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A review of microplastic pollution in seawater, sediments and organisms of the Chinese coastal and marginal seas

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HIGHLIGHTS

- Microplastic abundance in seawaters of Chinese coastal seas was 0.13–545 items/m^3.
- Microplastic abundance in the sediments from the estuaries was 20–7900 items/kg.
- High microplastic pollution was found in the estuaries, especially in rainy season.
- Microplastic level in Chinese seas was moderate or lower compared to other countries.

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ABSTRACT

China is considered to account for nearly a third of all plastic waste discharging from land to the ocean. To overall assess microplastic pollution status in Chinese coastal and marginal seas, this study summarized the abundance and characteristics of microplastics in the seawater, sediments and marine organisms. The results showed that the abundance of microplastics in the seawater of four major seas of China was 0.13–545 items/m^3, and microplastic abundance in the sediments from the estuaries was 20–7900 items/kg, which are at middle level or even lower than those detected in other countries. By contrast, severe microplastic pollution was recorded in the estuaries, suggesting that plastic waste and microplastic interception measures should be conducted on the rivers to prevent the input of microplastics. In addition, microplastics were widely detected in marine fishes, mollusks, zooplankton, mammals and birds, which highlights the potential impacts of microplastic pollution on the whole marine ecosystem. Compared to the dry season, higher microplastic abundance was found in the rainy season, revealing that plastic waste recycling should be strengthened before the onset of rainy season. We suggest that all countries respond actively to the ubiquitous microplastic pollution through practical policies and measures to prevent microplastics from further damaging the marine ecosystem.

1. Introduction

Microplastics (plastics with a diameter of 1–5000 μm) are ubiquitous in the oceans and could exist in the marine environments for hundreds of years due to their stable chemical properties (Arthur et al., 2009; Duncan et al., 2019). Marine microplastics mainly originate from primary and secondary sources. Primary microplastics are the plastic particles added in personal care products and cosmetics (Van Wezel et al., 2016). Lei et al. (2017) reported that approximately 7.1 % of facial cleansers in Chinese supermarkets contained microplastics, which could enter the ocean directly by daily washing (Hintersteiner et al., 2015). Secondary microplastics are derived from large plastic products through physical, chemical and biological degradation (Auta et al., 2017; Efimova et al., 2018). Microplastics from both sources can enter the ocean through surface runoff, wastewater treatment plant effluents, aquaculture and fisheries, dumping of domestic and industrial waste, and even atmospheric emissions (Talvitie et al., 2017; Simon et al., 2018; Wright et al., 2020). To date, microplastics are not only distributed in the seawater

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and sediments, but also readily ingested by a wide variety of marine organisms due to their small size (Gall et al., 2015; Galloway et al., 2017). Thus, microplastic pollution has become a potential threat to marine ecosystems.

China has more than 18,000 km of coastline and 3 million square kilometers of complex sea areas. A large number of studies have reported microplastics in the seawater, sediments and organisms in Chinese coastal and marginal seas (Wang et al., 2019a; Zhang et al., 2019a; Jiang et al., 2020). However, a panorama on microplastic pollution in offshore China is lacked until now. To better understand the state of microplastic pollution in offshore China, this study summarized and compared the abundances and characteristics of microplastics in different environmental and biological components. This study will provide background values for microplastics in Chinese coastal and marginal seas, which might help the government develop effective programs to control plastic pollution.

2. Methods of literature review

This literature review was designed according to the guidelines of Siddaway et al. (2019). Relevant peer-reviewed literatures were searched in Science Direct, Web of Science and PubMed data bases using the combination of terms including “microplastic”, “China”, “seawater”, “sediment”, “organism”, “estuary”, “mollusk”, “zooplankton”, “fish”, and “mangrove”. The search for literature was mainly conducted in August 2020 and updated in June 20, 2021.

Only original studies published in English language were included in the review, and the references without contamination prevention and QA/QC procedures were excluded. Finally, 87 references were used to show the spatial and temporal distribution of microplastics in the seawater, sediments, and organisms of the Chinese coastal and marginal seas. From each reference, the information including sampling location, time, sample tools and methods, sample types (seawater, sediment, different kinds of organism), digestion and floating methods, and identification instruments, microplastic size range, abundances, shapes and main types were created the data tables and figures.

3. Microplastics in the seawater

In most regions, fibers dominated the main shape, except in Qinzhou Bay fragments accounted for 94 % of the total microplastics (Li et al., 2018a). The majority of the microplastics were white, transparent and in the size range of 0.5–1.0 mm (Zhang et al., 2017; Wang et al., 2019a). The main polymer types were polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyethylene terephthalate (PET) (Zhang et al., 2017; Ding et al., 2019; Zheng et al., 2019). The composition of microplastics varied greatly among different regions. For example, PET accounted for 56 % of all tested samples from the seawater in Jiaozhou Bay (Zheng et al., 2019), while 51 % of the total microplastics in Bohai Sea was PE (Zhang et al., 2017). The distribution and characteristics of

