Status of Marine Litter Pollution and Management in the Republic of Korea

March 2020

Our Sea of East Asia Network

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CHAPTER 1. INTRODUCTION

Surrounded by Republic of Korea and People’s Republic of China, the Yellow Sea plays an important role not only in both countries but also in the global marine ecosystem. Recently, the environmental threat posed by microplastics, which have emerged as one of the major international environmental issues, has been very actively studied in both countries. What we’ve understood from the research of microplastics is largely focused on estimating how much pollution they cause and how much they will affect the ecosystem and our lives. Some of the microplastics are originally manufactured and produced in small sizes, which are called ‘primary microplastic’, but most of them are split from macro- and meso-sized ones. In order to prevent microplastics from entering the sea, as well as understanding the distribution and cause of meso- and macro-sized plastic litter, it is necessary to have a serious concern forthe prevention and efficient management of marine debris, and the evaluation of policies in each country.

This report summarizes marine litter pollution on the coast of the Yellow Sea including microplastics and meso- and macro-sized plastic pollution, though it needs to be noted that the Yellow Sea coastal areas were separated from other coasts of the Korean Peninsula in research publications we referred to. It also collected information on the damage caused by marine litter and national policies. The goal of this report is to create a comprehensive understanding of the state of marine litter pollution in the Yellow Sea. Therefore, Chapter 2 describes the distribution and sources of marine litter, and time-space trends. Chapter 3 summarizes the damage caused by marine litter, although it is not much researched. Chapter 4 introduces Korea's latest marine management policies. We look forward to contributing to the better future of the Yellow Sea Large Marine Ecosystem and to reducing the threat to the health of the people of RO Korea and PR China.

CHAPTER 2. DISTRIBUTION, SOURCES, AND TEMPORAL/SPATIAL TREND

2.1. Beach litter

Beach litter monitoring can be defined as the measurement of litter on the beach to detect temporal and spatial distribution pattern of litter on the beach. Beach has been the most popular and surveyed compartment of the marine environments where marine litter occurs. It is because beach is easily accessible and it costs less to get samples on the beach. In addition, beach is more likely to accumulate a large quantity of marine litter partly because it is close to land-based sources of it.

Beach litter is accumulated along the high-strandline in large quantities. In the back of the beach where vegetation engineered structures and terrestrial ecosystems are developed, a large quantity of litter also tends to be accumulated as the wind brings litter towards the backshore. The beach orientation is one of the factors which affect litter accumulation because it moves along the wind and currents, being deposited on some particular areas of beach and they can deposit litter on some particular areas of the beach. The gradients of beach can also be one of the considered factors. A gently-slopted beach is generally more susceptible to litter accumulation than a stiff one. Severe weather events like a storm can bring huge quantities of litter at the beach, suggesting the quantity of beach litter may vary according to season. The amount of beach litter can be changed by human activities. Visitors may leave litter on the beach and thus affect the litter abundance. It means the amount of beach litter can vary by seasons. Beach cleanup should also be considered when planning beach litter monitoring, because beach clean-up removes most of the litter from beaches (GESAMP, 2019).

In addition to beach characteristics described above, sampling items and methods should be carefully designed to get representative samples. Beach litter can be itemized by materials such as plastics, woods, metals, rubbers, and papers. In many cases sampling is targeted only for the plastics. Sampling methods can be applied for different sample sizes and different types of beach substrate.

Beach monitoring survey started in Korea in 2000 when the International Coastal Cleanup (ICC) was performed. However, scientifically meaningful monitoring data has been compiled since 2008 when the first phase of Korean National Marine Debris Monitoring Program (KNMDMP) started. After the ten-year long active surveys during the first phase, the KNMDMP has progressed into the second phase and has been continuously carrying out surveys on the same beaches with the number of the sampling sites being doubled in 2014. Besides, several more beach litter monitoring programs of various scales have been also conducted with in Korea. In this part we will review beach monitoring surveys that have been so far implemented in Korea including the methods and results of those surveys

2.1.1. Methodologies for quantification and qualification

One of the main objectives of beach litter monitoring is to better understand the current status of distribution and characteristics of beach litter in order to more effectively cope with this problem. Numerous studies have been conducted with aims of identification and quantification of beach litter worldwide. For elucidating the level of beach litter, data comparison between studies should be inevitable. However, the difference in methodologies used makes it difficult to compare results of different studies. This hampers the efforts for making policies and measures to mitigate and prevent beach litter. In this regard, this paper will review monitoring methods that are commonly used worldwide and those that are adopted in RO Korea to carry out beach monitoring.

■ Sampling

To elucidate the distribution of marine litter, it is needed to obtain the representative samples from sampling sites. Different approaches can be applied to collect beach samples. Samples can be obtained by selective, bulk, or volume reduced ways (Hidalgo-Ruz *et al*., 2012).

We can get a selective sample where we take the entire volume of the sample without reducing it during the sampling process. This method is the most appropriate to obtain large-sized marine litter like macro or mega debris. KNMDMP adopted selective sampling in which all items of litter have been collected in a designated area. The program was conducted for 10 years on 20 beaches of Korea from 2008 to 2013 and has been conducted for 40 beaches since 2014. In the first phase of KNMDMP which was conducted from 2008 to 2017, all items of macro litter larger than 2.5 cm were collected from 100m-transect of the monitoring sites (Figure 2.1; Figure 2.2). In the second phase of KNMDPM which was started in 2018, samples were collected from four 5m-subtransects within a 100m-transect of the monitoring sites (Figure 2.3; Figure 2.4).

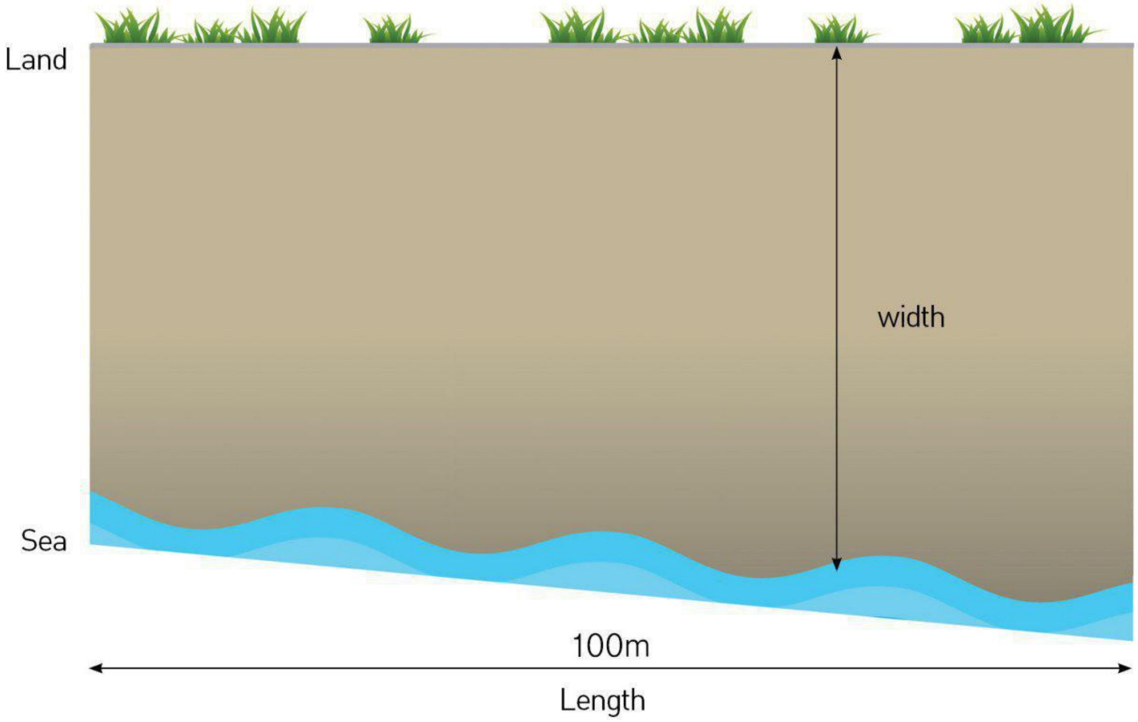


Figure 2.1. Scheme of sampling site on the first KNMDMP (2008~2017)

Figure 2.2. Monitoring activities during the first KNMDMP(2008~2017)

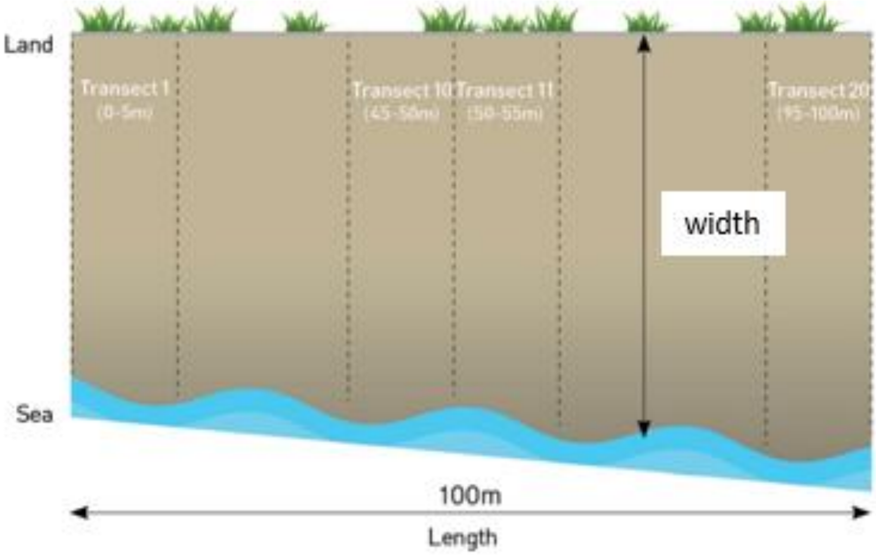


Figure 2.3. Diagram of sampling site during the second phase of KNMDMP (Guide to Korea national beach litter monitoring program, 2019) (2018~)

Figure 2.4. Monitoring activities during the second KNMDMP (2018~)

Bulk sampling refers to a method where the entire volume of a sample is collected without being reduced during the sampling process (Figure 2.5). Bulk sampling is the most appropriate to study marine litter that cannot be easily identified through visual observation for the following reasons: (i) they are covered by sediment particles, (ii) their abundance is small requiring sorting of a large volume of sediment, or (iii) they are too small to be identified with the naked eye. Bulk and volume-reduced samples require further processing in the laboratory (Hidalgo-Ruz *et al*., 2012). Bulk samples were applied to collect meso litter from Korean beaches (Lee *et al*., 2013;Lee *et al*., 2015;Lee *et al*., 2017).

Volume-reduced samples can be taken where the volume of the bulk samples is reduced during sampling (Figure 2.6), preserving only the concerned portion of the sample for further processing. For sedimentary environments, samples can be sieved directly on the beach. Microplastics were sampled with volume-reduced way on Korean beaches (Song *et al*., 2015a; Eo *et al*., 2018).

Figure 2.5. Sampling for a bulk-reduced samples (adapted from NOWPAP, 2020)

Figure 2.6. Sampling for a volume-reduced samples

- **Size**

Sampling sizes should be determined before carrying out sampling as they affect sampling methods. Proper sizes of sample should be selected to achieve research objectives. Unfortunately, however, size categorization has not yet been standardized. Several institutes and organizations suggested recommendations on how to classify beach debris by size (Table 2.1). NOAA Marine Debris Monitoring and Assessment and GESAMP Guidelines for Monitoring and Assessment of Plastic Litter divide marine litter into five categories of size including mega, macro, meso, micro and nano litter.

UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter and EU MFSD Guidance on Monitoring of Marine Litter in European Seas divide them into three categories like macro, meso, and micro litter (Table 2.1; Figure 2.7).

Table 2.1. Classification of marine litter by size (adapted from NOWPAP, 2020)

Category	NOAA	UNEP/IOC★	EU MSFD	GESAMP
Mega	>100 cm			>100 cm
Macro	2.5-100 cm	>2.5 cm	>2.5 cm	2.5-100 cm
Meso	5-25 mm	5-25 mm	5-25 mm	5-25 mm
Micro	<5 mm	<5 mm	<5 mm	<5 mm
Nano	<1 μm			<1 μm

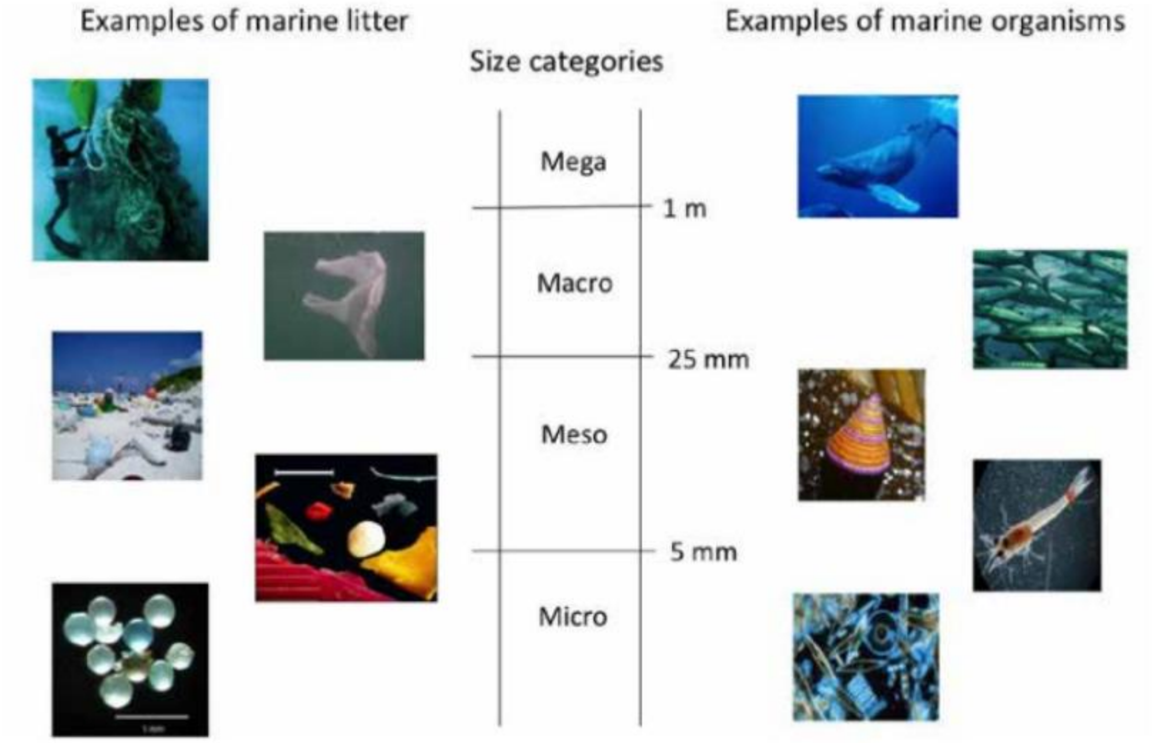


Figure 2.7. Schematic showing field descriptors, typical aquatic organisms in that size category, examples of marine litter and common size divisions(adapted from GESAMP, 2019).

In Korean beach monitoring, most of the beach litter studies categorized beach litter into macro, meso, and micro litter. In some studies micro litter (in specific, microplastics) has been divided into large micro- and small microplastics(Eo *et al*., 2018; Lee *et al*., 2013). In particular, meso litter has been exclusively monitored by some studies which revealed characteristics of its distribution(Lee *et al*., 2013, Lee *et al*., 2017).

■ Categorization of beach litter by materials

After collecting by size, samples were prepared and analyzed. For the analysis, they should be separated by classification criteria. Usually, beach litter items were categorized by shape, material, and polymer type. In Korean monitoring studies, beach litter items have been categorized by material and polymer. In surveys of macro and meso litter, items were categorized by material such as plastics, woods, metals, rubber, and paper. In microplastic studies, they were usually categorized by material and polymer.

■ Sampling depth

A beach monitoring survey requires collecting sand to examine meso and micro litter items. Sampling depth is one of the main factors which affect the litter abundance as Carson *et al*. (2011) revealed over a half of the plastics were present in the top 5 cm depth and nearly 95% were located in the top 15 cm. Lavers and Bond (2016) also elucidated that approximately 68% of litter items on the beach were buried < 10cm in the sediment. In Korean beach monitoring studies, sampling depths vary by study, but they were within a range from 2.5 to 5 cm(Lee *et al*., 2013; Lee *et al*., 2017; Song *et* *al*., 2015a; Eo *et al*., 2018; Eo *et al*., 2019).

- **Color**

Color of the litter can provide useful information about source and weathering of marine litter. More importantly it affects ingestion of plastic litter by marine wildlife (Boerger *et al*., 2010; Lavers and Bond, 2016; Santos *et al*., 2016).

However, visual identification of litter color can be very subjective (GESAMP, 2019). For this reason, color description was not usually performed in beach litter monitoring studies in Korea.

- **Unit**

Unit is one of the most important criteria that is used to describe the abundance of marine litter. However, there is no standardized unit for marine litter and it leads to confusion and difficulties in comparison of monitoring results. For macro and meso litter on Korean beaches, many studies used the number and weight per unit area and fewer cases were reported to use the number or weight per unit length. For microplastics, they were expressed mostly in terms of the number and weight per unit area, followed by the number and weight per unit volume of sediment

- **Study period (one off survey or long period) and geographic coverage**

Study period, along with repetitiveness and geographic coverage of a marine litter survey, is important to understand the spatial and temporal variation. For this purpose, selecting representative sampling sites and repetitive monitoring were crucial.

KNMMP has been monitoring macro litter for more than 10 years on the same sites with the number of sites being doubled in 2014.

The program covers the whole Korean peninsula. Therefore, the program has enabled us to track temporal and spatial variations of marine litter on beaches and develop proper countermeasures. Other macro litter studies were one-off survey carried out in various research designs.

■ Identification of microplastics

Macro litter is usually identified with the naked eye in situ and meso litter is also monitored with the naked eye after being sieved from the beach sediments. They are subject to classification and identification by criteria. However, several procedures should be preceded before identifying microplastics. After getting volume-reduced samples, separation, filtration and digestion are required before identifying microplastics. Once these processes are completed, microplastics are quantified and qualified with special instruments like FTIR and Raman Spectroscope (Figure 2.8; Figure 2.9). Several Korean studies adopted this method for microplastics analysis (Eo *et al*., 2018; Kim *et al*., 2015). Selecting large litter items with the naked eye from volume-reduced samples can be applied (Lee *et al*., 2013; Lee *et al*., 2015; Eo *et al*., 2018).

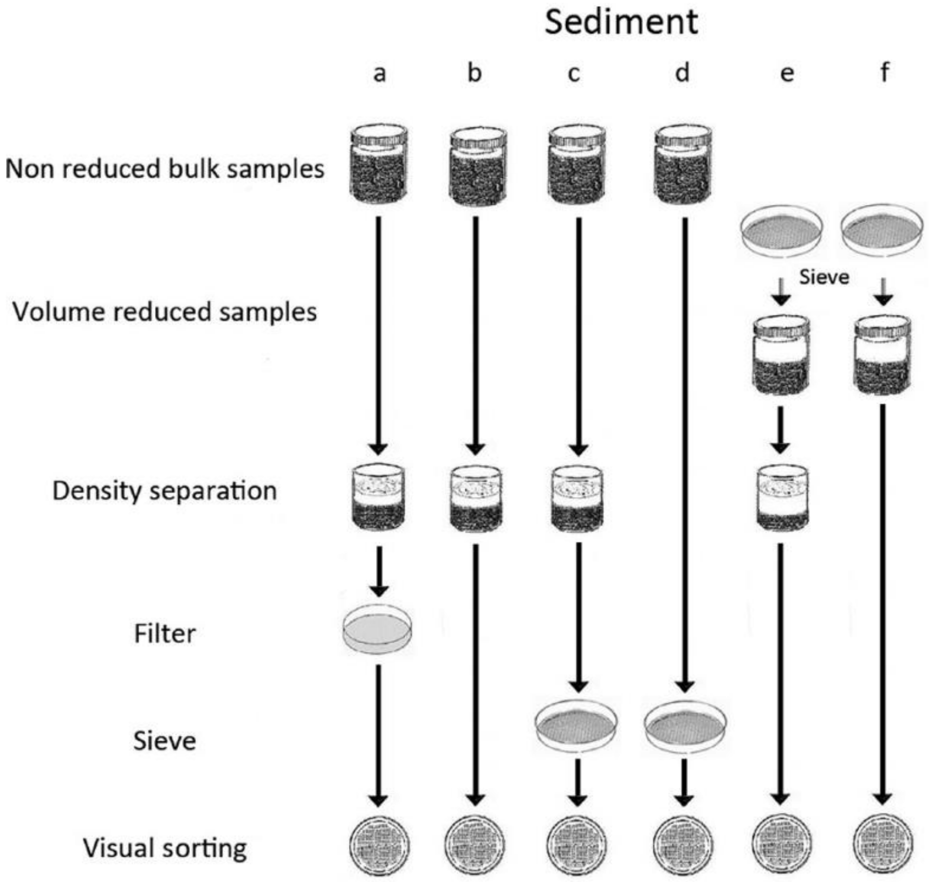


Figure 2.8. Steps of microplastics sampling process (adapted from Hidalgo-Ruz *et al*., 2012)

2.1.2. Distribution of macro-, meso-, and micro-sized litter

- **Distribution of macro-sized litter**

The Korean government has been combating the issue of marine litter since the late 1990s by investing in retrieval programs and research projects. However, the government has focused mainly on the retrieval of floating or deposited fishing gears from near shore coastal waters (Hong *et al*., 2013).

