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Assessing microplastic pollution in marine mammals: evidence from three cetacean species in the southeastern Black Sea

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Microplastic (MP) pollution has emerged as a pervasive environmental threat, with growing evidence of its accumulation across various marine trophic levels, including top predators such as cetaceans. This study investigates MP abundance, size distribution, morphology, color, and polymer composition in the gastrointestinal tracts (GITs) of three cetacean species sampled from the southeastern Black Sea. A total of seven individuals were examined, with MP abundances ranging from 5 to 139 particles per individual. Fiber-type MPs were predominant (75%), with black, green, and transparent colors being the most frequently observed. The majority of MPs were small in size, with an average length of 2002 ± 1961 μm, suggesting possible trophic transfer from lower-level organisms such as copepods and fish. Polymer analysis revealed polyamide (PA), polyacrylonitrile (PAN), and ethylene-vinyl acetate (EVA) as the most common polymer types, indicating both fishing gear and domestic wastewater as primary MP sources. Spatial patterns in stomach fullness and MP load suggest that local environmental conditions, such as fishing activity and tourism, influence exposure levels. The study highlights the significance of both incidental ingestion during feeding—especially through net interactions—and trophic transfer as key MP exposure pathways in cetaceans. These findings demonstrate the potential ecological risks posed by MPs at higher trophic levels and emphasize the urgent need for biodegradable alternatives to synthetic fishing gear and improved wastewater management. Moreover, collaborative efforts among local authorities and NGOs are recommended to raise awareness and support adaptive environmental management in the region.

KEYWORDS

microplastics, cetaceans, trophic transfer, polymer composition, southeastern black sea

1 Introduction

Microplastics (MPs) are contaminants smaller than 5 mm that originate from the fragmentation of plastic waste—an anthropogenic pollutant—via various driving forces (Galgani et al., 2015). Macro-sized plastics undergo degradation through a combination of environmental factors such as wind, sunlight, precipitation, and water currents (Grini et al., 2022). Particularly through surface runoff (e.g., river and rainwater), MPs are transported to their final destinations—marine and oceanic ecosystems (Thompson, 2015). The vectoral migration of MPs is unpredictable and inevitable, and both their lethal and sublethal effects on aquatic organisms have been previously discussed (Rakib et al., 2023). MPs not only exert direct impacts on aquatic life but also induce indirect ecological consequences by altering the structure of the food web (Eerkes-Medrano et al., 2015; Kaya et al., 2025). MPs ingested by organisms at lower trophic levels enter the food chain and are subsequently consumed by organisms at higher trophic levels (Davidson and Dudas, 2016; Jabeen et al., 2017; Minaz et al., 2024b; Kaba et al., 2025).

The effects of plastics on aquatic organisms may manifest through physical interactions such as entanglement resulting from ghost fishing (Kraus, 2018), strangulation (Derraik, 2002), and ingestion (Alexiadou et al., 2019). Ingestion of MPs by aquatic species can cause inflammatory responses and blockages in the gastrointestinal tract (GIT), potentially resulting in a false sense of satiety (Limonta et al., 2019). Furthermore, the ingestion of MPs also leads to chemical impacts on aquatic life (Barboza et al., 2020). Due to their diverse polymeric structures and the presence of plasticizers (e.g., bisphenols), MPs ultimately cause secondary toxicity in aquatic organisms (Rochman et al., 2013; Diler et al., 2022; Minaz et al., 2022b, 2022a, 2023, 2024a; Minaz and Kurtoğlu, 2024).

Cetaceans play a crucial role in the functioning and structural balance of marine ecosystems and are considered key indicators reflecting the overall health of these systems (Moore, 2008). In this context, the presence of MPs in the stomach, intestines, and feces of cetaceans has been previously reviewed (Zantis et al., 2021). The European Marine Strategy Framework Directive (MSFD) proposes marine mammals as biological indicators for both marine plastic debris and other organic pollutants (Galgani et al., 2014; Jepson et al., 2016). However, direct or indirect evidence of MP ingestion by cetaceans remains limited and is largely confined to European regions (Besseling et al., 2015; Baini et al., 2017; van Franeker et al., 2018). Due to their wide geographic distribution and presence across diverse habitats, cetaceans are valuable sentinel species for monitoring MP pollution. Given the rising levels of MP contamination globally, there is a critical need for more baseline data on MP ingestion by marine mammals and other species in non-European regions (Xiong et al., 2018). Therefore, comprehensive research conducted in these areas will significantly enhance our understanding of the impacts of MPs on marine wildlife.

