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Foraging Habit Determines the Amount of Microplastics Ingested in Five Fish Species from a Northern Adriatic Lagoon

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Abstract In this study we documented differences in the accumulation of microplastics (MP) in the gastrointestinal tract (GIT) of 5 commercially important lagoon fish species, also considering the concentration of MP in the water column and sediment of a lagoon in the Po River Delta (Northern Adriatic Sea). Two sampling campaigns were carried out in 2021 (spring and autumn), and a total of 201 fish were examined. MP contents in fish species varied widely, with ingestion frequencies ranging from 16% (*Atherina. boyeri*) to 92% (*Chelon ramada*). Polyethylene and polypropylene were the polymer types identified in GIT through µ-Raman spectroscopy. There were more fibers than fragments both in the water column and in sediments, but different relative proportions were found in the contents of the GIT of visually-oriented planktivorous and chemically-oriented benthivorous fish. In the detritivorous *Chelon ramada* a higher concentration of MP (with fibers in greater proportion) was found in comparison to planktivorous and benthivorous fish, probably as a consequence of their passive foraging. Our results indicate that the quantity of MP ingested seems to be more a function of the foraging habits of the species considered, rather than MP availability in the environment.

Keywords Fish fauna · Plastic ingestion · Po Delta lagoon · Northern Adriatic Sea

1 Introduction

The Northern Adriatic Sea is a shallow and very productive basin, characterized by large seasonal variations in environmental parameters which are strongly influenced by atmospheric forcing and river inputs (Russo & Artegiani, 1996). Main anthropogenic pressures include coastal pollution and eutrophication caused by the high nutrient loads (351,000 t y^{-1} of total nitrogen, 12,000 t y^{-1} of total phosphorus; Artioli et al., 2008) discharged particularly by the Po river. The Po river (654 km in length) has a catchment area of about 71,000 km^2 which includes almost all of northern Italy, with over 20 million inhabitants and many large cities (e.g. Turin, Milan), as well as areas of intense industrial and agricultural activities. The Po provides the largest contribution of continental waters to the Adriatic, with a daily average flow of 1500

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m^3 s^{-1} (Falcieri et al., 2014). A recent study highlighted how the Po river is also a major contributor of plastic waste to the Adriatic, with an estimated annual load of floatable plastic particles of 145 tons (Munari et al., 2021). Once at sea, plastic particles slowly degrade through a combination of photo-oxidation and mechanical abrasion, resulting in the production of microplastics (MP).

Fish and seafood contamination with MP is an emerging concern for global food security (Thiele et al., 2021), since MP ingestion has been demonstrated in a wide array of commercially harvested marine organisms (Dawson et al., 2021; Mercogliano et al., 2020). The ingestion of MP by fish is considered a relatively common phenomenon, as it seems that MP are mistaken for prey and then ingested (or ingested directly by prey already containing MP). A recent study has highlighted how some fish species caught in the Adriatic may contain MP in their digestive system (Mistri et al., 2022). Physical damage caused by ingestion of MP includes satiety, intestinal obstructions, oxidative stress, reduced growth and survival (Ding et al., 2021), while chemical damage is caused because MP are known to leach chemical additives and hazardous substances, including phthalates, bisphenol A, formaldehyde, and many others (Rochman, 2015).

The Sacca di Goro is a microtidal, coastal lagoon located in the southernmost Po Delta area (northern Adriatic Sea). The Sacca, which has a surface area of approximately 26 km^2, with an average depth of about 1.5 m, is spatially enclosed by a long natural sandbank, and receives freshwater from 2 of the 7 main branches that make up the Po delta system, the Po di Goro in its eastern part, and the Po di Volano in its western part. The Sacca therefore directly receives nutrients and pollutants, including plastics, carried by the Po River (Mistri et al., 2021). The Sacca di Goro is mainly renowned for clam farming, which occupies almost half of its surface, but it is also an important site for artisanal fishing, with ca. 1000 tons landed annually at the local fish market (Veneto Agricoltura, 2016). This study aims to provide insights into MP distribution in the most commercially important fish species caught in the Sacca di Goro. To evaluate the possibility that trophic level and feeding mode may influence the presence of MP in fish, 5 species with different ecological characteristics were analyzed in 2 different periods of the year characterized by a different contribution of water (and plastic particles) from the Po River.

2 Materials and Methods

2.1 Sampling Campaigns

Sampling was carried out in spring and autumn 2021 in the western part of the Sacca di Goro (44°48.408'N; 12°21.190'E). The area has an average depth of 0.6–1.0 m, and is characterized by the presence of "*barene*", i.e. sand banks covered by vegetation.