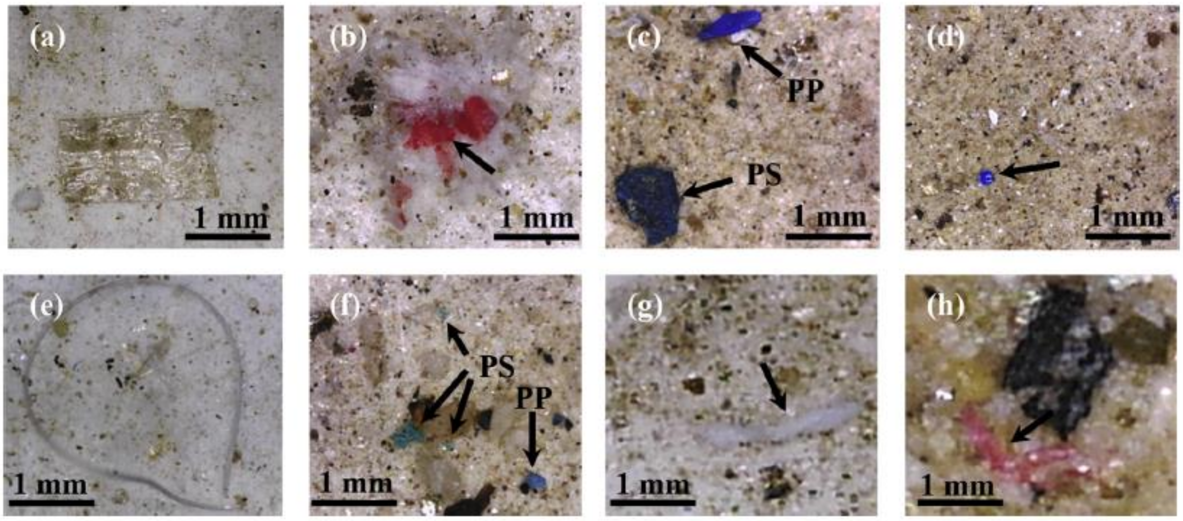


Figure 2.9. FTIR images showing various polymers of microplastics (adapted from Yu *et al*., 2016)

KNMDMP was developed on the legal basis of Marine Environment Management Act revised in 2008. The program was developed by the Ministry of Oceans and Fisheries (MOF) and the Korea Marine Environment Management Corporation (KOEM) to understand the levels of marine litter pollution and its characteristics. It is aimed to make countermeasure policies to combat marine litter problem on the scientific basis. Since its establishment, KNMDMP has been continuously monitoring macro litter for more than 10 years on 20 beaches around the Korean Peninsula. (Figure 2.10). The survey was conducted every two months by citizen scientists.

In the first phase of KNMDMP, collected litter items were classified into 12 categories such as plastic, paper, styrofoam, timber, metal, fiber, glass, rubber, medical/hygiene, cigarette, and fireworks, overseas and others. The program reported the number, weight, volume of macro litter on the basis of unit length. With this program, marine litter items on Korean beaches were continuously tracked and feasible countermeasures were established. Mean densities of macro debris for the period of 10 years (2008-2017) were 358 items/100m, 68 kg/100m and 352 ℓ/100m on the basis of number, weight, and volume, respectively (Hong et al., 2018) (Figure 2.11).

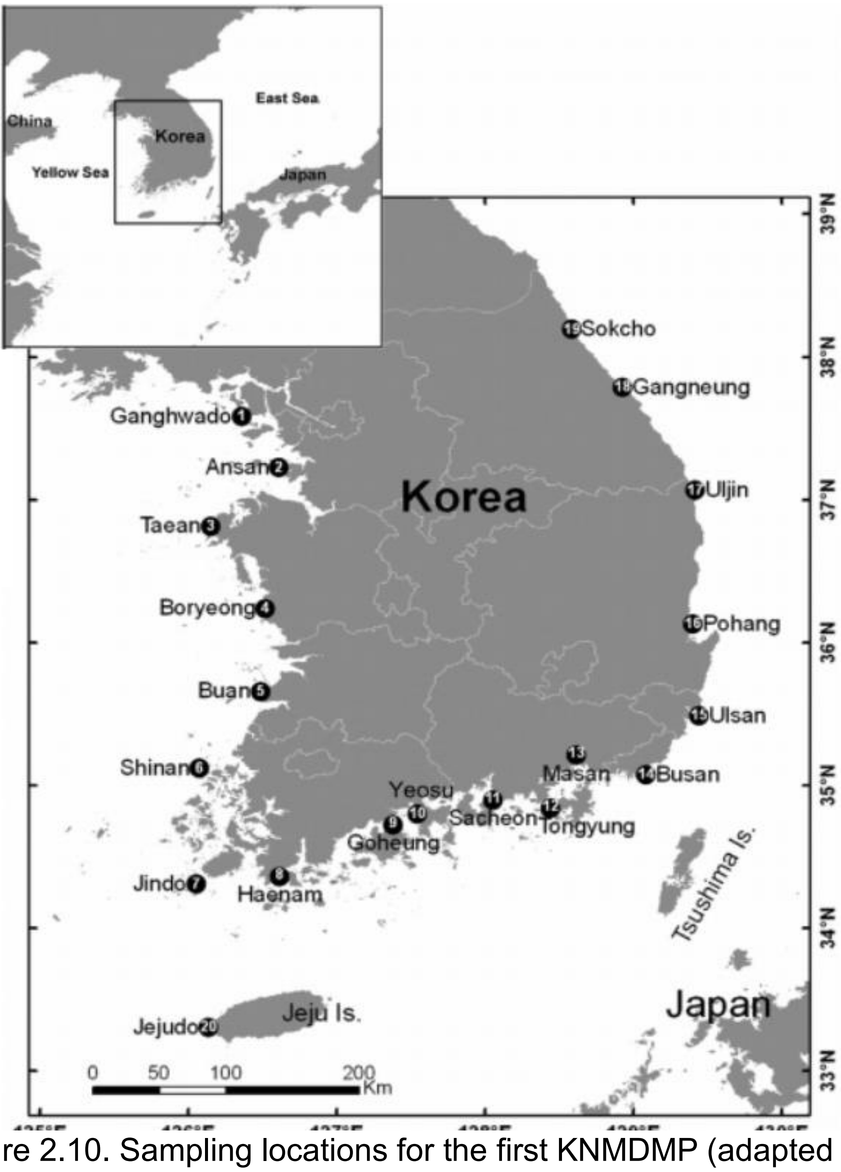


Figure 2.10. Sampling locations for the first KNMDMP (adapted from Hong *et al*., 2014)

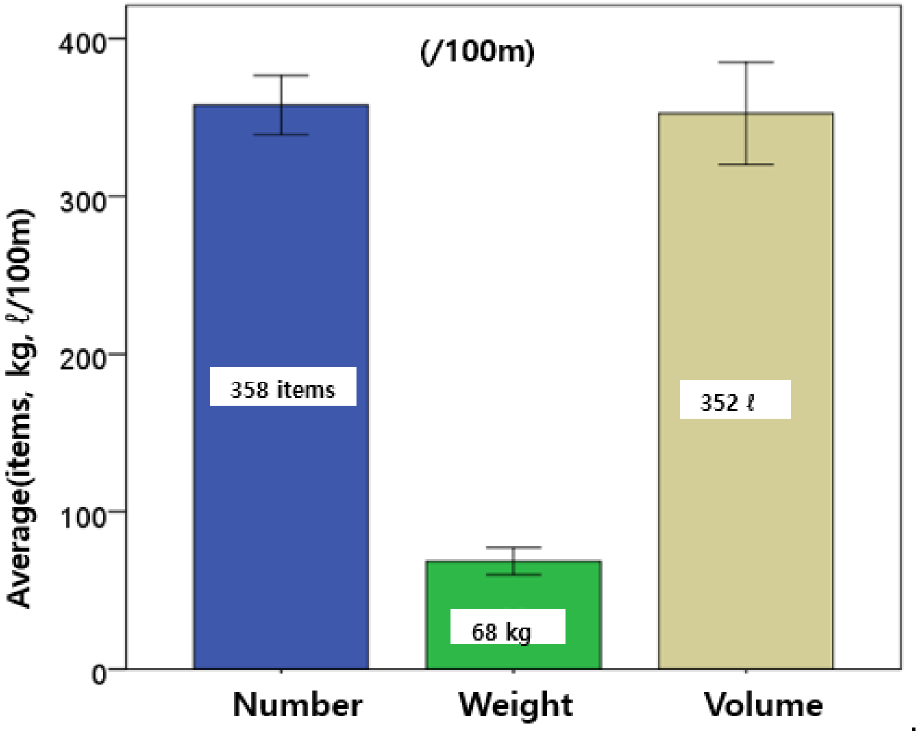


Figure 2.11. Mean abundance of macro litter from KNMDMP in 2008-2009 (adapted from Hong *et al*., 2018)

Survey protocol was revised in 2018 and thereafter macro litter has been monitored with the new protocol. On the second KNMDMP, macro litter items were classified into 8 categories such as plastic, wood, metal, natural fiber, glass, rubber, paper, and others and mixed material (Table 2.2). The most noticeable change is that the new monitoring protocol focuses on the plastic. Plastic items were subdivided into hard plastics, foamed plastics, fiber, film, and others and the number and weight of each subdivision was recorded. Litter items of the other categories were counted and weighed by category.

In addition, foreign debris was monitored both in the first and the second phase of KNMDMP. Litter items originating from China were the most abundant throughout the entire monitoring period though accounting for around 5% of the total amount of litter on Korean beaches. The number of foreign litter items seemed to be on the decrease (Table 2.3).

Table 2.2. Comparison of methods between the first and the second KNMDMP (adapted from Hong *et al*., 2018)

	KNMDMP I (2008~2017)	**KNMDMP II (2018~)**
Survey Interval	60 days±5 days	60 days±5 days
Litter Size	2.5 cm<	2.5 cm<
Litter Category	12 categories: as plastic, paper, styrofoam, wood, metal, fiber and clothes, glass, rubber, hygiene and personal care products, smoke and fire works, foreign and others (100 items)	7 categories: plastic, wood, metal, natural fiber, glass, rubber, paper, and others (50 items, focusing on plastics)
Measuring unit	Number, weight, volume (/100m)	Number (item) Weight(categories)

Table 2.3. Temporal trend of domestic and foreign items in KNMDMP (adapted from Hong *et al*., 2018)

Categories	**count/100m**	**kg/100m**	**ℓ /100m**
Domestic	▼	▼	▼
Overseas	▼		

Meanwhile Hong *et al*., (2014) published KNMDMP monitoring results for 2008-2009. In their study the mean abundance of macro litter was 480.9 ± 267.6 items/100m in number and 86.5 ± 78.6 kg/100m in weight.

Other macro litter researches were performed with different goals and protocols. Lee *et al*., (2013) surveyed 5 beaches on Geoje Island and a sand bar in the Nakdong River estuary in May before rainy season in 2012 (Figure 2.12). Subsequent surveys at three of the six sites (HN, WH, and MS) were performed in September after the rainy season in 2012. Plastics were classified into three size classes of large microplastics (1 mm to <5 mm), mesoplastics (5 mm to <25 mm), and macroplastics (25 mm). All macroplastic items were collected with two 10 m x 10 m quadrats along the strandline on a beach. Plastics were classified into 5 categories such as intact plastics, fragments, styrofoam, other foamed plastics and pellets. On the basis of number, the mean abundance of macroplastics was 0.97 items/m^2 in May and 1.03 items/m^2 in September.

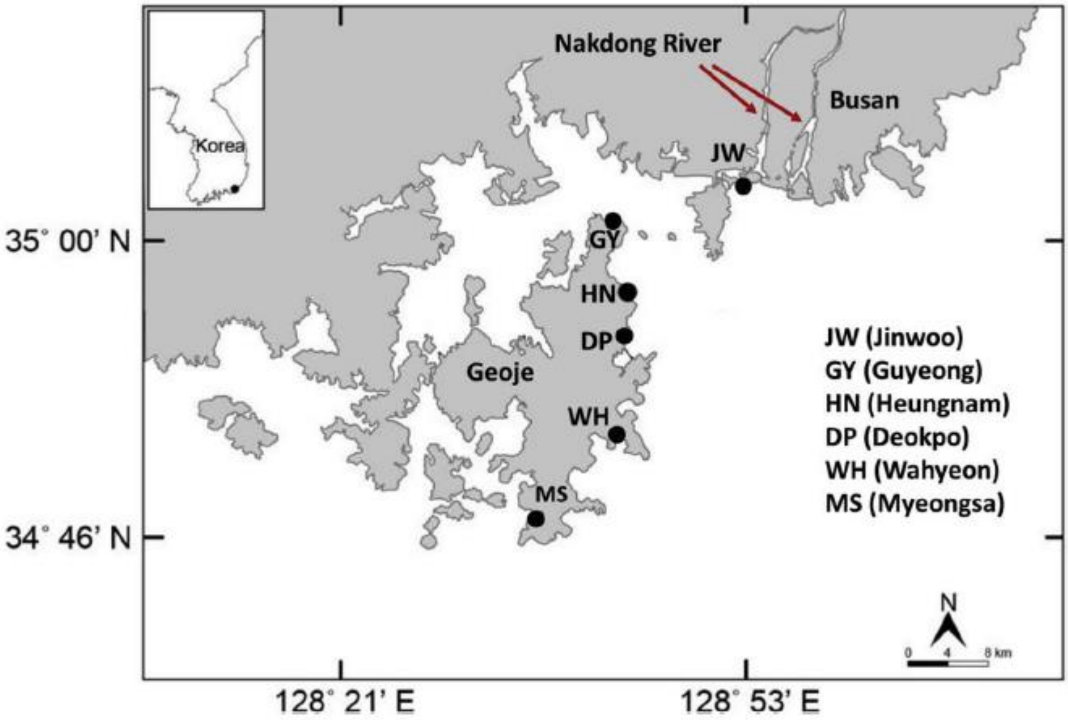


Figure 2.12. Sampling locations on 6 beaches in south coast of Korea (adapted from Lee *et al*., 2013)

Heo *et al*. (2013) elucidated the distribution of plastic litter on the Heungnam Beach in 2011. They studied on the spatial distribution of small plastic debris over 2 mm in size along the high strandline and cross-sectional line. In their study the mean abundances of litter at the high strandline were 50 ± 15 items/m^2 and 14 ± 4 items/m^2 for 10-50 mm in size and larger than 50 mm, respectively. However, in a cross section they were 11 ± 2 items/m^2 and 2 ± 0.5 items/m^2 for 10-50 mm in size and larger than 50 mm, respectively, showing 5 times lower than those in the high strandline. Another study determined the distributions of plastic litter on 12 beaches of Korea in 2013 and 2014 (Lee *et al*., 2015) (Figure 2.13).

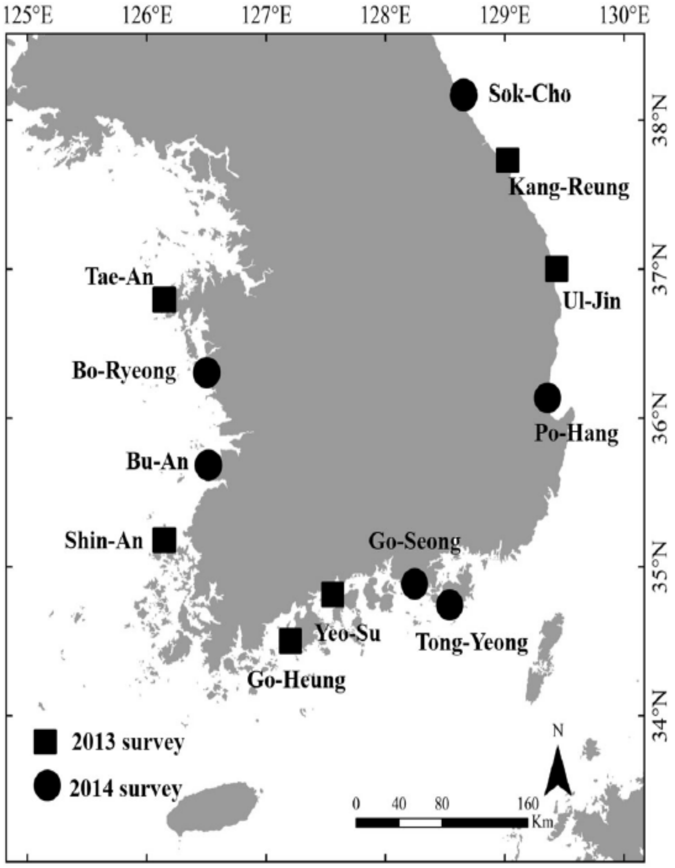


Figure 2.13. Survey sites for macro litter in 12 beaches of Korea (adapted from Lee *et al*. 2015)

In the study plastics were collected along the high strandline. The plastic litter items were classified into large micro- (1-5 mm), meso- (5-25 mm), and macroplastics (>25 mm). The researchers placed 5 x 5 m quadrats long the high strandline for collecting macroplastics on the beach and collected all plastics. The mean abundance of macroplastics was 1.0 items/m^2, showing similar to those of the six beaches in Geoje Island and Nakdong Estuary.

Meanwhile Jang *et al*. (2014b) surveyed six beaches of Korea and determined the abundance of macro litter collected from 10 quadrats of 5 X 5 m for each beach in 2013 (Figure 2.14).

The abundance of macro litter was 0.5 items/m^2 in number and 8.17 g/m^2 in weight. The abundance was somewhat lower than those of other studies (Heo *et al*., 2013; Lee *et al*., 2013; Lee *et al*., 2015) although they collected not only plastics but also other anthropogenic litter.

The level of macro litter in Korea was found to be higher than China and Russia (Table 2.4; Figure 2.15). The abundances were higher in Japan. However, the sample sizes were different. Japanese samples were visible items, indicating that it is likely to have collected smaller items less than 25 mm.

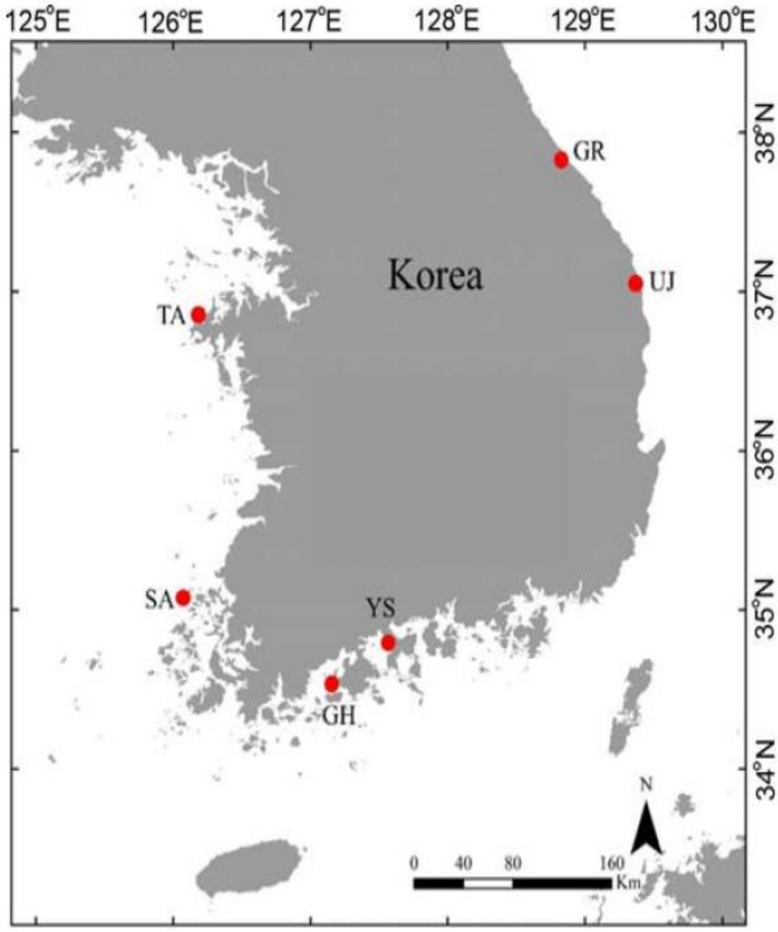


Figure 2.14. Survey sites for macro litter (adapted from Jang *et al*., 2014b)

Table 2.4. Mean abundance of macro litter in Korea and other regions (adapted from NOWPAP, 2020)

Country	Location	Sampling depth	Target size	Abundance	Unit	References
Korea	Nakdong River Estuary	Surface	>25 mm	0.97 (before rainy) 1.03 (after rainy)	Items/m^2	Lee *at al*. (2013)
Korea	Heungnam Beach	5 cm	>10 mm	64 (high strandline) 13 (cross-section)	Items/m^2	Heo *et al*. (2013)
Korea	6 beaches	Surface	>25 mm	0.5	Items/m^2	Jang *et al*. (2014b)
Korea	20 beaches	Surface	>25 mm	4.8 ± 2.68	Items/m	Hong *et al*. (2014)
Korea	12 coasts	Surface	>25 mm	1.0 (strandline) 3.9 (strandline & backshore)	Items/m^2	Lee *et al*. (2015)
China	4 beaches in Rizhao City (Shandong Province)	Surface	Visible item	0.26	Items/m^2	Zhou *et al.*(2015)
China	East China Sea	Surface	Visible item	0.029	Items/m^2	Zhou *et al*. .(2016)
Japan	Beaches along Sea of Japan	Surface	Visible	3.41	Items/m^2	Kusui and Noda (2003)
Japan	Awaji Island (inside Seto Inland Sea)			3.39	Items/m^2	Shimizu *et al*. (2008)
Russia	East coast of Russia	Surface	Visible	0.21	Items/m^2	Kusui and Noda (2003)
Oman	Gulf of Oman	Surface	Visible item	1.79 ± 1.04	Items/m	Claereboudt *et al*. (2004)
Brazil	Island of Santa Catarina	Surface	Visible item	1.02	Items/m^2	Widmer and Hennemann (2010)
The Caribbean	Bonaire	Few centimeters	>5 cm & bottle cap (2 cm)	291.0 (windward) 1.4 (leeward)	Items/m	Debrot *et al*. (2013)
Slovenia	The Slovenian Coast	Surface	>20 mm	1.51	Items/m^2	Laglbauer *et al*. (2014)
Brazil	Salvador and adjacent northern shore	Surface	>10 mm	0.81	Items/m^2	Leite *et al*. (2014)
Pakistan	Clifton, Beach, Karachi	Surface	>20 mm	8.9 ± 1.5	Items/m	Qari and Shaffat. (2015)
China	South China Sea	Surface	Visible	0.022	Items/m^2	Zhou *et al*. (2016)
Norway	Along the Norwegian coast	Surface	Visible	1.44 (OSPAR method) 4.02 (KNB method)	Items/m	Falk-Andersson *et al*. (2019)

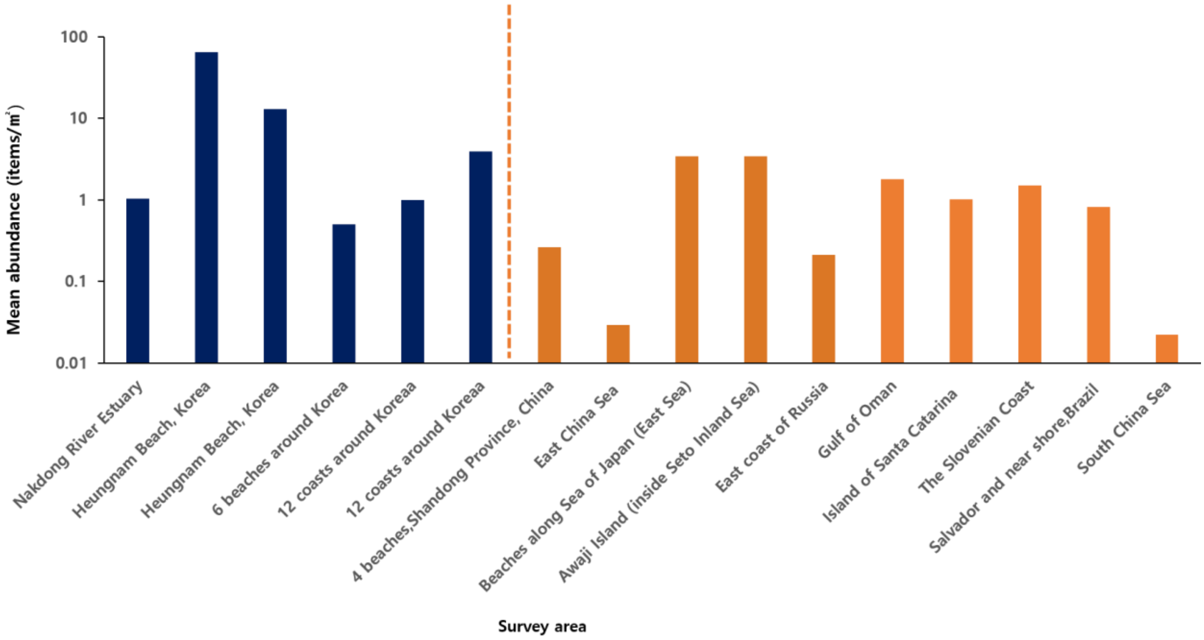


Figure 2.15. The levels of macro litter in Korea and other areas (adapted from NOWPAP, 2020)

Distribution of meso litter

Although more studies have focused on marine litter on the beach, meso litter has not been widely studied globally. As a result, distribution characteristics of meso litter such as abundance, composition, spatial and temporal trends have not been reported due to poor survey coverage in terms of geographical region or time-period. Considering that macro litter is fragmented and makes a huge number of smaller pieces like meso and micro litter, more attention should be given to meso litter. Monitoring of meso litter is relatively easier than microplastics because it can be visually observed separated from other materials after being sieved from beach sediments.. It doesn’t require complicated methods to quantify meso litter. After testing the relationship between the abundance of meso and micro litter, Lee *et al*. (2013) proved a strong correlation between meso and microplastics (Figure 2.16). Therefore, it could be very useful to find hot spots of microplastic pollution. A few studies reported survey results for meso litter in Korea (Lee *et al*., 2013; Lee *et al*., 2015; Lee *et al*., 2017). The levels of meso litter in Korea ranged from tens to hundreds Items/m^2(Table 2.5). It is of note that the levels were higher in sum of the strandline and back shore than in that of the strandline only (Lee *et al*., 2015). It is likely that meso litter is easier to be blown out to the backshore than macro litter and they are retained there probably because of the blockage by anthropogenic structures or vegetation. Furthermore, no difference was observed in the level of meso litter before and after rainy season (Lee *et al*., 2013). The result indicates that the seasonal variation is not high compared to variations resulting from different sampling locations within the sampling site.

