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Depth profiles of microplastic in sediment cores in seagrass and adjacent areas

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Abstract Seagrass beds are vital biodiversity hotspots, offering habitats for many species of fish and marine organisms. Additionally, they play an essential role in nutrient cycling, sequestering carbon, and mitigating coastal erosion. These ecosystems are facing growing threats from pollution, including microplastics (MPs) contamination (< 5 mm). mined The vertical distribution of microplastics in sediment cores (depths 0-20 cm) in seagrass beds and adjacent areas at Kalase Bay, located in Trang Province, facing to Andama sea, southern Thailand was investigated. The results revealed the presence of MPs in both seagrass and non-seagrass areas, with higher concentrations found in the surface area (depths 0-5 cm) than the bottom (depths 15-20 cm) at many stations. The main shapes of microplastics were mostly made up of fibers and fragments. The most prominent color consisted of transparent particles, followed by black and blue particles. This result suggested that microplastic was accumulated in the depth profile of sediment at both areas especially at seagrass beds may perform as effective sinks for microplastics, likely due to their root and leaf structures that support MPs trapping, highlighting the need for pollution management and conservation strategies in coastal ecosystems.

Keywords: Climate change, Thailand, Polymers, Blue ecoystem

Introduction

The 20th century was possibly better known as the plastics age, a class of man-made polymers that has made an extraordinary impact on the modern world in no more than a few decades. The production of plastics has expanded by anexponential proportion from a pathetic 0.35 million tons in 1950 to 359 million tons in 2018, and the number seems to grow with no signs of any reduction in sight (Shanmugam *et al.,* 2020). This sharp rise was largely indicative of a

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transformation in the plastics industry and the extent to which these materials have become so interwoven into the fabric of our lives.

Polymers like PE, PP, and PET have been incredibly successful worldwide for an unparalleled combination of low cost, lightweight, toughness, and processing versatility **(**Andrady, 2011). These are materials that virtually every industry uses, including packaging, construction, automotive manufacturing, and even health care. But now, these properties that make these plastics so enduring are what make them a dangerous environmental pollutant we are now facing.

This environmental crisis is rooted in the use of disposable products and inefficient waste management, resulting in a state in which only 9% of the plastic waste ever generated is recycled (Geyer *et al.,* 2017). The other plastic trash goes to landfills or most recently in the environment, with some 80 percent of the garbage found in marine ecosystems being of terrestrial origin, warns Thailand's Department of Marine and Coastal Resources (DMCR, 2025). Mismanagement of plastic waste leads to delivery to the ocean through complex river, stormwater, and sewage systems. This creates a chronic pollution that is a threat to marine biodiversity and the ability of the ecological system to provide key services.

Once in the ocean, plastics above a certain size known as macroplastics are exposed to a wide range of environmental conditions. Plastic debris, whether in the ocean's surface layer or on beaches, is continually broken down by photodegradation from UV light and physical abrasion. Due to the degradation process, those larger plastic objects break into smaller pieces known as microplastics (MPs: particles sized between 0.001 and 5 mm) (Barnes *et al*., 2009; Song *et al*., 2017) These microplastics fall into two main categories: those which were designed to be small by manufacturers—so-called primary microplastics—such as microbeads used in certain health and beauty products, and secondary microplastics, which result from larger plastic items breaking down. Many of the plastics found in the ocean also fall into this latter category, with examples including fibers from synthetic textiles, fragments from hard plastic containers, or pieces of plastic bag. Previous research has suggested that no more than 1% of plastic found in the marine environment appears as floating waste on the ocean surface, resulting in the sea surface being only a temporary sink, with over 99% of marine plastic waste estimated to reside in the deep ocean and at the seafloor (Pradit *et al*., 2022).

Some coastal ecosystems are especially effective at taking up these diminutive plastic particles as they sink. Seagrass habitats in particular have been identified to be important hotspots for microplastic accumulation. The structural habitat elements of seagrass, such as seagrass blades, can reduce water current velocity, promoting the deposition of suspended small particles, such as suspended matter and microplastics. Due to this physical trapping mechanism,

microplastics have a significantly higher abundance in the sediments of seagrass meadows (up to 17.6 times) than the nearby un-vegetated areas (Huang *et al.,* 2020).