Due to its nature as a semi-enclosed sea, the southeastern Black Sea is particularly vulnerable to MP pollution, which holds significant environmental implications for both ecosystems and aquatic organisms (Eryaşar et al., 2022). The geographic characteristics of the region provide critical breeding and feeding grounds for fish and cetaceans (Oguz et al., 2012). However, numerous rivers from Europe discharge into the Black Sea, making surface water runoff one of the primary pathways for MP transport. For instance, the Danube River delivers tons of plastic waste into the Black Sea on a daily basis (Lechner et al., 2014), thereby exposing the Eastern Black Sea—an essential region for aquaculture and fisheries—to anthropogenic threats (FAO, 2022). In one study, a total of 594 MPs were observed in river sediments flowing into the Black Sea along a 350 km Southeastern Black Sea coast (Mutlu et al., 2024a). Another study calculated the annual microplastic input from 29 rivers draining into the Black Sea to be approximately 1.49×10^{11} particles, with significantly higher MP concentrations identified, particularly in the eastern rivers (Terzi et al., 2025). In order to more comprehensively demonstrate the extent of microplastic (MP) pollution in the region, several studies conducted in recent years have reported significant MP accumulation in different environmental media along the Southeastern Black Sea coast. For example, microplastic concentrations of 77 ± 11 MP m^{-3} were detected in surface waters, 189 ± 108 MP m^{-3} in water column samples, and 24 ± 30 MP kg^{-1} in sediments (Aytan et al., 2025). Furthermore, an average accumulation of 108 MP kg^{-1} was detected in sediment samples from the region, demonstrating that this pollution has increased significantly over the years (Akkan et al., 2023). There is also evidence supporting regional microplastic pressure at the biological level; microplastic accumulations have been reported in the stomach contents of red mullet (Onay et al., 2023a) and seahorses (Onay et al., 2023b). These findings indicate that the Southeastern Black Sea is a significant focus of microplastic pollution and make it even more important to investigate this pollution in higher-trophic species living in the region.

Within the Black Sea ecosystem, only three cetacean species—the harbor porpoise (*Phocoena phocoena*), the common dolphin (*Delphinus delphis*), and the common bottlenose dolphin (*Tursiops truncatus*)—occupy the apex of the trophic pyramid as the top predators (Birkun et al., 2006). These species exhibit similar feeding behaviors, being exclusively piscivorous. The cetacean population in the Black Sea had been in a continuous state of decline until direct whaling was banned in neighboring countries such as the former USSR, Bulgaria, Romania, and Turkey (Özsandıkçı and Özdemir, 2024). Historical data suggest that while direct hunting was once the primary cause of cetacean mortality, current deaths predominantly occur due to by-catch, specifically through entanglement in fishing nets (Tonay, 2016; Popov et al., 2023). Although measures such as the prohibition of cetacean hunting have been implemented, these marine mammals continue to face anthropogenic contamination, including MP pollution. As a result, they serve not only as potential vectors for MPs but also suffer from the associated toxicological impacts.

According to IUCN sources, the Black Sea subspecies of cetaceans are classified at varying levels of conservation concern: the common dolphin (*Delphinus delphis*) is listed as Vulnerable (Birkun, 2008), whereas the bottlenose dolphin (*Tursiops truncatus*) and the harbor porpoise (*Phocoena phocoena*) are categorized as Endangered (Birkun and Frantzis, 2008; Birkun, 2012). Although the global populations of these species are generally listed as Least Concern, their Black Sea subspecies are under specific protection due to regional threats. Consequently, potential anthropogenic pollutants in the Black Sea pose a serious risk to the health of these cetaceans, as they do to all aquatic organisms. While MP pollution in the southeastern Black Sea has been investigated in prior studies (Eryaşar et al., 2021; Aytan et al., 2022; Gedik and Gozler, 2022; Onay et al., 2023b, 2023a), its impact on cetaceans remains underexplored. The impacts of MP pollution in the Southeastern Black Sea on ecologically critical cetaceans, which occupy the uppermost levels of the food chain, have been largely overlooked. Given the ecological importance of cetaceans as top predators and their vulnerability to plastic pollution, this study aims to address this critical gap by assessing the presence, characteristics, and possible sources of MPs in the gastrointestinal tracts (GITs) of three cetacean species inhabiting the southeastern Black Sea. To our knowledge, this is the first study to investigate MP ingestion in marine mammals from this region, providing novel insights into regional MP pollution pathways and potential trophic transfer mechanisms.

2 Material and method

2.1 Study area and sampling

Cetaceans were collected from the southeastern Black Sea during the 2024 and 2025 period. The sampling area is fed by numerous rivers originating from Türkiye (Alkan et al., 2022). Additionally, the coastal region is characterized by industrial, touristic, agricultural, and urban activities (Figure 1). Therefore, the sampling area has a potential risk of exposure to both point and diffuse sources of pollution (Aytan et al., 2021). In the present study, a total of seven cetaceans belonging to three different species were examined (Table 1). These species were *Tursiops truncatus* (D1 and D3), *Phocoena phocoena* (D2, D4, and D6), and *Delphinus delphis* (D5 and D7). The individuals were obtained as fisheries by-catch (dead) after becoming entangled in commercial gillnets. The body lengths of the cetaceans were measured using a measuring tape with 0.1 cm precision, while body weights were recorded using a digital electronic scale with 20 g sensitivity. Samples were kept on ice during transportation to the laboratory and subsequently stored at −20°C until dissection.

