Science of the Total Environment 658 (2019) 62–68

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Microplastic pollution in the Maowei Sea, a typical mariculture bay of China

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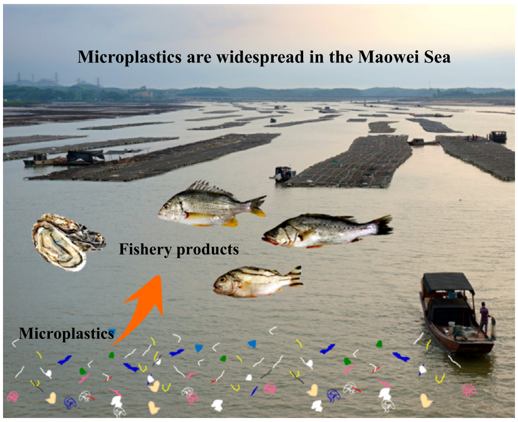
HIGHLIGHTS

- Microplastics are widespread in the Maowei Sea, a typical mariculture bay
- Microplastic abundance in the Maowei Sea is comparable to that in inflowing rivers
- The gastrointestinal tract has more microplastics than the gills in many fish species.
- Microplastics were also detected in the soft tissue of all oyster samples.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 17 October 2018
Received in revised form 11 December 2018
Accepted 12 December 2018
Available online 13 December 2018

Editor: Damia Barcelo

Keywords:
Maowei Sea
Microplastics
Surface water
Fishery products

ABSTRACT

The ingestion of microplastics by organisms presents a potential exposure route for humans via seafood consumption. Although mariculture has become an essential source of seafood worldwide, the content of microplastics in the mariculture zone has received less scrutiny than in the wild environment. The Maowei Sea is a semi-closed bay that is rich in fishery resources. The specific levels of microplastics in the Maowei Sea and its fishery products remain undetermined. In this paper, we detail the distributions and characteristics of microplastics in the aquaculture water and biota of the Maowei Sea. Microplastics were detected in the range of 1.2–10.1 particles/L in Maowei Sea surface water, with high microplastic content in estuarine oyster nursery (10.1 particles/L) and Qinzhou harbor (8.8–9.5 particles/L) sites. In water samples from the three inflowing rivers, the abundances ranged from 2.9 to 4.5 particles/L, which is comparable to that in Maowei Sea surface water. Of 66 collected fish belonging to 12 species, microplastics were observed in all of the gastrointestinal tracts (GITs) and in the gills of 40 individuals. In the GIT and gill tests, the abundances of microplastics ranged from 2.0 to 14.0 and from 0.0 to 8.5 particles/individual, respectively. The enhanced particles/individual figures in the GIT relative to the gill are particularly noteworthy. Demersal species showed significantly higher abundances of microplastics than pelagic species ($p < 0.05$). Microplastics were also detected in the soft tissues of all oyster samples, with abundances ranging from 3.2 to 8.6 particles/individual. The microplastic composition was dominated by

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https://doi.org/10.1016/j.scitotenv.2018.12.192

rayon and polyester and tended to be white in color and fibrous in shape. Altogether, these results correspond to high levels of microplastics in the Maowei Sea. As the study region is a mariculture bay, the observed microplastics contamination in its fishery products presents a route for human exposure.

Capsule abstract: Microplastics are widespread in the aquaculture water and biota in the Maowei Sea, a mariculture bay.

1. Introduction

In recent years, microplastics have been recognized as emerging pollutants of concern. Microplastics are defined as small plastic pieces <5 mm in length (GESAMP, 2015). It has been reported that microplastics are present in all types of environments around the world, from marine to fresh water (Law et al., 2014) and from loci of human activities to pristine places (Hirai et al., 2011). Ingestion of microplastic debris is a potential environmental risk to organisms (Desforges et al., 2015; Wright and Kelly, 2017), and microplastics have been detected in >2000 marine species (Jabeen et al., 2017; Devriese et al., 2015; Lusher et al., 2015; https://litterbase.awi.de/interaction_detail; date accessed: December 2018), including organisms intended for human consumption such as fish and crustaceans, which provide an exposure route for humans via seafood consumption (Van Cauwenberghe and Janssen, 2014; Rochman et al., 2015). Marine aquaculture (mariculture) has rapidly expanded over the past two decades and become an essential source of seafood worldwide (Bouwman et al., 2013). Maricultured fish are also considered to be of higher quality and offer more diverse options in terms of species choice than fish raised in tanks or ponds. However, the microplastics content in the mariculture zone has received much less attention than that in the wild environment.