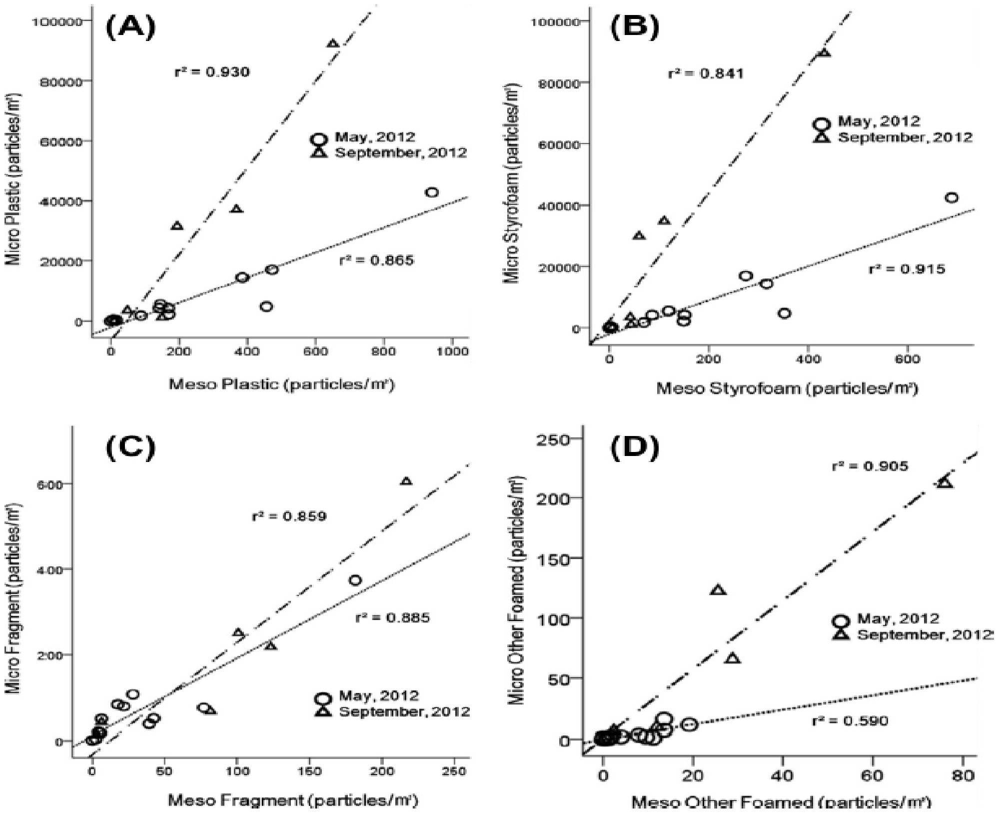


Figure 2.16. Relationships between the abundance of meso plastics and micro

plastics (adapted from Lee *et al*., 2013)

Table 2.5. Mean abundance of meso litter in Korea and other regions (adapted from NOWPAP, 2020)

Country	**Location**	**Sampling depth**	**Target size**	**Abundance**	**unit**	**References**
Korea	12 coasts	2 cm	5-25 mm	37.7 (strandline) 897.3 (strandline & backshore)	Items/m^2	Lee *et al*. (2015)
Korea	20 coasts	2.5 cm	5-25 mm	13.2	Items/m^2	Lee *et al*. (2017)
Korea	Nakdong River Estuary	5 cm	5-25 mm	238 (before rainy) 237 (after rainy)	Items/m^2	Lee *et al*. (2013)
The Maldives	Coral island	1 cm	>5 mm	13.2 ± 17.7 (daily) 383 ± 417 (long term)	Items/m^2	Imhof *et al*. (2017)
Brazil			5-15 mm	64.4	Items/m^2	Ivar do Sul *et al*. (2009)
U.S.A.	Hawaii		4.75-15 mm	450.3	Items/m^2	McDermid and McMullen (2004)

The levels of meso plastics on the strandline of the 12 coasts and the 20 coasts of Korea were similar to those in the Maldives and Brazil (Table 2.5; Figure 2.17). On the strandline & backshore, they were in the same order as that in Hawaii, USA.

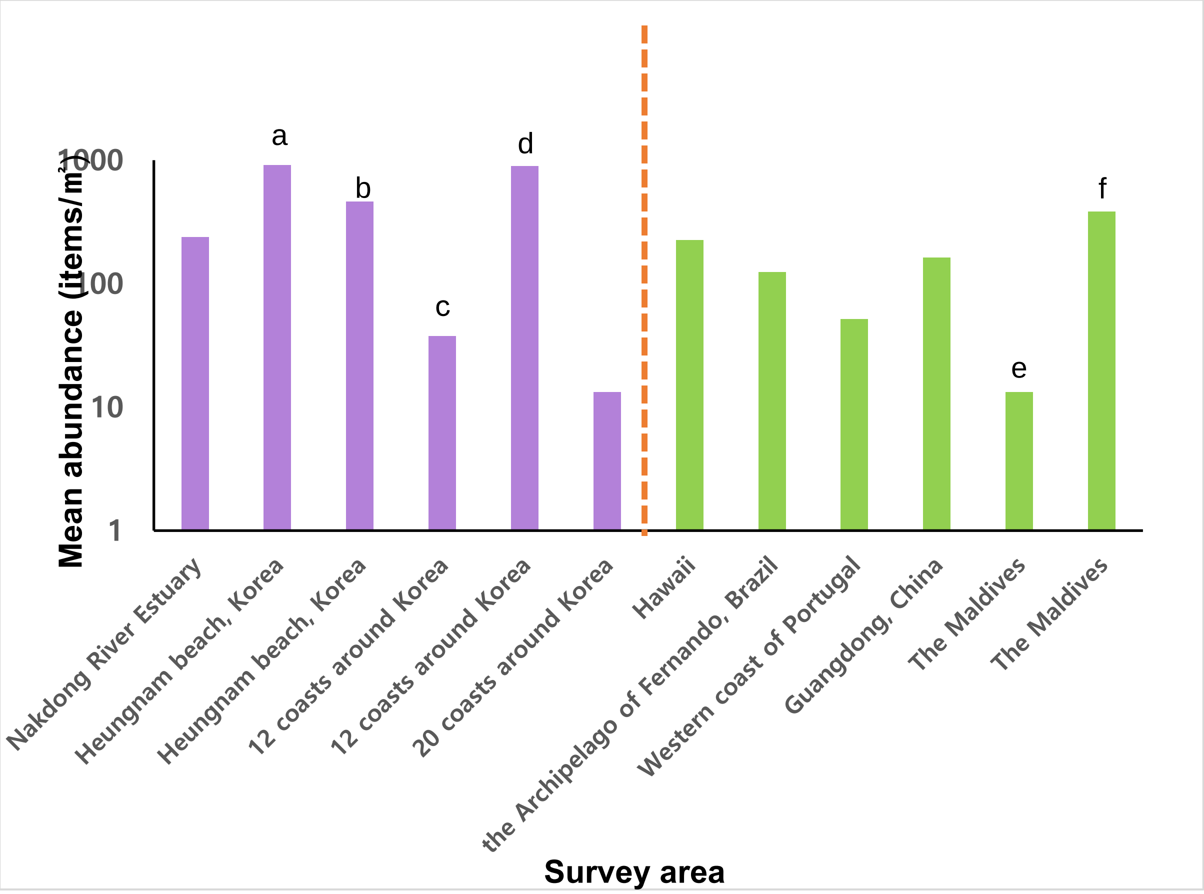


Figure 2.17. The levels of meso litter in Korea and other regions. a: high strandline, b: cross-section, c: strandline, d: strandline& backshore, e: daily, f: long term (adapted from NOWPAP, 2020)

- **Distribution of microplastics**

Massive production and use of plastics, improper management, and huge amount of plastics entering into the ocean make plastics accounting for about 80% in the marine litter (Derraik, 2002; Imhof *et al*., 2017; Leite *et al*., 2014). Plastics are persistent and stay long in the environment and cause impacts on marine organisms. Researches on plastic litter have recently surged in number, especially those to study smaller-sized plastics such as microplastics. Microplastics refer to plastic litter items less than 5 mm although some researchers define them as particles smaller than 1 mm. (Fendall and

Sewell, 2009; Betts, 2008; Moore, 2008). Thus, the authors refer to microplastics as micro litter in the marine environment in the report.

Microplastics on beaches have been actively studied in Korea (Table 2.6).The levels of microplastics were high in the Nakdong River Estuary and Soya Island. Note that the level of microplastics in the Nakdong River Estuary represents that of large microplastics only (1-5 mm). In particular, they were recorded as high as 285,673 items/m^2 in Soya Island (Figure 2.18) which represents the highest level globally (Figure 2.19) (Kim *et al*., 2015). The authors found that the north-side beach contained a 100-fold lower than two south-side beaches that faced southerly wind and currents that prevailed throughout the study season, indicating that wind and currents would be the driving force of the distribution of microplastics. In addition, it was suggested that quite high levels of microplastics both in the Nakdong River Estuary and Soya Island were resulted in from aquaculture farms near the sampling sites where styrofoam buoys were used in huge quantities (Lee *et al*., 2013; Kim *et al*., 2015)

Table 2.6. Mean abundance of micro litter in Korea and other regions (adapted from NOWPAP, 2020)

Country	**Sampling Location**	**Sampling Depth**	**Target size**	**Abundance**	**Unit**	**References**
Korea	12 coasts	2 cm	1-5 mm	880.4	Items/m^2	Lee *et al*. (2015)
Korea	Nakdong River Estuary	5 cm	1-5 mm	8205 (before rainy) 27,606 (after rainy season)	Items/m^2	Lee *et al*. (2013)
Korea	Heungnam beach	5 cm	>2 mm	976 ± 405 (high stranded line) 473 ± 866 (cross-section)	Items/m^2	Heo *et al*. (2013)
Korea	20 coasts	2.5 cm	1-5 mm	251.9 ± 405	Items/m^2	Eo *et al*. (2018)
			<1 mm	13,435 ± 18,072	Items/m^2	
Korea	Soya Island	2 cm	0.05-5 mm	46,334 ± 71,291	Items/m^2	Kim *et al*. (2015)
China	Bohai Sea	2 cm	<5 mm	102.9 ± 39.9 - 163.3 ± 37.7	Items/kg (D.W.)	Yu *et al*. (2016)
China	Jiaozhou Bay	< 10 cm	<5 mm	25 ± 13	Items/kg (D.W.)	Zheng *et al*. (2019)
Japan	Oosumi Peninsula	5 cm	1-8 mm	13,489	Items/m^2	Majanga *et al*. (2015)
Hong Kong		4 cm	0.315-5 mm	5,595	Items/m^2	Fok and Cheung, (2015)
Malta Island		surface	1.9 to 5.6 mm	39.3	Items/m^2	Turner and Holmes, (2011)
St. Lawrence River		10-20 cm	0.40-2.16 mm	13,832	Items/m^2	Castañeda *et al*. (2014)
Slovenia		5 cm	0.25-5 mm	133.3 (shoreline)/155.6 (infralittoral)	Item/kg (D.W.)	Laglbauer *et al*. (2014)
Turkey	Scapa Flow	3 cm	<5 mm	3000 (particle + fiber)	Item/kg (D.W.)	Blumenröder *et al*. (2017)
Germany			<1 mm	1.3 – 2.3	Item/kg (D.W.)	Dekiff *et al*. (2014)
Italy	Subtidal		0.7 μm-1mm	672 - 2175	Item/kg (D.W.)	Vianello *et al*. (2013)
Portugal			1.2 μm--5 mm	133.3	Items/m^2	Martins and Sobral, 2011)

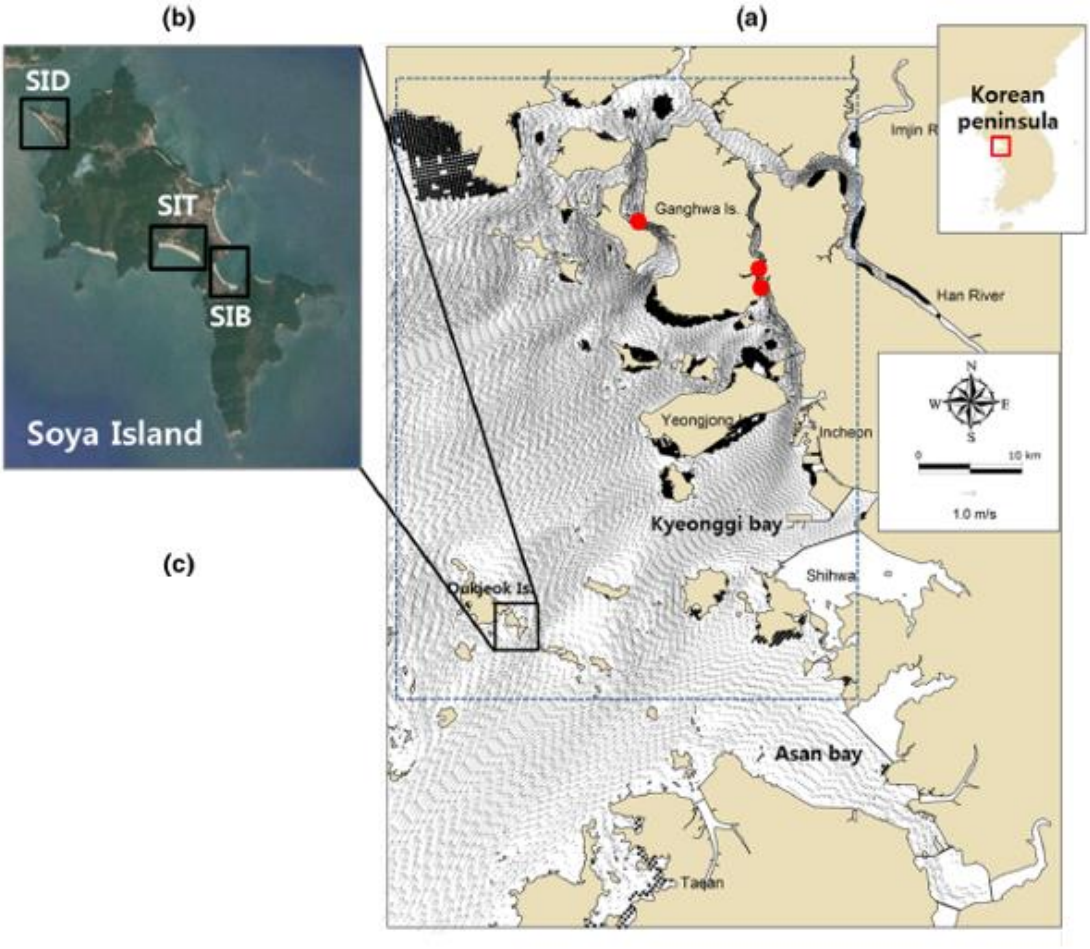
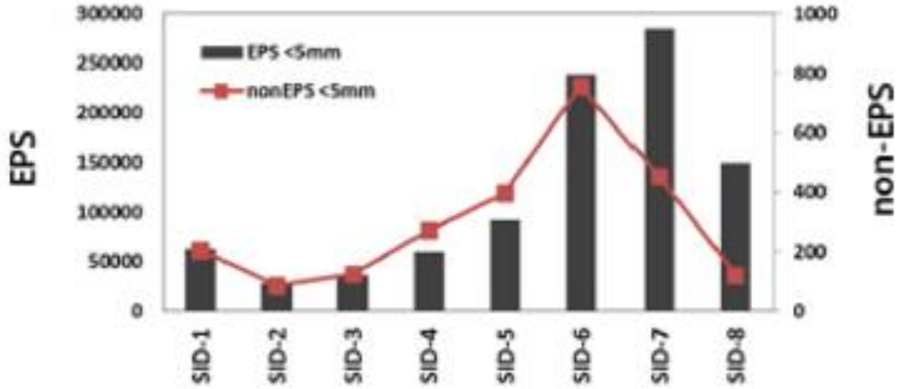
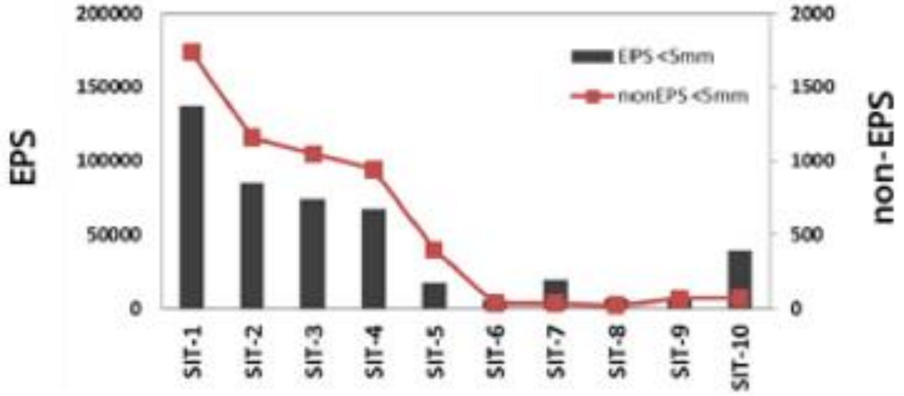


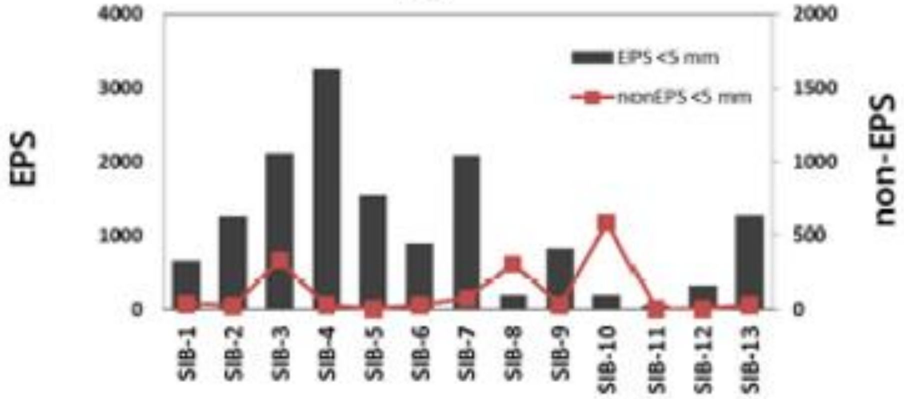
Figure 2.18. Sampling locations of microplastics in Soya Island. Site SID faces north, SIT and SIB face south (adapted from Kim *et al*., 2015).



(a) SID



(b) SIT



(c) SIB

Figure 2.19. The levels of microplastics in Soya Island, Korea (adapted from Kim *et al*., 2015).

The levels of large microplastics (1-5 mm) around Korea showed the same order in the three studies (Table 2.6) (Heo *et al*., 2013; Lee *et al*., 2015; Eo *et al*., 2018). Considering the microplastics are fragmented in the environments and produce huge numbers of smaller particles, the levels described above would represent high levels of pollution of microplastics.

Comparison of the levels of microplastics was shown in Figure 2.20. The microplastic levels were higher in Korea than those in other countries reviewed in this study. Only St. Lawrence River showed the same order of microplastics. As mentioned above, expanded polystyrene (EPS) particles would have contributed to the high pollution of microplastics in the Korean beaches. Intensive aquaculture farms are extensively deployed in the west and south coasts of Korea. EPS floating buoys have been used in large quantities for more than ten years.

