11. CHINA

Summary of research topics: *China leads the region in terms of number of research papers on marine plastics (128 peer-reviewed papers published since 2015), which are focused on several topics of interest. There is a particular emphasis on monitoring surveys for microplastics, focused on quantification of microplastics spanning all marine environs including a variety of different habitat types and marine biota. Similarly, studies of ecological and environmental impacts have a particular focus on presence of microplastics, rather than intake/absorption mechanisms and food chain transfer. By contrast, there seems to be little research on macroplastics and their degradation, source differentiation, movement of plastics, accumulation and hotspots, ALDFGs, social perception and socio-economic impacts. Published articles and the number of institutions involved show China's leading research capacity in plastic research.*

Summary of understanding at national level: *There appears to have been a near country-wide sampling for marine microplastics abundance in a number of abiotic and biotic environments. These studies include polymer identification as well as associated contaminants. Much of the research is conducted at relatively high levels of technology, particularly evident in the frequent use of spectroscopy and the studies of sorption dynamics of specific chemicals. However, there is still a lack of standardised protocols for detection, sampling and extraction of plastics. The plastic classification system proposed by Wang et al. (2019) may be useful on this path of harmonisation or consistency in preferred sampling protocols.*

Keywords/research fields: *National approach; solid waste; trade of plastic waste; research foci; marine environs; upstream research; waste management; surveys and monitoring; methodology for the monitoring and assessment of marine litter; source differentiation; contribution from fisheries; ALDFG; accumulation zones; hotspots; ecological and environmental impact; socio-economic impact; adsorption-desorption of contaminants; organic contaminants; inorganic contaminants; plastics as transport vector; plastic additives; heavy metals; main players*

11.1 Context

11.1.1 National approach to plastic waste and its management

China's decision to ban the import of plastic waste in 2017 (effective in January 2018) shows the country's realisation of plastic issues raised by its management and pollution impacts. Despite new initiatives being implemented on the reduction of plastic consumption and waste, China does not seem to place plastic waste management as a top priority in their environmental policy agenda (Garcia et al., 2019). In contrast, there are varying extents of plastic waste management being carried out at sub-national levels, which is especially evident in coastal provinces and cities due to their proximity to seas.

According to data from the National Bureau of Statistics, China disposes of most of their waste at landfills, while only a small proportion is incinerated (BBC, 2019: available https://www.bbc.com

/news/world-asia-50429119). However, an increase in the amount of waste produced by population growth could threaten the capacity of their landfills. For example, the Jiangcungou landfill in Shaanxi Province, the largest landfill in the country, appears to be already filled when it would have been expected to last for another 25 years (BBC, 2019: available https://www.bbc.com/news/world-asia-50429119).

On 19 January 2020, the National Development and Reform Commission and the Ministry of Ecology and Environment announced a new policy to reduce the production, sale and use of single-use plastic products, including banning plastic bags in all of China's major cities by the end of 2020, extending the ban in all cities and towns by 2022, and banning single-use straws in the restaurant industry by the end of 2020. (China Daily, 2020: available http://www.chinadaily.com.cn/a/202001/20/WS5e24181da310128217272097_2.html).

This phased approach is expected to provide the time for the development of manufacturing of biodegradable and alternative products to replace single-use plastics (Forbes, 2020: available https://www.forbes.com/sites/trevornace/2020/01/20/china-to-ban-all-single-use-plastics/).

11.1.2 Plastics as a proportion of solid waste

The 2016 MSW for China was estimated at 220 million tonnes and is projected to reach 295 million tonnes in 2030 and 336 million tonnes in 2050 (Kaza et al., 2018). Meanwhile for Hong Kong SAR, the 2016 MSW was estimated at 5.7 million tonnes, and is projected to reach 6.9 million tonnes in 2030 and 7.6 million tonnes in 2050.

Estimates of the proportion of plastic in MSW in 1996 varied between 2 to 14% in different cities, where Shenzhen, a major city in the Guangdong Province scored the highest (Wang and Nie, 2001). Jambeck et al. (2015) estimated that about 11% of the national MSW was composed of plastics.