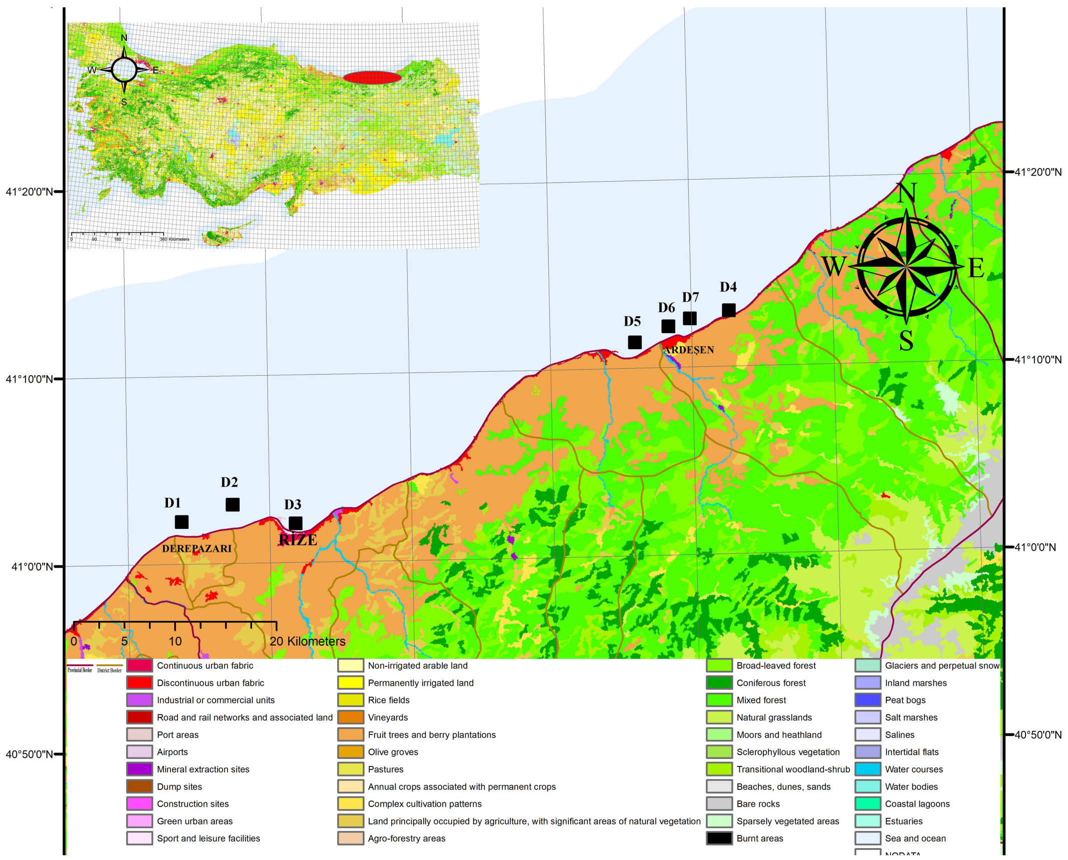

FIGURE 1
Location of sampling sites for cetaceans.

TABLE 1 The characteristic properties of cetaceans in the current study.

Code	Species	Date	Length (cm)	Weigth (kg)	CF (g cm^{-3})	Gender
D1	*Tursiops truncatus*	24.03.2024	154	63.3	1.73	Female
D2	*Phocoena phocoena*	25.03.2024	130	35.4	1.61	Female
D3	*Tursiops truncatus*	29.02.2024	162	74.0	1.74	Male
D4	*Phocoena phocoena*	10.03.2025	68	10.0	3.18	Female
D5	*Delphinus delphis*	10.03.2025	85	12.9	2.10	Female
D6	*Phocoena phocoena*	10.03.2025	130	34.0	1.55	Female
D7	*Delphinus delphis*	10.03.2025	160	63.6	1.55	Male

2.2 MP extraction procedure

The gastrointestinal tracts (GITs) of cetaceans were carefully weighed and transferred into glass containers. Potassium hydroxide (KOH, 10% v/v) was added at a ratio of 1:3 (w/v) relative to the GIT weight to ensure efficient tissue digestion. The mixture was incubated at 60 ± 5°C for 6 hours and subsequently allowed to rest overnight at room temperature to complete the digestion process. On the following day, the digested GIT contents were filtered using a vacuum filtration system equipped with a fiberglass filter (1.6 µm pore size, GF/A Whatman). The filtration procedure was finalized with successive rinses of ultrapure water. The processed samples were then transferred to glass petri dishes and stored for further microscopic examination under a stereomicroscope (Schirinzi et al., 2020). For analytical evaluation purposes, microplastics were divided into five size classes:<0.2mm, 0.2–1mm, 1–2mm, 2–5mm and >5mm.

2.3 Polymer identification

Following the filtration process, the retained materials on the filters were examined under a stereomicroscope (Nikon SMZ1000). Suspected plastic particles were photographed using a high-resolution camera (Nikon DSFI1) mounted on the microscope and subsequently archived. Each plastic-like particle was documented according to its color, morphological features, and size. To determine the polymer composition, Fourier Transform Infrared (FTIR) spectroscopy was employed using a Perkin Elmer Spectrum 100 instrument. Analyses were conducted in Attenuated Total Reflection (ATR) mode, and only spectra with a match quality above 70% were considered reliable for polymer identification. The instrument's detection limit was set at >100 µm. Spectral data were collected within the range of 4000–650 cm^{-1}, using 18 scan repetitions at a resolution of 1 cm^{-1}. Polymer types were identified through comparison with the reference spectra provided in the Perkin Elmer SEARCH Plus® library and FTIR spectrums were presented in Supplementary Material 1.

2.4 QA/QC

Given the high risk of external contamination in MP research, all laboratory procedures were conducted with utmost care and precision. In alignment with established protocols, laboratory access was strictly limited, and personnel wore cotton laboratory coats to minimize fiber shedding. Throughout the processes of filtration, storage, and microscopic examination, only glassware (e.g., vials, flasks, beakers) and metal tools (e.g., tweezers, scissors) were employed to avoid plastic contamination. Prior to use, all equipment was thoroughly rinsed with ultrapure water. Experimental procedures were carried out under a high-efficiency laminar flow cabinet to maintain a clean working environment. Sample containers, including beakers and petri dishes, were consistently covered with aluminum foil to prevent airborne contamination. During stereomicroscopic analysis, petri dishes were handled inside a fume hood to further reduce contamination risks. To assess background contamination, a single blank sample containing 10% KOH and 20% HNO_3 was processed under identical conditions. No microplastic particles were observed in the procedural blank sample, indicating no airborne contamination occurred during the sample preparation and analysis process.

