystems. MPs can accumulate in the GIT of prawns, potentially causing physical blockages, reduced feeding efficiency, and energy allocation towards dealing with ingested particles instead of growth or reproduction.[81] Over time, this can adversely affect their survival and population dynamics. On a larger scale, MPs that prawns have ingested will transfer to higher trophic levels through the food web. There is therefore concern about the issue of bioaccumulation and biomagnification.[15] In many cases, MPs are carriers of harmful pollutants such as POPs and heavy metals that desorb inside the organisms, leading to toxic effects.[82] These interactions could lead to oxidative stress, inflammation, and disruptions of normal physiological processes. For marine ecosystems, MP contamination can alter the structure and function of habitats, affecting biodiversity and ecosystem services. The ingestion and egestion of MPs by marine organisms can also influence sediment composition and nutrient cycling, creating long-term ecological imbalances.[83] Future studies should further explore these impacts to better understand the ecological consequences of MP contamination and inform mitigation strategies.

Overall, the study on MP contamination in the GIT of the marine prawn *Metapenaeus kutchensis* provides valuable insights into the widespread presence of MPs in marine ecosystems, especially in high-fishing regions like Gujarat. MPs, primarily composed of PE, PET, and PP, have been identified as significant pollutants affecting marine life and human health. Recent studies have highlighted the growing environmental concerns related to MP pollution and its impact on aquatic organisms.[84,85] The methodology employed in the current study, including the use of KOH digestion and density gradient techniques, aligns with best practices for MP isolation.[86] Furthermore, research on the biogeochemical behavior of MP-derived dissolved organic matter in aquatic environments has underlined the complex interactions between microplastics and marine ecosystems, stressing the importance of understanding these interactions to mitigate their effects.[85] The finding that MP contamination was ubiquitous across all specimens further corroborates similar studies on MP persistence and distribution in marine life.[87] Additionally, the characterization of MP particles such as their size, shape, and color aligns with the growing body of knowledge on MP distribution and its ecological ramifications.[88] Given the significant impact of microplastic pollution, future studies could consider exploring the potential for bioremediation or innovative material solutions to reduce MP presence in marine ecosystems, as suggested by recent research on geopolymerization techniques and the interaction of MPs with contaminants.[89] The findings from this study offer crucial data for conservation efforts and the management of marine ecosystems, highlighting the need for continued monitoring and mitigation strategies.

4. Limitations of the study

This study has certain limitations that should be acknowledged. First, the focus was limited to a single endemic prawn species, which does not provide a comprehensive understanding of the entire marine environment or the broader ecological implications of MP contamination. Second, the study did not investigate the potential toxicological effects of MP contamination on prawn health, such as immune response or tissue damage. Future research should aim to include multiple species across different trophic levels and assess the health impacts of MP contamination to provide a more holistic view of its effects on marine ecosystems.

5. Conclusion

The present research provided essential insights into MP contamination in *M. kutchensis*, an endemic species found on India's north-west coast. The findings revealed a significant concentration of MPs within the gastrointestinal tract, averaging 3.94 ± 2.40 MPs per g, with Okha displaying the highest levels, followed by Sartanpur and Mithapur. The study found no direct correlation between the body size and MP accumulation. Among all the study sites, fibers were the most prevalent in terms of shape-wise classification. However, the majority of the blue and black MPs were reported in the 1–2 mm size class. Polymer analysis identified PE, PET, and PP as the polymer compositions of extracted MPs. Potential sources of MPs include wastewater runoff, tourism, religious pilgrimages, and commercial fishing activities along Gujarat's coast. These findings underscore the need for further research into the ecotoxicological impacts of MPs on *M. kutchensis* and other marine species to better understand the environmental and health implications.

Data availability

Data will be made available upon request.

Author contributions

Heris Patel and Vasantkumar Rabari: investigation, methodology, data curation, formal analysis, writing original draft, and software. Ashish Patel and Dipak Kumar Sahoo: visualization, software, writing – review & editing, and validation. Jigneshkumar Trivedi: conceptualization, methodology, visualization, formal analysis, writing – review & editing, and project administration.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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