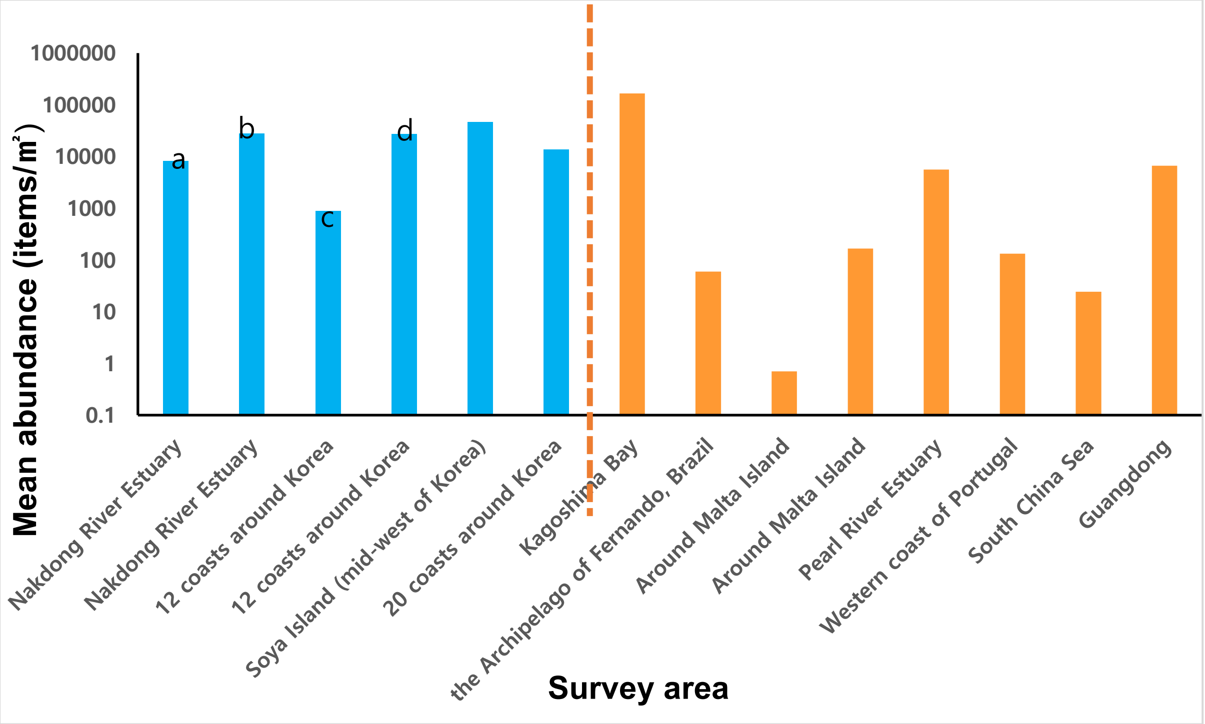


Figure 2.20. The levels of micro litter in Korea and other areas (adapted from

NOWPAP, 2020). a: before rainy season, b: after rainy season, c: strandline, d: strandline & backshore

2.1.3. Composition and source

- **Composition and source of macro litter**

Several studies elucidated macro litter composition in Korea. Monitoring surveys from 2008 to 2009 under the KNMDMP showed that plastic occupied 49.8% of all anthropogenic litter on the basis of number, followed by styrofoam (16.9%) and wood (8.4%). However, wood took the first place in weight, occupying 37.9% of all. Plastics were in the second place, making up 30.3%. On the basis of volume styrofoam ranked the first, occupying 31.6% of all, followed by plastic (30.7%), and wood (23.6%) (Figure 2.21). Plastics occupied the largest number of the 10 most common items of marine litter after glass (Table 2.7). Sixteen items which at least once included in the top 10 items also revealed most of them were composed of plastics. Considering styrofoam is a unique item among plastics, this material was found as a serious contributor to litter pollution in Korea.

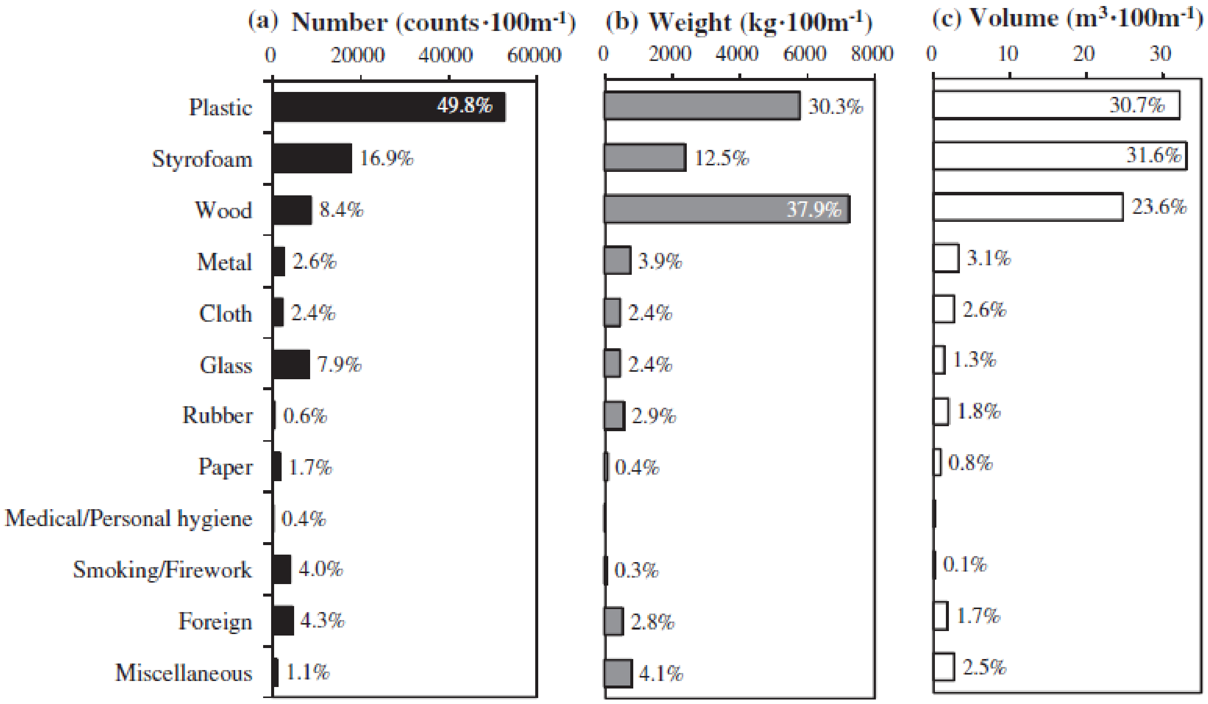


Figure 2.21. Composition of marine litter of 2008-2009 KNMDMP (adapted from Hong *et al*., 2014)

Table 2.7. The most frequently ranked items on TOP 10 in KNMDMP for 2008-2017 (adapted from Hong *et al*., 2018)

Categories	Items	Frequency within top-10 rank
Styrofoam	Styrofoam buoys (2.5~50 cm)	10
Plastic	Beverage bottles (<2 liter)	10
Plastic	Plastic lids, caps	10
Plastic	Plastic bags	10
Plastic	Ropes (2.5~50 cm)	10
Glass	Beverage bottles	10
Plastic	Plastic food wrappers	10
Styrofoam	Miscellaneous items	8
Plastic	Miscellaneous items	8
Plastic	Ropes (50 cm <)	7

Plastic	Plastic buoys	1
Overseas	Beverage bottles	1
Smoking/firework	Cigarette/cigarette filters	1
Timber	Timber for ships, aquaculture	2
Plastic	Packaging band (50cm <)	1
Styrofoam	Styrofoam fishing box	1

Heo *et al*. (2013) also reported that styrofoam was the most abundant component on the Heungnam Beach, especially for 10-50 mm in size. On the other hand, fiber and fabric were the most abundant items in the Nakdong River Estuary (Lee *et al*., 2013) and 6 beaches around Korea (Jang *et al*., 2014b).

Given that styrofoam buoys are used intensively in aquaculture and aquaculture nets and ropes are composed of fiber, fishery-related activities have been polluting Korean beaches. It is contrast to the general assumption that marine litter consists up to 80% of land-based items. Jang *et al*. (2014b) attempted to assess their sources. The sources of litter were assessed by allocating source-probability scores to each litter items and weighing the number of litter items by the probability of sources. Their result showed that macro litter in Korean beaches was mainly composed of sea-based items (Figure 2.22). They also suggested that ropes and nets produced a lot of fiber and significantly contributed to the marine liter in Korean beaches. Furthermore Hong *et al*. (2014) revealed that plastics and styrofoam occupied the majority of debris composition and that the main sources of debris were fishing activities including commercial fisheries and marine aquaculture. Especially styrofoam buoys from aquaculture were the biggest contributors to marine debris pollution on the beaches.

The results described above suggest that Korean beaches were contaminated by fishery related items such as ropes, nets, and EPS buoys.

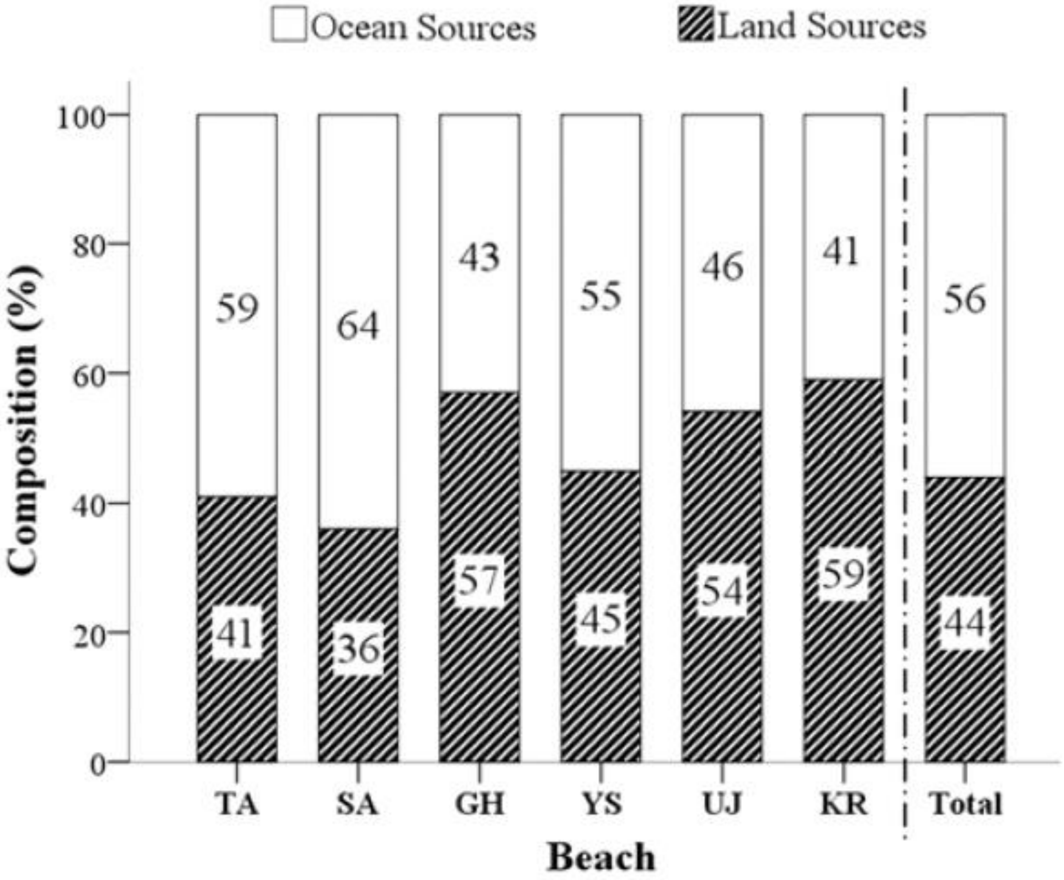


Figure 2.22. Composition of macro litter in 6 beaches around Korea (adapted from Jang *et al*., 2014b)

- **Composition and source of meso litter**

Styrofoam was the dominant component of the meso plastics in Korean beaches in all three studies reviewed, followed by hard plastics (Lee *et al*., 2013; Lee *et al*., 2015; Lee *et al*., 2017). (Figure 2.23; Figure 2.24). As mentioned above, Styrofoam buoys are widely used in Korea to keep buoyancy of aquaculture structures like ropes and nets in. Styrofoam buoys are used without covers and directly exposed to the environment. They are very easily lost or fragmented into numerous small pieces. They contribute serious pollution of marine litter in Korean beaches.

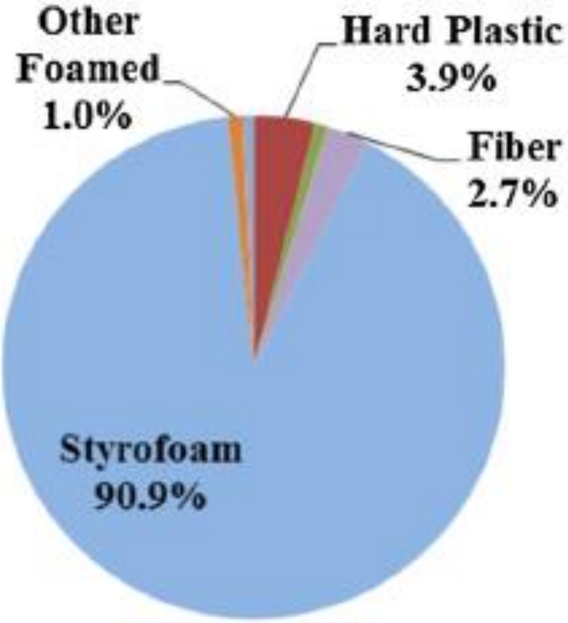


Figure 2.23. Composition of meso plastics on 12 beaches in Korea (adapted from Lee *et al*., 2015)

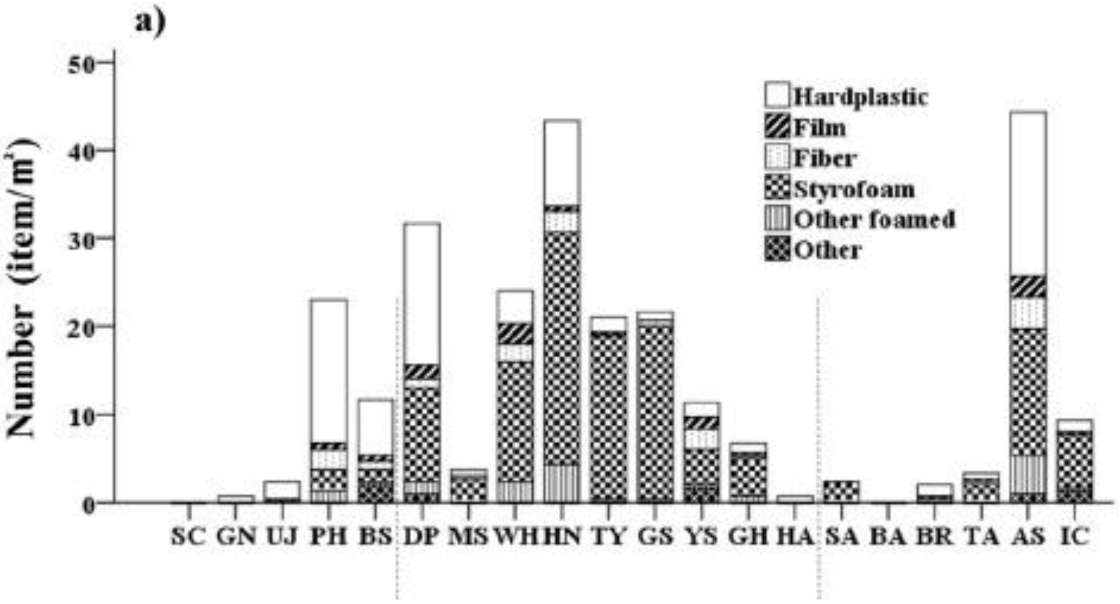


Figure 2.24. Composition of meso plastics on 20 beaches in Korea (adapted from Lee *et al*., 2017)

- **Composition and source of micro litter**

Most of the microplastic researches in Korea divide microplastics into large microplastics (L-MPs) sized 1-5mm and small microplastics (S-MPs) < 1 mm particles, respectively. Among L-MPs, EPS accounted for 95% of all. On the other hand, S-MPs were predominantly composed of polyethylene (PE) and polypropylene (PP) (Eo *et al*., 2018) (Figure 2.25). These differences may be attributable to their degradation processes and detection techniques. Meanwhile, EPS was overwhelmingly dominant in Soya Island which is located in the northwestern coast of Korea (Kim *et al*., 2015). It was found that the most abundant microplastics in Soya Island were fragmented EPS (Figure 2.26) (Kim *et al*., 2015). On average, they accounted for > 87% in all sampling locations. They also accounted for 95% of L-MPs (1-5 mm) on the 20 Korean beaches (Figure 2.25) (Eo *et al*., 2018). Large fragments and fiber were weathered on beaches and fragmented into S-MPs.

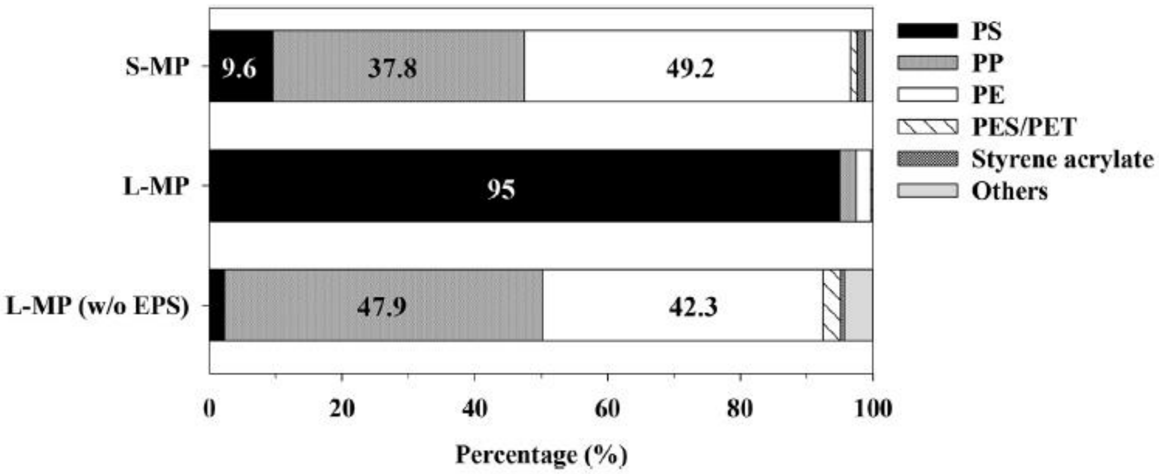
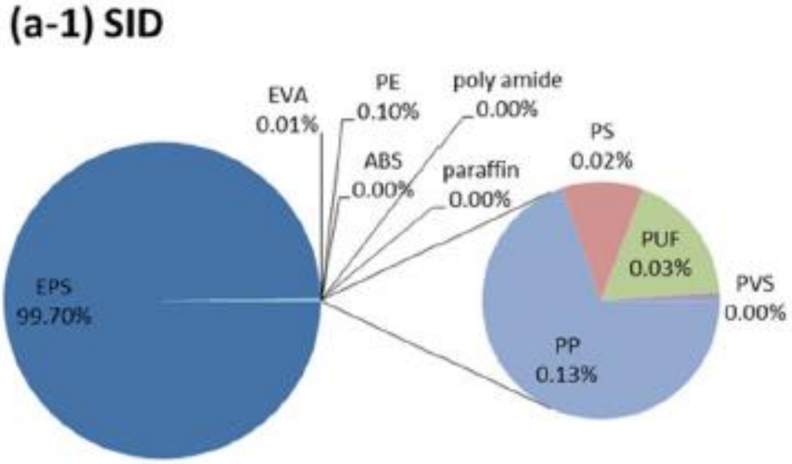


Figure 2.25. Composition of microplastics on 20 beaches in Korea (adapted from Eo *et al*., 2018)



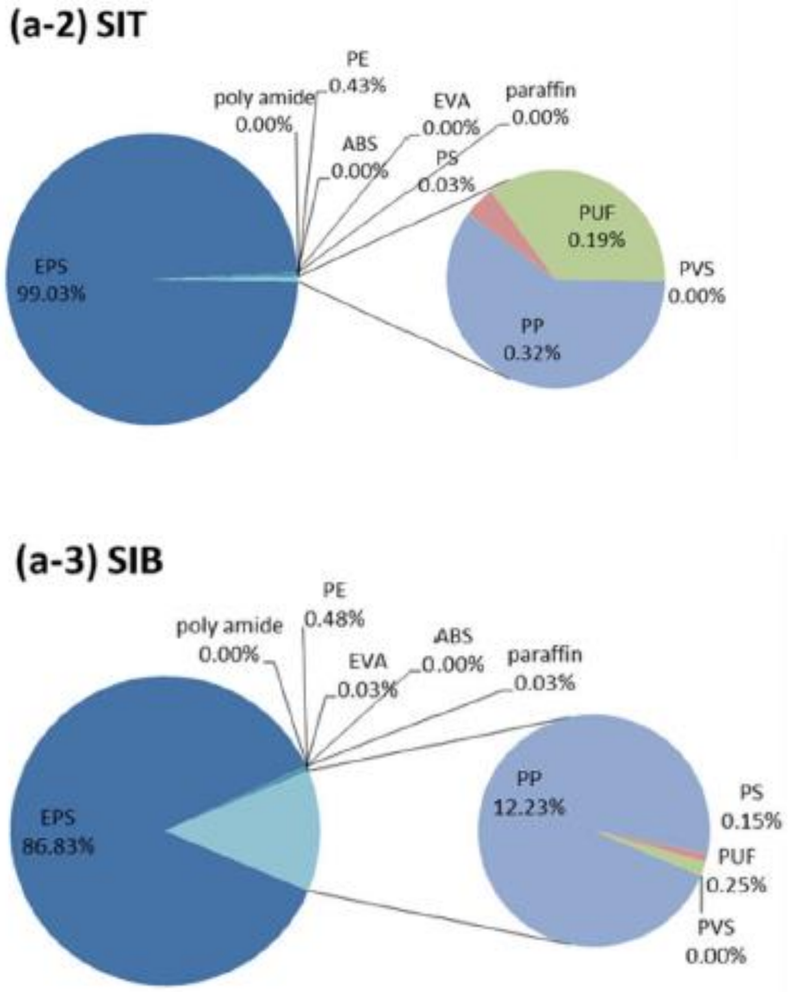


Figure 2.26. Composition of meso plastics in Soya Island, Korea (adapted from Kim *et al*., 2015)

2.1.4. Spatial and temporal trend

- **Spatial and temporal trend of macro litter**

GESAMP (2019) defined monitoring as a process of repeated measurements of characteristics of the environment, with an aim of detecting a trend in terms of space or time. Marine litter monitoring can be further defined as repeated measurements of marine litter distribution in space and time. One of the main objectives of marine litter monitoring would be a better understanding of the distribution and fate of it to combat litter pollution and its related problems. For this purpose, selecting monitoring sites and period should be adequately selected and designed. KNMDMP would be a good example as the monitoring sites spread evenly throughout the Korean Peninsula and the survey has been continued since 2008. It has shown temporal and spatial trends of macro marine litter distribution in terms of number, weight, and volume. As for the temporal trend of distribution of macro debris, the number, weight and volume decreased significantly for the 10-year period (Figure 2.27).