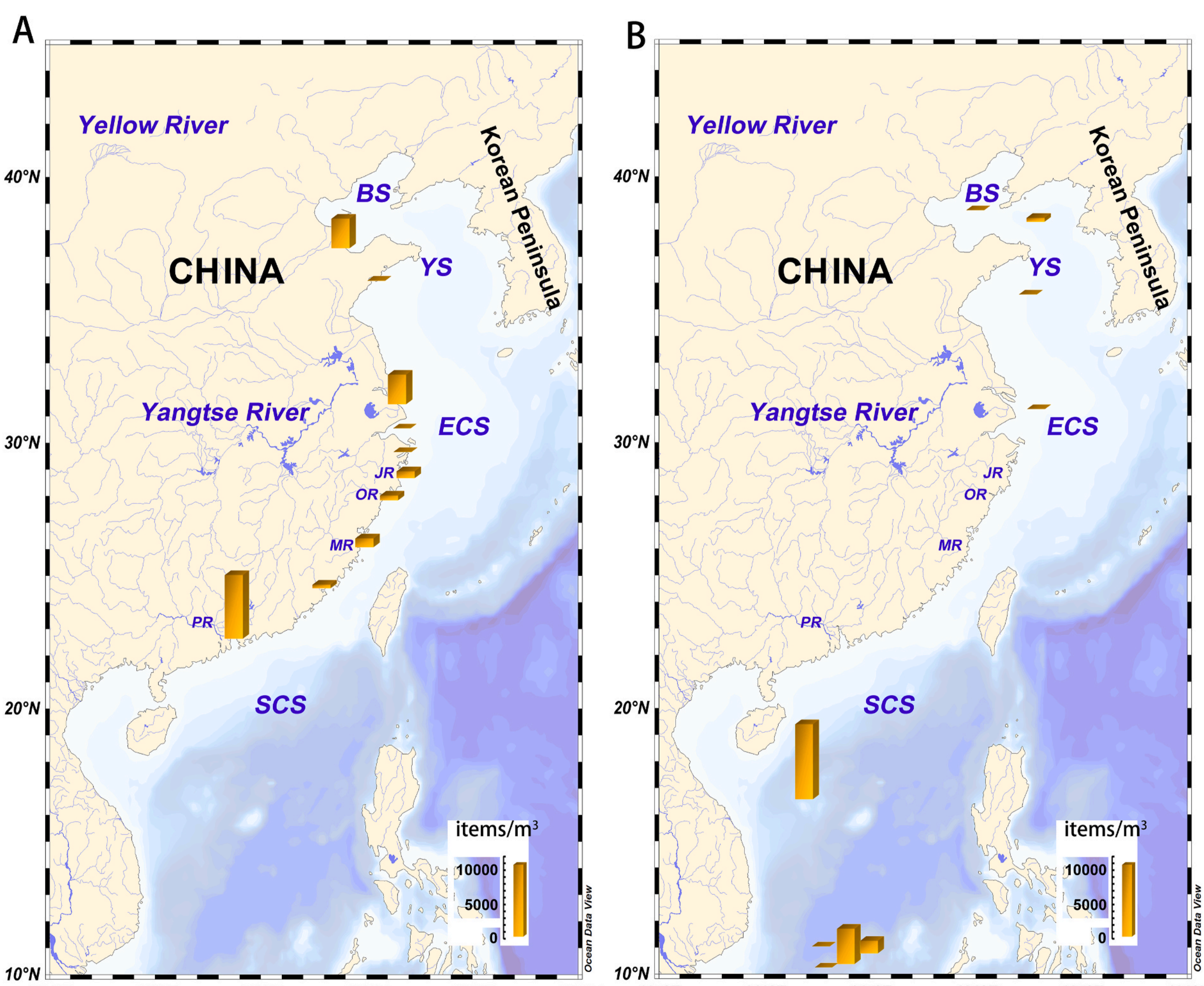

Fig. 1. Microplastic abundances in the seawater of estuaries, bays (A) and islands (B) distributed in Chinese coastal regions. BS: Bohai Sea; YS: Yellow Sea; ECS: East China Sea; SCS: South China Sea; JR: Jiaojiang River; OR: Oujiang River; MR: Minjiang River; PR: Pearl River. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

microplastics in different regions are described in the following sections.

3.1. Microplastics in the seawater of four major seas

Microplastics have been detected in all inland and marginal seas of China (Fig. 1A). The average abundance of microplastics in the seawater of Bohai Sea, Yellow Sea, East China Sea, and South China Sea were 0.33 ± 0.34 items/m^3, 0.13 ± 0.20 items/m^3, 0.17 ± 0.14 items/m^3, and 0.47 ± 0.22 items/m^3, respectively (Zhao et al., 2014; Zhang et al., 2017; Sun et al., 2018; Wang et al., 2019c). PE, PP, and PS were the main types of microplastics in Bohai Sea, North Yellow Sea and South Yellow Sea, while the majority of microplastics in the seawater of South China Sea was PET (Table S1). Fiber was the main shape in all sea areas and accounted for more than 40 % of the total particles in South Yellow Sea (Wang et al., 2019b). However, a recent study reported that approximately 91.8 % of fibers from global oceanic surface waters were not plastic, but originated from plants and animals, indicating that the previous studies might overestimate the microplastic levels in marine environments (Suaria et al., 2020). Thus, more accurate methodology should be developed to identify the microfibers.

3.2. Microplastics in the seawater of estuaries

Estuaries are the transition zone between inlands and marine ecosystems, and thus facilitate the migration and accumulation of microplastics. The abundance of microplastics in the surface water of the Yangtze Estuary was 4137.3 ± 2461.5 items/m^3, which was significantly higher than that in the seawater of the East China Sea (0.167 ± 0.138 items/m^3, Table S2). Similarly, Hu et al. (2018) reported that the highest abundance of microplastics in the Yangtze Estuary was 21,520 items/m^3, which was significantly higher than those in the adjacent offshore areas. In comparison, the average abundance of microplastics in the Pearl River estuary (8902 items/m^3) was significantly higher than that in the Yangtze River estuary (4137.3 items/m^3), and microplastic abundance in the Yellow River estuary was the lowest (Fig. 1A). These findings suggested that the abundance of microplastics in the seawater of estuaries decreased from the South to the North regions, which might be attributed to the fact that more plastic waste is released from densely populated and industrialized watersheds in the South of China.