11.1.3 Illegal trade of plastic waste

The government first introduced 'Operation Green Fence' in 2013 in an attempt to increase the quality of plastic waste being imported into China and to reduce the illegal trade of plastic waste into China. Under this operation, plastic imports were accepted under the caveat that there was little or no contamination and to that, customs inspects were enhanced (Velis, 2014). Whilst this operation was successful to improve the control of legally imported plastic waste, it seemed to have been unable to sufficiently curb the illegal trade of plastic waste that was still happening. In 2017, China announced a new import policy known as the 'National Sword Policy' to permanently ban the imports of non-industrial plastic waste, among the 23 other types of waste (Chinese Ministry of Environmental Protection, 2017: available http://www.mee.gov.cn/gkml/hbb/bgg/201708/t20170817_419811.htm?COLLCC=3069001657&).

This ban took effect in 2018 and China seems to have seen results, with the amount of plastic received being halved in 2018. In 2016, it had received 7.35 million tonnes of plastic waste from 43 countries, accounting for 52% of global plastic exports in that year. Since reporting began in 1992, China and Hong Kong cumulatively received 72.4% of all plastic waste (Brooks et al., 2018).

This policy is widely considered to have caused a global crisis in the trade and recycling of plastic waste trade which resulted in the re-routing of illegal trade of plastic waste to alternatives countries, particularly those in Southeast Asia (Greenpeace, 2019).

11.2 Research review of pollution from marine plastic

11.2.1 Research overview

There has been an extensive amount of research on marine plastics in China, especially in recent years. It appears to be a nation-wide effort, as numerous research institutions are involved, covering a wide geographic range from its coastal provinces along the eastern and southern coastlines of China, to the major inland rivers that lead out to the open ocean (i.e. Pearl River and Yangtze River), as well as to the waters around the Paracel and Spratly Islands (i.e. South China Sea basin).

Marine plastics research in China had the largest amount of published peer-reviewed articles among the ASEAN+3 member states (n=129). For the scope of this study, we limited our review to English-language peer-reviewed published articles between 2015 and 2019. It is expected that the number of articles on marine plastics published in China and in Chinese-language in peer-reviewed journals will be much higher, as well as institutional reports and grey literature, which could not be covered in this report. The decision to select 2015 as the start date for inclusion of studies in this report is based on the observation that 90-95% of articles were published from 2015 onwards. This time frame is therefore expected to better reflect current trends in marine plastics research in China.

Around 76% of this research effort was published between 2018 and 2019. The research covers a wide range of topics across 14 different research foci (Figure 1.2.11.1). Of these, there is an emphasis on the understanding of the pollution status through surveying and monitoring (n=76), on assessing the ecological and environmental impacts of plastics (n=38) and on understanding the sorption mechanism of contaminants on plastics (n=32).