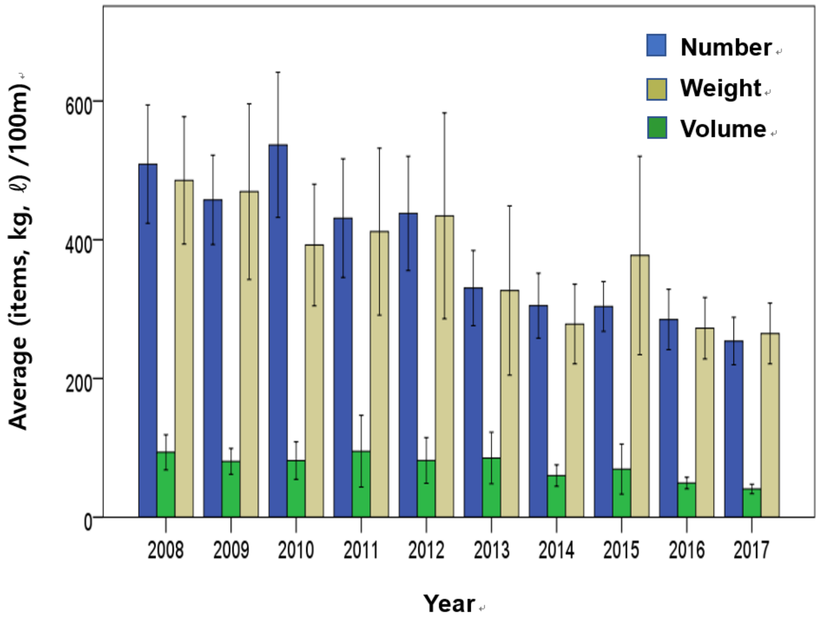


Figure 2.27. Temporal distribution trend of macro litter for 2008-2017 in Korea (adapted from Hong *et al*., 2018)

- **Spatial and temporal trend of meso litter**

Due to the limited data, temporal trend of meso litter distribution in Korea could not be properly identified. However, Lee *et al*. (2017) surveyed 20 beaches surrounding the Korean Peninsula and elucidated the level of meso plastic pollution (Figure 2.28). The level of meso plastics was higher in the west and south coasts than in the east coast of Korea.

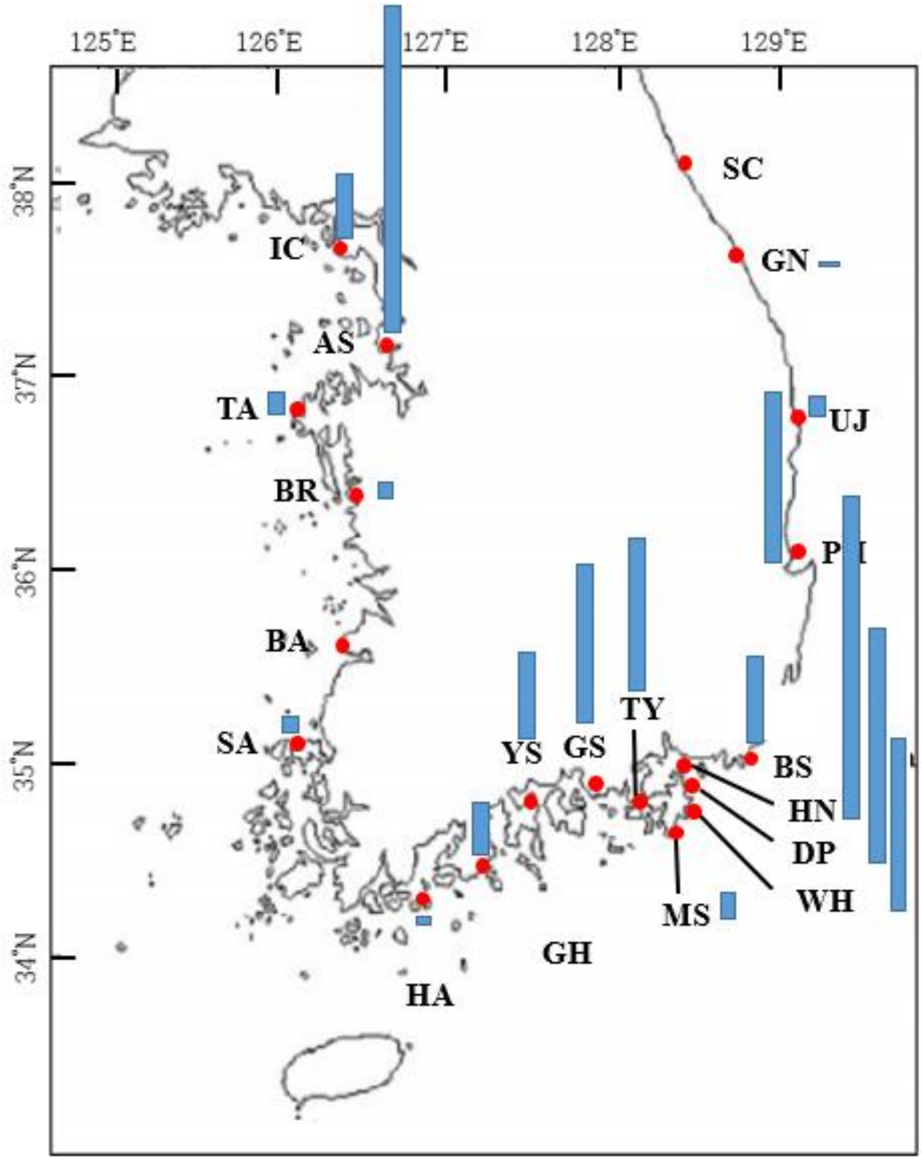


Figure 2.28. Spatial distribution of meso plastics in Korea (adapted from Lee *et al.*, 2017)

- **Spatial distribution and temporal trend of micro litter (microplastics)**

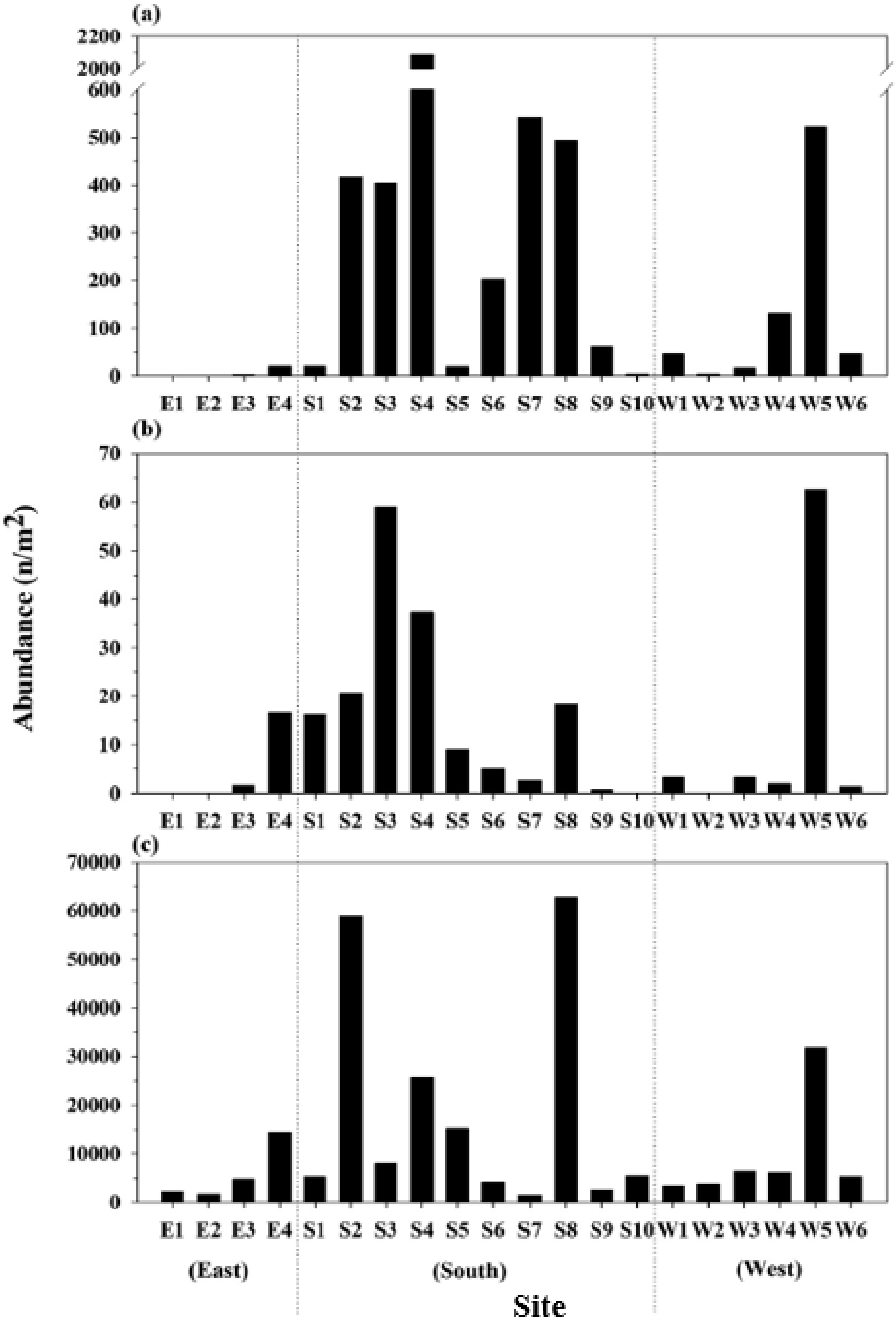


Figure 2.29. Spatial distribution of (a) L-MPs (1-5 mm) (n=5038), (b) L-MPs, excluding EPS (n=260) and S-MPs (n=268700) at 20 beaches in Korea (adapted

from Eo *et al*., 2018)

Eo *et al*. (2018) surveyed 20 beaches around Korea and determined the levels of microplastics (Figure 2.29). The mean number of L-MPs (1-5 mm) was decreasing in the order of the south, west, and east coast. The abundance in the east coast was was significantly different from that of in the west and south coasts. The mean number of S-MPs (<1 mm) was the highest in the south, followed by the west and east, although the abundance was not significantly different (Eo *et al*., 2018).

2.2. Floating litter

Marine litter enters the marine environment either from land or sea, and it is transported along the currents and winds, expanded into other oceanic compartments and is finally accumulated on shore or seabed. Thus, to address the issue of marine litter, it is necessary to figure out its movements and quantify and qualify its distribution. In the earlier stage, more attention has been given to beach litter in Korea because the monitoring of beach litter is relatively easy and less costly (Lee *et al*., 2013; Hong *et al*., 2014; Jang *et al*., 2014b; Lee *et al*., 2015; Lee *et al*., 2017). In recent years, however, intensive studies have been conducted for the floating marine litter in Kore, mainly by an active research group in the Korea Institute of Oceanic Science & Technology (KIOST).

Floating litter is especially important because it crosses into neighboring countries with movements of the winds and currents. Therefore, understanding the distribution characteristics and movement of floating litter is crucial as it is likely to bring about debate among countries. In the following subchapters, we will review the monitoring surveys of floating litter in Korea and their results, as well as the methodologies applied.

2.2.1. Methodologies for quantification and qualification

- **Mesh size**

Various sampling methods are used to get representative floating litter samples from the surface and different depths of seawater column (Table 2.8; Table 2.9). Surface sampling is carried out using a Manta trawl and neuston net (Chae *et al*., 2015; Kang *et al*., 2015; Song *et al*., 2014; K. Zhang *et al*., 2017; W. Zhang *et al*., 2017; Zhao *et al*., 2014). Both types of net are suitable for use on vessels and they have a wide sampling coverage to better represent a given site (Song *et al*., 2018). Sieve can be used to get samples from surface microlayer (Chae *et al*., 2015; Song *et al*., 2014, 2015a, 2015b). Teflon water pump is used to get samples from a certain depth (Zhao *et al*., 2014, 2015). Hand net, Niskin hydrophore, and sight survey are also used in other studies (Shiomoto and Kameda, 2005; Song *et al*., 2014).

The sizes of sampled marine litter items are limited to the mesh size of the net. Mesh sizes also depend on sampling methods such as Manta trawl, neuston net, hand net, and water pump. Most researchers in Korea use meshes ranging from 0.02 to 2 mm in size (Table 2.10). The number of microplastics increases with decreasing mesh sizes and the majority of them are < 300 ㎛(Song *et al*., 2014). Therefore, collecting samples using a net with meshes larger than 300 μm can underestimate the abundance of microplastics (Figure 2.30).

Various kinds of equipment were used to elucidate the influence of sampling method on the abundance of microplastics (Song *et al*., 2014) (Figure2.31; Figure 2.32). Researchers collected micro-sized polymer particles from the sea surface with different pieces of equipment. The abundance of microplastics was the highest with surface microlayer sampler, followed by hand net > bulk water > Manta trawl net. Their mesh sizes were 0.75 μm, 0.75 μm, 50 μm, and 330 μm for surface microlayer, bulk water, hand net, and Manta trawl, respectively.

Table 2.8. Methods used for sampling plastics in the open water surface compartment (adapted from GESAMP, 2019)

Method	Explanation	Advantages	Limitations
Net tows (Manta trawl, neuston net)	Fine-mesh net attached to a large rectangular frame (e.g. 0.5 to 1.0 m wide and 0.4m high) developed for sampling surface and water column waters for plankton, insects and other small biota. Manta trawl with floating wings to keep it on the surface. Net length typically 1-8m. Mesh size typically 200-333μm Standard deployment configured with long side parallel to water surface	Can be deployed from small to large vessels. Underway sampling Use of flow meter to estimate volume.	Use is weather dependent Care needed to minimize contamination from sampling vessel and tow ropes. Can only estimate volume of water filtered when flow meter is used and the frame completely immersed Towing speed and time must be limited to avoid clogging the net and under-sampling surface waters; vessel speed may need to be restricted Under-samples material smaller than mesh size.

Mega net	Large net, up to 4 m, wide for sampling larger litter than with a standard Manta or neuston net	Captures macro and meso litter	Use is weather dependent Infrastructure needs to store, deploy and retrieve are great
Bulk water sample	Sampling large volume of water and volume reducing	Known volume sampled Can sample from vessels of opportunity	Limited volume can be processed restricting it to smallest litter fractions Volume reducing sample on a working deck may expose sample to contamination
Visual observations from a ship	Visual survey of floating marine litter from the surface of a vessel at sea Use either fixed width transects (assumes all items seen) or distance sampling (corrects for decrease in detection probability with distance from the vessel)	Easy to do from vessels of opportunity Low cost, needs only binoculars (but ideally also a good quality digital SLR camera and telephoto lens)	Limited to waters adjacent to the ship (up to 50 m typically) Bias against dark items and subsurface items; white and buoyant items easier to spot Report start/stop observation times, observer effort, etc. to be useful.
Photographic and aerial Surveys	Visual survey of floating marine litter from an airplane or a drone	Cover large areas; ideal for mega litter	High cost to charter expensive photography equipment Limited to macro and mega plastic, with one study (Lebreton *et al.* 2018) observing items as small as 10 cm Bias against dark items and subsurface items

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Table 2.8. Methods used for sampling plastics in the open water surface

compartment (adapted from GESAMP, 2019)

Method	Explanation	Advantages	Limitations
Net tows (Manta trawl, neuston net)	Fine-mesh net attached to a large rectangular frame (e.g. 0.5 to 1.0 m wide and 0.4m high) developed for sampling surface and water column waters for plankton, insects and other small biota. Manta trawl with floating wings to keep it on the surface. Net length typically 1-8m. Mesh size typically 200-333μm Standard deployment configured with long side parallel to water surface	Can be deployed from small to large vessels. Underway sampling Use of flow meter to estimate volume.	Use is weather dependent Care needed to minimize contamination from sampling vessel and tow ropes. Can only estimate volume of water filtered when flow meter is used and the frame completely immersed Towing speed and time must be limited to avoid clogging the net and under-sampling surface waters; vessel speed may need to be restricted Under-samples material smaller than mesh size.
Mega net	Large net, up to 4 m, wide for sampling larger litter than with a standard Manta or neuston net	Captures macro and meso litter	Use is weather dependent Infrastructure needs to store, deploy and retrieve are great
Bulk water sample	Sampling large volume of water and volume reducing	Known volume sampled Can sample from vessels of opportunity	Limited volume can be processed restricting it to smallest litter fractions Volume reducing sample on a working deck may expose sample to contamination
Visual observations from a ship	Visual survey of floating marine litter from the surface of a vessel at sea Use either fixed width transects (assumes all items seen) or distance sampling (corrects for decrease in detection probability with distance from the vessel)	Easy to do from vessels of opportunity Low cost, needs only binoculars (but ideally also a good quality digital SLR camera and telephoto lens)	Limited to waters adjacent to the ship (up to 50 m typically) Bias against dark items and subsurface items; white and buoyant items easier to spot Report start/stop observation times, observer effort, etc. to be useful.

Photographic and aerial Surveys	Visual survey of floating marine litter from an airplane or a drone	Cover large areas; ideal for mega litter	High cost to charter expensive photography equipment Limited to macro and mega plastic, with one study (Lebreton *et al.* 2018) observing items as small as 10 cm Bias against dark items and subsurface items

Table 2.9. Methods used for sampling plastics in the open water surface compartment (adapted from GESAMP, 2019)

Method	Explanation	Advantages	Limitations
Bongo nets, or horizontally hauled plankton nets	Cylindrical-conical shaped, often used for mid-water sampling	Can be deployed from vessels Can be used at variable depths Use of flow meter allows volume estimate Not weather dependant Paired bongo net allows replicate sampling	Risk of sample contamination when the sample is handled on the vessel deck after each sampling procedure Under-samples material < 300, 110 and 65 µm Vessel speed may need to be restricted
Underway pumps	Utilizing seawater intakes from vessels	Can sample a known volume of water over a given time or distance Can control for contamination on vessel	Intakes are small and can limit the upper size range Adverse sea states can affect the position of vessel in water, intake depth variable May be contamination from the sampling apparatus including the hose
Submersible pumps	Deck pump lowered to a known depth	Can sample a known volume of water	Vessel needs to be stationary

			Intakes are small and can limit the upper size range
Bulk sample	Sampling large volume of water and volume reducing	Known volume	Volume reducing sample on a working deck may expose sample to contamination, Care must be taken
CPR	Continuous plankton recorder towed from ships underway Have been in use since 1946	Can be used over a large distance from vessels of opportunity Can be archived samples	Water depth sampled is approximately – 10 m, i.e. cannot sample surface waters Restricted size of intake may underestimate larger particles
Fisheries observer	Opportunistic capture of plastic marine litter by towed pelagic fishing gear	No equipment necessary Observing long line fisheries that capture mostly nets and line	Dependent on fisheries reporting litter Not systematic survey of a given area

Table 2.10. Different sampling methods for collecting water samples (adapted from NOWPAP, 2020).