3.3. Microplastics in the seawater of bays

Bays are highly influenced by anthropogenic activities, such as recreational activities, aquaculture and sewage disposal. Thus, the abundance of microplastics is relatively higher in these regions. The highest abundance of microplastics was found in the coastal waters of Xiamen (514.3 ± 520.0 items/m^3), followed by the coastal waters of Hong Kong (0.51–279 items/m^3) and Jiaozhou Bay (20–120 items/m^3; average: 46 ± 28 items/m^3) (Tsang et al., 2017; Tang et al., 2018; Zheng et al., 2019). By contrast, Hangzhou Bay (0.14 ± 0.12 items/m^3) and Xiangshan Bay (4.6–20.1 items/m^3) had relatively lower microplastic levels (Table S3). PE, PS and PP were the main types of microplastics in the seawater of Xiangshan Bay and Hangzhou Bay, but 56.3 % of the total microplastics in Jiaozhou Bay was PET (Chen et al., 2018; Wang et al., 2020).

3.4. Microplastics in the surface water around islands

The microplastic abundance in the seawater around Nansha Islands was very low (0.056 ± 0.036 items/m^3), which was due to the less intervention of anthropogenic activities (Tan et al., 2020). However, the abundance of microplastics in Ma'an Islands, Xisha Islands, Nanxun Reef and Zhubi Reef were at quite high levels (200–45200 items/m^3, Fig. 1B; Table S4). Fibers and granules were the most common types of microplastics. The distribution and abundance of microplastics in the seawater around Nanxun Reef varied greatly due to the influence of the southwest wind and ocean currents in summer (Nie et al., 2019). It is worth to note that the islands in the South China Sea have lots of coral reefs, and microplastic pollution has become a serious threat to the coral reefs (Tan et al., 2020).

4. Microplastics in the sediments

4.1. Microplastics in the sediments from four major seas

Microplastic abundance in the sediments of four major seas of China is summarized in Fig. 2 and Table S5. The abundance of microplastics in the South Yellow Sea sediments (560–4205 items/kg) was close to that in the Maowei Sea of the South China Sea (750–14000 items/kg), but higher than those in Bohai Sea (171.8 items/kg) and North Yellow Sea (123.6 items/kg) (Zhao et al., 2018; Zhu et al., 2018; Li et al., 2019; Zheng et al., 2019; Ibrahim et al., 2021). The microplastics were mainly fibrous, and the proportion of fibers in Bohai Sea was even higher than 90 % (Zhao et al., 2018). In addition, microplastic abundances were positively correlated to the water depth of the sediments, demonstrating that microplastics could accumulate in the ocean floor (Wang et al., 2019b).

4.2. Microplastics in the sediments from estuaries

The abundance of microplastics in the sediments of the Yangtze Estuary was 20–340 items/kg, which was comparable to the sediments of the East China Sea (142 ± 38 items/kg; Fig. 2A; Table S6). Similar to the results of the seawater, the sediments of Pearl River Estuary had the highest abundance of microplastics (851 ± 177 items/kg) (Zuo et al., 2020). In addition, the abundance of microplastics in the sediments of Yangtze River Estuary increased over time, indicating that the river continually discharges microplastics from the land to the ocean (Peng et al., 2017; Hu et al., 2018).

4.3. Microplastics in sediments from the bays and beaches

To date, microplastic abundances are usually expressed by two units, items/kg and items/m^2, which makes it difficult to compare the microplastic levels in different studies. On the other hand, the different sampling and floating methods might affect the results of microplastics in the sediments, which should also needs attention when comparing the data. The abundance of microplastics in estuarine sediments of Maowei Sea (520–940 items/kg) was relatively lower than that in gulf sediments (1780–2310 items/kg, Table 1), which is significantly different from the distribution pattern of microplastics in water bodies, and it may be attributed to the accumulation effects of sediments settling with water flow (Li et al., 2019a). In the southern China, microplastic abundance in the sediments was in the range of 3242–6675 items/m^2 and 781.3–12852 items/kg (Qiu et al., 2015; Cheung et al., 2016; Chen et al., 2018). Microplastic abundance in the sediments of the northern China were comparatively low, with 740.1 ± 2458.2 items/kg in coastal beaches of Shandong province and 180 ± 50 items/kg in Hangzhou Bay (Zhou et al., 2018; Fraser et al., 2020). PS, PP, and PE were the dominant polymer forms of microplastics in most of the beach and bay sediments, except the PET accounted for 51.35 % of the total microplastics in the sediments of Jiaozhou Bay (Zheng et al., 2019)[24]. Several environmental factors could influence microplastic abundance and characteristics in the sediments of the bays. For example, Wang et al. (2019a) reported that typhoons increased the abundance of microplastics in Sanggou Bay by approximately 40 % and dramatically changed the compositions of microplastic shapes, sizes and colors. In addition, the accumulation of microorganisms and plankton could increase the density of floating microplastics and thus accelerate their sedimentation (Näkki et al., 2019). The organic debris was another important factor for microplastic sinking because these sticky substances could wrap microplastics and form high-density aggregations (Turner et al., 2015; Porter et al., 2018).