2.5 Data analyses

All data were shown in mean ± standard deviation. The Kolmogrov-Smirnov test was used to assess normal distribution. In general, data sets showed normal distribution. Therefore, all statistical analyses were performed with parametric tests. One-way ANOVA and Tukey tests were used to determine significant differences in MP sizes between groups. *p*-values of less than 0.05 were considered statistically significant. All data sets were analyzed by the SPSS 25 software package for Windows.

Condition factor (CF) of the samples was calculated by following equation (Fulton, 1904).

$$CF = W/(TL^b) \times 100$$

Where *CF, W, TL*, and *b* represent condition factor, fish weight, total length, and growth constant of fish (b=3), respectively.

3 Results

3.1 MP abundance in dolphins

Figure 2 illustrates the GIT weights and the number of MPs detected within the GIT contents of seven different cetacean individuals. The highest MP abundance was recorded in individual D2, with 139 MPs. In contrast, the lowest MP abundance was observed in individual D5, with only 5 MPs. The GIT weights showed a similar trend to the MP abundances, ranging from 38 g to 324 g.

3.2 Size groups of MPs

Figure 3 illustrates the distribution of MP sizes and the proportional composition of MP size groups in individual cetaceans. No statistically significant difference was observed in MP sizes among the cetaceans ($p>0.05$; $\eta^2 = 0.031$). Overall, MPs exhibited a wide range of variation, with an average size of 2002 ± 1961 µm across all individuals. Although the largest MP size group (>5 mm) was most prominent in individual D7, the presence of a greater number of smaller-sized MPs contributed to a balanced overall MP size profile. Conversely, individual D5, which had a relatively lower proportion of >5 mm particles, showed a comparatively larger MP size distribution due to a high percentage of MPs in the 2–5 mm size group.

3.3 MP classification

The chord diagram displays the relationships between MP categories (fiber, fragment) and colors (e.g., black, blue, transparent, red, green, etc.) with individual cetaceans (Figure 4). The most prevalent MP type was fiber (75%), while fragments accounted for 25% of total MPs. Among colors, black, transparent, and green were frequently observed. A large proportion of MPs found in individual D6 were transparent and classified as fragments. In contrast, individuals D1 and D2, which exhibited the highest MP abundances, predominantly contained black and green-colored fibers, respectively. In individual D3, MPs were evenly distributed between fibers and fragments, each comprising approximately half of the total MP count.

In the Figure 5, the Sankey diagram illustrates the relative proportions of eight identified polymer types: polypropylene (PP), polyvinyl alcohol (PVA), polyamide (PA), polyvinyl chloride (PVC), polyethylene terephthalate (PET), ethylene-vinyl acetate (EVA), and polyacrylonitrile (PAN). PA, EVA and PAN were the most frequently detected polymers, with D6 showing the highest PAN proportion (67%), while D1 and D2 showed a more balanced distribution across multiple polymer types. In addition, PA was the most abundant polymer species observed in the present study.

4 Discussion

The southeastern Black Sea has become a hotspot for MPs due to the currents generated by numerous rivers flowing from northern Türkiye (Mutlu et al., 2024a, 2024b). Several studies conducted in this region have demonstrated the presence of ingested MPs in the gastrointestinal tracts (GITs) of various aquatic organisms (Aytan et al., 2021, 2022; Eryaşar et al., 2022; Gedik et al., 2023; Onay et al., 2023b, 2023a). However, while most existing studies have focused on fish species, research on marine mammals in the region remains quite limited (Zantis et al., 2021). Therefore, the present study aims to fill this gap by investigating MP ingestion potential in three different cetacean species. While the detection of microplastics in all individuals provides important information about pollution trends,

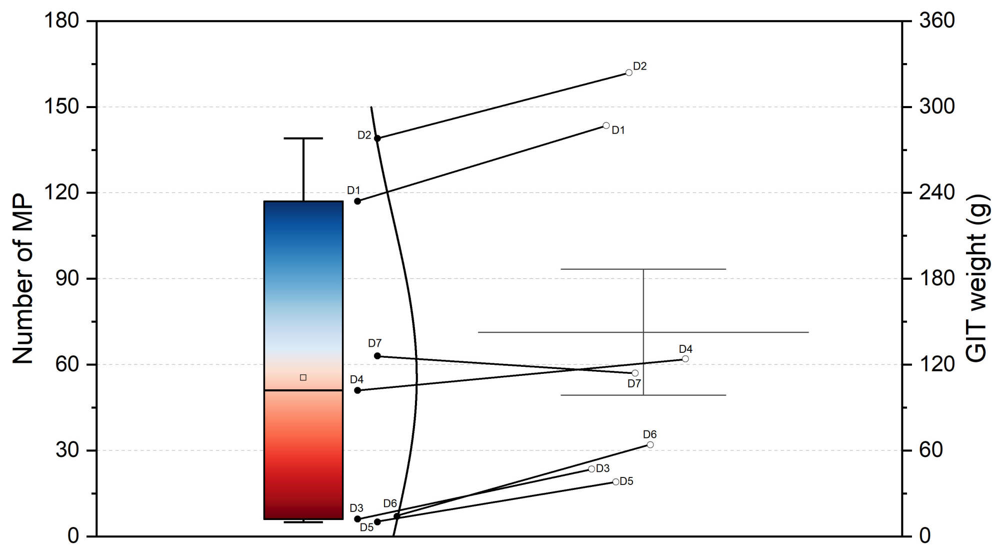

FIGURE 2
MP abundance and GIT weight distribution among cetacean individuals. The bar plot on the left represents the number of MPs detected per individual (D1–D7), while the overlaid violin plot illustrates the data distribution. The grey bars on the right indicate the GIT weights (g) of each cetacean, with corresponding individual IDs. The dual-axis format visually demonstrates the relationship between MP load and GIT mass. Although a partial visual trend appears between GIT weight and MP abundance, no statistical correlation test was performed due to the limited sample size (n = 7); thus, this relationship is presented descriptively.