China has the largest mariculture zone, and many native and introduced marine species have been successfully cultivated along China's 18,400 km of coastline (Liu and Su, 2017). In 2014, China accounted for >60% of global marine fish production (FAO, 2016). Microplastic pollution has been reported in near- and offshore environments along the coastline of China in recent years, including the Bohai Sea (0.33 ± 0.34 particles/m^3; Zhang et al., 2017), the Yellow Sea (0.33 ± 0.28 particles/m^3, Wang et al., 2018a), the Pearl River Estuary (2.4–8.6 particles/L; Li et al., 2018a), the Three Gorges Reservoir (1597–12,611 particles/m^3; Di and Wang, 2018), and Taihu Lake (3.4–25.8 items/L; Su et al., 2016). Microplastics have also been detected in many fishery product samples taken from China's supermarkets and coastal waters, including fish and bivalves (Li et al., 2015, 2016; Jabeen et al., 2017). Li et al. (2016, 2018b) compared the microplastics in farmed and wild mussels from China and the United Kingdom and found that more debris was detected in wild mussels than in farmed mussels. Cheung et al. (2018) also found that wild mullets from off the eastern coast of Hong Kong have a higher risk of microplastic ingestion than their captive counterparts. However, a recent study on Xiangshan Bay indicated that mariculture-derived microplastics accounted for 55.7% of the microplastics in seawater (Chen et al., 2018). It is urgent that mariculture-derived microplastics and their effects on cultured seafood be investigated.

To assess microplastics in the mariculture zone and their distribution in fishery products, the Maowei Sea, a semi-closed bay in the northwestern part of the Beibu Gulf, South China Sea, was investigated. (Fig. 1). The Maowei Sea is fed by the Qin, Dalan, and Maoling rivers and connects to the Beibu Gulf by a narrow channel. The Maowei Sea is rich in fishery resources, including various species of fish and shellfish. It also encompasses wetlands and natural mangroves along the shoreline (about 2784 hm^2) (Wang et al., 2017). Rapidly expanded mariculture and peripheral industrialization have resulted in numerous environmental impacts in the bay over the past few decades, including frequent occurrences of eutrophication and harmful algal blooms and heavy metal contamination in the Maowei Sea (Wu et al., 2014; Zhang et al., 2014; Liu et al., 2015). Although plastic pollution, including a high loading of mariculture waste, is another important issue in the Maowei Sea, to our knowledge no study on microplastic pollution has been performed to date in this area. To address this gap in the literature, in this paper we detail the distributions and characteristics of microplastics in the aquaculture water and biota of the Maowei Sea.

2. Materials and methods

2.1. Sample collection

Sample collection was carried out on October 11, 2017. Although there was no rain that day, it had rained the previous 2 days. As the inner bay in the northwestern part of the Maowei Sea is filled with sinking mattresses, the sampling boat could not enter it. The geographic locations of the sampling sites are given in Fig. 1. Microplastics in the surface water were collected from the Maowei Sea (S_1–S_{20}) and its three inflowing rivers (R_1–R_3). As a result of the numerous floating and sinking oyster mattresses across the Maowei Sea, it was impossible to tow a trawl net across many sites. A total of approximately 5 L of surface water samples was collected using a stainless-steel sampler, with three replicates taken separately at each sampling site (Qu et al., 2018). Different types of fish and oysters (*Crassostrea hongkongensis*) were acquired from local fishermen in October 2017 and frozen prior to analysis.

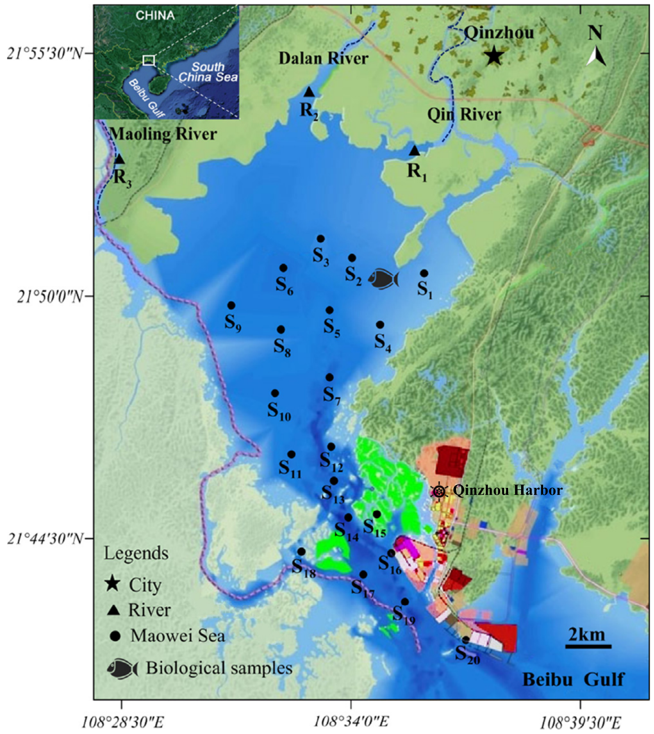

Fig. 1. Geographic position of sample sites in the Maowei Sea (S_1–S_{20}) and inflowing rivers (R_1–R_3).