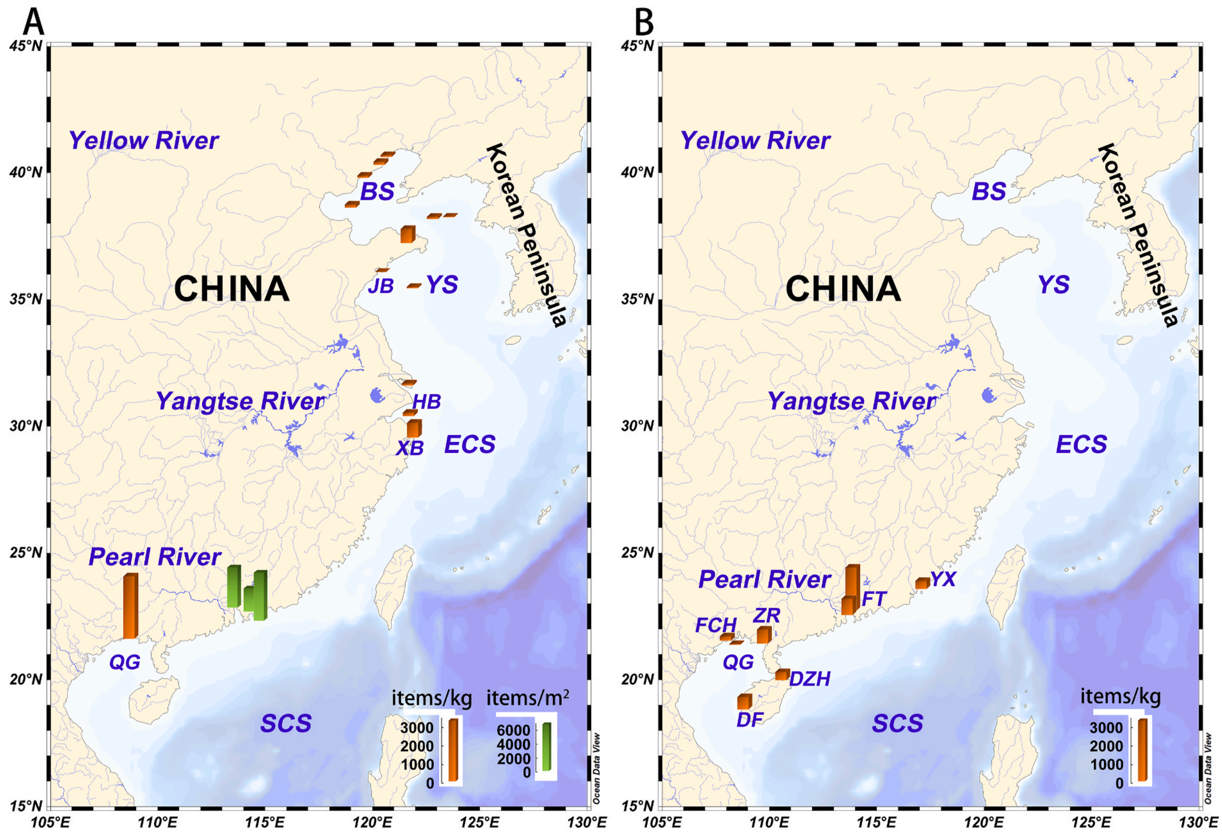

Fig. 2. Microplastic abundances in the sediments from coastal and estuarine areas (A) and mangroves (B) of China. BS: Bohai Sea; YS: Yellow Sea; ECS: East China Sea; SCS: South China Sea; JB: Jiaozhou Bay; HB: Hangzhou Bay; XB: Xiangshan Bay; QG: Qinzhou Gulf; DZH: Dongzhai Harbor; DF: Dongfang; FCH: Fangcheng Harbor; FT: Futian; YX: Yunxiao; QG: Qinzhou Gulf; ZR: Zhangjiang River. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Since the sediment has become an important sink for microplastics, the potential impacts of microplastic pollution on marine benthic ecosystem merit attention.

4.4. Microplastics in sediments of mangroves

Due to the unique ecological status and the large biomass, microplastic pollution in mangroves has aroused great concerns (Fig. 2B). Mangroves can act as a "sieve" to effectively trap the microplastics, and microplastics in the size range of 500–5000 μm accounted for 61.1 % of the total microplastics in mangrove sediments of Southern China (Li et al., 2018a, 2020, 2020). The highest abundance of microplastics (2249 ± 747 items/kg) was found in the Futian mangrove, which is located in the Pearl River Estuary (Li et al., 2020). By contrast, the mangroves in Qinzhou Gulf had the lowest microplastic abundance (42.9 ± 26.8 items/kg, Li et al., 2018a). In other mangroves, the abundances of microplastics in the sediments ranged from 227 to 851 items/kg (Table S7). Mangrove sediments might have the retention capacity of microplastics due to the low water mobility in these regions. In addition, the main shape and polymer type of microplastics were fiber and PP, which is consistent with the general characteristics of microplastics in the ocean.

5. Microplastics in marine organisms

The ingestion of microplastics has been observed in a variety of marine organisms. As the primary consumers, zooplankton can pass microplastics in the food webs and contaminate the higher consumers, including crustaceans, fish, and sea birds (Sun et al., 2018; Zhang et al., 2020a; Zheng et al., 2020). Among them, bivalve mollusks are filter feeders and are more susceptible to the uptake of microplastics; Fishes, as the intermediate members of food chain, can ingest the microplastics directly or indirectly by preying on other organisms containing microplastics (Jabeen et al., 2017; Koongolla et al., 2020). Mammals and birds are the most advanced consumers, and their microplastic content has important reference in the protection of the marine ecosystem (Zhu et al., 2019a; Carlin et al., 2020).