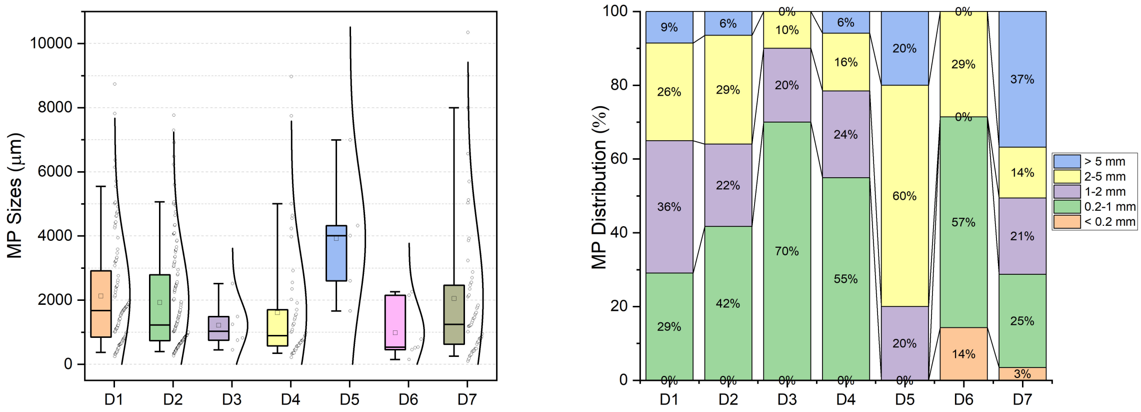

FIGURE 3
Distribution of MP sizes and the percentage composition of MP size groups in individual cetaceans. The left panel shows the size distribution of MPs (in µm) detected in the gastrointestinal tracts (GITs) of seven cetacean individuals (D1–D7), represented as boxplots with overlaid density curves. The right panel presents the proportional distribution (%) of MPs across five defined size categories (<0.2 mm, 0.2–1 mm, 1–2 mm, 2–5 mm, and >5 mm) for each individual. Variations in size distribution indicate individual-specific exposure patterns and potential ingestion sources.

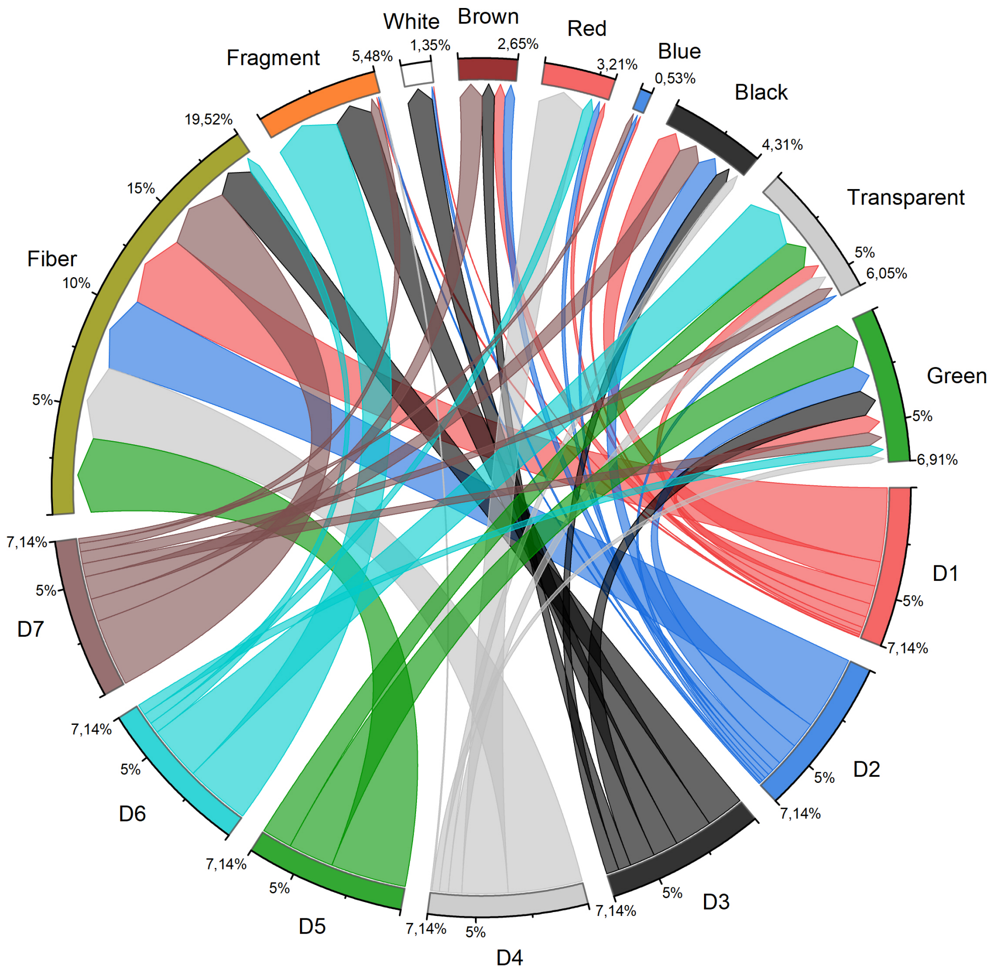

FIGURE 4
MP types and color distribution among cetacean individuals. Each ribbon indicates the proportion of a specific MP type or color found in each cetacean.