Country	**Location**	**Sampling method**		**Water depth**	**Target size**	**Mesh size**	**References**
Korea	Kyeonggi and Asan Bays (West coast of Korea)	Surface microlayer	Sieving	<400 μm	50-5000 μm	0.75 μm	Chae *et al*. (2015)
		Surface seawater	Hand net	0-30 cm	50-5000 μm	20 μm	
			Trawl net	0-20 cm	50-5000 μm	330 μm	
Korea	Geoje (Southeastern Sea of Korea)	Hand net	Net collection	0-20 cm	>50 μm	50 μm	Kang *et al*. (2015a)
		Manta trawl	Net collection		>330 μm	330 μm	
Korea	Geoje (Southeastern Sea of Korea)	Sieving		1 mm	<5 mm	0.75 μm	Song *et al*. (2015a)
Korea	Geoje (Southeastern Sea of Korea)	Surface microlayer	Sieving	1 mm	<5 mm	0.75 μm	Song *et al*. (2014)
		Bulk water	Bucket collection	0-20 cm	<5 mm	0.75 μm	
		Hand net	Net collection	0-20 cm	<5 mm	50 μm	
		Manta	Net	0-20 cm	<5 mm	330 μm	

		trawl	collection				
Korea	Off coast of Korea	Surface,	Bucket collection	0-20 cm	20 μm-5000 μm	20 μm	Song *et al*. (2018)
		Middle	Pump	3~27 m	20 μm-5000 μm	20 μm	
		Bottom	Pump	5~58 m	2 μm-5000 μm	20 μm	

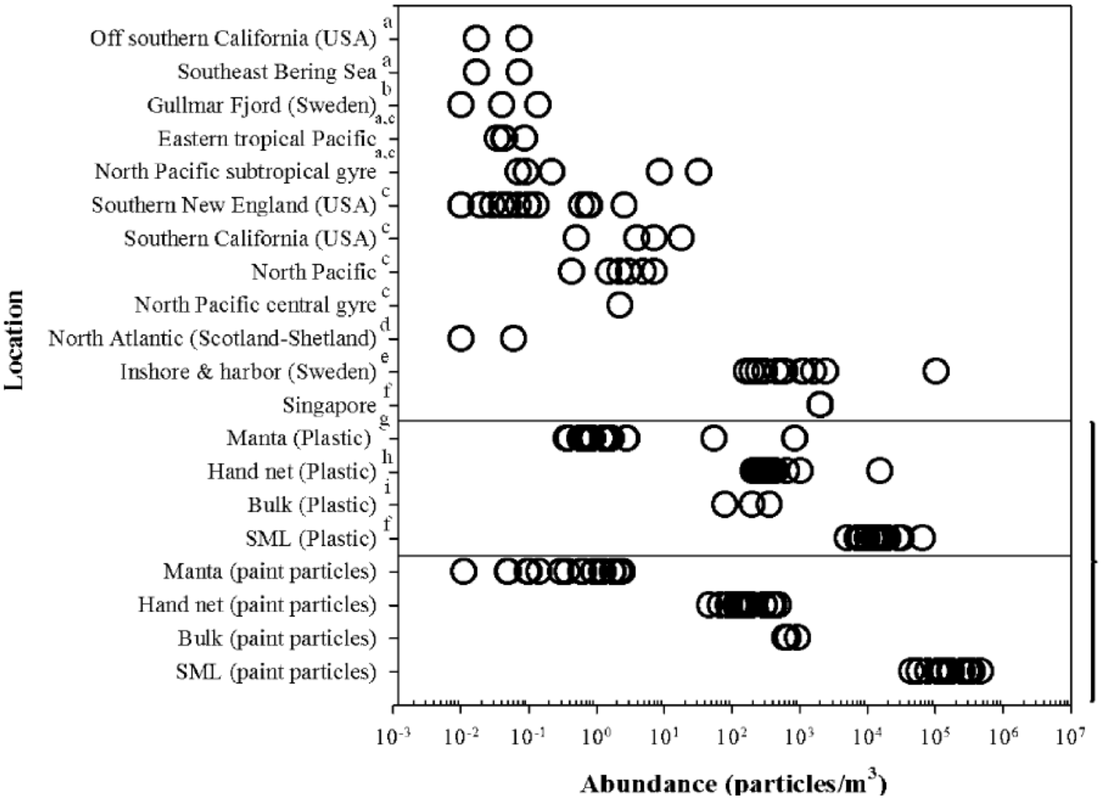

Figure 2.30. Comparison of floating microplastics abundance in surface water. The superscript letters indicate net mesh size or sample type: a, 505 μm; b, 450 μm; c, 333 μm; d, 280 μm; e, 80 μm; f, SML; g, 330 μm; h, 50 μm; and I, bulk surface water (adapted from Song *et al*., 2014)

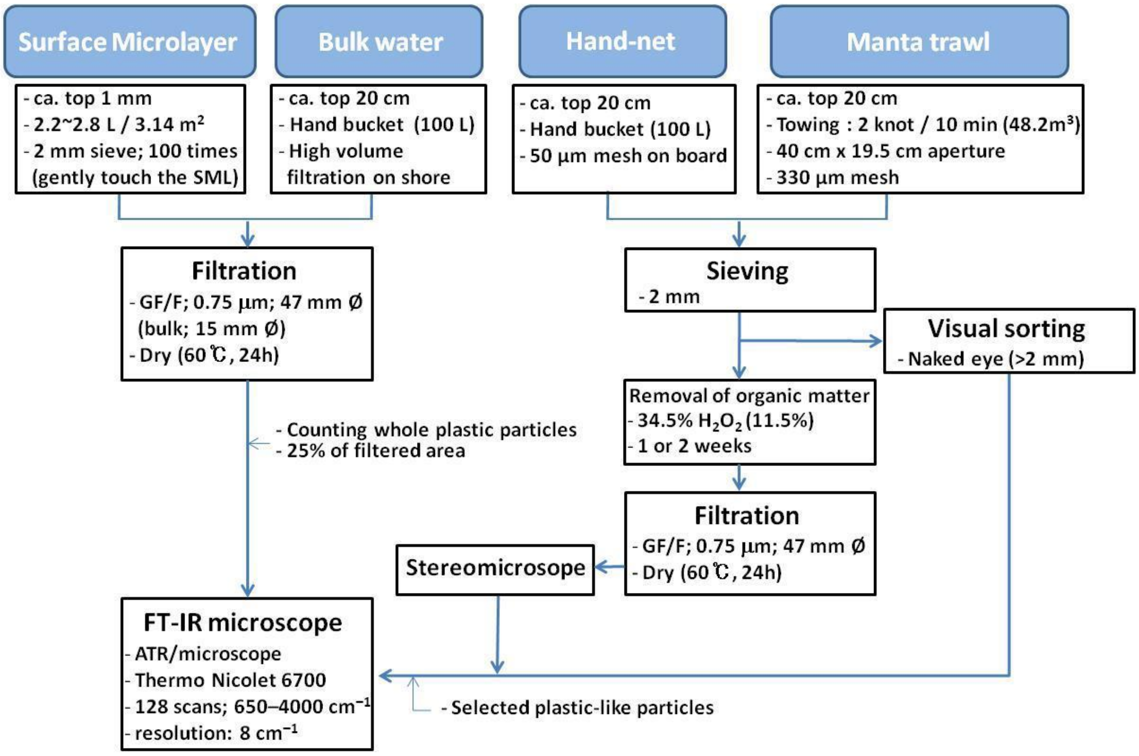

Figure 2.31. Schematic diagrams of four sampling methods (surface microlayer, bulk surface water filtering, hand net, and Manta trawl) for floating microplastics (adapted from Song *et al*., 2014)

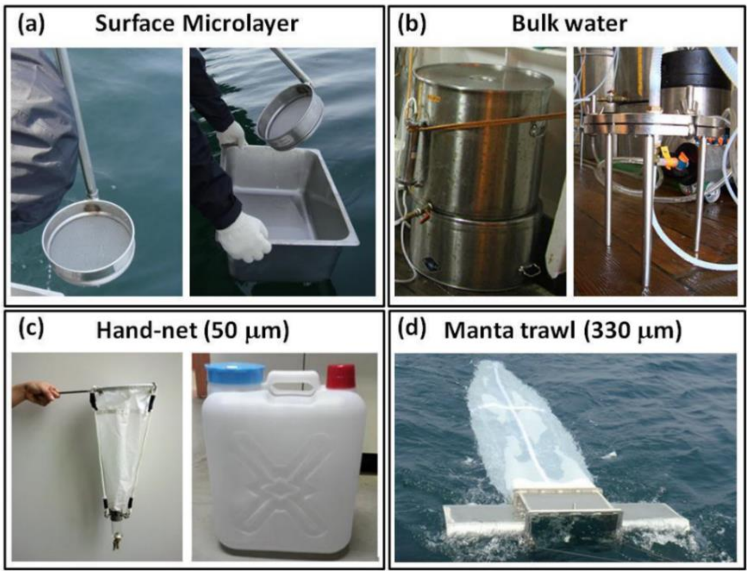

Figure 2.32. Photographs of four sampling methods for floating microplastics: (a) sea surface microlayer, (b) bulk water, (c) hand net, and (d) Manta trawl (adapted

from Song *et al*., 2014)

- **Sampling depth**

  Each study collected samples from the surface layer or different depths of the water column according to its survey purpose. Until recently, neuston net was used to get samples at surface. Song *et al*. (2018) tried to understand vertical profile of the abundance of floating litter through modeling transportation and mixing of the microplastics in the water column. They investigated the microplastics profile by depth and elucidated the distribution and composition characteristics of them at the surface at different layers of sea water column. The concentration of microplastics was higher in the surface water (> 20 cm) than those in the middle (at a certain depth of water column ranging between 3~27 m according to the sampling station) and bottom (5~58 m) of the water column. However, the total number of microplastics in the middle of the water column was higher than that in surface water because of a large volume of water containing microplastics, indicating that a large proportion of microplastics were retained in the water column of coastal zones.

- **Sorting and identification**

  Quantification of marine litter in the environment should be conducted by an appropriate method because environmental samples come with various unnecessary materials. Water samples should be sieved(or filtered) to get targeted floating litter items. After sieving (or filtering), marine litter items are visually sorted to be separated from other materials. This process is especially useful for large litter items like meso (5~25 mm) and macro (> 25 mm) debris (Lee *et al*. (2013) was followed for size definition.). A microscope is usually used to separate litter items sized 1-5mm. As floating litter is mainly composed of small plastics less than 1 mm (Song *et al*., 2014, 2018), most studies are conducted with analytical instruments for proper identification. Separated microplastics undergo Fourier transform infrared spectroscopy(FTIR) or Raman-spectroscopic analysis (Figure 2.33). However, detection of microplastics is influenced by all processes applied. Indeed, the quantification of microplastics is most significantly affected by method and equipment used for identification.

Such influence was well studied by Song *et al*. (2015a) who elucidated the different abundances of microplastics resulted in by different methods of microscopic and spectroscopic identification. Two methods didn’t produce a consistent result, revealing that more fiber items were counted with a microscope than with a spectroscope, whereas more fragments were detected with a spectroscope than with a microscope (Figure 2.34). The result shows that to properly quantify microplastics, an identification process which suits for sample type should be considered. Furthermore, consistent criteria should be applied when sampling and analyzing microplastics

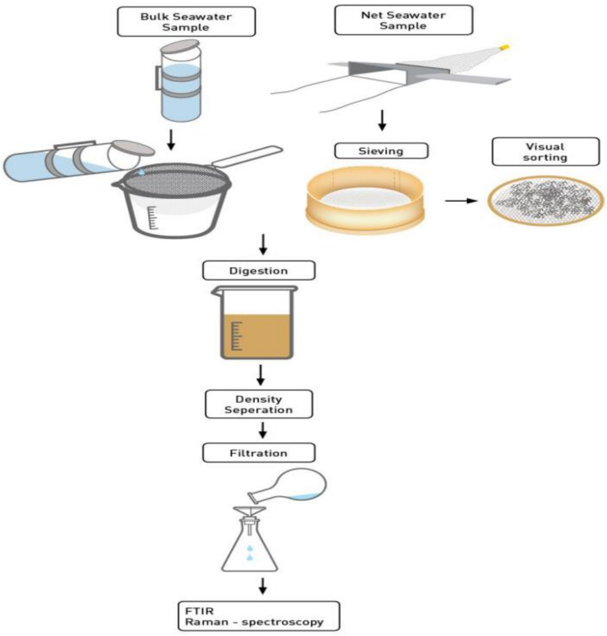

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Figure 2.33. A schematic diagram of processing samples for microplastic analysis.

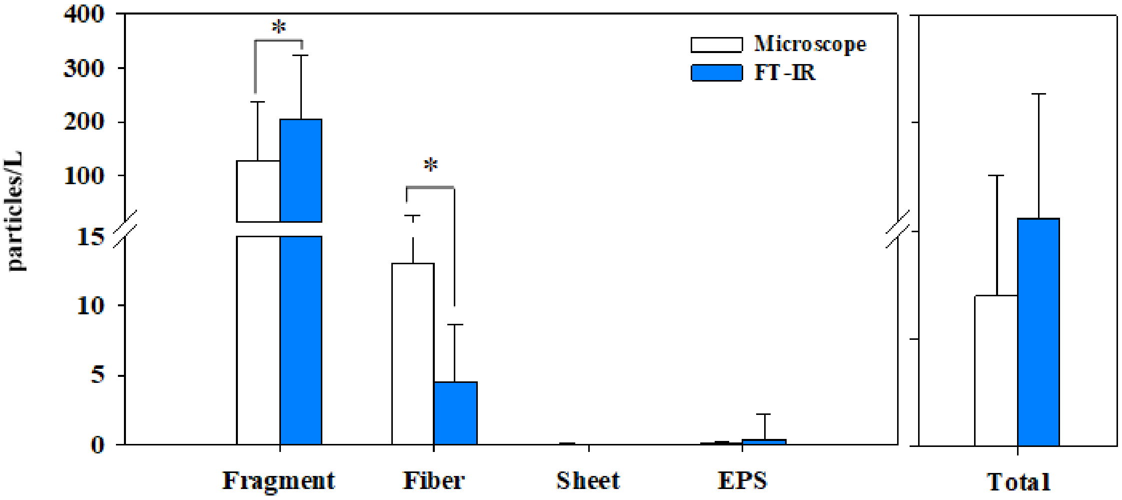


Figure 2.34. Comparison of the abundance of microplastics by type in the sea surface microlayer identified using a stereomicroscope and FTIR (adapted by Song *et al*., 2015a).

- **Measuring unit**

Most of the studies reported the abundance of floating litter using particle numbers in a certain volume. The reason is that the water sample was mainly collected in mainly bulk or volume-reduced way, in which a large volume of water is filtered with nets.

The abundances of microplastics were reported in a volume-based unit (items/m^3 or items/L) in some researches, while others were reported in an area-based unit (items/m^2 or items/km^2).

2.2.2. Distribution of floating litter

A large proportion of floating litter is composed of microplastics. Zhao *et al*. (2014) revealed that more than 90% of floating litter was composed of plastics smaller than 5 mm. Zhu *et al*. (2018) reported that more than 70% was made up of plastics smaller than 1 mm. For this reason, most of the studies for floating litter in Korea have been focused on microplastics. Therefore, floating litter means microplastics and the main interest of this report is the distribution and characteristics of microplastics. The abundance of microplastics was associated with different types of nets and their mesh sizes, which were shown in Song e*t al*. (2014) and Kang *et al*. (2015b). Therefore, interpreting and comparaing data should be carefully approached. The abundance of microplastics around Geoje island (fragment: 206 ± 117 items/L (convertible to 206,000 ± 117,000 items/m^3), EPS: 0.4 ± 1.8 items/L, fiber: 4.5 ± 4.1 items/L,) was highest in the surface waters by FTIR inspection (Song *et al*., 2015a) (Table 2.11). They collected water samples from the surface microlayer with a 2 mm mesh sieve and filtered them through a GF/F filter (0.75 μm) and inspected the microplastics with FTIR and stereomicroscope. A similar method was used and the result showed the same order of microplastic abundances in Kyeonggi and Asan Bays, which are located on the western coast of Korea. The light weight of some polymers and high surface tension of the sea surface microlayer would be attributed to the high abundance of microplastics (Song *et al*., 2014). Furthermore, the abundances of microplastics collected by hand net or bulk sampler were three or four orders higher than those taken by Manta trawl with a net ranging from 330 to 350 μm mesh size (Kang *et al*., 2015b; Song *et al*., 2014) (Table 2.11).

Table 2.11. The levels of floating microplastics in Korea (adapted from NOWPAP, 2020).

Country	Location	Sampling method		Mesh size	Identification	Range	Abundance	References
Korea	Kyeonggi and Asan Bays (western coast of Korea)	Surface microlayer	Sieving	0.75 μm	FTIR	48,092-359,748 items/ m^2	152,688±92,384 items/m^3	Chae *et al*. (2015)
		Surface seawater	Hand net	20 μm	FTIR	10-4,227 items/m^2	1,602±1,274 items/m^3	
			Trawl net	330 μm	FTIR	0.06-0.45 items/m^2	0.19±0.14 items/m^3	
Korea	Geoje (Southeastern Sea of Korea)	Hand net	Net collection	50 μm	Microscope, FTIR	260-1,410 items/m^2, 210-15,560 items/m^2 (before and after rainy season	-	Kang *et al*. (2015b)
		Manta trawl	Net collection	330 μm	Visual, microscope, FTIR	0.62-57 items/m^2 , 0.64-860 items/m^2 (before and after rainy season)	-	
Korea	Geoje (Southeastern Sea of Korea)	Sieving		0.75 μm	Stereo microscope	-	Fragment: 127±111 items/L EPS: 0.1±0.2 items/L fiber: 13±15 items/L	Song *et al*. (2015a)
				0.75 μm	FTIR	-	Fragment: 206±117 items/L EPS: 0.4±1.8 items/L fiber: 4.5±4.1 items/L	
Korea	Geoje (Southeastern Sea of Korea)	Surface microlayer	Sieving	0.75 μm	FTIR	-	16,272±13,457 items/m^3	Song *et al*. (2014)
		Hand net	Net collection	50 μm	FTIR	-	1,143±3,353 items/m^3	
		Bulk water	Bucket collection	50 μm	FTIR	-	213±141 items/m^3	
		Manta trawl	Net collection	330 μm	FTIR	-	47±192 items/m^3	
Korea	Off coast of Korea	Surface ,	Bucket collection	20 μm	μ-FTIR	-	1736±1179 items/m^3	Song *et al*. (2018)
		Middle	Pump	20 μm	μ-FTIR	-	423±342	

							items/m^3	
		Bottom	Pump	20 µm	µ-FTIR	-	394±443 items/m^3	

The levels of microplastics in Korea were compared with other regions to determine the status of contamination by floating litter (Table 2.12). The heterogenous sampling methods and different equipment have been used for surveying microplastics in seawater and the most frequently used nets worldwide to collect microplastics in seawaters were Manta trawl and neuston nets with 250-505 µm mesh size. We selected survey results using 250-505 µm mesh size and compared them with those of other studies using similar mesh sizes (Table 2.11).

Table 2.12. Comparison of abundance of microplastics collected with 250-505 µm mesh size in seawaters (adapted from NOWPAP, 2020).

Region	Location	Mesh size (µm)	Abundance (items/m^3)	References
Korea	Southeastern Sea of Korea	330	1.92-5.51	Kang *et al.* (2015a)
	Kyeonggi and Asan Bays, Korea	330	0.19	Chae *et al* (2015)
	Geoje, southeastern Sea of Korea	330	47	Song *et al* (2014)
Other region	Jiaojiang, Oujiang, and Minjiang Estuary (south-eastern China)	333	100-4100	Zhao *et al* (2015)
	Bohai Sea, China	330	0.33	Zhang *et al* (2017)
	Rudong offshore wind farm (Yellow Sea)	333	0.330	(Wang *et al*. (2018)
	North Pacific Gyre	333	2.23	Moore *et al*. (2002)

	Seto inland	335	0.39	Isobe *et al* (2014)
	East Asian Sea	335	3.7	Isobe *et al*. (2015)
	East China Sea	333	0.167	Zhao *et al* (2014)
	Southern California	333	37.25	Moore *et al*. (2002)
	Southern California-Santa Monica Bay	333	3.92	Lattin *et al* (2004)
	South east Bering Sea	505	<0.1	Doyle *et al* (2011)
	Northeast Pacific Ocean	505	0.004-0.19	Doyle *et al* (2011)
	Portuguese Coastal waters	280	0.002-0.036	Frias *et al*. (2014)
	Central-Western Mediterranean Sea	500	0.15	de Lucia *et al* (2014)
	Northeast Atlantic (Celtic Sea)	250	2.46	Lusher *et al* (2014)

The abundance in Kyeonggi and Asan Bays, Korea showed the same order of those in Bohai Sea and Rudong offshore wind farms in China and Central-Western Mediterranean Sea. On the other hand, the sea around southeastern Korea showed a similar level of microplastics to that of North Pacific Gyre, East Asian Sea, Southern California-Santa Monica Bay, and Northeast Atlantic (Celtic Sea). The abundance of microplastics in Geoje in Korea was in the same order of that in Southern California.

■ Size distribution of microplastics

In virtue of advanced analytical instruments like FTIR and Raman-spectroscope, we can detect microplastics at scales down to 10 μm with several size fractions. Thereafter the researchers for microplastics tried to elucidate the abundance and size distribution of them in the ocean (Isobe *et al*., 2014). According to Cózar *et al*. (2014) who assembled a data set for floating marine litter (FML) and examined their size distribution, abundance of plastic fragments peaked around 2 mm with a gap below 1 mm. Theoretically, the abundance increases toward as the size decreases because plastics are fragmented as time passes. Several hypothesized processes were suggested that there was a substantial loss of smaller plastic particles in the ocean surface. Isobe *et al*. (2014) elucidated size distribution of microplastics, supporting the previous finding.

Meanwhile, Song *et al*. (2018) surveyed microplastics in Korean coastal waters using a bulk sampler and a water pump for determining the horizontal and vertical distribution of microplastics. They reported that size-related abundances were different by shapes of microplastics. Non-fiber microplastics smaller than 300 μm accounted for 86% in the total amount of microplastics and their peak was observed in the 100-150 μm size. On the other hand, fibers smaller than 300 μm accounted for 30% and their abundance peaked in the size range from 1,000 to 2,000 μm (Figure 2.34). These results supported that size-related distributions of microplastics are dependent upon the sampling method and shape of microplastics.

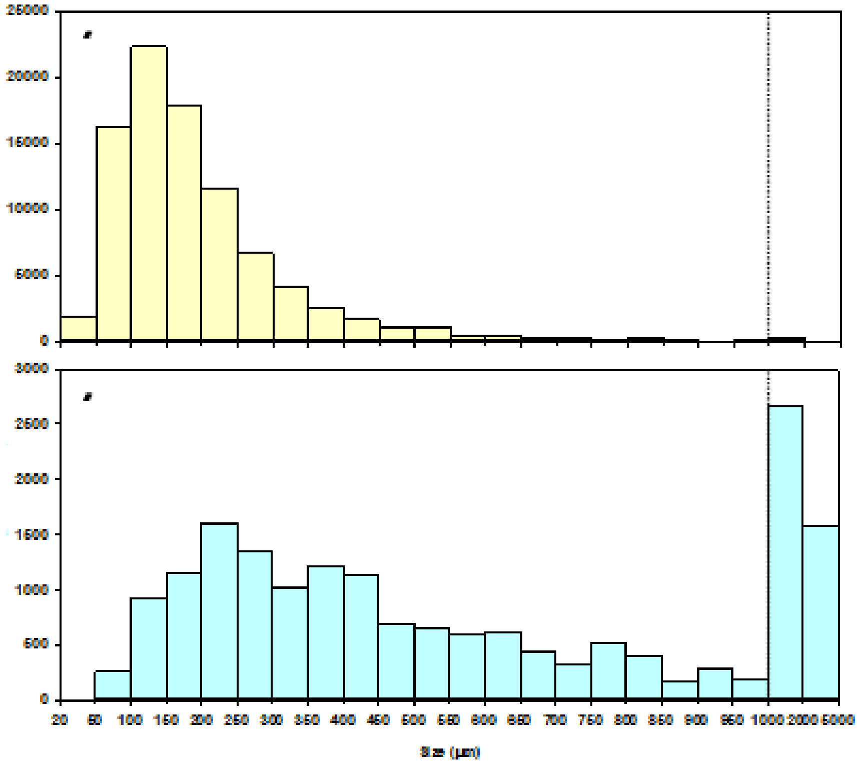


Figure 2.35. Size distribution of (a) non-fiber and (b) fiber microplastics (adapted from Song *et al*., 2015a)

■ Vertical distribution of microplastics

Microplastics are widely distributed in vast regions of the ocean and several studies have tried to elucidate the transport, mixing, and fate of them by the ocean currents, winds, and unknown factors (Kukulka*et al*., 2012; Reisseret a., 2015; Song *et al*., 2018). They determined vertical transport and distribution which are important processes for understanding how and where microplastics are moved and accumulated in the marine environment. Kukulka *et al*. (2012) surveyed microplastics in the surface and subsurface waters of the North Atlantic subtropical gyre and showed that plastics not only simply stayed in the surface but are vertically distributed within the mixed layer. Furthermore, plastic concentrations decreased sharply with increasing water depths and smaller pieces showed lower rising velocities and were more vulnerable to vertical transport (Reisser *et al*., 2015). These two studies were conducted in the open ocean at a sampling depth of 20 m, in which vertical mixing by wind can occur. Song *et al*. (2018) conducted microplastics sampling in nearshore areas in Korean coastal waters where biological production is high. The study determined the depth profile of microplastics to better understand vertical distributions of microplastics. Seawater samples were collected from the surface layer from 0 to 20 cm in depth using a customized surface water sampler made from a stainless tray. Samples were also collected from the middle layer ranging from 3 to 27 m depth and the bottom with depths ranging from 5 to 58 m using a submersible water pump. The abundances of microplastics decreased with greater depths for all particle sizes. The abundance was found to be 423 particles/m^3 in the mid column and 394 particles/m^3 in the bottom. These were one order lower than that of the surface water (1,736 particles/m^3), but still significantly high(Figure 2.36). These results supported that microplastics prevailed not only in the sea surface but also throughout the water column (Kulkulka *et al*., 2012 and Reisser *et al*., 2015).