5.1. Microplastics in marine fishes

Since fish are popular seafood consumed by human beings, microplastic pollution in commercial sea fishes is considered as an emerging issue for food security and human health (Carbery et al., 2018). Microplastics are more frequently found in the digestive tracts of fishes captured near the urban areas, which is associated with high input of microplastics form land (Fig. 3). For example, the microplastics in *Thryssa kammalensis* from Haizhou Bay, South Yellow Sea had the highest abundance (22.21 ± 1.70 items/individual or 11.19 ± 1.28 items/g), which was much higher than that in *Thamnaconus septentrionalis* from Yangtze Estuary (7.2 ± 2.8 items/individual), *Boleophthalmus pectinirostris* from Hangzhou Bay (5.3 ± 2.4 items/individual), and *Larimichthys polyactis* from Yellow Sea (2.6 items/individual, Table S8). Moreover, the microplastic abundance in benthic fishes was much higher than that in the pelagic species and planktonic species in the South China Sea, indicating that more microplastics might appear in the benthic environments (Li et al., 2019b; Koongolla et al., 2020). Microplastics were also observed in fish gills and skins, but not in the muscles and livers (Huang et al., 2020). Microplastic abundances were positively correlated with the body length of fish, indicating that larger fish are more readily to ingest the microplastics (Sun et al., 2019).

Table 1
Sampling areas, sampling time, sampling tools, depth, digestion solution, floating solution, abundance, particle size and characteristics of microplastics from sediments in some beaches, bays of China.

Sampling areas	Sampling time	Sampling tool	Depth	Drying method	Digestion solution	Floating solution	FTIR	Size (μm)	Abundance	Shapes	Types	References
Beaches of Bohai Sea	2015.7	metal ring	20-cm depth	50 °C for at least 48 h	–	NaCl (1.27 g/mL)	a Nicolet iN10 FTIR microscope	>1	102.9 ± 39.9 items/kg 163.3 ± 37.7 items/kg 117.5 ± 23.4 items/kg	Fragments, films, fibers	PE, PP, PS, PEVA	Yu et al. (2016)
Jiaozhou Bay	2017.11	a Van Veen Grab Sampler and clean stainless-steel shovel	no deeper than 10 cm	50 °C for at least 16 h	–	1.5 g/mL $ZnCl_2$	μ-FT-IR	1200 ± 780	average: 15 ± 6 items/kg	Fibers (93.11 %), fragments, granules	PET, PP, PE, PA, cellophane, PVC, PS	Zheng et al. (2019)
Sishili Bay	–	a stainless steel box sampler	5 cm	60 °C for 72 h	30 % H_2O_2	–	FTIR	average: 746.84 ± 839.69 34.97–4983.73	average: 499.76 ± 370.07 items/kg	Fibers (86.37 %), fragments (7.83 %), films (5.40 %) and pellets (0.39 %)	Rayon (58.41 %), PE, PP, PA, PET, PS, PMMA and PU	Zhang et al. (2019a)
Coastal beaches in Shandong	2015.4–5	a clean stainless-steel shovel	top 2 cm	105 °C for >12 h	–	saturated NaCl solution (1.2 g/cm) and saturated NaI solution (1.6 g/cm)	FTIR	100–5000	1.3–14,712.5 average: 740.1 ± 2458.2 items/kg	Flakes (69.0 %), foams (27.8 %), fragments (1.1 %), fibers (1.0 %)	PE, PP, PS, PEU	Zhou et al. (2018)
Hangzhou Bay	2019	a gravity corer	0–5 cm and 15 cm for depth	freeze-drying	KOH	$CaCl_2$ saturated solution (1.38–1.40 g/mL)	μ-FTIR	50–5000	130–280 average: 180 ± 50 items/kg	Fibers (50 %), fragments (43 %), films (5 %), microbeads (2 %)	PE, PS, PET, cellulose	Fraser et al. (2020)
Xiangshan Bay	2017.10	a metal shovel and an Ekman sampler (Ejer, China)	5 cm	50 °C for at least 48 h	–	$ZnCl_2$ solution (1.75 g/mL)	FTIR microscope	1330 ± 1690	781.3 ± 258.3 items/kg	Fibers, foams	PE, PS, PP, PET, cellulose	Chen et al. (2018)
Laizhou Bay	2017.8	a Van Veen grab	top 5 cm	60 °C for 72 h	30 % H_2O_2	NaCl (1.20 g/mL)	μ-FTIR	average: 876.8 ± 1027.5 28–4933.0	193-1053 items/kg average: 461.6 ± 167.0 items/kg	Fibers (94.10 %), films (3.59 %)	CP (85.4), PET (8.9 %), PP, PVAc, PPA, PA, PAN, PE, PEA, PVC	Teng et al., 2020
Coastal beaches in Hong Kong	2015.6–2016.3	an Ekman dredge	–	freeze-dried	30 % H_2O_2	saturated NaCl solution	ATR-FTIR	10–4700	49–279 items/kg	Fragments (63.6 %), lines (6.9 %), fibers (6.3 %), granules (23.2 %)	PP, LDPE, HDPE, PP	Tsang et al. (2017)
	2014.7–9	a shovel	0–5 cm to over 20 cm	–	–	seawater through a 0.315 mm sieve	–	315–5000	5595 ± 27,417 items/m^2	Expanded PS (92 %), fragments (5 %), granules (3 %)	PS	Fok et al. (2015)
Coastal high tide zones of beaches in Hong Kong	2014.7.7–9.6 2015.1.16–3.21	a metal shovel	4-cm-deep	–	–	seawater through a 0.315 mm mesh wire cloth	ATR FT-IR	315–5000 315–5000	5595 ± 3950 items/m^2 3242 ± 1991 items/m^2	–	PS	Cheung et al. (2016)
Beaches in Guangdong Province	2015.7	a metal shovel	top 4 cm	40 °C	–	seawater through a 0.315-mm stainless steel sieve	ATR FTIR	315–5000	6675 ± 7021 items/m^2	Foams, granules, fragments, pellets	PS, PP, PE, PP/EPR	Fok et al. (2017)
Beaches in Qinzhou Bay	2016.12	–	top 2 cm	air-dried	–	$CaCl_2$ solution (1.38 g/cm^3)	FT-IR spectroscopy					Li et al. (2018a)
Bays in Maowei Sea	–	–	–	60 °C	30 % H_2O_2	a potassium formate aqueous solution (1.5 g/cm3)	Micro-Raman spectrometer	<1000	1780–2310 items/kg	–	PE, PP and PS	Li et al., 2019
Beibu Gulf	2014.5–6	a watch glass	–	at 50 °C	–	NaCl (300 g NaCl/L) solution	Micro-FTIR	–	5014–8714 items/kg	Strips, granules, and films	HDPE, PET, polyester, PS	Qiu et al. (2015)