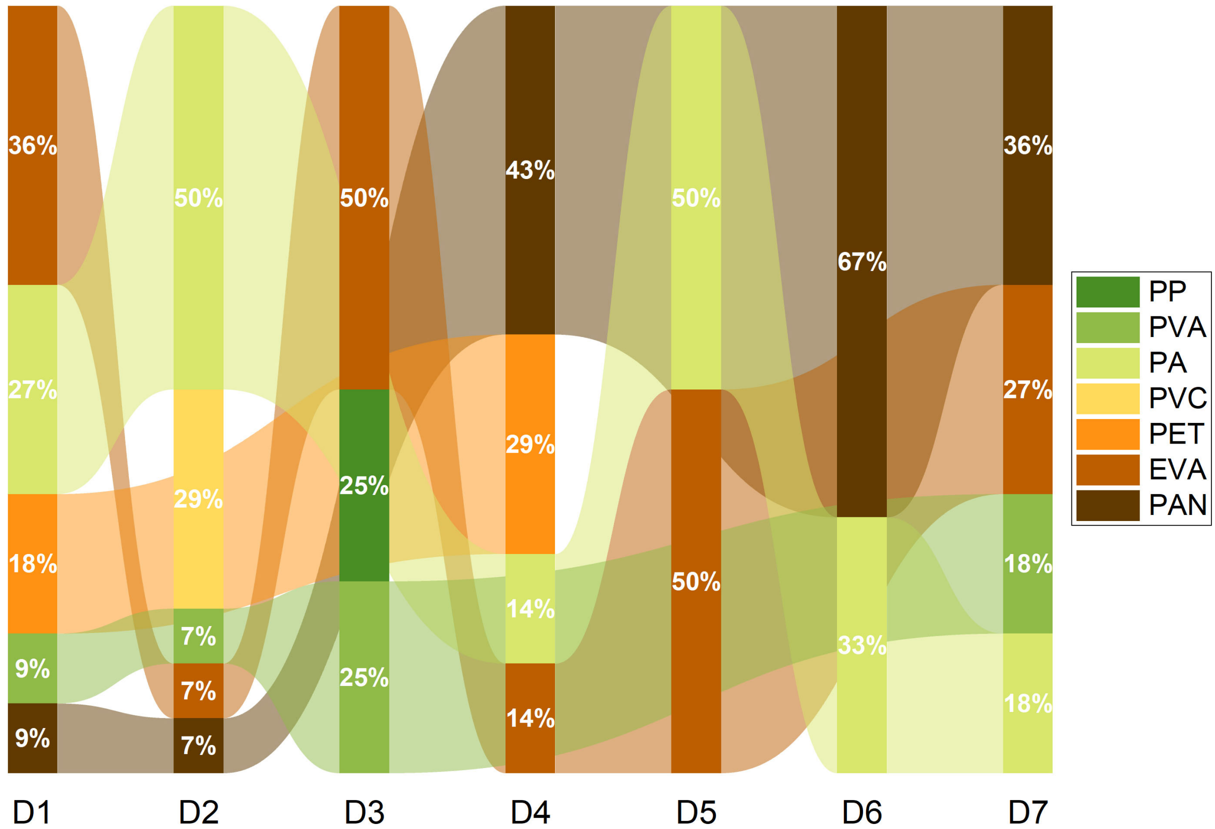

FIGURE 5
Polymer type distribution of MPs detected in the GITs of individual cetaceans (D1–D7).