Surface sediment samples were collected at 4 sites along a E-W, 2 km-long transect, using a steel corer (diameter 15 cm). The uppermost 5 cm of the collected sediments were placed in 2 L glass jars, transported to the laboratory, and frozen at −20°C.

Floating MP samples were collected along the same transect using a Hydro-Bios Manta trawl (300 µm mesh). The manta trawl was released from side of the boat and floated on the water surface. Sampled water volumes were recorded with a mechanical flowmeter (Hydro-Bios model 438–110). Trawling was carried out along the whole transect at an approximate speed of 2 knots. After each tow (Ntow = 4), the manta net was lifted on board and thoroughly rinsed with seawater from the exterior and from the net mouth towards the cod-end. The material retained in the cod-end was then transferred in 2 L glass jars and transported to the laboratory.

For fish sampling, a "*reda*" was used (Fig. 1). It is a barrier net (with a 6 mm mesh), 1.5 m high and 40 m long, placed perpendicular to the coastline, held in place by wooden poles driven into the lagoon bed at a distance of approximately 2 m from the other. At the end of the net there is a conical net trap, the so-called "*bertovello*", which prevents the fish from escaping. Being placed on the bottom, and intercepting the entire water column, this net is traditionally used for catching both benthic and pelagic fish. The net was positioned approximately halfway along the 2 km long transect, and was kept fishing for 24 h, after which the fish trapped in the *bertovello* were collected. Individuals of the 5 most commonly caught fish species were anesthetized by immersion in ice water, and immediately taken to the laboratory. Fish considered in this study were anchovies (*Engraulis*

Fig. 1 The fishing gear used for sampling fish fauna: the *reda* with the *bertovello* at its end. One end of the net is fixed to the *barena*, and the net is laid out perpendicularly to it, to intercept the passing fauna. Attempting to escape, fishes get trapped in the *bertovello*, where are finally collected by the fishermen

encrasicolus), sandsmelts (*Atherina boyeri*), flounders (*Platichthys flesus*), grass gobies (*Zosterisessor ophiocephalus*), and thinlip grey mullets (*Chelon ramada*).

2.2 Laboratory Procedures

At the laboratory, sediment samples and floating MP samples were sieved on a 5 mm stainless steel sieve to separate MP (< 5 mm) from meso/macroplastics (> 5 mm) and biological debries (shells, plant debries, fragments of leaves, twigs). The MP fraction was subjected to wet peroxide oxidation (Masura et al., 2015) using 30% hydrogen peroxide to remove small residues of organic matter. The resulting solutions were filtered under vacuum on GF/F fiberglass filters (0.7 µm). Filters were rinsed with deionized water and then sealed in Petri dishes. Meso/macroplastics were visually identified with the naked eye, while MP were visually identified under a dissection microscope (Nikon SMZ45T, magnification 3.35-300x), following GESAMP (2019) guidelines. Plastic particles were categorized according to shape. Plastic particles in sediment were reported as items kg^{-1}, while floating plastic particles were reported as items m^{-3}.

Total body length (TL, mm), and body weight (W, g) were measured for each fish. Each specimen was dissected to remove the whole gastrointestinal tract (GIT), according to Lusher et al. (2013). GITs were weighted and frozen at −20°C, until the analyses. For MP extraction, the procedure of Avio et al. (2015) and Bour et al. (2018) was followed. Each GIT was transferred to 250 ml glass beaker and filled with 100 mL of a 10% potassium hydroxide (KOH) solution. Samples were incubated at 50 °C for the necessary time (36 h for the smaller species, up to 96 h for mullets) to ensure the digestion of the GIT. The MP were collected from the digests by density-floating method: each sample was added to 250 ml NaCl hypersaline solution (d≈1.2 g cm^{-3}; NaCl was calcinated at 700 °C for 3 h to remove any trace of MP), stirred and decanted for 10 min. Then a first aliquot of supernatant was collected. This resuspension step was carried out twice. The supernatant of each resuspension was collected in a glass beaker and filtered under vacuum on GF/F fiberglass filters (0.7 µm). Filters were rinsed with 5 mL of filtered deionized water and 5 mL of hexane, and then sealed in Petri plates.