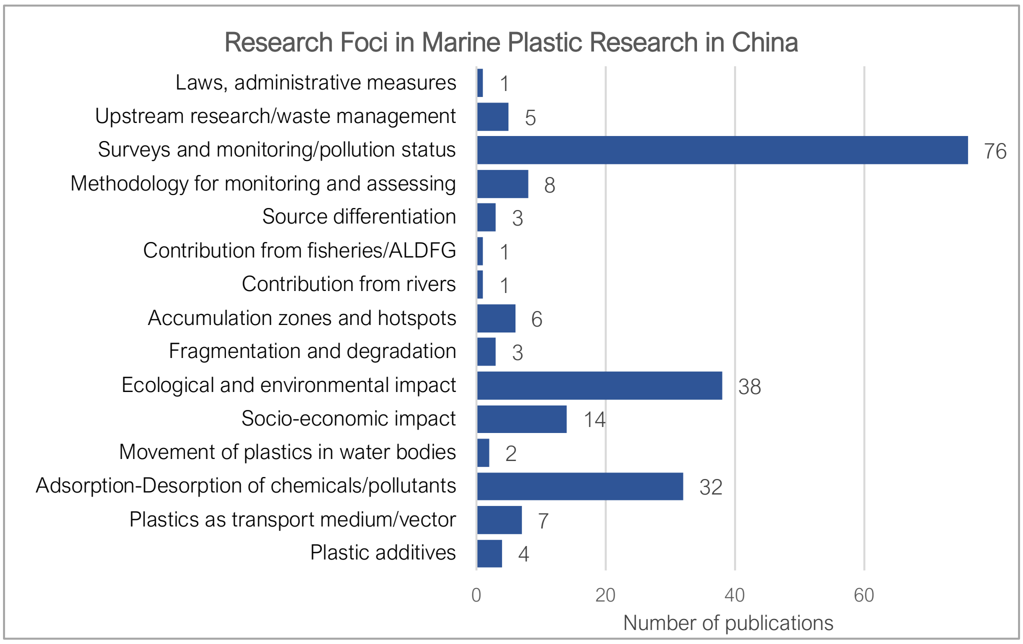

Figure 1.2.11.1. Research foci of marine plastic research conducted in China.

11.2.2 Types of research conducted

Types of plastics research foci

Of the 129 studies examined, microplastics appear to be of greatest concern with the highest number of published articles (n=113). By contrast, only four articles are solely focused on macroplastics and 11 studies examined both macro- and microplastics.

Articles concerning microplastics focused mostly on surveying and monitoring presence, abundance, and polymer types in various marine environs. Other articles focused on plastic litter as a pathway or vector for contaminants and its related sorption mechanisms, on hydrodynamic modelling of movement microplastic debris and on originating sources based on different hypotheses (i.e. personal care products).

There have been some attempts to examine polymer-specific plastic contaminants, both as plastic additives and non-additives (i.e. sorbed contaminants), mostly done in a laboratory setting. The polymers selected in these studies were those that can be found on some of the polymers already observed in the natural environment.

Coverage of marine environs

There is a balanced number of studies in the four marine environs (Figure 1.2.11.3), with a greater emphasis on sea surface waters (n=44) and in selected marine biota (n=44), followed by the shoreline (n=30) and finally, the surface and subsurface sediments of the seafloor (n=23).

Of note, there were a number of studies realised in laboratory settings that focused on potential mechanisms of impacts, movement or pathways of microplastics in the natural environment.

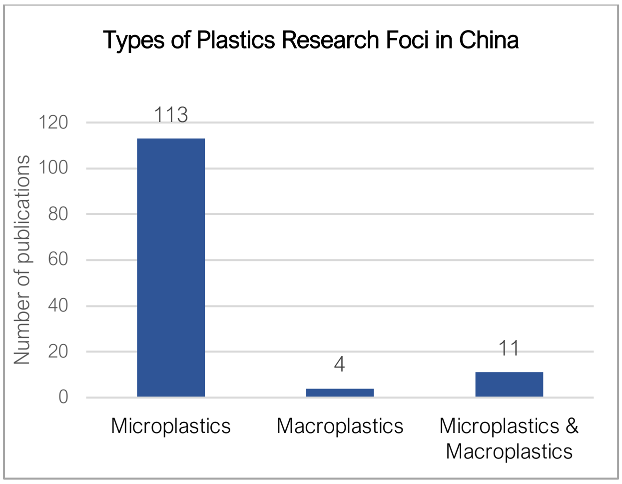

Figure 1.2.11.2. Distribution of marine micro-/macro-plastics researched in China.