the limited sample size (n=7) reduces the power of statistical analyses in the current study. This is due to the ethical and logistical challenges encountered in accessing cetacean individuals that have washed up on shore or were obtained as bycatch from fisheries. Additionally, the limited sample size (n = 7) reduces statistical power and limits the generalizability of the results; therefore, the apparent relationship between GIT weight and MP abundance should be considered descriptive rather than inferential. No clear relationship was observed between body weight and stomach fullness among the cetacean individuals examined. For instance, although cetaceans D1 and D3 belong to the same species and exhibit similar body weights, D1 had a full stomach, whereas D3's stomach was nearly empty. This finding is consistent with previous research indicating no correlation between cetacean body length and MP content in the stomach (Hernandez-Gonzalez et al., 2018). Cetaceans with empty stomachs generally exhibited lower MP abundance. The two cetaceans with the highest stomach fullness were sampled from closely located sites, and their MP ingestion trends mirrored their stomach content levels. However, rather than an active tendency to ingest MPs, this is likely a result of incidental ingestion during feeding activities (Hajisamae et al., 2022). The low MP abundance observed in empty stomachs may be attributed to the ability of fish, as prey items, to excrete ingested MPs and nanoplastics (NPs) via feces (Bhat et al., 2024). Alternatively, the absence of MPs in the gastrointestinal tract (GIT) may be due to their translocation across the intestinal epithelial membrane into other fish tissues (Browne et al., 2008). In the present study, the primary factor influencing stomach fullness in cetaceans was found to be their geographic location. The region with the highest stomach fullness—Derepazarı, where cetaceans D1 and D2 were sampled—is characterized by relatively low fishing activity, which may allow prey species to utilize the area as a refuge and feeding ground. Consequently, cetaceans are likely to exploit the potentially high fish abundance in this area. The elevated stomach fullness in these individuals suggests a possible relationship between MP ingestion and location. In fact, the site where the highest number of MPs were observed in the GITs of two different cetacean species (Station 10) had previously been studied and reported to exhibit high MP abundance in water samples (Terzi et al., 2025). This elevated MP abundance is likely associated with short-term tourism pressure in the region. Nearby beaches such as Sarayköy and adjacent sandy shores support recreational activities like swimming and sunbathing, thereby contributing to increased anthropogenic pollution. Prior studies conducted on similar sandy shores in the vicinity have also highlighted elevated MP concentrations, particularly at the end of the tourist season (Gül, 2023). Microplastic abundance increased from 21.4 ± 13.95 items/kg before the tourism season to 28.85 ± 31.97 items/kg after the season, based on 270 sediment samples collected from Sarayköy and nearby beaches. Statistical analysis confirmed that this increase was significantly influenced by time, beach cleaning frequency, and proximity to city centers (GLMM, time × cleaning frequency × proximity, $z = 6.596$, $p < 0.001$). Furthermore, seasonal population increases likely raise airborne MP concentrations, which in turn may exert additional pressure on the riverine systems discharging into the area (Kernchen et al., 2022). Therefore, this spatial variability in microplastic abundance may be further shaped by the hydrodynamic inputs of rivers emptying into the Southeastern Black Sea. Previous studies have shown that these rivers, particularly those flowing through areas with high population and industrial density, are major persistent sources of MP pollution in the region (Mutlu et al., 2024a; Terzi et al., 2025). Cetaceans that feed in near-coastal waters and exhibit opportunistic feeding behavior are top-level predators most likely to encounter MPs originating from these rivers. Therefore, variation in MP abundance observed among individuals may depend not only on biological factors but also on proximity to active MP discharge zones. Earlier studies investigating MP abundance in cetacean GITs across different locations consistently reported the presence of at least one MP particle in each individual (Xiong et al., 2018; Hart et al., 2022). Many studies have reported MP ingestion rates of nearly 100% in cetacean species from different regions (Zantis et al., 2021). Species studied include *Phocoena phocoena*, *Delphinus delphis*, *Stenella coeruleoalba*, and *Tursiops truncatus*. In our study, the presence of MP in all three cetacean species sampled in the Southeastern Black Sea corresponds to the highest detection range compared to global data and highlights the serious MP pollution in the region. Even before the attention to MP pollution, it was well established that large plastic debris negatively affected cetaceans either through ingestion or entanglement, often as a result of ghost fishing (Baulch and Perry, 2014). Although large debris and MPs may not pose the same mechanical risks, fragmentation driven by various environmental forces increases the risk of contaminant transfer. For instance, MPs can serve as vectors for persistent organic pollutants (POPs) and heavy metals, which may be indirectly ingested by dolphins. Some studies have identified a correlation between MP abundance and the concentration of phthalate esters in fin whales (Fossi et al., 2014, 2016; Baini et al., 2017).

MPs have been shown to be generally similar in size to the prey and forage organisms consumed by aquatic species (Jinhui et al., 2019). However, direct ingestion of MPs as food items by cetaceans is considered unlikely due to their small particle size (Lusher et al., 2015). Therefore, MP ingestion by cetaceans is most plausibly the result of accidental intake (Xiong et al., 2018) or trophic transfer through prey species (Lusher et al., 2018). The trophic transfer of MPs has previously been investigated and confirmed in predator-prey relationships, such as between grey seals (*Halichoerus grypus*) and Atlantic mackerel (*Scomber scombrus*) (Nelms et al., 2018). A similar mechanism has been suggested for cetaceans, with evidence from a study conducted in Northeast Asia showing that MPs can be transferred to cetaceans via the ingestion of contaminated prey fish (Jabeen et al., 2017). In the Southeastern Black Sea, the predominant prey species in the feeding regime of dolphins (especially *Delphinus delphis*) is anchovy (*Engraulis encrasicolus*). Studies on this species have confirmed the ingestion of microplastics by anchovies, suggesting that microplastics can be passed to top-level predators through trophic transfer (Gedik et al., 2023). In addition to anchovies, microplastics have also been detected in other benthopelagic cetacean diets, such as red mullet (*Mullus barbatus*) and whiting (*Merlangius merlangus*) (Eryaşar et al., 2022; Onay et al., 2023a). These species-specific findings strongly support the possibility that dolphins in the region are exposed to microplastics through contaminated prey species.

In general, the size of MPs found in the GITs of aquatic organisms is associated with the size of the organism's mouth opening. However, this phenomenon is less applicable to cetaceans, as MP ingestion in these species is largely attributed to accidental intake or trophic transfer. This mechanism also explains the presence of small-sized MPs observed in the present study. Considering a potential indirect trophic transfer pathway starting with copepods, the detection of small MPs becomes predictable (Domínguez-López et al., 2022). In addition to trophic transfer, incidental ingestion of microplastics through water filtration or during feeding has been increasingly recognized as a plausible exposure route for cetaceans. Cetaceans, particularly those feeding in nearshore areas similar to our study, may unintentionally ingest MPs suspended in the water column or associated with prey movement (Zhu et al., 2019). The presence of MPs in individuals with low stomach content further supports the possibility of non-dietary, passive exposure. Including this exposure route provides a more comprehensive understanding of MP accumulation mechanisms in marine mammals and highlights the ecological complexity of pollution pathways. Moreover, MPs have been shown to be generally similar in size to the prey and forage organisms consumed by aquatic species (Jinhui et al., 2019). Therefore, the observation of relatively larger MPs in the present study, compared to those reported in fish-based studies, may be explained by differences in prey size and feeding strategies specific to cetaceans.