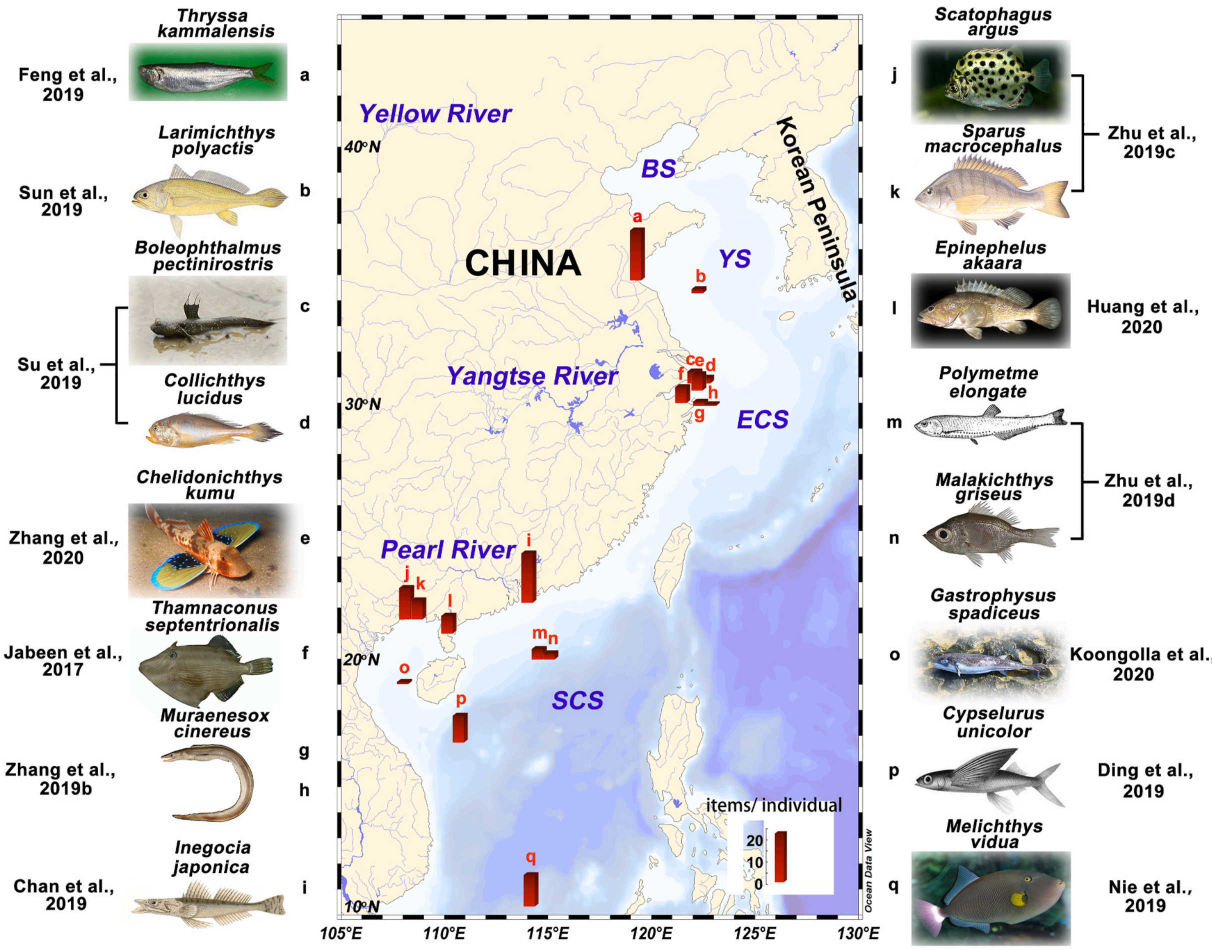

Fig. 3. The distribution of microplastics in the marine fishes with the highest abundance in China sea areas. BS: Bohai Sea; YS: Yellow Sea; ECS: East China Sea; SCS: South China Sea. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Generally, fibers were the most common type, and microplastics <1 mm were dominant in the gastrointestinal tracts of fishes (Zhang et al., 2019b, 2020b, 2020b).