Filters were then stained by 1 mL of Nile red (9-diethylamino-5H-benzo[α]phenoxazine-5-one; Acros Organics) solution (10 µg mL^{-1} in hexane) in 5 cm closed Petri plates for 30 min as in Maes et al. (2017), and the excess dye was removed filtering 5 mL of hexane and then 5 mL of a mixture of 3 alcohols (4.50 mL ethanol, 0.25 mL methanol, 0.25 mL isopropanol) to remove background staining. The MP were counted under a Nikon SMZ745T stereomicroscope (equipped with a 10 W blue LED and an orange photo filter). The images were recorded with a Nikon C-Mount TP5100 digital camera and processed by Alexasoft X-Entry to identify size.

All necessary precautions were adopted to minimize contamination while handling and processing the samples: cotton lab coats and nitrile gloves were worn in the laboratory, all solutions (tap water included) were filtered by GF/F fiberglass filters (0.7 µm), all the glassware was accurately rinsed at least two times, and the samples were capped with aluminum foil and glass caps during the identification and analysis to avoid airborne contamination. Quality control blanks were conducted during the extraction process (a clean filter left out during dissection and filtering processes), and the visual sorting (a clean filter left out for the duration of visual inspection at microscope), to check for airborne contamination in the laboratory.

µ-Raman spectroscopy was used to verify the identity of fluorescing particles found on a subsample of filters (n = 20, 4 filters for each species) from the spring campaign. Only filters were analyzed, since the study was not intended to monitor the polymeric composition of plastics in the environment (see Mistri et al., 2021), but to verify that the particles stained by Nile red were actually plastics, as it is reported that Nile red can also bind to other macromolecules (Jana et al., 2013). The μ-Raman spectroscopy was carried out with a LabRam HR800 spectrometer (Horiba) with a focal length of 800 mm, equipped with a digital camera and coupled with an Olympus BXFM optical microscope. The spectrometer was equipped with air-cooled CCD detector (1024 × 256 pixels) set at −70 °C, and, with 600 grooves/mm grating, was used to send the collected signals to the detector. The excitation source was a He–Ne laser (632.8 nm line) with a maximum laser power of 17 mW, controlled over the sample using ND filters. The Raman spectra were recorded in the range of 100–4000 cm-1 with an exposure time varying between 5–20 s and 7–15 accumulations. Exposure time, beam power and accumulations were optimized for each sample to obtain informative spectra while avoiding alteration of the sample. The wavelength scale was calibrated using a silicon standard (520.5 cm^{-1}) and the acquired spectra were handled with LabSpec 6 software and compared with BioRad spectral database using KnowItAll spectroscopy software, and scientific published data, with a minimum library match of 70% was considered sufficient for a validation. 38.4% of all particles were validated using Raman analysis, which is deemed sufficient for reliable confirmation by Thiele et al. (2021). According to Tamminga et al. (2017), Nile red staining can interfere with u-Raman signals so particles on each selected filter were photobleached (8.50 mW for 10 min) before the acquisition of spectra. All the particles analyzed were found to be plastic.

2.3 Statistical Analysis

Any statistically significant differences in MPs concentration in the environment (water and sediment), in fish, and between seasons were tested by permutational multivariate analysis of variance (PERMANOVA; Anderson & Gorley, 2008) using Euclidean distances to calculate the similarity matrices. PERMANOVA was performed using the "unrestricted permutation of raw data" (number of permutations: 9999). P-values have been obtained through Monte Carlo random draws (P(MC)) from the asymptotic permutation distribution (Anderson & Robinson, 2003). All statistical analyses were performed using PRIMER v6 software package (Clarke & Gorley, 2006), including the PERMANOVA + add-on package (Anderson & Gorley, 2008).

3 Results

3.1 Plastics in the Environment

In the spring campaign, a total of 141 floating MP particles were recovered, of which 75.2% were fibers, and 24.8% were fragments. The concentration of MP particles resulted in 0.127 items m^{-3} (± 0.062 SD). A total of 18 meso/macroplastics were also recovered, 100% of which were transparent films (concentration: 0.0015 ± 0.0006 items m^{-3}). In the autumn campaign, the number of floating MP particles recovered was 303, of which 65.3% were fibers, and 34.7% were fragments (0.346 items m^{-3} ± 0.099 SD). Meso/macroplastics were 26 (46.4% fibers, 53.6% fragments), with a concentration of 0.032 ± 0.01 items m^{-3}.