Due to methodological limitations, it is not possible to precisely determine the specific sources of individual MPs. Therefore, characteristics such as color, type, and polymer composition of MPs can offer insight into their potential origins. In the present study, the proportion of fiber-type MPs was significantly higher than that of fragments. The most frequently observed colors were green, black, and transparent, with the majority of fragment MPs being transparent. Among aquatic organisms, ingestion of MPs based on color has been documented as a behavioral response (Okamoto et al., 2022). However, since MPs are considerably smaller than typical prey items for cetaceans, the observed color trends are more likely explained by trophic transfer mechanisms. In this context, the transparent exoskeletons of certain crustaceans may lead to smaller organisms ingesting transparent MPs under the assumption they are prey (Nadal et al., 2016). Furthermore, preference-based MP ingestion studies have reported that fish tend to favor transparent MPs (Klangnurak and Chunniyom, 2020). Another study demonstrated that, in the absence of food, fish ingested black-colored MPs, revealing a strong association between MP ingestion and color (Ory et al., 2018). The predominance of black and transparent MPs in grey seal (*Halichoerus grypus*) scat also aligns with the findings of the current study (Nelms et al., 2018). Regarding the relationship between incidental MP ingestion and MP color, it is important to consider that cetaceans in the southeastern Black Sea feed on a variety of fish species throughout the year. In addition, they have been known to attack fishing nets as an opportunistic feeding behavior (Mitchell, 1975; Balık, 2016). Since the cetaceans in this study were sampled outside of the official fishing season in Türkiye, it is likely that they attempted to feed by attacking set gillnets. Indeed, there have been previous reports of cetaceans becoming entangled in turbot gillnets in the southeastern Black Sea (Bilgin et al., 2018). These gillnets, typically used outside the regular fishing season, are often green in color to enhance fishing efficiency (Steinberg and Bohl, 1985). Furthermore, trawl codends are known to be constructed from highly durable green-colored materials. Therefore, we suggest that the high abundance of green-colored MPs observed in the present study may be linked to the incidental ingestion of plastic fibers resulting from cetaceans' interactions with such fishing gear.

Among the identified polymer types, PA was the most frequently observed. The high occurrence of PA in cetacean samples may be attributed to its extensive use as a primary polymer in fishing nets, thereby contributing to incidental MP ingestion (Cerbule et al., 2025). Nylon (PA) polymers are commonly utilized in gillnets due to their high durability, which makes them persistent in marine environments and a potential source of both ghost fishing and MP pollution (Standal et al., 2020). Another frequently detected polymer was PAN, which is mainly found in acrylic textiles and is introduced into aquatic environments via domestic wastewater, laundry effluents, and textile fibers (Adegbola et al., 2020; Khayyam et al., 2020; Plastic Europe, 2021). In the current study area, domestic wastewater is discharged into the sea through deep-sea outfall systems (Alkan et al., 2025). Consequently, MPs originating from domestic sources—particularly laundry effluents—may enter lower trophic level aquatic organisms and be transferred to higher trophic levels through trophic transfer mechanisms. Additionally, EVA is commonly used in packaging materials and auxiliary fishing gear such as buoys and floating devices (Silva and Masini, 2023). The presence of EVA in the samples reflects the extent of anthropogenic pollution in the region.

5 Conclusion

Although various studies have previously investigated MPs in the southeastern Black Sea, findings on MP abundance in cetaceans emphasize that these particles can be transferred not only through direct ingestion but also via trophic pathways. A critical consideration emerging from this study is the incidental ingestion of MPs by cetaceans during feeding activities, particularly when attacking fishing nets. The prolonged persistence of gillnets in the marine environment may serve as a significant contributor to MP abundance affecting aquatic organisms. Therefore, exploring the use of biodegradable materials could offer protection not only to lower trophic level marine species but also to top predators such as cetaceans. In addition, polymer composition analysis suggests that another major source of MPs in the region may be domestic wastewater discharged via deep-sea outfall systems. Future research should focus on the environmental distribution and ecological impacts of MPs in this biodiversity-rich region. In this context, awareness campaigns led by local governments and non-governmental organizations are essential to combat plastic pollution. Immediate measures must be implemented to safeguard aquatic and terrestrial biodiversity within the watershed, along with promoting adaptive management strategies to ensure long-term ecosystem and human health protection.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the study involving animals in accordance with the local legislation and institutional requirements because Because already dead cetacean (by-catch) were used. No need to take ethical approval for this study.

Author contributions

HO: Writing – review & editing, Investigation, Formal analysis, Conceptualization. AE: Formal analysis, Writing – review & editing, Methodology. MM: Data curation, Writing – original draft, Visualization. ME: Resources, Writing – review & editing. YC: Resources, Writing – review & editing, Supervision. TA: Resources, Writing – review & editing. BK: Writing – review & editing. GD: Writing – review & editing, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2025.1657648/full#supplementary-material

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