2.2. Isolation of microplastics

To avoid contamination, all solutions, e.g., tap water and potassium hydroxide, were filtered through a 5-μm pore size filter membrane prior to use. All glassware and stainless-steel containers were rinsed three times with filtered tap water (Yang et al., 2015; Jabeen et al., 2017). The samples were covered with lids or tinfoil immediately after collection to avoid contamination from airborne microplastics. Five negative controls without samples were performed in the experimental design.

Water samples were filtered onto a 47-mm diameter filter membrane with a 20-μm pore size (Millipore NY2004700) using a vacuum system following the methodology used in Su et al. (2016). Material collected on the filter was washed into a glass jar that was then filled with a 10% KOH solution (analytical reagent grade, Sinopharm Chemical Reagent). The jars were incubated at 40 °C and stirred for 48–72 h at 80 rpm. Digestates were filtered onto 47-mm diameter filter membranes with a 5-μm pore size, and the filter membranes were then placed in clean Petri dishes with lids and dried at room temperature for further examination.

The body length and weight of each biota sample were recorded before dissection. The gastrointestinal tract (GIT) and gills of the fish and the soft tissue of the oysters were dissected, weighed, and digested in 10% KOH solution (Xiong et al., 2018; Jabeen et al., 2017). In the fish, the GIT and gill of each individual were separated and used as respective replicates. We collected 20 *Crassostrea hongkongensis* individuals and divided the group into five replicates, with the soft tissues of four oysters employed as one replicate. The amount of KOH added was at least three times the volume of the biological material (Foekema et al., 2013). The jars were incubated at 40 °C and stirred for 48–96 h at 80 rpm until complete dissolution of the organic material was observed (Karami et al., 2017). The digested liquids were filtered through a 5-μm pore size filter membrane using a vacuum system. All substances, together with the filter membranes, were stored in clean Petri dishes with lids for further examination.

2.3. Observation and validation of microplastics

The filter membranes were observed under a Cnoptec SZ680 stereo microscope (Chongqing, China), with all images taken using an AxioCam digital camera. The morphotypes of microplastics were identified using visual assessment according to the physical characteristics presented in Hidalgo-Ruz et al. (2012). A number of conventional plastic-like and indeterminate particles were selected and verified using a micro-Fourier transformed infrared spectroscope (μ-FT-IR, Thermo Nicolet iN10 MX) in transmittance mode. Each spectrum was directly compared with the library of polymers provided by Thermo Fisher Scientific in their software (OMNIC Picta) following the methods of Vianello et al. (2013). Any spectrum that could be matched with a quality index of >60% was accepted (Yang et al., 2015). A total of 158 out of 1723 particles were identified, with 73% of the plastic-like particles confirmed as plastics. The final amount of microplastics was revised by removing the verified non-plastic particles (Su et al., 2016).

2.4. Data analysis

Using standard propagation of error methods, the abundance of microplastics in water (three replicates per site) was expressed as average particles per liter ± SEM (Bevington and Robinson, 2003). The abundance of microplastics in the biota samples (3–16 individuals per species) was expressed as average particles per individual and per gram of digested tissue, respectively, ±SEM. Statistical analyses were performed using SPSS and GraphPad Prism. All data were tested for normality of distribution, with the non-normal data processed using a logarithmic transformation. Differences in the abundances and characteristics of microplastics were determined using one-way analysis of variance (ANOVA) with Dunnett Testing. Independent sample *t*-testing was used for two-group comparison and a linear regression analysis was used to determine the relationship between the microplastic levels in the fish GITs and gills.

3. Results

3.1. Microplastic pollution in water

Contamination was prevented during handling the samples, only 0.5 ± 0.2 particles was detected in the procedural blank samples, which may be induced by the airborne microplastics (Dris et al., 2015; Prata, 2018). The reported abundance was corrected by the procedural blank data. Microplastics were detected in all 23 water sample sites from the Maowei Sea and its inflowing rivers (Fig. 2). The spatial distribution of microplastics in the Maowei Sea showed significant variation, with abundances ranging from 1.2 to 10.1 particles/L (average: 4.5 ± 0.1 particles/L). High numbers of microplastics were observed in the estuarine oyster nursery (S_2: 10.1 particles/L) and Qinzhou harbor ($S_{16, 20}$: 8.8, 9.5 particles/L) sites (Fig. 2). The abundance of microplastics ranged from 2.9–4.5 particles/L (average: 3.7 ± 0.3 particles/L) in the water samples from inflowing rivers.

Different polymers were identified in the selected particles, with dominant types including polyester, polypropylene, and polyethylene (Fig. 3). Compared with the inflowing river samples, those from the Maowei Sea showed a higher microplastic composition diversity, including 2.8% polyoxymethylene (POM) and 2.5% polyether urethane (PU) (Fig. 4). Detected microplastics were colored white, yellow, blue, green, red, and black, with white particles most abundant. Multiple types of microplastics, including fiber, flakes, foam, and fragments, were observed. Fiber was the dominant component across the water samples. The morphology of the microplastics did not show significant variation across the 23 water sample sites (Supplementary Fig. 1).