In the sediment, in the spring campaign a total of 514 MP particles were recovered, of which 52.5% were fibers, 41.4% fragments, 5.3% films and 0.8% pellets. The concentration of MP particles resulted in 128.5 items kg^{-1} (± 63.4 SD). A total of 50 meso/macroplastics were also recovered, 48% of which were fragments, 24% films, 22% fibers, and 6% pellets (concentration: 12.5 ± 8.38 items kg^{-1}). In the autumn campaign a total of 536 MP particles were recovered (56.5% fibers, 38.3% fragments, 5.2% films; 134.0 ± 47.2 items kg^{-1}). Meso/macroplastics were 19 (42.1% fibers, 57.9% fragments), with a concentration of 4.8 ± 2.2 items kg^{-1}.

The concentration of MPs between water and sediments differed in a statistically significant way (P(MC) = 0.0026), in both seasons (spring: P(MC) = 0.03; autumn: P(MC) = 0.055). The concentration of floating MPs in the water was significantly higher in autumn (P(MC) = 0.012), likely due to the different flow of continental water in that season (Munari et al., 2021).

3.2 Plastics in the Biota

The fish belonging to the 5 species differed in terms of size and weight, according to their biological characteristics. Anchovies and sandsmelts exhibited similar, smaller body sizes compared to the other species, whereas thinlip grey mullets showed the largest specimens. In spring, a total of 106 fish were examined (25 anchovies, 25 sandsmelts, 24 flounders, 20 gobies, and 12 mullets), 37 of which were found to contain MP in their GIT (meso/macroplastics were not found in any specimen). In autumn, the number of fish examined was 85 (10 anchovies, 25 sandsmelts, 10 flounders, 25 gobies, and 15 mullets), 34 of which contained MP (meso/macroplastics were not found in any specimen). In Table 1, the total number of fish examined per species, feeding group (following the classification of Franco et al., 2008), average length (cm), body and GIT weight (g), number of fish positive to MP, ingestion frequency, and average number of MP particles per positive fish are shown. MPs in fish ranged in size between 0.151 and 0.802 mm. Fibers were found in the GIT extracts, but, as they did not show any fluorescence after Nile red staining (Fig. 2, red arrows), they were not considered. Figure 3 shows, for the samples in Fig. 2, the acquisition spectra and their matching with the database spectra.

Concerning the shape, in spring, of the 216 plastic particles found in GIT, fragments (52.8%) were found slightly more frequently than fibers (47.2%). In autumn, on the contrary, fibers (53.2%)were found with a slightly higher frequency than fragments (46.8%). Regarding the frequency of shape types in the examined GITs there were some differences depending on the species: flounders and sandsmelts generally showed a higher content of fragments than fibers, while grey mullets a higher content of fibers than fragments. Figure 4 shows the distribution of fibers and fragments found in GITs by fish species. Of the 83 particles analyzed with μ-Raman spectrometry, 61.5% were identified as polyethylene, 38.5% as polypropylene, confirming the observation that these two polymers are those most present in the Sacca (Mistri et al., 2021).

Table 1 Number of fish examined per species and season, functional group (FG), average length, body and GIT weight, number of fish positive to MP, ingestion frequency, and average number of MP particles per positive fish (BE = benthivorous; DV = detritivorous; PL = planktivorous)

Season	Species	FG	N	Avg length (cm)	Avg weight (g)	Avg GIT weight (g)	Individuals postive to MPs	Frequency of ingestion (%)	Avg MPs per positive individual
Sp	*Platichthys flesus*	BE	24	14.1 ± 2.4	25.8 ± 14.3	1.3 ± 1.2	9	38	3.3 ± 1.3
	Zosterisessor ophiocephalus	BE	20	12.4 ± 1.0	25.9 ± 7.5	0.7 ± 0.2	8	40	2.8 ± 1.8
	Chelon ramada	DV	12	35.7 ± 3.6	345.3 ± 69.3	35.9 ± 5.9	11	92	13.2 ± 7.9
	Engraulis encrasicolus	PL	25	9.8 ± 0.7	5.2 ± 1.1	0.2 ± 0.04	5	20	2.4 ± 1.5
	Atherina boyeri	PL	25	7.1 ± 4.7	4.4 ± 1.5	0.2 ± 0.2	4	16	1.7 ± 1.5
Au	*Platichthys flesus*	BE	10	15.1 ± 1.8	29.5 ± 8.8	1.4 ± 0.6	5	50	2.6 ± 0.5
	Zosterisessor ophiocephalus	BE	25	12.3 ± 1.8	24.3 ± 7.7	0.8 ± 0.1	6	24	2.0 ± 0.9
	Chelon ramada	DV	15	32.7 ± 3.3	320.8 ± 48.3	31.6 ± 6.1	12	80	11.8 ± 4.7
	Engraulis encrasicolus	PL	10	10.9 ± 1.8	6.1 ± 0.4	0.2 ± 0.1	3	30	1.4 ± 1.3
	Atherina boyeri	PL	25	8.3 ± 3.5	4.9 ± 1.1	0.19 ± 0.1	8	32	1.5 ± 0.5