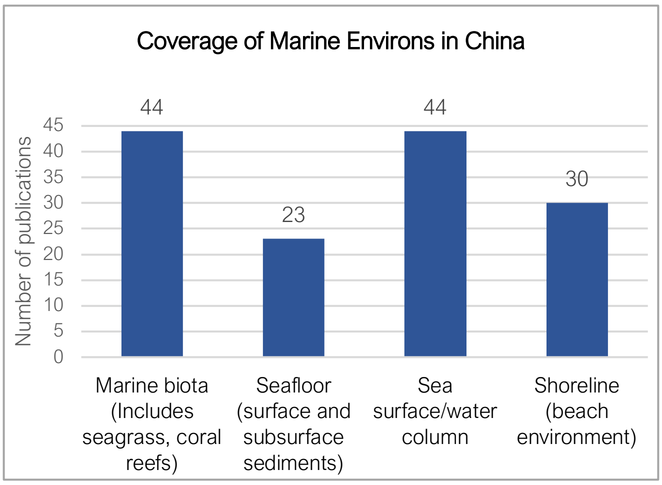

Figure 1.2.11.3. Distribution of marine environs researched in China.

Of the studies in sea surface waters, 22 papers were surveys in near-shore environments, 11 papers were in open seas, while the remainder were general literature reviews. None of the papers sampled from deeper sections of the water column.

With respect to the 44 papers on plastics in marine biota, 12 focused on surveying the presence/ absence of plastics in commercial species and 10 were laboratory based.

Of the 30 papers on shoreline, 20 were surveys of different habitats: mangroves, mudflats, sandy beaches as well as papers on multiple habitats.

Of the 23 papers on seafloor environs, 13 were monitoring surveys and the remainder were general literature reviews or methodology papers. Nine survey and monitoring papers examined near-coastal benthic sediments within estuaries or bays, while four papers examined sediments in deeper waters, in the Yellow Sea and in the East China Sea.

Three recent papers deserve particular attention. One paper assessed sorption mechanisms of antibiotics on microplastics collected from sediments (Guo & Wang, 2019) and two papers assessed pollutants such as hydrophobic compounds (Lo et al., 2019) and heavy metals (Mohsen et al., 2019) carried by microplastics found in sediments.

11.2.3 Survey and monitoring

Surveying and monitoring counted for more than half of marine plastic research in China with a focus on microplastics and in various marine environs, reporting the extent of plastic contamination.

Microplastics

Microplastics are found to be prevalent in a wide array of environments although the distribution and reported abundance is varied. In addition to the four environs focused on for this study, other studies focused on other commercial food items such as common table salt (Yang et al., 2015).

Some studies have focused on presence/absence and quantification of microplastics in marine biota. These include marine biota in the wild (Chan et al., 2015; Ding et al., 2019; Jabeen et al., 2017; Li et al., 2015, 2016, 2018; Su et al., 2019; Sun et al., 2017, 2019; Zhang et al., 2019), farmed marine biota (Feng et al., 2019; Teng et al., 2015; Wang et al., 2018, 2019), and those in both wild and farmed conditions (Cheung et al., 2018). One study conducted by Zhu et al. (2019) examined deep-sea fish from depths of 200 to 209 m and 453 to 478 m and reported a uniformity of microplastics ingestion in fish collected from different depths. The dominant microplastics found were of cellophanes in film structures. The contamination of microplastics however, were examined to be seemingly low.

Quantification of microplastic in the three abiotic marine environments was also conducted. Most of the studies examined microplastics in the sea surface or water column (Cai et al., 2018; Cheung et al., 2018; Cheung & Fok, 2016; Huang et al., 2019; Li et al., 2018; Luo et al., 2019; Mai et al., 2018; Pan et al., 2019; So et al., 2018; Wang et al., 2019; Xu et al., 2018; Yan et al., 2019; Zhang et al., 2019; Zhao et al., 2015). Microplastics on the shoreline was also an area of interest where there was surveying in different ecological habitats. These ecological habitats include those of coastal beaches (Cheung et al., 2016; Fok et al., 2017; Fok & Cheung, 2015; Qiu et al., 2015; Yu et al., 2016; Zhou et al., 2015, 2018; Zhang et al., 2015), mangrove ecosystems (Li et al., 2019) and saltmarshes (Yao et al., 2019). A mix of different ecological habitats on the shoreline has also been examined in several studies (Lo et al., 2018; Li et al., 2018; Zhou et al., 2016).