This crisis is particularly disconcerting given that seagrass beds hold immense environmental value. They serve as critical nursery grounds for a diverse array of commercially important fish and crustacean species, providing essential habitats that support their growth and development. Beyond their role as nurseries, seagrass meadows also play a crucial role in safeguarding coastlines against erosion and act as potent "blue carbon" sinks, storing carbon in their sediments at highly significant rates **(**Lamb *et al*. 2017) But the accumulation of microplastics in these crucial areas poses numerous threats. One concern is the potential for trophic transfer through the food chain, such as when benthic animals absorb polluted sediments into thier bodies. This is a multifaceted threat not just by the physical consumption of microplastics, but also the chemical implications. Microplastics have the ability not only to release hazardous additives, such as phthalates and BPA, but also to function as vectors of waterborne persistent organic pollutants (POPs), since they can adsorb or desorb them from the water they occupy (Agbo and Abaye, 2016; Rios-Fuster *et al*. 2021)). And these microplastics can collect toxins into the food chain, risking human health, especially for those who love to eat seafood. Many studies report the ingestion of these particles by marine species, such as invertebrates and fish (Fossi *et al.,* 2017).

Although the global implications of plastic pollution are well-known, there is a dearth of information in many ecologically vulnerable locales, such as the Andaman coast of Thailand and Trang Province. This research is hypothesized that there are differences in the abundance of microplastics between different habitats, with seagrass areas having a higher abundance of microplastics compared to mudflats. These knowledge gaps are essential for devising strategies to reduce plastic pollution which is attempted to protect the priceless marine ecosystems upon the ecological balance rest as well as human health and well-being.

Materials and methods

Sample collection and storage

Sediment samples were collected from Kalase Bay, Trang Province in January, 2025, Thailand (Figure 1). Nine stations were collected, consist of three bare sites (S1-S3) and six seagrass-vegetated sites (S4-S9) (Figure 1). Using a core (5 cm diameter, 20 cm deep) to obtained the sediment sample and

immediately sectioned into four layer, each layer was 5 cm depth (0-5, 6-10, 11-15, and 16-20 cm). All samples were then oven-dried at 60°C, ground, and stored for laboratory analysis later.