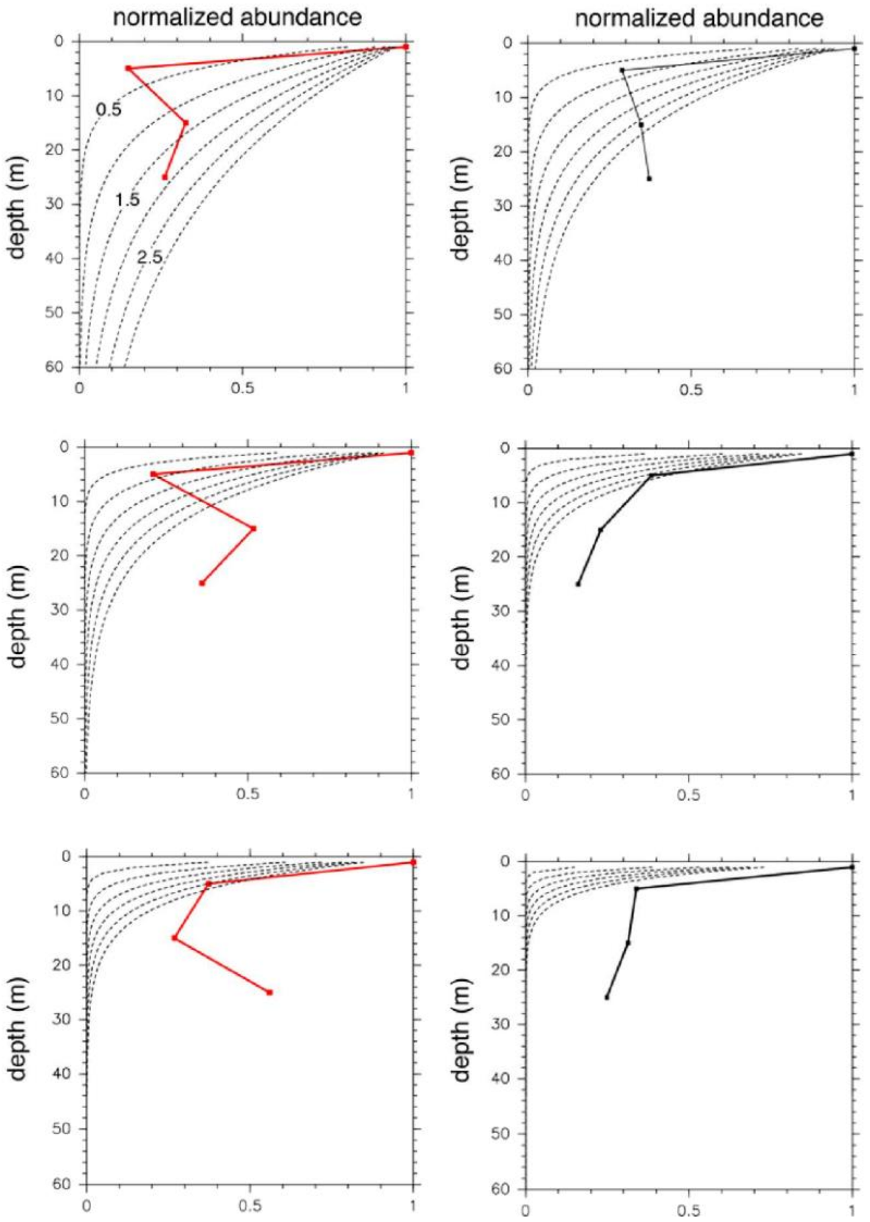


Figure 2.36. Average microplastic abundance (particle count per unit seawater volume) normalized to the abundance at the surface layer superimposed over the exponential curves. Left and right panels show cases with wind speeds higher and lower than 3 m/s, respectively. The upper, middle, and lower panels show microplastics with sizes of <0.3 mm, 0.3-0.5 mm, and 0.5-1.0 mm, respectively. The dotted curves mean significant wave heights of 0.5-3 m (see the upper left panel) (adapted from Song *et al*., 2018).

2.2.3 Composition and source

- **Composition by shape**

Fragment and fiber accounted for the majority of microplastics in the sea surface microlayer in Geoje,(Song *et al*., 2015a). Interestingly, the abundances of fragments and EPS were measured higher with FTIR than with microscope, while the mean abundances of fiber and sheet (film) were measured lower with FTIR, indicatingvarious detection capacities of instruments. Abundant fibers were likely derived from fishing ropes used for aquaculture, fishing nets, and ships in the neighboring seas around Korea.

Chae *et al*. (2015) found that ship paint particles accounted for the majority of microplastics in the surface seawaters of the coastal region of Incheon/Kyeonggi. . Song *et al*. (2015a) also found that paint particles were the most abundant microplastics in the sea surface microlayer in the southeastern sea of Korea (Table2.13), implying that fishing boats were the source of paint particles in these areas, as a frequent number of fishing activities occur there.

Table 2.13. The abundance of paint particles vs plastics in the southeastern sea of Korea (adapted from Song *et al*., 2014)

Size (㎛)	Abundance (particles/L)	
	Paint particles	Plastics
<50	95±57	8.0±12
50-100	67±40	1.2±3.3
100-200	22±20	1.2±2.69
200-500	10±11	1.5±2.9

500-1000		2.7±3.5
>1000	0.5±1.5	1.6±2.6
total	195±114	16±14

Little difference was found in the distribution of microplastics among different shapes of microplastics at different sampling depths below the sea surface around the Korean peninsula (Song *et al*., 2018).

- **Composition by polymer**

Plastic production has increased dramatically and its cumulative production including additives reached 8,300 million tons by 2015 (Geyer *et al*., 2017). PE (36%), PP (21%), and PVC (polyvinylchloride, 12%) are the major polymers among non-fiber production, followed by PET (polyethylene terephthalate), PUR (polyurethane), and PS (polystyrene) (<10% each). Among all PP&A (polyester, polyamide, and acrylic fibers) fiber production, polyester, most of which is PET, accounts for 70%. These seven groups mentioned above account for 92% of all plastics ever made. Packaging is the biggest sector in which approximately 42% of all non-fiber plastics have been used and they are predominantly composed of PE, PP, and PET (Geyer *et al*., 2017). Plastics have outgrown most man-made materials and have long been under environmental scrutiny. However, robust global information, particularly about their end-of-life fate, is lacking. As of 2015, approximately 6,300 Mt of plastic waste was generated, around 9% of which was recycled, 12% incinerated, and 79% was accumulated in landfills or the natural environment. If the current trend of production and waste management continues, roughly 12,000 Mt of plastic waste will be in landfills or in the natural environment by 2050. PE and PP are easy to float because of inherent buoyancy, broad utility, and high production (Engler, 2012). However, plastics with high density will float only with entrapped air in them.

Souces of plastic debris could be traced with a better understanding of polymer composition. Polymer composition of plastics is widely determined with FTIR, Raman microspectroscopy, and Pyrolysis gas chromatography. The identification of polymers in Korea was also conducted with FTIR (Song *et al*., 2014; Chae*et al*., 2015; Kang *et al*., 2015a; Song *et al*., 2015a; Song *et al*., 2018). Despite the different polymer composition particle size, and density by depth, PP and PE were the dominant throughout the water column regardless the low density and particle size in the Korean coastal waters (Song *et al*., 2018). On the other hand, alkyds and polyacrylate/styrene were the most abundant type of polymers both in the south and west coast of Korea (Song *et al*.; 2014, Chae*et al*., 2015; Kang *et al*., 2015b). These polymers originated from paints and the fiber-reinforced plastic (FRP) matrix used on ships (Song *et al*., 2014). Vigorous fishing and shipping activities were suggested as sources of this particular phenomenon, although further study is required to evaluate the major input pathway of paint particles in these areas. 2.3. Marine litter deposited on seafloor

Marine litter that enters marine compartments is accumulates in the shorelines, floats in the ocean and moves along the wind and currents. After they deposited on the beach or coast, plastics are degraded by UV radiation and fragmented into small pieces. Numerous small plastic pieces float in the ocean and can be ingested by marine organisms. However, a large proportion of them are thought to eventually snk and are accumulated on the sea floor far from the coast (Bagulayan *et al*., 2012).

Marine litter on the sea floor may negatively impact on not only marine wildlife but on fishing operations. On the other hand, the distribution and abundance of them are yet to be revealed. It is probably because assessing the effect of marine litter on the sea floor is relatively difficult compared with those on shorelines or even in the ocean. Carrying out surveys on the sea floor can help better understanding the quantity, quality and fate of marine debris and finally establishing mitigation strategies.

We will review the researches of marine litter on the sea floor in Korea and try to understand characteristics of its distribution..

2.3.1 Methodologies for quantification and identification

The surveys of deposited marine litter on sea floor have been targeted for large-sized litter items such as rope, net, pot, plastic bottle and plastic bag in Korea. For the researches, side scan sonar(Kim and Kang, 2012; Park *et al*., 2016), trawl net (Kim *et al*., 2006; Kim *et al*., 2010), and trap/gill-net(Kim *et al*., 2014) were used and elucidated the distribution and composition of the litter. It is mainly because objectives of the researches for the submerged marine litter were to elucidate the influence of the submerged litter on fisheries and estimate expenditure for collection of marine litter items from the fishing grounds and their disposal (Kim & Kang, 2012). Surveying depths for side scan sonar ranged from 15 m to 40 m around the southwestern coast of Korea (Kim and Kang, 2012). 2.3.2. Distribution and composition

Distributions of submerged marine litter in Korea are shown in Table 2.14. The estimated amount of submerged marine debris by side scan sonar at the Pohang Port was 61,759 kg in 103.8 ㎢, which is equivalent to 528.30 kg/㎢ (Park *et al*., 2016). They were mainly composed of nets, ropes, traps, anchors, woods, tires, and plastics. Nets and traps were the most abundant items, occupying 88.1 % of the total amount and the combination of irons, traps, and anchors accounted for 11.9 %.

The frequent occurrence of fishing gears was probably because the sampling locations were close to a fishing port where many fishery activities occurred nearby. Another survey research of submerged marine litter was conducted around 5 islands located off southeast Korea (Kim & Kang, 2012). The litter was composed of various items and its abundance ranged from 534 kg/㎢ to 4,350 kg/㎢ depending on whether fishing grounds were present.

The abundance was the highest in Younghungdo Island, followed by Heuksando Island which is located in the west coast of Korea. Younghungdo Island is famous for abundant catches around the island and fishing activities are intensive in the area. It was likely that a large quantity of fishing gears was lost during fishing activities and contributed to the high abundance of macro litter in the area. The litter was composed of traps, anchors, ropes, nets, and wires.

Kim *et al*. (2006) conducted a similar survey in the Busan Port and estimated the amount of submerged marine litter as 355kg/㎢. Plastics were the most predominant in number and fishing gear ranked the highest in terms of weight. The authors suggested that considering the abundance of household items, the litter came from nearby villages. Marine litter items on the seafloor in the south coast of Korea and the East China Sea were surveyed by Lee *et al*. (2006). Distribution densities of marine debris in the south coast of Korea and the East China Sea ranged from 59.8 to 109.8 kg/ km^2 and from 30.6 to 42.8 kg/ km^2, respectively. The marine litter on seafloor was sampled with bottom trawl nets. It was found that the litter consisted of fishing instruments such as pots, nets, octopus jars, and fishing lines. The gear occupied 42-

72% and 37-62% of the total in the East China Sea and the south coast of Korea, respectively. The densities of marine litter on seafloor (Kim & Kang, 2012; Kim *et al*., 2006; Park *et al*., 2016) were higher in the port areas than in the offshore (Lee *et al*., 2006). The debris compositionwas found to be clearly different among different survey areas. Especially in the Busan Ports, the debris showed a high proportion of plastics, implying villages may be the major source of marine litter on the seafloor near a highly-populated city.

Furthermore, active fishing operations in the vicinity of fishing grounds seemed to contribute to the high abundances of submerged litter. It is noteworthy that it can cause ghost fishing and negative impact on the navigation. Hong *et al*. (2017) investigated navigational threats caused bydiscarded fishing gears from 2010 to 2015 and found that the frequency of propeller entanglement was 2.3 times per ship and 397.7 times per year. The study emphasized that the adverse impact of derelict fishing gears has been persistent and ubiquitous across the study area. Though a submerged fishing gear is less likely to cause entanglement compared to a floating gear in the water column, it can still be floating by oceanographic movements and pose threats to marine organisms. Under these circumstances, mitigating policies and regulations related to the submerged marine litter should be properly developed and enacted.

Table 2.14. Comparison of marine litter pollution level on seafloor

Country	Location	Sampling depth	Target size	Abundance	unit	References
Korea	Pohang Port		Mainly fishing gear	528.30	kg/km^2	Park *et al*. (2016)
Korea	Wanndeung-do Younghung-do Jawol-do Saengil-do Heuksan-do	30 m 20 m 15 m 25 m 40 m	Mainly fishing gear	686 4,350 534 708 1,686	kg/km^2	Kim and Kang (2012)
Korea	Busan Port		Fishing gear, household item	355	kg/km^2	Kim *et al*. (2006)
Japan	Tokyo Bay		Fishing gear, household item	20.1 (1995) 10.4 (2000)	kg/km^2	Kuriyama *et al*. (2003)
Japan	Kagoshima Bay	80-220 m	Fishing gear, household item	30.0	kg/km^2	Fujieda *et al*. (2009)
Japan	Pacific coast of northern Japan	183-521	Fishing gear, household item	54-57 (2003) 89-94 (2004) 233-332 (2011)	Items/kg^2	Goto and Shibata (2015)
China	Bohai Sea/Yellow Sea	12-78 m	0.06–5 mm	171.8 (Bohai Sea) 123.6 (Northern Yellow Sea) 72 (Southern Yellow Sea)	Items/kg (D.W.)	Zhao *et al*. (2018)
China	Changjiang Estuary	-	<5 mm	121 ± 9	Items/kg (D.W.)	(Peng et al., 2017)
China	Rudong		<5 mm	2.58±1.14	Items/g(D.W.)	Wang *et al*. (2018)
China	North Yellow Sea		<5 mm	37.1±42.7	Items/kg(D.W.)	Zhu *et al*. (2018)
Russia	Baltic Sea	3-30 m	0.175-5 mm	34 ± 10	Items/kg(D.W.)	(Zobkov and Esiukova, 2017)
Belgium	Sublittoral zone of Belgian coast	-	0.038-1 mm	97.2 ± 18.6 (sublittoral zone) 166.7±92.1 (harbor)	Items/kg(D.W.)	Claessens *et al*. (2011)
Deep sea world wide	Porcupine Abyssal Plain Polar Front Distal lobe of Congo Canyon Nile Deep Sea Fan	4842-4844 m 2749 – 4881 m 4785 1176	0.035–1 mm	0.5	Items/25 cm^2	Van Cauwenberghe *et al*. (2013))
Portugal	Southern Portuguese shelf	7.1–27.4 m		0.01± 0.001	Items/g	Frias *et al*. (2016)
	Mediterranean Sea Atlantic Ocean Indian Ocean	300-3500 m	0.032-5 mm	13.4 ± 3.5	Items/50ml	Woodall *et al*. (2014)
France	Brest Bay		0.0016 mm	0.97 ± 2.08	Items/kg (D.W.)	Frère *et al*. (2017)
Spain	Mediterranean Sea	1.5 10 m	0.063–5 mm	0.90 ± 0.10	Items/g	Alomar *et al*. (2016)
Europe	Southern European deep sea	42 – 3500 m	0.032-5 mm	6,965± 3,669	Items/m^2	Sanchez-vidal *et al*. (2018)

CHAPTER 3. NEGATIVE IMPACTS ON MARINE ECOSYSTEMS AND SOCIO-ECONOMY

3.1. Wildlife

Hong *et al*. (2013) investigated the damage of wild animals caused by marine litter in Korea using citizen science and network research methods. The survey included a contribution from wildlife rescue centers, migratory bird research centers, bird watchers and local conservation groups (Table 3.1.).

Table 3.1. Institutes and organizations that provided information on wild animal damages from marine debris (Hong *et al*., 2013).

Classification	**Organization**	**Data collected by**
Wildlife rescue center	Wildlife rescue center in Busan Wildlife rescue center in Chungnam Wildlife rescue center in Jeju	Vets Vets Vets
NGO	Korea Wild Birds Protection Association Jeju Wildlife Research Center PGA Wetland Ecology Institute Our Sea of East Asia Network Gang Hwa People's Network	Birdwatchers Birdwatchers Scientists Scientists Birdwatchers
Research Institute	Korea Ocean Research and Development Institute Migratory Birds Center of National Park Research Institute	Scientists Vets/Scientists

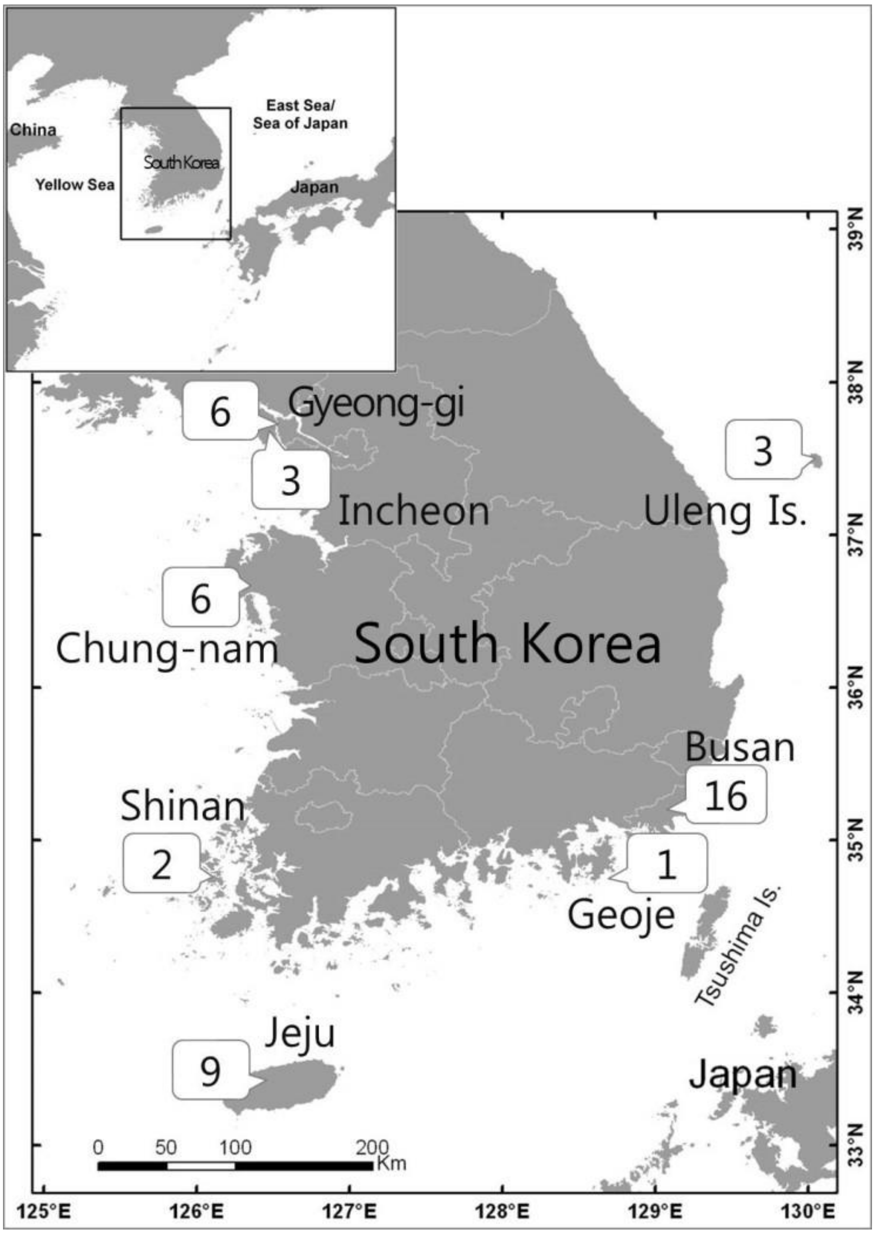


Figure 3.1. Location of detected wild animals damaged by marine debris in South Korea. The number in the squares show the frequency of entanglement or ingestion reported for each region. (Hong *et al*., 2013)

The survey collected 45 cases of wildlife damage caused by marine litter in Korea. There were 21 species, among which birds accounted for about 85%. Mammals, marine mammals and crustaceans have been damaged by marine debris. Five species among them are protected under the Korean law, listed as international endangered species, and registered as natural monuments of Korea.

The most seriously damaging litter was from recreational fishing. This includes fishing lines, hooks, and lead weights. Litter items produced by recreational fishing accounted for more than 70% of the total, much higher than commercial fishing gears. Wild animals are mainly affected by ingestion and entanglement.