Surface and subsurface sediments of the seafloor were less studied but still common in several studies (Cheang et al., 2018; Peng et al., 2017; Zhao et al., 2018; Zhang et al., 2019). In a number of studies, microplastic quantification was not done in a single isolated environment but as a combination (Chen et al., 2019; Ho & Not, 2019; Tsang et al., 2017; Wang et al., 2018; Zhu et al., 2018; Zheng et al., 2019).

In attempts to draw meaningful comparisons of microplastic contamination in marine biota with the surrounding abiotic environments, some studies quantified microplastics in both marine biota and the physical environment (Ding et al., 2019; Mohsen et al., 2019; Nie et al., 2019; Sun et al., 2018; Qu et al., 2018; Wang et al., 2019; Zhu et al., 2019).

Microplastics in these studies, where defined, were generally denoted as being <5 mm, with some studies showing a further classification into finer size classes. There is a good proportion (92%) of studies that further examined plastics into its specific polymer types. Microplastics found in the natural environment appears to be commonly of polymer types PE, PP, PS, PET and PVC as well as less commonly found polymers such as PA, LDPE, CP and nylon. The majority of studies (94%) also identified the morphology of microplastics sampled, and most commonly found fibres, fragments, and films.

The reported quantification from these studies were often in a diversity of units but may be comparable when converted to the same standard (with the caveat that different methodologies can lead to less comparable results):

- In marine biota studies, microplastics examined are from various body parts of marine biota (e.g. entire gastrointestinal tract, stomach, intestines, gills, liver, muscles, etc.) and are generally measured for abundance (number of items per individual; gram of tissue wet weight; gill).
- In sea water and surface columns, microplastics could be examined from different depths or volume and were mostly measurement of abundance (number of items per m^3; $100m^3$; km^2; litre).
- On the shoreline and along the seafloor, microplastics could be examined from different ecological habitats and niches, and were measured for abundance in terms of number of items (per kg dry sediment; 50g dry sediment; 100g dry sediment; kg sediment; kg sand; m^2; m^3) and in weight or volume (g or mg per m^2; m^3; $100m^3$).

Much of the research was conducted at relatively high levels of technology. Spectroscopy techniques were used in the majority of survey and monitoring papers to analyse polymers sampled, and several additionally used SEM to describe the surface morphology of weathered microplastics sampled.

Macroplastics

There was only one surveying attempt on macroplastics in Zhou et al. (2016). In this research, the team examined macroplastic debris on 23 sites on beaches of coastal mainland China and in their adjacent waters). They reported that plastic was the most common debris type.

11.2.4 Source differentiation and pathways

Many papers which surveyed marine plastic debris in the natural environment suggested mariculture and industrial activities as likely sources. Several studies conducted in Hong Kong and Guangzhou suggested that the Pearl River was a major contributor to marine plastic debris in the area (e.g. Fok & Cheung, 2015, Li et al., 2018), while a later paper refuted this suggestion (Cheung et al., 2018; notably by the same authors who first suggested that the Pearl River was a major source of marine debris).

However, few papers aimed to directly identify the sources of marine plastic debris. Cheung & Fok (2016) and So et al. (2018) both investigated microbeads that had been sampled from coastal waters around Hong Kong and found their appearance and composition had matched those found in cosmetic products sold in Hong Kong.

A 2019 study by Wang et al. explored the possibility of typhoons as a major factor influencing an increase in marine plastic following high rainfall run-off. It discussed the role of infrequent natural phenomena in the pathways of microplastic distribution.

In the context of plastic as a pathway for pollutants other than plastics polymers, its associated contaminants (either plastic additives or other potential pollutants that are sorbed on the plastics), are important in understanding pollution from marine plastics. China has shown notable research interest on this topic of plastic as a pathway. Most of these studies examined the sorption mechanism and behaviours of contaminants to specific plastic polymers in laboratory settings (n=32). There were also studies examining the toxicity impacts of selected polymers on certain marine biota (n=4) and the potential of plastic as a transport vector of contaminants in the natural environment (n=3). Specific polymers used in these studies notably coincided with those found in the natural environment as previously mentioned. Contaminants that have been studied include various organic pollutants of antibiotics, lubricating oil, organic filters, polyhalogenated carbazoles, phthalate esters, BFRs, PAHs, OCPs, OPEs, BPAs, and HBCDD. Several studies also examined inorganic heavy metals including those of lead, copper, cadmium, strontium, zinc, manganese, chromium, nickel and arsenic.