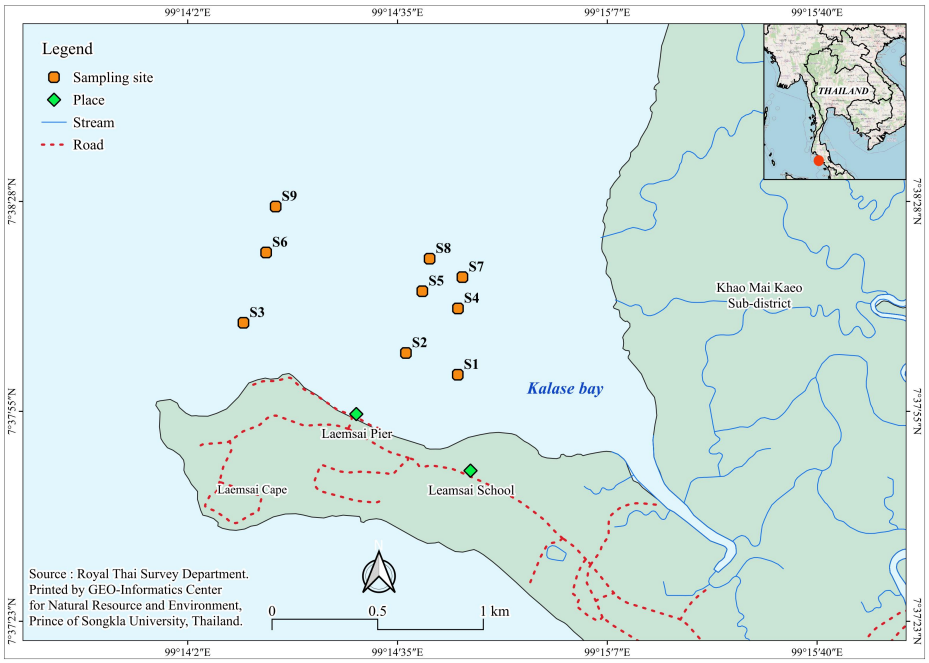

Figure 1. Map of the study area and locations of the sampling stations

Microplastic extraction

The extraction of microplastics from sediment was carried out by a density separation and chemical digestion approach modified from Masura *et al.* (2015). 20 g of each dry sediment sample was added to a 600 ml beaker and mixed with 200 ml of saturated sodium chloride (NaCl) solution. The mixture was stirred and allowed to settle for one hour, permitting denser sediment to settle down while less dense particles remained suspended. The supernatant was subsequently poured gently and filtered through a 300 µm filter net. This was repeated three times with 100 ml NaCl solution, stirring, settling for 1 h, and decanted.

All material retained on the 300 µm filter net was rinsed into a separate beaker for organic matter digestion. Wet peroxide oxidation (WPO) was performed by adding 10 ml H_2SO_4 and 10 ml of H_2O_2 to the samples and then heating the solution on a hot plate at less than 75°C.

After digestion, 6 g of NaCl was added to every 20 ml of solution to optimize further plastics separation, and samples were kept still for 24 h at room temperature. The resulting remaining material was filtered through a 300 µm filter net and transferred to a Petri dish, which had been marked.

To isolate the smaller microplastic fraction, the filtrate that passed through the 300 µm cloth was then filtered through a 20 µm filter cloth. The material retained on this second filter underwent the same WPO digestion process described above. The final digested liquid was filtered through a Whatman GF/C glass microfiber filter, and the filter paper was placed in a Petri dish. Finally, all Petri dishes were oven-dried at 60°C for three hours before analysis under a microscope. Petri dishes were oven-dried for 3 h at 60°C before being observed by microscope.

Microplastic identification

The microplastics (MPs) were observed to determine their physical morphology under a stereomicroscope (Leica EZ4W; Leica EZ4W; Leica system). The Leica Application Suite was used to capture the particle photos and measure sizes. Hidalgo-Ruz's rules (Hidalgo-Ruz *et al.,* 2012) were used to identify organic and non-organic materials. Moreover, the hot needle test (Witte *et al.,* 2014) was used to distinguish organic materials and plastic alike. The shape, size, and color of the microplastics were recorded.

Statistical analysis

Microplastic concentration was analyzed using descriptive statistics (mean and standard deviation, SD). The T-test was used to compare the number of microplastics found in the seagrass area and bare area. The significance level was set at $p < 0.05$.

Contamination control

To avoid contamination of extraneous microplastics, plastic tools were used as little as possible to reduce the risk of contamination, and all laboratory glassware, beakers, and storage cylinders were glass. All solutions, including saturated NaCl and distilled water used in this study, were filtered by a Whatman® GF/B glass microfiber filter (1 µm pore size) before the experiment. Analyzed sample containers were covered with aluminum foil to avoid airborne contamination. A control sample (blank sample), which was a beaker containing the filtered distilled water, covered, was also left in the laboratory along with the test samples to detect any background contamination. Additionally, 100% cotton

lab coats and rubber gloves were worn during all of the procedures to avoid contamination of the samples, following the previously described protocols (Pradit *et al.,* 2023; Chinfak *et al.,* 2021).