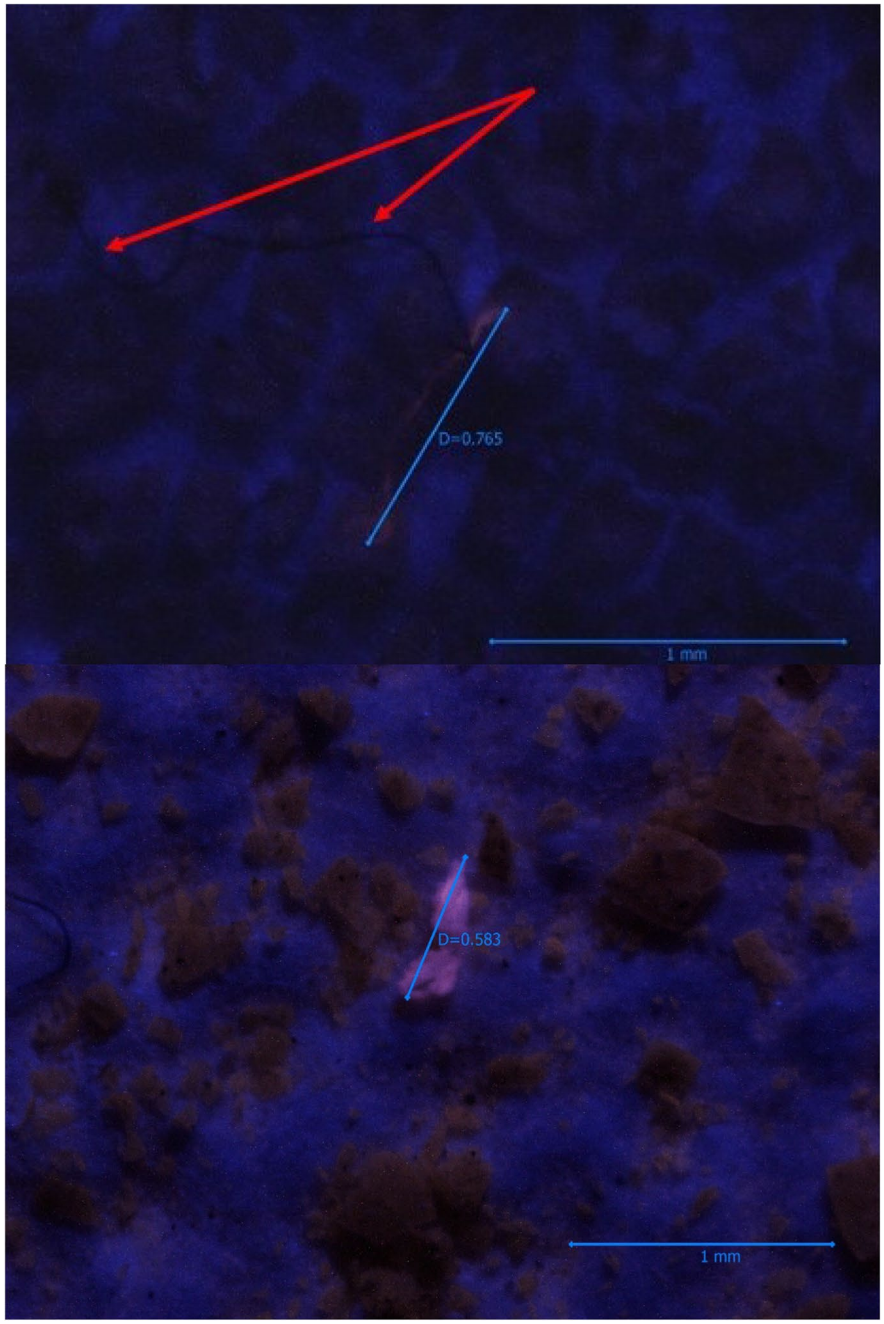

Fig. 2 Top: MP fiber from GIT stained with Nile red (*C. ramada*, specimen #8; autumn); the red arrows indicate a fiber that does not fluoresce with Nile red, and is therefore not plastic. Bottom: MP fragment as above (*C. ramada*, specimen #1; autumn)

The PERMANOVA design incorporated 2 factors, i.e. "season" (2 fixed levels), and "fish species" identity (5 fixed levels). There were significant differences in the quantities of MPs ingested by different fish species (P(MC) = 0.0001). Table 2 shows the result of the pairwise tests within the factor "fish species": grey mullets (detritivorous) ingested significantly more MPs than other species, while flounders (benthivorous) had more MPs than sandsmelts (planktivorous).