11.2.5 Movement of plastics, accumulation and hotspots

There is little research studying movement of plastics in the marine environment except in literature reviews (Wang et al., 2016 and Zhang 2017). Zhang (2017) provides an in-depth literature review discussing processes of behaviour of plastic particles and challenges encountered in its study. Some surveys also discuss distribution and areas of accumulation of higher concentration (e.g. in saltmarsh, Yao et al., 2019).

11.2.6 Ecological and environmental impacts

There is a strong and diverse research interest in the environmental impacts of marine plastic pollution. 26 articles discuss studies of *in situ* uptake of microplastic in marine organisms, predominantly in fish (Cong et al., 2019, Chan et al., 2019, Nie et al., 2019; Su et al., 2019; Sun et al., 2019; Zhang et al., 2019; Zhu et al., 2019a) and bivalves (Luo et al., 2019; Li et al., 2018; Li et al., 2016; Li et al., 2015), as well as marine mammals (Xiong et al., 2018, Zhu et al., 2019b), seabirds (Zhu et al., 2019c), zooplankton (Sun et al., 2017, Sun et al., 2018), and less commonly studied taxa such as sea cucumbers (Mohsen et al., 2019), starfish (Wang et al., 2019), jellyfish (Sun et al., 2017) and crustaceans (Zhang et al., 2019). 12 of these studies were conducted on commercial species, either farmed or caught in mariculture areas.

These papers were able to use advanced methods of spectroscopy to characterise and identify the polymers found, primarily FTIR spectroscopy. A few papers used Raman spectroscopy, infrared spectroscopy, or even scanning electron microscopy. They tended to find fragments and fibres, consisting of a wide variety of polymers such as PP, PE, PVC, PET, polyester, nylon, and more. Units were typically expressed in item counts, though they were split in whether individuals or tissue wet weight were used. Notably, two papers (Su et al., 2019, Zhang et al., 2019) specifically examined microplastic in fish gills in addition to their digestive tracts, which was not investigated in papers from any other country in the region which typically either did not distinguish between organs or sampled only the digestive tract.

There are no papers quantifying macroplastic ingestion, or entanglement records.

China leads the region in laboratory studies investigating the physio-chemical impacts of plastic exposure to marine organisms (n=12). These studies span diverse taxa, such as marine microalgae, bivalves, polychaetes, and fishes, and primarily focus on effects such as mortality, development, and reproduction. Both direct ingestion and exposure to plastic leachates were investigated, originating from different polymers, including PS, PE, PP, and PVC, though most studies focused on the effects of one type among these.

Zhang et al. (2019) suggested that trophic transfer of plastic debris occurs in the wild, finding a correlation between higher microplastic abundance and species of a higher trophic level. However, this paper compared microplastics per individual and did not consider the influence of size and varying food intake rates. More research is needed for understanding trophic transfer of plastic in the wild.

11.2.7 ALDFG

There is only one published peer-reviewed study on ALDFG. Chen et al. (2018) quantified microplastics in the surface waters, intertidal sediments, and benthic sediments of Xiangshan Bay, Zhejiang, while attempting to distinguish their likely sources based on polymer types. The most common polymers found were PE, synthetic cellulose, and PP. They estimated that about 55.7% of seawater microplastics and 36.8% of sediment microplastics originated from mariculture activities.

11.2.8 Social perceptions and socio-economic impacts

There were no peer-reviewed studies published by Chinese authors which directly studied social perceptions regarding plastic pollution, or economic and monetary impacts.