Results

MP abundance

The microplastic abundance at different depths in sediment cores from stations S1– S9 is shown in Figure 2. Because the sediment at S3 was harder than other stations, we obtained a shorter core. Microplastics were detected in 30 sediment samples from 32 samples with a total of 87 pieces from S1–S9. The abundance of microplastics in sediment cores ranged from 5-16 particles/20g of sediment (dry weight and average 9.67±3.5 pieces) with an average abundance in cores S1 to S9 were 3.0±1.63, 3.00±0.0, 2.50±2.89, 4.00±2.83, 2.75±0.96, 1.50±1.29, 2.50±2.08, 1.5±1.73 and 1.25±0.96 particles/20g of sediment respectively. Based on the depth profile, it is obvious that there was not a single, uniform trend in abundance of microplastics with depth for all cores. The vertical patterns of all particles are quite different between stations, suggesting that local effects at each station largely determine the manner in which microplastics are incorporated and buried over time. At several stations, the highest concentration of microplastics is not found on the surface but in layers just below. This pattern is most pronounced in (S4, S5, S8), some stations did not have clear trend and concentration fluctuates and decreases towards the middle layers then increases with depth (S1, S6, S9), in other station it is constant through depth (S2 and S3) while the last one has higher concentrations at shallowest depths 0-5 cm which tends to decrease and stabilizes at deeper sections. For statistical analysis, A t-test was conducted to compare the abundance of microplastics in bare sediment areas compare with seagrass meadows**.** The analysis revealed that the mean microplastic abundance in the bare sediment area **(**Mean = 11**.**00, SD = 1**.**00**)** was higher than that in the seagrass meadows **(**Mean = 9**.**00, SD = 4**.**20**).** The t**-**test indicated that this difference was not statistically significant, t **(**6**.**65**)** = **-**0**.**99, p = 0**.**817**.** The results were not supported the hypothesis that seagrass meadows accumulated a significantly higher number of microplastics than bare areas**.**