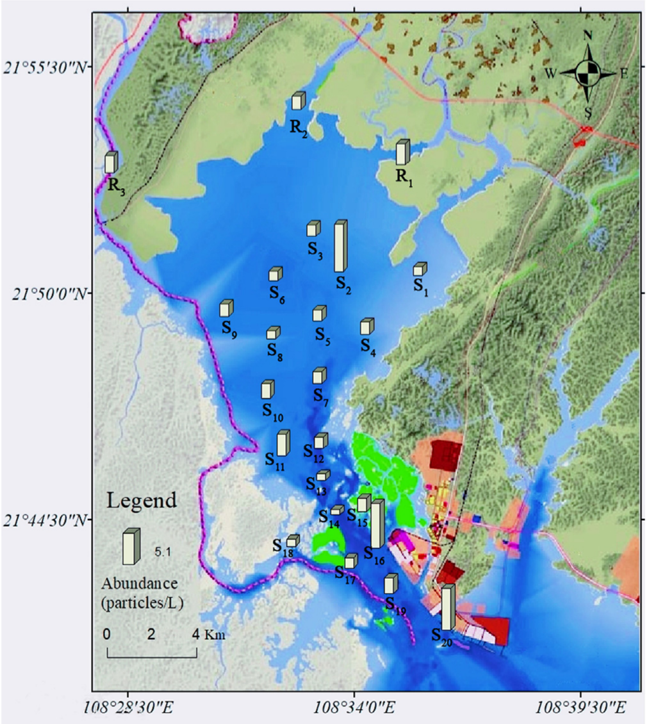

Fig. 2. Distribution and abundance of microplastics in the Maowei Sea and inflowing river surface water.

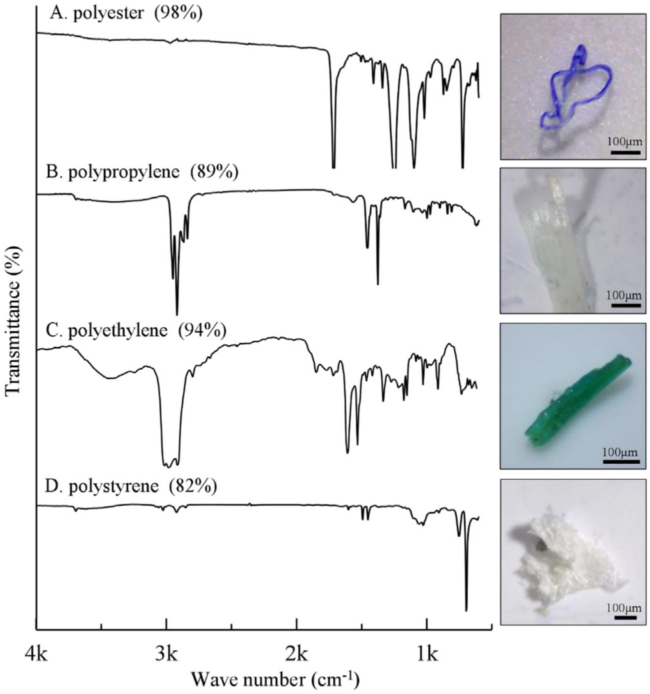

Fig. 3. Typical identified microplastics and their compositions. Scale bar = 100 μm.

3.2. Microplastic pollution in fish gastrointestinal tract and gill

The 66 individual fish samples belonged to a total of 12 identified species (Table 1). Microplastics were observed in all fish GITs and in 40 fish gills (belonging to eight species), with each sample containing at least one microplastic particle and all samples containing particle counts significantly higher than the procedural blank ($P < 0.01$). The fish GIT tests detected microplastic abundances ranging from 2.0 to 14.0 (average: 5.4 ± 0.3) particles/individual and from 0.2 to 14.6 (average: 3.6 ± 0.4) particles/g, while the fish gill tests revealed abundances ranging from 0.0 to 8.5 (average: 2.0 ± 0.2) particles/individual, corresponding to a range of 0.0–12.3 (average: 2.0 ± 0.3) particles/g of gill weight (wet weight). The abundances of microplastics by particle/individual were primarily higher in the GIT than in the gill ($p < 0.01$) (Fig. 5A). The results also indicated that the abundance of microplastics in demersal fish was significantly higher than in pelagic fish ($p < 0.05$) (Fig. 5B, D). Linear regression analyses found no relationship between the numbers of microplastics in the fish GITs and gills.