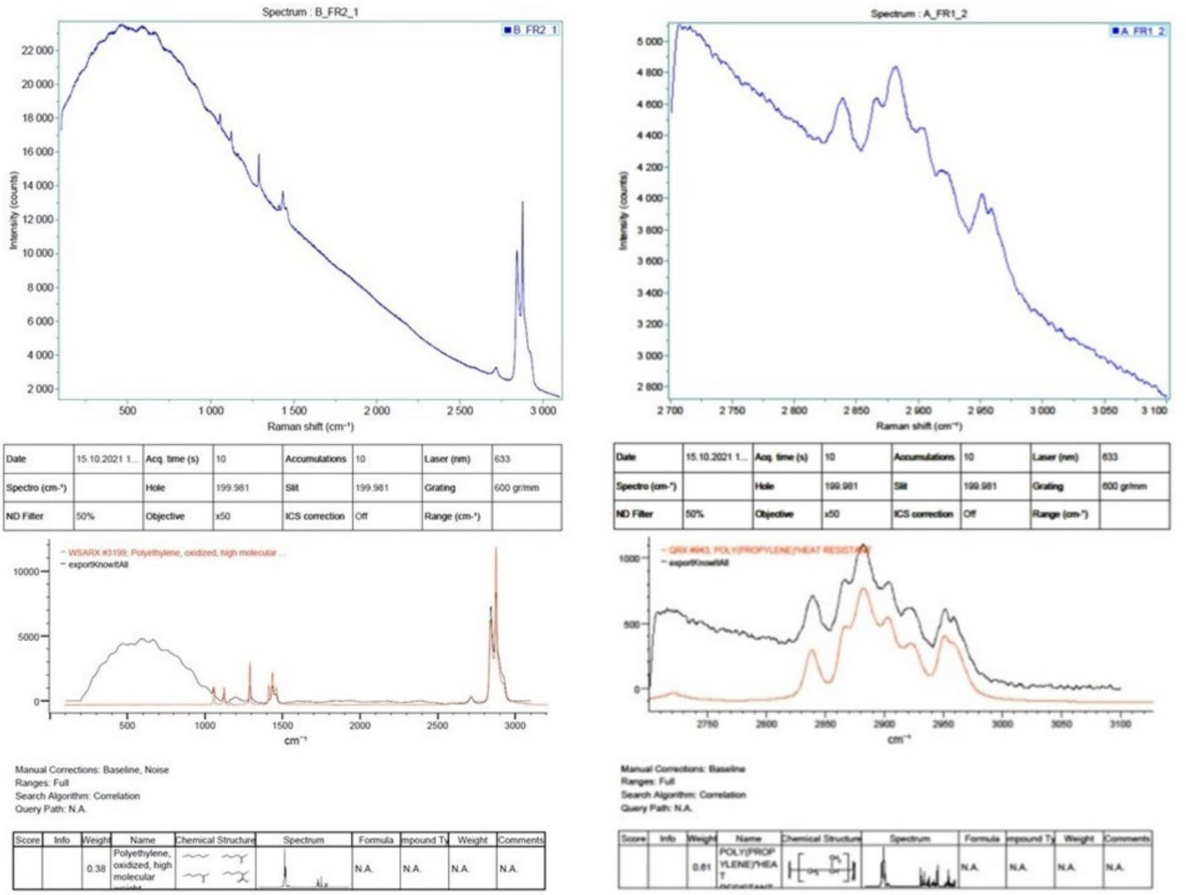

Fig. 3 Top: sample spectrum with corresponding acquisition parameters; bottom: sample spectrum overlaid with the matching database spectrum. Left: PE fiber (*C. ramada*, specimen #8; autumn); right: PP fragment (*C. ramada*, specimen #1; autumn)

Fig. 4 Mean amount of fibers and fragments found in GITs by species (bars are standard deviation)