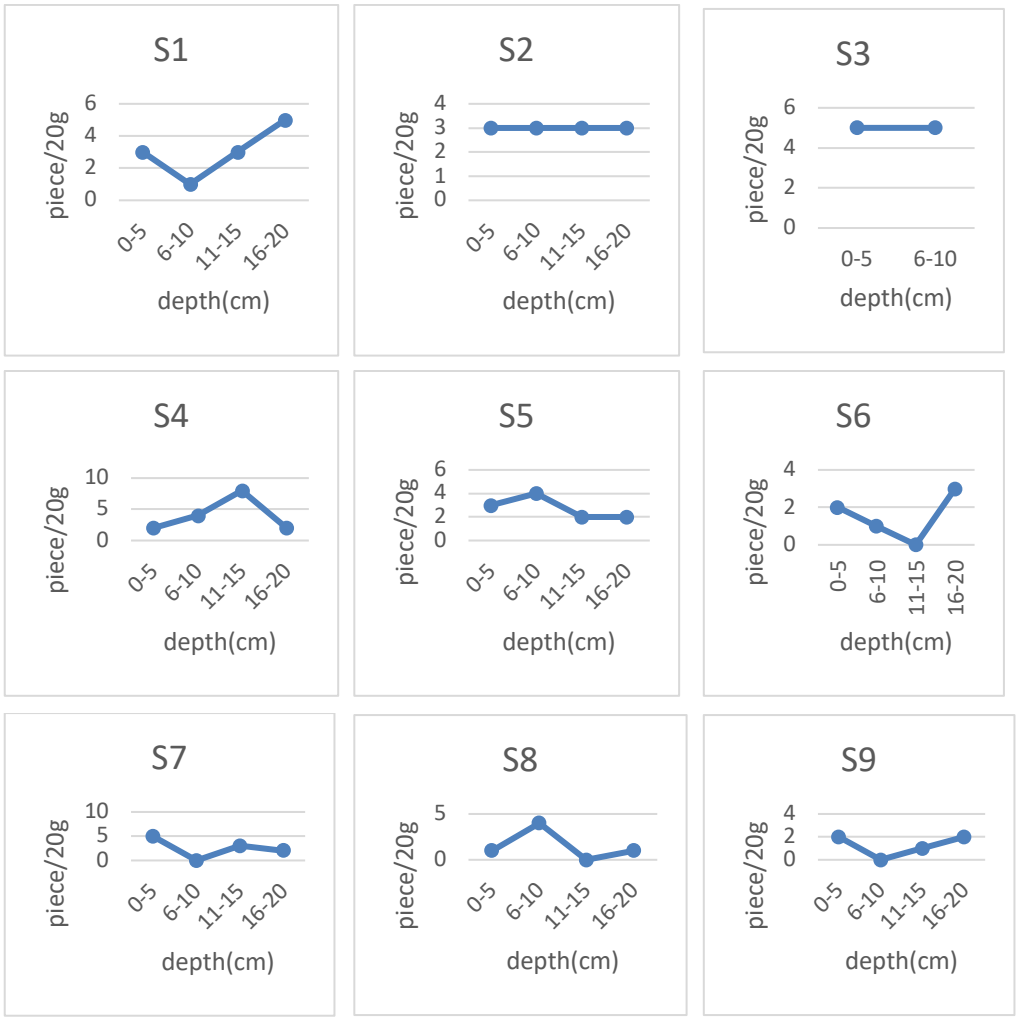

Figure 2. Abundance of microplastics at different depths in sediment cores.

MP characteristics (shape, color and size)

The microplastic observation at 9 stations showed that fibers were the most dominant shape, with 69 pieces, surpassing all other shapes. Fragments were the second most common, with 17 pieces, while films were the least common, with just 1 piece. For color, the most abundant microplastic color was blue (23%) and followed closely by black (21%), transparent and dark blue (16%). The particle size range was 157 µm–4196 µm, and the average particle size was 18.1515 ± 89.1036 µm. The size of microplastics was classified into three size classes: <1

mm, 1-2mm, >2-3mm, >3-4mm and >4-5mm. The 1-2mm size class was the most dominant (44%), followed by the <1 mm size class (33%).
The number of MP shapes, color and size for each station is shown in Figure 3,4 and 5 respectively and example of the shapes and color of microplastics found in the study is shown in Figure 6.

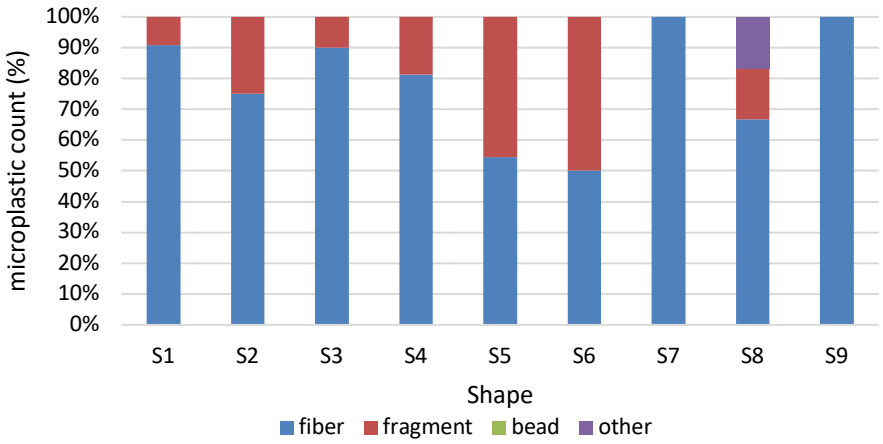

Figure 3. Shape of microplastics found in the sediment from three bare sites (S1-S3) and six seagrass-vegetated sites (S4-S9)