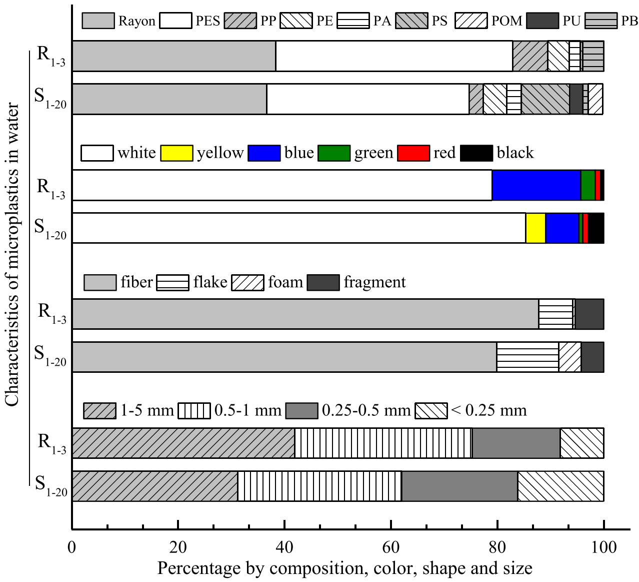

Fig. 4. Characteristics of microplastics in the Maowei Sea ($S_{1–20}$) and inflowing river ($R_{1–3}$) surface water. Abbreviations: PES/polyester; PP/polypropylene; PE/polyethylene; PA/polyamide (nylon); PS/polystyrene; POM/polyoxymethylene; PU/polyether urethane; PBT/polybutylene terephthalate.

Rayon, polyester, and polypropylene were the most common polymer types of microplastics in the fish samples (Fig. 6). White and blue particles were prevalent in both the fish GITs and gills. White particles were most common in the fish GITs, accounting for 50–93% of the microplastics. Fiber was the dominant component across all fish samples. In *Chelon affinis*, *Perca fluviatilis*, *Oreochromis* spp., and *Platycephalus* gills, fiber accounted for 100% of the microplastics (Supplementary Fig. 2). Flake particles were more frequently observed in fish GITs (25%) than in gills (4%). No significant differences were found in terms of microplastic size between fish GITs and gills.

3.3. Microplastic pollution in oyster tissue

Microplastics were found in the soft tissue of all oyster samples, with abundances ranging between 3.2 and 8.6 particles/individual (0.7 and 1.1 particles/g tissue wet weight). The average presence of microplastics was 4.7 ± 0.3 particles/individual (0.8 ± 0.2 particles/g tissue) (Table 1).

Rayon and polyester were the dominant polymer types in the oyster tissue samples, accounting for 50 and 39% of the microplastic content, respectively (Fig. 7). The most prevalent color was white, accounting for 76% of the particles, followed by blue, yellow, and black. Fiber particles accounted for 69% of the microplastics in the oyster samples. Microplastic particles with sizes of <0.25 mm were more frequently observed in oyster (31%) and fish samples (29%) than in water samples (12%) ($P < 0.05$).

4. Discussion

4.1. Microplastic pollution features in water

Our results suggest widespread contamination by microplastics in the Maowei Sea. The measured abundance of microplastics in Maowei Sea aquaculture water (4.5 ± 0.1 particles/L) is much higher than in some other Chinese seas, including the Yellow (0.33 ± 0.28 particles/m^3, Wang et al., 2018a) and Bohai Seas (0.33 ± 0.34 particles/m^3, Zhang et al., 2017), and is comparable to levels detected in the Pearl River Estuary (2.4–8.6 particles/L; Li et al., 2018a) and in mussels in the waters surrounding Zhoushan and Qingdao cities (1.5–6.3 particles/L; Qu et al., 2018). The Maowei Sea is a semi-closed bay with a poor seawater exchange capacity in which it is difficult to discharge microplastic contamination from inflowing rivers and mariculture.

The abundance of microplastics in the Maowei Sea demonstrated significant spatial variability, with high numbers of microplastics observed in the estuarine oyster nursery and Qinzhou harbor sites (Fig. 2). Levels of microplastic pollution are known to be correlated with anthropogenic activities (Barboza and Gimenez, 2015; Cole et al., 2011). The Qin River is the largest land river in Qinzhou and plays a significant role in the lives of local residents. The abundance of microplastics in the Qin estuary is much higher ($p < 0.05$) than in either the Maoling or Dalan Rivers. These area-specific contamination patterns match closely with anthropogenic activities. It is well understood that rivers are a dominant pathway for the deposition of microplastics into adjoining oceans (Lebreton et al., 2017). The abundance of microplastics in the inflowing rivers (3.7 ± 0.3 particles/L) is slightly lower than in the Maowei Sea (4.5 ± 0.1 particles/L), suggesting that, although river discharge is a pollution source, contamination from mariculture is also an important factor. The polymer composition of microplastics in the Maowei Sea surface water showed more diversity than that in inflowing

Table 1
Abundance of microplastics in fish and oyster samples from the Maowei Sea.