5.2. Microplastics in mollusks

Mollusks are the most common benthic species inhabiting the sediments and intertidal zones. As filter feeders, bivalve mollusks can directly absorb the microplastics from surrounding environments, which results in the residue of microplastics in the gills and soft tissues. The abundance of microplastics in soft tissues of bivalves in China was 2.1–10.5 items/g (Fig. 4; Table S9). For example, microplastic abundances in the soft tissues of *Saccostrea Cucullata* from the Pearl River Estuary and *Ostrea Denselamellosa* from Xiangshan Bay were 1.4–7.0 items/individual (1.5–7.2 items/g) and 1.67 ± 0.44 items/individual (0.31 ± 0.10 items/g), respectively (Li et al., 2018b; Wu et al., 2020). Similarly, the oysters from the Maowei Sea had 3.2–8.6 items/individual (0.7–1.1 items/g) of microplastics, which were positively correlated with the microplastic abundance in the surrounding seawater (Zhu et al., 2019b). Compared to the northern oysters (2.41 items/individual, 0.328 items/g), the southern oysters have significantly higher microplastic abundance (3.4 items/individual, 0.88 items/g, $P < 0.05$, Teng et al., 2019). In the above studies, the majority of microplastics in oysters were fibrous, and the colors were mainly transparent, white, and blue, with a larger proportion of the smaller size (<500 μm). Ding et al. (2018) reported that the average abundance of microplastics (25–5000 μm) in the cultured mussels (*Mytilus galloprovinciali*) from the local markets of Qingdao was 3.17 items/g, which was higher than that in the wild mussels (2.0 items/g). While Li et al. (2016) found that the wild mussels (*Mytilus edulis*) ingested more microplastics (2.7 items/g, 5–5000 μm) than the cultured groups (1.6 items/g), and the microplastic abundance in the two groups varied from 0.9 to 4.6 items/g. Qu et al. (2018) found that the microplastics in the mussels (*M. edulis* and *Perna viridis*) from 25 sites along the coastal waters of China had an abundance of 1.52–5.36 items/g, with smaller size as compared to those in the seawater.

5.3. Microplastics in zooplankton

Zooplankton are more susceptible to ingest microplastics because their prey has a similar size to microplastics (Galloway et al., 2017). Compared to marine fishes and mollusks, there are relatively few studies on microplastic pollution in zooplankton (Table 2). Sun et al. (2019) found that the abundances of microplastics ingested by five natural zooplankton groups in the northern South China Sea were 4.1 items/m^3 for Net I (mesh size: 505 μm) and 131.5 items/m^3 for Net II (mesh size: 160 μm), respectively. Among them, copepods had the highest microplastic abundance, followed by shrimps, chaetognaths, and fish larvae. Fibers accounted for 70 % of the total microplastics, and the main component was polyester. Zheng et al. (2020) found that the abundance of microplastics in zooplankton groups of the Bohai Sea in the rainy season was 2.03 ± 2.87 piece/m^3, which was significantly higher than that in the dry season (0.41 ± 0.38 piece/m^3). Medusae had the highest number of MPs, followed by fish larvae and Copepoda. Considering the importance of zooplankton in the marine ecosystem, more field studies were recommended to explore the interaction between microplastics and zooplankton.

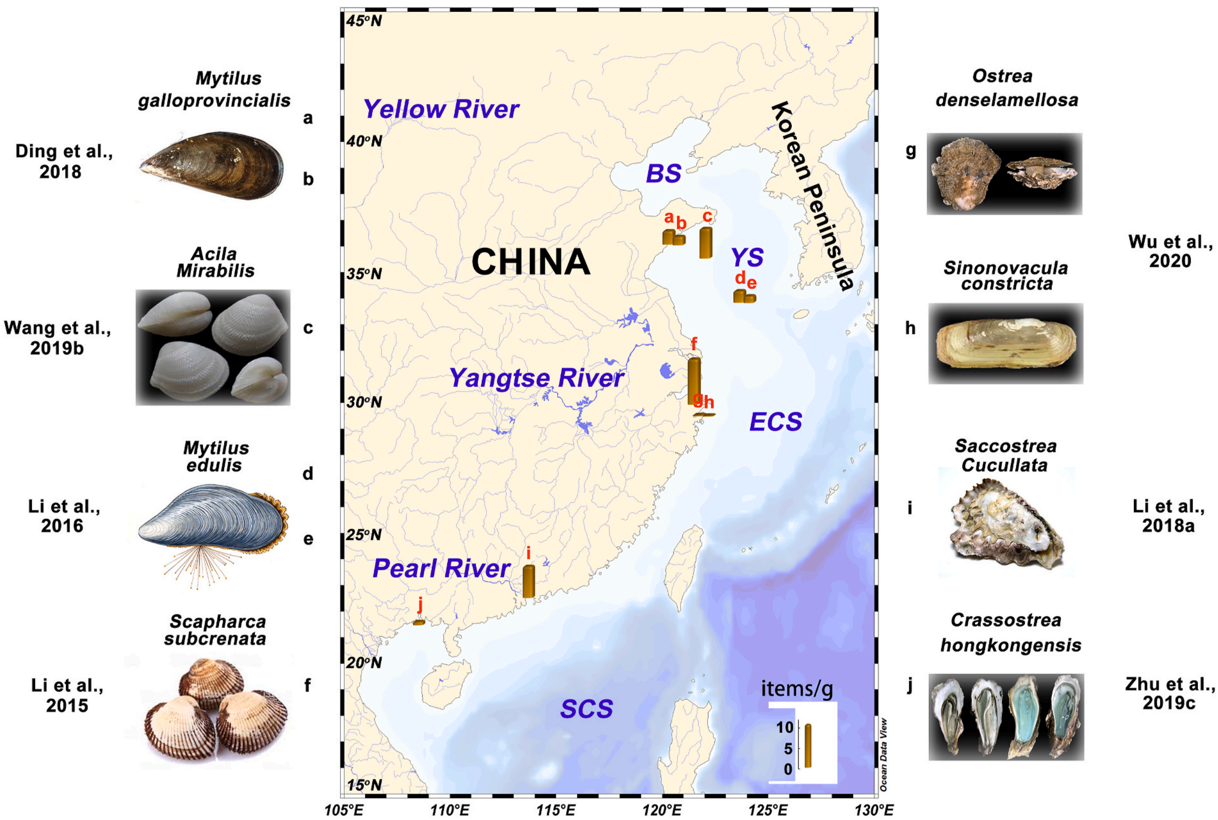

Fig. 4. The distribution of microplastics in the mollusks with the highest abundance in China sea areas. BS: Bohai Sea; YS: Yellow Sea; ECS: East China Sea; SCS: South China Sea. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Abundance, particle sizes and characteristics of microplastics in zooplanktons collected from major seas in China.