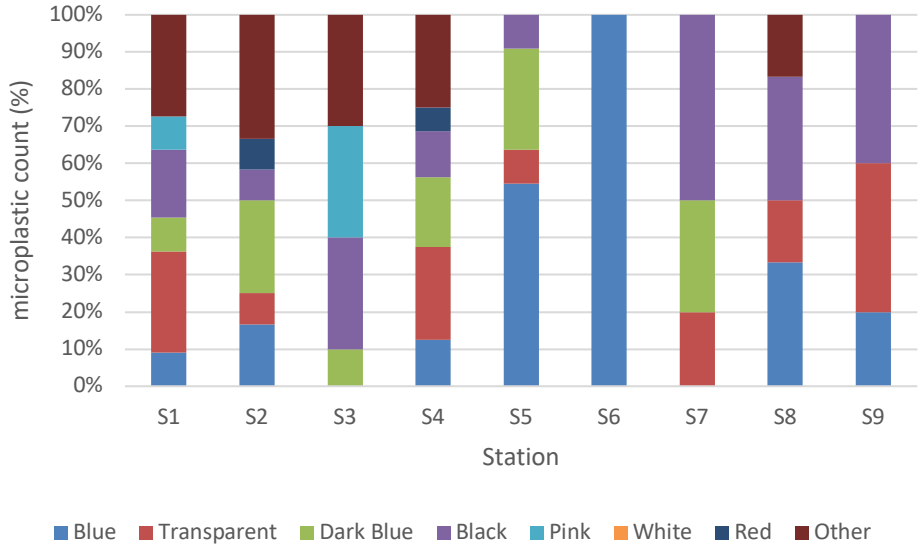

Figure 4. color of microplastics found in the sediment from three bare sites (S1-S3) and six seagrass-vegetated sites (S4-S9)

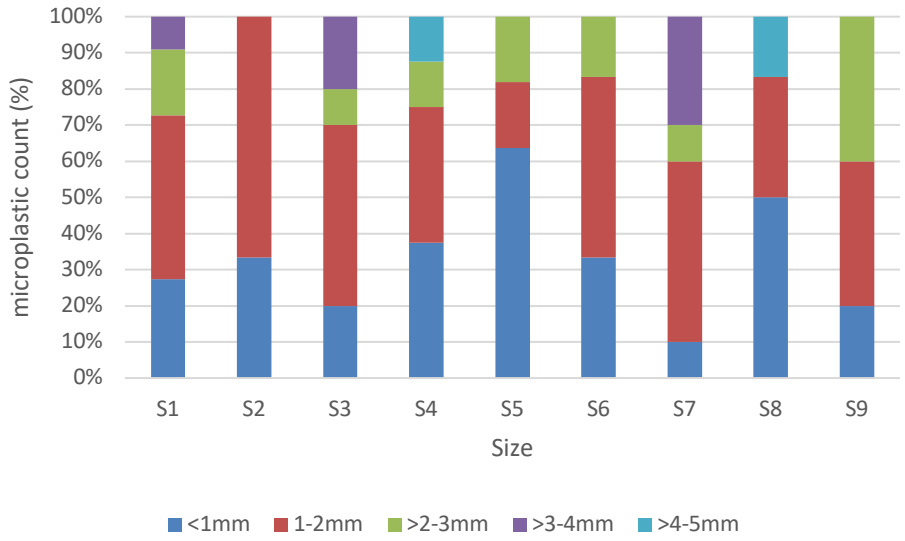

Figure 5. size of microplastics found in the sediment from three bare sites (S1-S3) and six seagrass-vegetated sites (S4-S9)