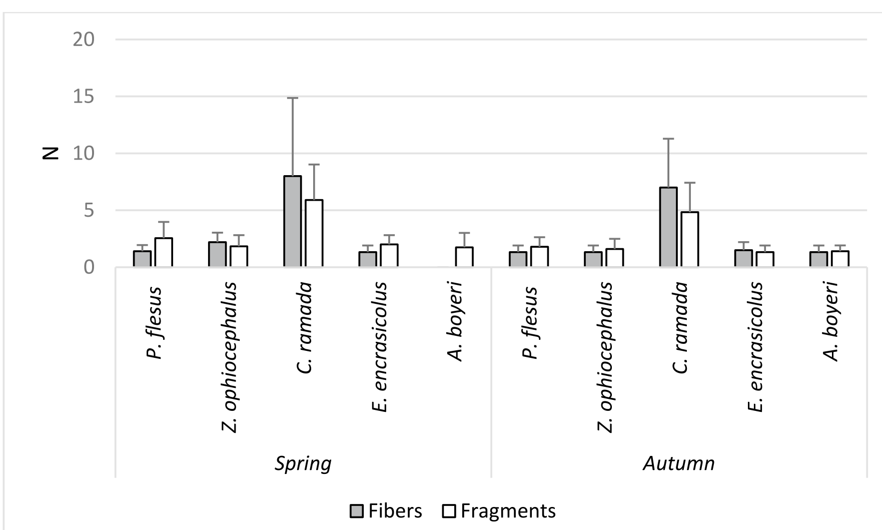

Table 2 Pairwise tests within the factor "fish species"; statistical significance is in bold (PF: *Platichthys flesus*; ZO: *Zosterisessor ophiocephalus*; EE: *Engraulis encrasicolus*; AB: *Atherina boyeri*; CR:*Chelon ramada*)

Groups	t	P(perm)	Unique perms	P(MC)
PF, ZO	1.143	0.271	9792	0.258
PF, EE	1.107	0.286	9701	0.287
PF, AB	3.402	0.003	9798	0.003
PF, CR	5.333	0.0001	9833	0.0001
ZO, EE	0.013	0.989	9777	0.990
ZO, AB	1.517	0.152	9658	0.144
ZO, CR	5.740	0.0001	9828	0.0001
EE, AB	1.628	0.123	9536	0.122
EE, CR	4.259	0.0002	9841	0.0002
AB, CR	5.576	0.0003	9827	0.0001

4 Discussion

This study presents data on the presence of MP in fish species representative of different feeding modes and trophic levels within a brackish lagoon. A first result of this study is that MP were found, albeit in different amount, in every species analyzed, providing further evidence for the widespread MP contamination in the aquatic biota. We found that MP contents in fish species varied widely, with ingestion frequencies ranging from 16% (*A. boyeri*; spring) to 92% (*C. ramada*; spring), partially reflecting results from the literature (Table 3). However, the different extraction methods used in the various studies reported in the Table make a direct comparison between different species risky. For example, the separation method utilized in our study does not allow the collection of e.g. polyester, whose density (1.23—1.38 g cm^{-3}) is higher than that of the NaCl solution we used (≈1.2 g cm^{-3}). However, among the so called "big six" polymers (Paul-Pont et al., 2018), five of them can be collected with NaCl hypersaline solution (Bour et al., 2018). It is therefore possible that we underestimated the MP content.

The influence of habitat on MP content in fish appears ambiguous. Despite the higher MP concentrations observed in sediments compared to the water column, both planktivorous and benthivorous fish showed similar MP loads in their GITs, indicating that feeding strategy or trophic behavior might play a stronger role than habitat in determining exposure. Recent studies (Cimmaruta et al., 2022; Filgueiras et al., 2020; Güven et al., 2017; Lefebvre et al., 2019; Neves et al., 2015) indicate that the amount of MP ingested by fish seems to be more related to the degree of plastic pollution in the environment, and consequently to their availability, rather than to the feeding habits or trophic levels of the fish considered. The results of the present study seem to slightly differ: the higher the concentration of MP in the environment, the greater the possibility that MP will be ingested by fish, however the quantity of MP ingested seems to be more a function of the foraging habits of the species considered, rather than MP availability in the environment. Bour et al. (2018) suggest that MP ingestion may vary by feeding strategy: MP can enter fish through accidental or deliberate ingestion (if the fish mistakes the particle for prey), or transfer through the food chain. Fibers likely have an additional route of entry into fish, as they can be sucked into the mouth of fish when they breath (but in this case they would accumulate preferentially on the gills rather than in the GIT). Most planktivorous fish species have well-developed eyes and rely on vision to find food, while many benthivorous fish species, in addition to vision, also have chemosensory capabilities to distinguish edible from inedible food items (Juanes et al., 2002). In this study we identified differences in MP ingestion by different fish species, but this pattern cannot be explained only considering the different habitat use of the species analyzed. In terms of ecological and feeding strategies, the species selected for this study include pelagic and demersal species. *A. boyeri* and *E. encrasicolus* feed on zooplankton (and in turn also represent the main prey of several pelagic predators, such as large fish and seabirds; Lopes et al., 2020), *P. flesus* and *Z. ophiocephalus* are carnivores that prey on zoobenthos such as annelids, molluscs, crustaceans and insect larvae, while *C. ramada* is basically detritivorous, swallowing the surface layer of sand and mud from which it retains plant organisms (unicellular algae and filamentous algae), but the diet can be integrated with benthic invertebrates (Scapin et al., 2019). It follows that foraging activity and prey choice is predominantly passive in *C. ramada*, and predominantly active in the other species considered. The higher concentration of plastic particles found in grey mullets may be a consequence of their passive foraging. In fact, although we found the concentration of plastic particles in the Sacca to be higher in the sediments than in the water column, the content