Species	Number	Habitats	Body weight (g)	Microplastics in GIT		Microplastics in gill	
				particles/individual	particles/g	particles/individual	particles/g
Fish							
Acanthopagrus latus	15	pelagic	58.7 ± 4.7	4.1 ± 2.0	2.3 ± 1.3	3.0 ± 0.2	2.6 ± 0.3
Chelon affinis	4	pelagic	32.9 ± 0.9	3.8 ± 0.6	1.5 ± 0.6	2.3 ± 0.7	1.5 ± 0.5
Konosirus punctatus	3	pelagic	79.0 ± 6.3	2.0 ± 0.2	0.7 ± 0.4	0. 0 ± 0.0	0.0 ± 0.0
Pachycormus	3	pelagic	542.2 ± 24.7	3.0 ± 1.3	0.2 ± 0.3	0.0 ± 0.0	0.0 ± 0.0
Perca fluviatilis	6	pelagic	261.4 ± 7.5	5.3 ± 1.4	0.9 ± 0.7	3.0 ± 0.6	0.3 ± 0.1
Sillago sihama	4	pelagic	19.6 ± 1.3	1.7 ± 0.5	4.3 ± 1.3	0.5 ± 0.2[a]	1.5 ± 0.5
Ctenogobius giurinus	16	demersal	8.5 ± 0.2	4.6 ± 1.3	14.6 ± 2.3	0.3 ± 0.1[a]	1.2 ± 0.2
Oreochromis spp.	3	demersal	117.7 ± 4.7	8.5 ± 1.8	1.9 ± 0.5	2.5 ± 0.5	1.0 ± 0.2
Platycephalus	3	demersal	79.2 ± 3.6	10.0 ± 1.6	3.5 ± 0.7	2.0 ± 0.6	1. 0 ± 0.4
Scatophagus argus	3	demersal	106.2 ± 7.4	14.0 ± 2.7	1.3 ± 0.4	1.0 ± 0.3	0.5 ± 0.3
Sparus macrocephalus	3	demersal	25.8 ± 3.7	2.0 ± 0.7	1.8 ± 0.6	8.5 ± 0.8	12.3 ± 1.4
Terapon theraps	3	demersal	20.1 ± 0.6	5.7 ± 1.8	9.6 ± 1.9	1.0 ± 0.2	2.5 ± 0.6
Oyster				Microplastics in oyster			
Crassostrea hongkongensis	20	attached on shallow sea objects	45.1 ± 2.4	4.7 ± 0.3	0.8 ± 0.2		

[a] No significant difference in abundance from the procedural blank.

rivers. For example, polystyrene foams, which are commonly used in packaging and fishery industries (Wang et al., 2019), were only frequently observed in the Maowei Sea surface water. Chen et al. (2018) reported that mariculture-derived microplastics account for 55.7% of the microplastics in seawater in Xiangshan Bay, a semi-enclosed narrow bay.

4.2. Microplastic pollution features in biota

The abundance of microplastics in 66 fish selected from the Maowei Sea ranged from 2.0 to 15.0 (average: 7.4 ± 0.4) particles per fish. This microplastic level is much higher than in many fish samples reported in the literature. Peters et al. (2017) reported 0.5–1.4 particles per fish in six marine fish species from the Gulf Coast of Texas in the United States. Murphy et al. (2017) observed 1.8 ± 1.7 particles per fish in demersal and pelagic fish from Northeast Atlantic around Scotland. Rummel et al. (2016) reported significantly lower levels of microplastics contamination in the North and Baltic Seas, with only 0.03 ± 0.18 particles per fish. The abundances detected in this study are consistent with those reported in 21 sea species and six fresh species from China (1.1–7.2 particles per fish, Jabeen et al., 2017), large pelagic fish from the Mediterranean Sea (4–16 particles per fish, Romeo et al., 2015), and sunfish bluegill and longear fish from the Brazos River Basin, USA (10.1–13.9 particles per fish, Peters and Bratton, 2016).

Demersal species showed significantly higher abundances of microplastics than pelagic species in terms of both particles/individual and particles/g units ($p < 0.05$) in this study. This finding is consistent with the results reported in fish from the Yangtze estuary, East China Sea, and South China Sea (Jabeen et al., 2017). Coincidentally, of the fish that ingested microplastics along the Portuguese coast, 63.5% were benthic and 36.5% were pelagic species (Neves et al., 2015). As reported by Neves et al. (2015), pelagic species ingested more particles while benthic species ingested more fibers. In this study, we found that both demersal and pelagic species ingested more fibers, which accounted for 33–90% of the detected microplastics (Supplementary Fig. 2). This suggests that habitats play important roles in the ingestion of microplastics.