Sampling areas	Sampling time	Particle sizes (μm)	Abundance (items/m^3)	Shapes	Types	References
Bohai Sea	2018.8 (rainy season)	1300 ± 1520	2.03 ± 2.87	Fibers (92 %)	Cellophane (53 %) Polyester (18 %)	Zheng et al. (2020)
	2018.11–12.6 (dry season)	1040 ± 1060	0.41 ± 0.38	Fibers (93 %)	Cellophane (68 %) Polyester (20 %)	
Yellow Sea	2015.8–9	154.62 ± 152.90	Siphonophores: 3.57 ± 9.57 Copepods: 2.44 ± 4.90 Krills: 1.41 ± 3.87 Cephalopods: 1.36 ± 7.39	Fibers (46 %)	–	Sun et al. (2018)
Northern South China Sea	2015.6	505	Total: 4.1 Copepods: 2.19 Trichomaxilla: 0.67 Jellyfishes: 0.12 Shrimps: 0.81 Larva fishes: 0.29	Fibers	Polyester	Sun et al. (2017)
		106	Total: 131.5 Copepods: 103.49 Trichomaxilla: 20.03 Jellyfishes: 2.83 Shrimps: 5.16	Fibers		

5.4. Microplastics in other marine fauna

Microplastics have been detected in farmed sea cucumber (*Apostichopus japonicas*) from the Bohai Sea and the Yellow Sea in China, with 0–30 items/intestine (Mohsen et al., 2019). The dominant types of the polymers were cellophane, polyester, and polyethylene terephthalate. Further examination found that the microplastics were firstly stuck on the branches of the respiration tree and then transferred to the fluid of body cavity (Mohsen et al., 2020). Recent studies revealed that colored microplastics were more likely to be ingested by marine organisms, especially mammals, for they could attract the attention of animals more easily (Li et al., 2019b). For example, Zhu et al. (2019) reported that the intestines of coastal delphinid (*Sousa chinensis*) in Guangxi Beibu Gulf, China contained 6.8–15.5 items/g microplastics, which were mainly polyester fibers, white and blue items in the size range of 1–5 mm. Similarly, the abundance of microplastics detected in humpback dolphins (*Sousa chinensis*) in the Pearl River Estuary were 11–145 items/individual, and majority were 1–5 mm PP and PE fibers (Zhang et al., 2020b). Marine birds also mistakenly ingest the plastic debris as food. Zhu et al. (2019) detected 52 microplastics in 4 marine birds from South China Sea, and approximately 90 % of the total microplastics were blue and thread. The presence of microplastics in these apex predators highlights the potential impacts of microplastic pollution on the whole marine ecosystem, which deserves more attention and further study.

6. Conclusion and perspective

Microplastics are ubiquitously distributed in Chinese marine ecosystems, including the seawater, sediments, and marine fauna. We would have thought that microplastics pollution along the China coast must be much higher than that in other countries. Whereas, the facts revealed moderate or lower level of microplastics in the Chinese coastal and marginal seas as compared to other regions. For example, the microplastic abundance in the surface water of South Korea bays was as high as 1736 items/m^3 (Song et al., 2018), and high numbers of microplastics (42–6595 microplastics kg^{-1}) were observed in Arctic Deep-Sea Sediments (Bergmann et al., 2017), which were 3–5 orders of magnitude higher than the average abundance of microplastics in Chinese coastal and marginal seas. One study even found that the microplastic abundance in the pack ice of Fram Strait (Arctic) was 1.2×10^7 items/m^3 (Peeken et al., 2018). In contrast, abundance of microplastics in the seawater of four major seas of China were only 0.13–545 items/m^3, and microplastic abundance in the sediments from the estuaries of China were in the range of 20–7900 items/kg (Fok et al., 2015; Sun et al., 2018; Zhu et al., 2018; Zuo et al., 2020).

Undoubtedly, microplastics pollution has become a common human challenge, which needs every government to unite to solve this problem. We urge the governments to draw up "United Nations Framework Convention on microplastics pollution". It is necessary to legislate to avoid the use of disposable plastic products and ban the use of microplastics in personal care products, which would dramatically reduce the production and discharge of microplastics at source. Secondly, the plastic waste and microplastics interception measures should be installed on the rivers to prevent the input of microplastics from land to ocean, since serious microplastic pollution was observed in the estuaries. Compared to the dry season, higher microplastic abundance was found during the rainy season, suggesting that plastic waste recycling should be done to prevent the input of microplastics from the land and the work must be strengthened before the rainy season. In addition, municipal sewage treatment process should be improved to increase the removal efficiency of microplastics. We suggest that the governments and local communities of all countries should actively respond to our common environmental problem through practical policies and measures to prevent microplastics from further damaging the marine ecosystem.

Declaration of competing interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chemosphere.2021.131677.

Authors' contributions

All authors contributed to the information gathering, ideas and concepts, construction of figures, and/or writing of the manuscript.

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