Table 3 Functional groug (FG), concentrations of microplastics (MP), frequency of ingestion and predominant MP type in fish species from the Mediterranean (PL = planktivorous; PV = piscivorous; BE = benthivorous; HE = herbivorous; OM = omnivorous; DV = detritivorous)

Species	FG	MP content (item ind^{-1})	Frequency of ingestion (%)	Predominant MP type	Ref
Sardina pilchardus	PL	1.77 ± 1.42	87	fibers	[1]
Engraulis encrasicolus	PL	1.25	91	fibers	[2]
Trachurus trachurus	PV	1 ± 0	10	fragments—films	[3]
Coryphaena hippurus	PV	3.9	65	fibers- fragments	[4]
Merluccius merluccius	PV	1.38	27	fibers	[5]
Diplodus vulgaris	BE	1 ± 0	29	fragments—fibers	[3]
Mullus barbatus	BE	1.5 ± 0.3	32	fragments	[6]
Mullus surmuletus	BE	1.56 ± 0.53	60	fibers	[1]
Solea solea	BE	1.73 ± 0.05	95	fragments	[7]
Sparus aurata	BE	7.3 ± 6.6	100	fibers	[8]
Lithognathus mormyrus	BE	1.88	35	fibers	[9]
Scomber scombrus	BE/PV	1.3 ± 0.5	70	fragments—films	[3]
Pagellus erythrinus	BE/PV	2.1 ± 1.6	50	fibers	[8]
Galeus melastomus	BE/PV	0.1	8	fibers	[10]
Chelidonichthys lucerna	BE/PV	1.3 ± 0.5	44	fragments—films	[3]
Gobius paganellus	BE/PV	0.93 ± 1.23	47	fibers	[11]
Dicentrarchus labrax	BE/PV	0.22 ± 0.53	18	fibers	[12]
Diplodus annularis	BE/HE	2.85	69	fibers	[9]
Spondilosoma cantharus	OM	1 ± 0	55	fragments—fibers	[3]
Boops boops	OM	1.8 ± 0.2	56	fibers	[13]
Chelon auratus	DV	9.9 ± 8.1	95	fibers	[8]

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of MP in the 2 benthivorous species was quite similar to that of the 2 planktivorous species. The proportion of MP fibres and fragments was different in the water column than in planktivorous fish. In the water column, fibres were more numerous than fragments but, in GITs, there were generally more fragments than fibers. However, Ory et al. (2018) found that the visually-oriented planktivorous *Seriolella violacea* (Centrolophidae) was more susceptible to capture MP resembling or floating close to the planktonic prey, and MP not directly targeted by the fish may be swallowed when captured accidentally together with food. These results could support the hypothesis that the planktivorous (and perhaps the benthivorous) species we considered in this study ingested more fragments than fibers because fragments more closely resembled their prey, or where captured accidentally during foraging activity.

This study adds to the evidence that fish contamination by MP is a widespread phenomenon, not only in the sea but also in coastal transitional environments. The results of this study, although based on a limited number of fish species, lead to the hypothesis that, at least in the brackish lagoon considered, the MP content in fish is more dependent on feeding mode than on MP concentrations in the environment.

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Data Availability All data generated or analyzed during this study are included in this published article. Furthermore, the data supporting this study's findings are available on request from the corresponding author, [Mistri M].

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of interest The authors declare that they have no conflict of interest.

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