The abundance of microplastics in terms of particles/individual unit was found to be generally higher in fish GITs than in gills, although no

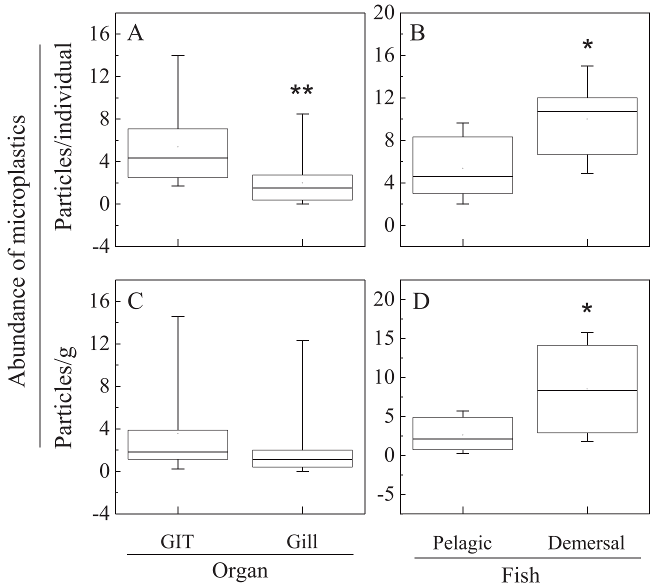

Fig. 5. Comparison of abundances of microplastics in different groups. Fish gastrointestinal tract (GIT) and gill (A, C); pelagic and demersal species (B, D). * indicates $p < 0.05$; ** indicates $p < 0.01$.

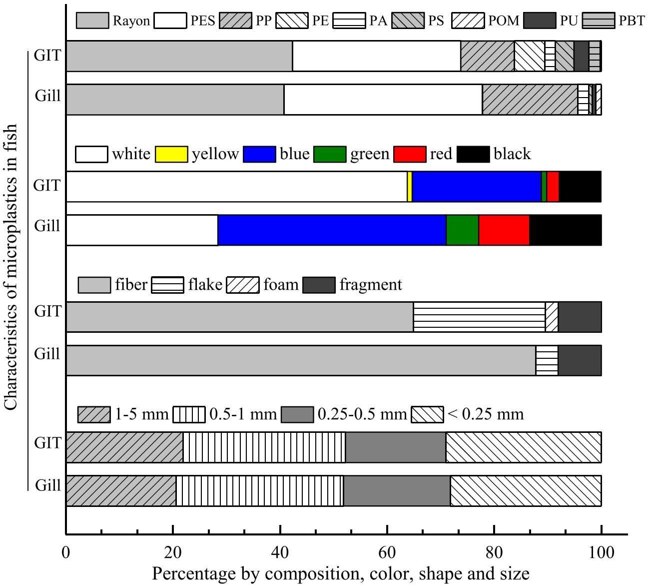

Fig. 6. Characteristics of microplastics in fish gastrointestinal tract (GIT) and gills. Abbreviations: PES/polyester; PP/polypropylene; PE/polyethylene; PA/polyamide (nylon); PS/polystyrene; POM/polyoxymethylene; PU/polyether urethane; PBT/polybutylene terephthalate.

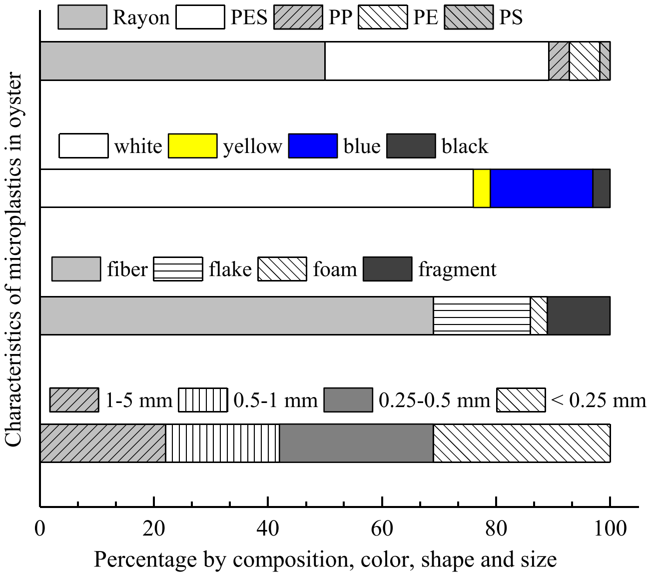

Fig. 7. Characteristics of microplastics in oyster tissue. Abbreviations: PES/polyester; PP/polypropylene; PE/polyethylene; PS/polystyrene.

relationship was found between the numbers of microplastics found in the fish GITs and gills. Jabeen et al. (2017) reported significant variations in plastic abundance between the stomach and intestines in fish, which suggested an organ-specific localization of microplastics. In *Sparus macrocephalus* individuals, we found significantly more microplastics particles in the gills than that in the GIT (Table 1). To clarify this disparity, the structure of the gill in *Sparus macrocephalus* should be further studied.