However, there is a strong interest in the potential impact of microplastics on human health and food safety in China (n=13). Microplastics have been quantified in seafood either obtained from fish markets or caught from mariculture areas, primarily fishes (n=7 papers) and bivalves (n=6 papers), with one paper on sea cucumbers (Mohsen et al. 2019). All the papers found microplastic fibres and fragments in at least half of their samples. The most commonly found polymers were PE, PET, and cellophane, and some papers also mentioned high levels of PVC, PP, and rayon. In addition, Yang et al. (2015) measured microplastics in commercial table salt sold in China, which was among the first papers to look for microplastics in a sea-derived, non-biotic product. They found abundant levels of microplastics in all brands of salt they had sampled, particularly in sea salts, with the most common polymers being PET and PE fragments and fibres.

Brook et al. (2018) investigated the impact of China's ban on the import of plastic waste on the displacement of the plastic waste trade, and described current global patterns of the plastic scrap and waste trade. They estimated that about 111 million metric tons of plastic waste would be displaced by 2030 due to China's import ban.

11.3 Main players in marine plastic research

Majority of authors are local researchers working in Chinese research institutions, with 3 papers headed or co-authored by researchers from the United States. Many institutes are involved in marine plastic pollution research, mainly from coastal areas.

Figure 1.2.11.4. Composition of research efforts in China.

Across over a hundred different institutions, the most prolific include East China Normal University (ECNU), the Chinese Academy of Sciences (Yantai, Qingdao, Wuhan, Guangzhou), the University of the Chinese Academy of Sciences, Qingdao National Laboratory for Marine Science and Technology, Xiamen University, the Education University of Hong Kong, and the University of Hong Kong.

Out of over 80 corresponding authors on these papers, two researchers stand out as particularly prolific. Lincoln Fok, from the Education University of Hong Kong, has conducted many surveys on plastic pollution around Hong Kong. Huahong Shi, from East China Normal University, has an interest in surveying plastic pollution and ingestion in wild marine organisms.

11.4 Summary of understanding

China leads the region in terms of number of research papers on marine plastics, focused on a few key topics of interest. There is a particular emphasis on monitoring surveys, spanning all marine environs and a variety of different habitat types, from sandy beaches to mangroves, from estuarine waters to coral reefs, including less frequently studied habitats such as the deep ocean floor. However, there is still a lack of standardised protocols for detection, sampling and extraction of plastics. The plastic classification system proposed by Wang et al. (2019) may be useful on this path of harmonisation and consistency in preferred sampling protocols for different environs, polymers and/or their associated contaminants.

There is also a strong interest in understanding ecological and environmental impacts, partly on human health, including through the monitoring of absorption of plastics by selected species used as indicators or proxies, as well as the interactions of microplastics with other pollutants through understanding the sorption dynamics of a wide variety of chemicals on microplastics.

All these studies are overwhelmingly focused on microplastics, with extremely little discussion of macroplastics (from which microplastics may originate) and sources. In particular, despite the importance of the mariculture industry highlighted in the human health/food safety papers, there is little focus on ALDFG and its impacts on the environment, or entanglement of fishing gear in marine biota. Understanding the presence and effect of macroplastics, in conjunction with the advanced technological expertise present in many papers, would lend well to more in-depth analyses on fragmentation and weathering processes from macro- to micro- or even nano-plastics.

There is little research outside of a few focal topics, though there is likely an existing interest in advancement into other topics. While many studies are clustered around major rivers (e.g. Pearl River, Yellow River), riverine contributions are not often quantified beyond a general influence. Given the large volume of data on the pollution status of marine debris in China, it would be highly advantageous to employ modelling of plastic transport and more in-depth investigation into accumulation areas and hotspots in the region, as well as source differentiation.

The status of marine plastic pollution research conducted in China is voluminous, with involvement from a large number of institutions and diverse research groups. Much of the research is conducted at relatively high levels of technology, particularly evident in the frequent use of spectroscopy in pollution surveys and in understanding sorption dynamics of specific chemicals. This high level of interest and technological ability place research in this region in an advantageous position to broaden the scope of study and deepen the understanding of the effects of plastic pollution on the marine environment, wildlife, and human society in a global context.