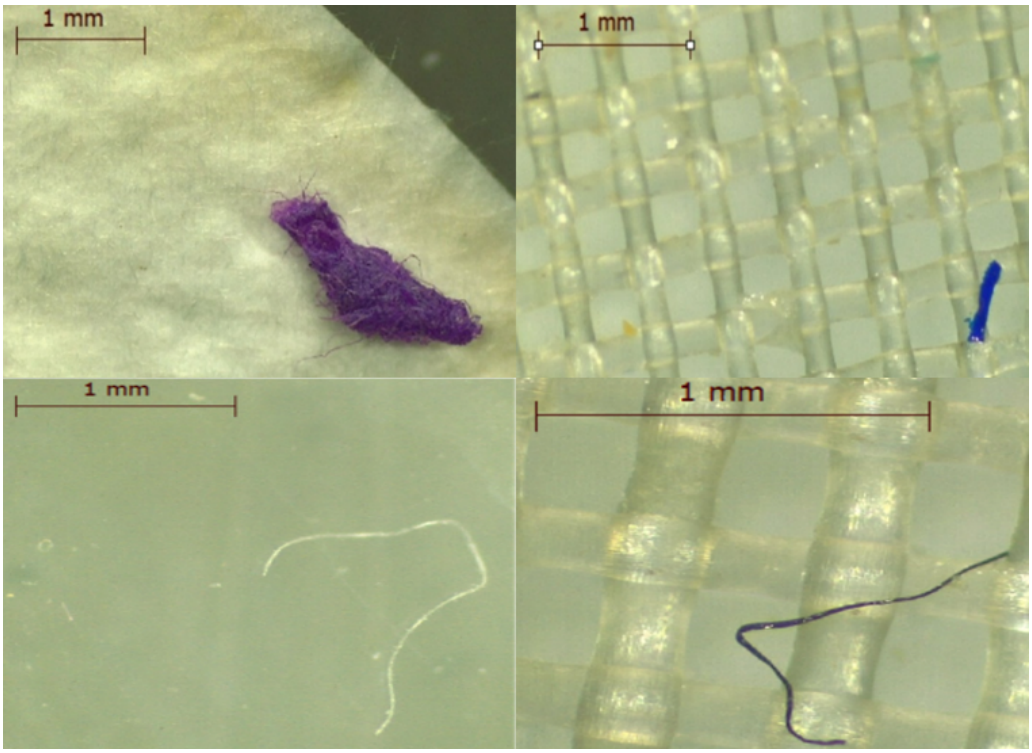

Figure 6. Example of the shapes of microplastics found in the study

Discussion

MP abundance

The results from statistical analysis were not supported the hypothesis that seagrass meadows which accumulated a significantly higher number of microplastics than bare areas**.** This study's findings contradicted earlier studies from various regions that reported higher microplastic accumulation in seagrass areas compared to non-grass areas (Jones *et al*., 2020 and Tang *et al.,* 2024).

For depth profile, the result showed that there was no fixed pattern for the relationship between depth and the amount of microplastics found at each layer. Moreover, in many study areas, the accumulation of microplastics was found to be higher in the upper layers than in the deeper layers like studies in Turneffe Atoll, Belize (Radford *et al.*, 2024).

MP characteristics (shape, color and size)

Fibers were the most dominant shape of microplastics (79%), significantly surpassing all other shapes. The second most common shape was fragments (20%). These findings aligned with numerous previous studies in Thailand, which also identified fibers as the most prevalent microplastic shape. Similarly, studies from Scotland and southern Portugal reported that 50% and 70% of the microplastics found were fibers (Jones *et al*., 2020; Tahir *et al.,* 2019). The high presence of fiber-shaped microplastics could originate from materials used in clothing and fishing gear. Since the study site is near a fishermen's harbor and village, various fishing gear such as nets, traps, and lines are commonly found in the area. Even ropes from fishing boats can deteriorate and end up in the sea (Pattanasirinon and Suriyaphan*,* 2021; Pradit *et al*., 2022; Pradit *et al.,* 2024).

In part of color, blue was the most abundant microplastic color (40%), followed by black (21%) and both transparent and dark blue (16%). Comparisons with previous studies from Thailand and Indonesia revealed that black, white, and blue were the most dominant colors (Pattanasirinon and Suriyaphan, 2021; Cozzolino *et al*., 2020). Other colors such as red, pink, brown, and green were observed in smaller amounts.

Size-wise the >1 mm size class was most abundant (44%), followed by the <1 mm size class (33%), similar to previous studies. The same was shown for seagrass beds in the Baltic Sea (Kreitsberg *et al*., 2021). Moreover, the <1,000 µm size class also turned out to be dominant on India waters (Jeyasanta *et al.,* 2020). The smaller MP size is due to the degradation of large plastic into pieces that are small enough to be ingested by both the surface and bottom organisms, as microplastics usually have approximate similar sizes with their food (Leslie *et*

al., 2013; Kasamesiri and Thaimuangphol, 2020). Due to their small size, strong hydrophobicity, and large surface-area-to-volume ratio, microplastics can effectively adsorb organic pollutants and metals onto their surfaces (Zhou *et al.,* 2019).

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Conflicts of interest

The authors declare no conflict of interest.

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