The level of microplastics in oyster (4.7 ± 0.3 particles/oyster; 0.8 ± 0.2 particles/g) observed in this study is higher than in *Crassostrea gigas* specimens obtained from French (2.1 ± 1.7 particles per oyster, Phuong et al., 2018), German (0.5 ± 0.2 particles/g, Van Cauwenberghe and Janssen, 2014), or American coastlines (0–2 particles/oyster, Rochman et al., 2015) and is higher than in *Mytilus edulis* mussels from Belgium (0.3–0.5 particles/g, De Witte et al., 2014), Germany (0.4 ± 0.1 particles/g, Van Cauwenberghe and Janssen, 2014), or the French–Belgian–Dutch coastline (0.2 ± 0.3 particles/g, Van Cauwenberghe et al., 2015). In terms of bivalves from the coastline of China, the microplastic abundance by particles/individual unit in Maowei Sea oysters is comparable with those in oysters from the Pearl River Estuary (1.4–7.0/individual, Li et al., 2018a) and mussels from Chinese coastal waters (1.5–7.6/individual, Li et al., 2016). However, in terms of particles/g unit the abundances in Maowei Sea oysters are significantly lower (1.5–7.7 particles/g, Li et al., 2018a; 2.7 particles/g, Li et al., 2016). It is possible that the maricultured oysters obtained from the Maowei Sea in this study were fatter and larger than in other waters, leading to a reduced number of particles per gram of tissue.

4.3. Potential impact of microplastics on fishery aquaculture

Seafood is a carrier for the transference of microplastics into the human food chain. The Maowei Sea outputs about 600,000 tons of fish and oyster per year, and consumers of oyster from its waters are expected to take in about 80 microplastic particles per 100 g of oyster diet. This is not only an issue for Maowei Sea fishery product consumers but also reflects the global spread of microplastics in the marine environment. Similar studies have detected microplastics in bivalve species in other waters and in supermarkets in China (Li et al., 2018a; Qu et al., 2018; Li et al., 2015, 2016) as well as in supermarkets in France, Belgium, and the United Kingdom (De Witte et al., 2014; Van Cauwenberghe and Janssen, 2014; Li et al., 2018b). The ubiquity of microplastics in fishery products has raised concerns about the potential threats of these materials to the safety of seafood. Compared with the consumption of oyster, it is only fish fillet that be taken in, while the primary absorption of microplastics by fish takes place in the GIT. Rochman et al. (2013, 2015) showed that ingested plastic particles could transfer hazardous chemicals to fish, resulting in hepatic stress and altered endocrine system function genes. The actual risks to human health of consumption of microplastics from seafood remain uncertain.

The effects of microplastics on the health of different aquatic species are categorized as: a) physical (related to the shape, color and dimension of the particles) and b) chemical (related to the presence of additives and/or sorbed chemical contaminants) (Rezania et al., 2018; Wang et al., 2018b). There is potential for microplastics to clog and block the feeding appendages of marine invertebrates or even to become embedded in tissues (Derraik, 2002; Wright et al., 2013): plastic fragments and PP and/or monofilament line have been found in the tissues of two filter feeding salps - *Thetys vagina* - collected from neuston samples in the NPCG (Moore et al., 2001). Moreover, the sorption of chemicals on microplastics may transfer harmful substances such as persistent, bioaccumulative and toxic (PBT) chemicals into the food chain (Bakir et al., 2012; Rochman et al., 2013; Rockstrom et al., 2009). Rochman et al. (2013, 2015) showed that ingested plastic particles could transfer hazardous chemicals to fish, which caused hepatic stress and altered endocrine system function genes. It is reported that Maowei Sea was polluted by heavy metal, antibiotics, and numerous persistent organic pollutants (Wu et al., 2014; Zhang et al., 2014). It shows that microplastics will further affect the ecological environment.

5. Conclusions

In this study, we found that microplastics are widespread in the aquaculture water and biota (e.g., various fish and oyster species) of the Maowei Sea. To the best of our knowledge, this is the first published report on microplastic pollution of this mariculture zone. Inflowing river discharge and mariculture activities are important contributors to microplastic pollution in the Maowei Sea. The source analysis of microplastics and the technology to decrease the microplastic pollution should be further studied. The microplastic contamination of fishery products presents a route for human exposure, and it will be important to scrutinize potential links to human health risks resulting from the consumption of fishery products.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2018.12.192.

Acknowledgements

This work was supported by grants from the research fund of Guangxi Education Department (grant nos. 2018KY0617, KY2016YB487), the Guangxi Natural Science Foundation (grant nos. 2016GXNSFBA380142, 2018JJB150065), the Start-up Foundation of Qinzhou University (grant no. 2018KYQD07). and the National Natural Science Foundation of China (grant nos. 41776174, 41466001 and 4160010672). We thank the Ministry of Agriculture of the People's Republic of China (Chinese White Dolphin Conservation Action) for help with field sampling.

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