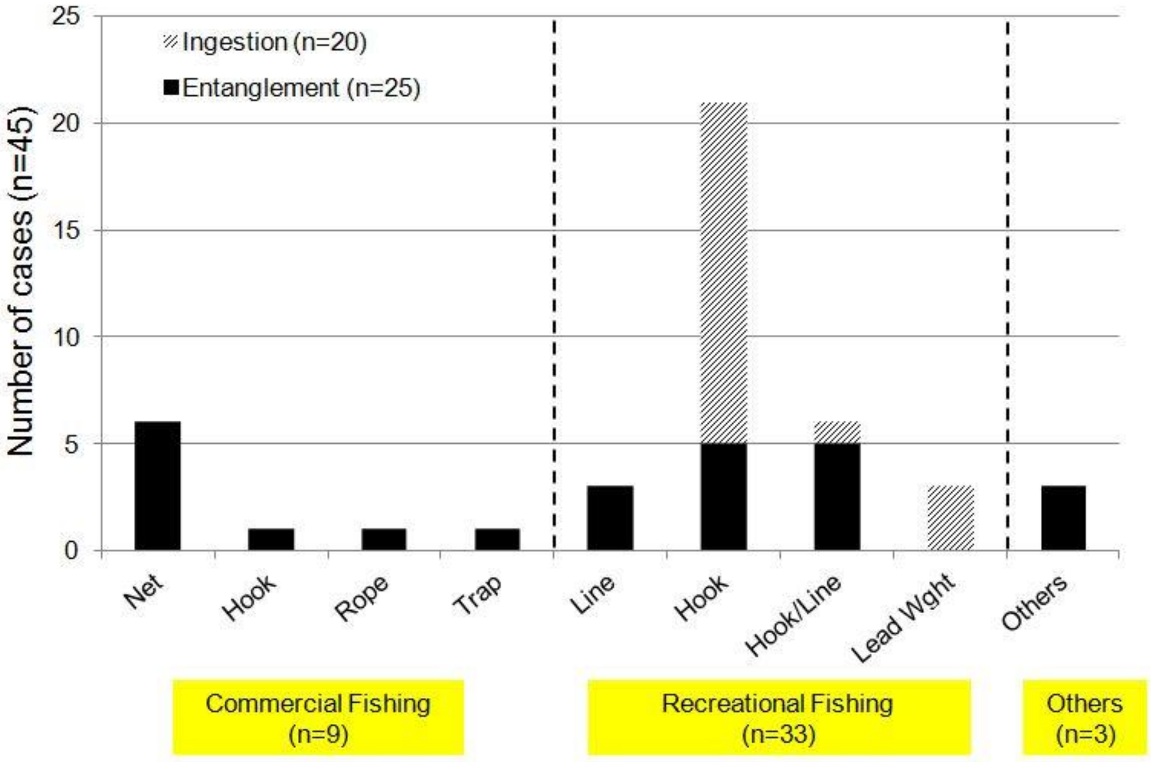


Figure 3.2. Marine debris and damage types impacting the wild animals in Korea. The source of marine debris was mainly classified into commercial and recreational fishing activities (Hong *et al*., 2013).

Table 3.2. Wild animal species impacted by marine debris in South Korea. Sixteen species are newly reported, including three internationally threatened species (‡) (IUCN, 2011) and three domestically protected species (*) (Hong *et al*., 2013).

Order / Species	**N (%)**	**Marine debris (Damage type)**
Charadriiformes	24 (53.3)	
Black-tailed Gull *Laruscrassirostris*	19	Recreational Fishing Hook (I, E), Recreational Fishing Hook and Line (I, E) Recreational Fishing Line (E)
Greater Painted Snipe *Rostratula Benghalensis**	1	Commercial Fishing Net (E)
Herring Gull *Larusargentatus*(a)	1	Plastic Bag (E)
Black-headed Gull *Larusridibundus* (a)	1	Recreational Fishing Hook (I)
Slaty-backed Gull *Larusschistisagus*	1	Recreational Fishing Hook (E)
Ancient Murrelet *Synthliboramphus Antiquus*	1	Commercial Fishing Net (E)
Pelacaniformes	7 (15.6)	
Great Egret *Egretta alba (Casmerodiusalbus)*(b)	2	Recreational Fishing Hook and Line (E), Plastic band (E)
Black-faced Spoonbill *Platalea minor*$^{\ddagger *}$	2	Commercial Fishing Net (E), Recreational Fishing Hook (E)
Night Heron *Nycticoraxnycticorax*	1	Recreational Fishing Hook and Line (E)
Grey Heron *Ardeacinerea*	1	Recreational Fishing Hook (E)
Temminck's Cormorant, *Phalacrocoraxcapillatus*	1	Recreational Fishing Line (E)
Anseriiformes	3 (6.6)	
Whooper Swan *Cygnus Cygnus**	3	Recreational Fishing Lead Weight and metallic gear (I)
Gaviiformes	2 (4.4)	
Pacific Diver *Gaviapacifica* (c)	1	Recreational Fishing Hook (I)
Black-throated Diver *Gaviaarctica*	1	Recreational Fishing Hook (I)
Procellariiformes	2 (4.4)	
Short-tailed Shearwater *Puffinustenuirostris* (b)	2	Commercial Fishing Rope (E), Recreational Fishing Hook (I)

Anseriformes	2 (4.4)	
Mallard *Anas platyrhynchos*	2	Commercial Fishing Trap (E), Commercial Fishing Net (E)
Ciconiiformes	1 (2.2)	
Little Egret *Egrettagarzetta*	1	Recreational Fishing Hook (E)
Podicipediformes	1 (2.2)	
Great Crested Grebe *Podicepscristatus*	1	Commercial Fishing Net (E)
Cetacea	1 (2.2)	
Finless Porpoise *NeophocaenaPhocaenoides*[‡]	1	Commercial Fishing Hook (E)
Artiodactyla	1 (2.2)	
Water deer *Hydropotesinermis*[‡]	1	Commercial Fishing Net (E)
Crustacean (Crustacea)	1 (2.2)	
De Haan's shore crab *Chiromantesdehaani*	1	Commercial Fishing Net (E)
Total (11 orders, 21 species)	**45 (100.0)**	

3.2. Tourism

Jang *et al*. (2014a) estimated the amount of lost revenus for the tourism in the southern coastal city of Geoje due to marine litter. In 2011, a flood occurred in the Nakdong River nearby Geoje City, which caused a large amount of litter to intrude into the the coast of Geoje. This pollution event prevented many tourists from coming to the beaches of Geoje. The reduced number of tourists and the resulting loss in their potential spending lead to a reduced revenue for the tourism and the study attempted to quantify the lost revenue. .

The number of visitors to Geoje beaches in 2011 was 63% lower than in 2010 (Table 3.3). It was revealed that the reduction in tourists was 79 to 100% attributable to the marine litter pollution. Given that the average spending on daytime activities is US$

48/day per tourist, the plummeted number of visitors resulted in a decreased expenditure of US$ 27 million in daytime activities after the pollution(Table 3.4). In addition, proportion of visitors who spent money on lodging was 44% and average expenditure on lodging per night per person was US$ 40 according to the survey of this study. Therefore, decrease in expenditure on lodging was US $10 million (Table 3.5). In total, the lost tourism revenue of Geoje Island was estimated to be US $37 million.

The study elucidated that number of visitors to Geoje beaches in 2011 was 63% less than in 2010 (Table 3.3) and that marine litter pollution contributed 79 to 100% of the total decrease of tourists. Given that US$ 48/day per capita for tourists was spent on daytime activities, decrease expenditure on day time activities at the beaches of Geoje Island in 2011 was US$ 27 million (Table 3.4). In addition, proportion of visitors who spent money on lodging was 44% and average expenditure on lodging per night per person was US$ 40 according to the survey of this study. Therefore, decrease in expenditure on lodging was US$ 10 million (Table 3.5). In total the lost tourism revenue of Geoje Island was estimated to be US$ 37 million.

Table 3.3. The number of visitors to beaches in Geoje Island in 2010 and 2011 (extracted from (MCST, 2012)). The number of visitors decreased by 560,228 (63%) in 2011 compared with 2010, resulting in an economic effect to the tourism industry (Jang *et al*., 2014a).

Name of beach	No. of visitors in 2011 (a)	No. of visitors in 2010 (b)	Decrease	Decrease in the no. of visitors (b-a)
Hwang Po (HP)	4,129	7,465	45%	3,336
Nong So (NS)	5,055	12,790	60%	7,735
Wa Hyun (WH)	61,986	230,280	73%	168,294
Gu Jo Ra (GJR)	74,890	247,805	70%	172,915
Hak Dong (HD)	144,405	307,315	53%	162,910
Ham Mok (HM)	5,292	13,000	59%	7,708
Yeo Cha (YC)	9,010	21,015	57%	12,005
Myoung Sa (MS)	25,440	50,765	50%	25,325
Total	330,207	890,435	63%	560,228

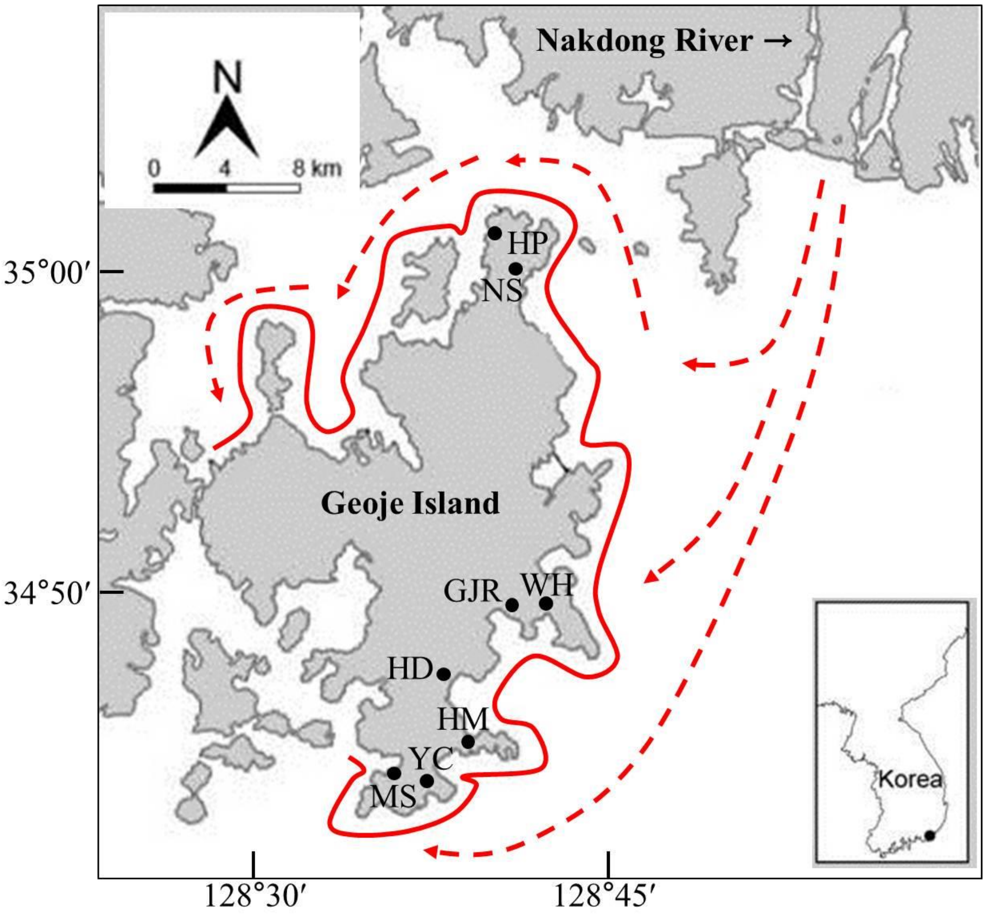


Figure 3.3. Location of Geoje Island and Nakdong River. Debris from Nakdong River affected the northern, eastern, and southern coasts marked with a bold red line. The

red dotted arrows show the likely pathways for the debris. Beaches where economic losses were recorded by the tourism industry due to debris pollution are marked with black dots: HP (Hwang Po), NS (Nong So), WH (Wa Hyun), GJR (Gu Jo Ra), HD (Hak Dong), HM (Ham Mok), YC (Yeo Cha), and MS (Myoung Sa). (Jang *et al*., 2014a).

Table 3.4. Estimated lost tourism revenue by daytime activities at the beaches of Geoje Island due to marine debris pollution event in 2011. (Jang *et al*., 2014a).

Item	Value
Decrease in the number of visitors in 2011 vs. 2010 (MCST, 2012) (a)	560,228 persons
Average expenditure on daytime activities (KCTI, 2012) (b)	US$ 48
Decreased expenditure on daytime activities at the beaches of Geoje Island in 2011 *vs*. 2010 (c = a×b)	US$ 27 million

Table 3.5. Estimated lost tourism revenue by lodging at the beaches of Geoje Island due to marine debris pollution event in 2011. (Jang *et al*., 2014a).

Item	Value
Decrease in the number of visitors in 2011 vs. 2010 (MCST, 2012) (a)	560,228 persons
Proportion of visitors who spent money on lodging (surveyed in this study) (b)	44%
Number of people who stayed overnight (c = a x b)	246,500 persons
Average expenditure on lodging per night per person (surveyed in this study) (d)	US$ 40
Decrease in expenditure on lodging (e = c x d)	US$ 10 million

3.3. Navigational threat

Hong *et al*. (2017) investigated the number of entanglements of the naval ship by derelict fishing gear (DFG) in Korea, using ship repair record of salvage and rescue unit of Republic of Korea Navy (ROKN). The records of the past six years indicate that about 200 ROKN vessels were affected by more than 400 times by derelict fishing nets or ropes each year. The number of incidents tended to decrease slightly, but the amount of fishing gear entangled was increasing.

Table 3.6. Frequency of cases of ROKN ships entangled (proportion of DFG removal among total vessel hulls), amount of DFG removed from propellers, and labor and time required for removal over six years. (Hong *et al*., 2017)

Category	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Sum**	**Mean**	**SD**
Frequency (number/yr)	465	403	351	393	391	383	2,386	397.7	37.5
Amount of removed DFG (ton/yr)	9.89	8.69	8.86	8.94	10.66	13.08	60.12	10.02	1.68
Labor* (diver/yr)	1,300	1,100	1,000	1,200	1,200	1,700	7,500	1,250.0	242.9
Time* (hr/yr)	143.3	133.3	116.7	131.7	131.7	158.3	815	135.8	13.9

* underwater work only.

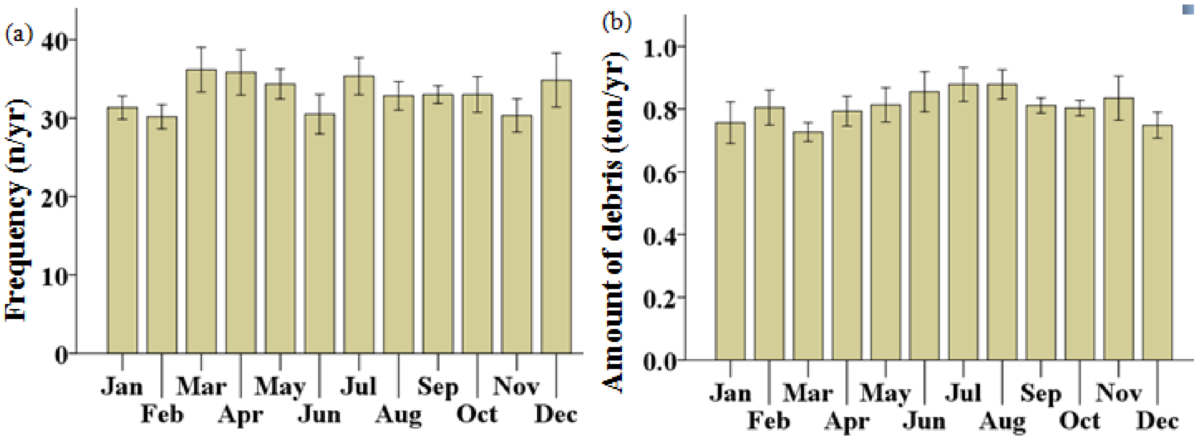


Figure 3.4. Seasonal trends of the cases. Frequency (a) and amount of DFG (b) of the cases that occurred from January 2010 to December 2015 (Hong *et al*., 2017).

Hong *et al*. (2017) also estimated the amount of economic damage resulting from such accidents. Takehama (1990), who conducted a similar study for fishing boats in Japan, calculated based on the amount of money received from insurance corporation. Using the method of Takehama (1990), ROKN ships were estimated to suffer US$ 3.78

million annually. If divers' wages are used instead of insurance, the amount would increase to US$ 68.2 million annually.

Table 3.6. Estimated economic loss due to propeller entanglement in South Korea

Classification	**Economic loss (US$/yr)[†]**	**Method**
ROKN ships[*]	3,781,546	Applying 1,338,400 JPY per case (Takehama, 1990)
(100~15,000 GT)	201,648	Applying only divers' wage
Fishing vessels[*]	82,261,925	Applying 102,100 JPY per case (Takehama, 1990)
(0~1,000 GT)	57,473,283	Applying only divers' wage

* The number of ROKN ships is confidential and the total number of fishing vessels in South Korea is 49,308 (Jang *et al*., 2014a).

† Currency exchange (¥-₩-$) and inflation rates (for 30 years) were considered.

CHAPTER 4. LEGISLATURE, POLICIES, AND ACTION PLANS

4.1. Laws and regulations

Marine Environment Management Act is the major legal framework for marine litter management in Korea. The Act on the Promotion of Saving and Recycling of Resources is an important legal framework, considering single-use plastic waste. Marine Waste and Marine Pollutant Sediment Management Act has been passed by the National Assembly in 2019 and will be implemented in 2020 (Table 4.1).

Table 4.1. National laws and regulations adopted/enacted since 2008 (NOWPAP, 2020)

Name of Law and regulation	Main contents	Notes
Environment Policy Basic Law (1990)	Providing the overall supervision of management of the environmental protection	
Act on the Promotion of Saving and Recycling of Resources	Promoting the use of recycled resources by means of controlling the generation of wastes and facilitating recycling.	[Enforcement Date 21. Jan, 2016.] [Act No.13036, 20. Jan, 2015., Partial Amendment]
Resource Circulation Basic Law (2018)	Providing the overall supervision of sustainable resource circulation	
Waste Management Act (1991)	Concerning the collection and treatment of industrial and household wastes	
Marine Environment Management Act	Aiming to prevent the marine and coastal environment from hazardous pollutants (mainly from ships) such as oil, sewage and garbage.	
Coastal Management Act (2000)	Aiming towards the sustainable use of the coastal environment, including beaches and public swimming areas, and regulates coastal construction.	
Marine and Fisheries Development Basic Law (2002)	Setting forth basic principles for the development of ocean-related industries including fisheries.	
Port Management Law (2008)	Prohibiting the discharge of waste in the port area for safe navigation and describes the development,	

	maintenance and management of ports and their facilities	
Act on Marine Environment Conservation and Utilization (2017)	Providing the basic direction of the policy on the conservation and utilization of the marine environment and its establishment and implementation system.	[Enforcement Date 22. Sep, 2017.] [Act No. 14746, 21. Mar, 2017., Enacted]
Marine Waste and Marine Pollutant Sediment Management Act	Identifying the concept of marine waste and providing the leading principles, obligation, tools and supporting systems on marine waste management.	Enforcement Date 4. Dec, 2020.] [Act No. 16699, 3. Dec, 2019., Enacted]

4.2. Institutional arrangements

The Ministry of Oceans and Fisheries (MOF) is a leading institution in marine litter management in Korea. The Ministry of Environment (MOE) is also a leading institution in waste management. The Korea Marine Environment Management Corporation (KOEM) is a public company and plays an important role in implementing the governmental action plan. Korea Maritime Institute (KMI) has a key role to support policy development. Korea Institute of Ocean Science and Technology (KIOST) is conducting research and development on microplastics and collection and treatment technology for marine litter.

Table 4.2. Institutional arrangements (agencies and their roles) in Korea

Name of agency	Main roles	Notes
Ministry of Oceans and Fisheries (MOF)	Leading ministry in marine litter management (Enacting and establishing policies)	
Ministry of Environment (MOE)	Leading ministry in waste management (Enacting and establishing policies) / single-use plastic waste	
Korea Coast Guard (KCG)	Fishermen awareness / ship safety guide	
Korea Marine Environment Management Corporation (KOEM)	Implementing the marine litter management policies	Public company
Korea Fishing Infrastructure Public Agency (FIPA)	Implementing the marine litter management projects in fishing villages and ports	Public agency
Korea Maritime Institute (KMI)	Developing management and policies	Research institute
Korea Institute of Ocean Science and Technology (KIOST)	Research and development on microplastics	Research institute
National Institute of Fisheries Science (NIFS)	Developing biodegradable fishing gears	Supporting agency

(Source: NOWPAP, 2020)

4.3. Outcomes of the 2nd National Action Plan

The 2nd National Marine Litter Management Plan (2014~2018) has four strategies: 1) to manage the sources of marine litter and solid waste, 2) to strengthen the capacity for collecting and treating marine litter, 3) to establish a basis for marine litter management, and 4) to increase citizen participation in and strengthen international cooperation on reducing and managing marine litter.

4.3.1. Managing the sources of marine litter and solid waste

Land-based marine litter was retrieved by the Ministry of Environment (MOE) and local governments which have shared the cleanup cost. The regulation on single-use plastics has been strengthened. An integrated management system for DFG including EPS buoys has been developed as a research project. And replacement of EPS buoys into durable buoys is underway. Floating barges for volunteer retrieval of used fishing gears from fishermen have been distributed by the Ministry of Oceans and Fisheries (MOF).

Table 4.3. Prevention of marine litter input in Korea (NOWPAP, 2020)

Name of program or action	Contents	Notes
	Land-Based	
Prevention of marine litter through river and estuary	Cleanups around rivers and estuaries through collaboration among local agencies	MOE with local governments
Regulations on single use plastics	Identifying the responsibilities of business operator's on controlling the use of disposable products and prohibit providing disposable products free of charge	MOE
Regulation on microbeads	Banning use of microbeads in product types such as cosmetics (for rinse-off, scrub, etc) and sanitary aids (gargle, tooth paste, and teeth whitening)	Ministry of Food and Drug Safety
Public awareness campaign on marine litter	Advertisements using mass media	MOF (KOEM)
	Sea-Based	
Strengthen management of used EPS buoy	Establishing the integrated management system for EPS buoy	MOF
Dissemination of biodegradable fishing gears	Development of biodegradable fishing gears and supporting the fishers buying the gears with subsidy	MOF (NIFS)
Clean Fishery Communities Program	Voluntary bring-back and cleanup of marine litter by fishing villages	MOF (KCG)
Marine Litter Collection by Floating Receptacles	Installation of deck barges in fishery ports for collecting marine litter from fishing boats	MOF (Local government)
Developing education materials on marine litter	School teacher guides and lecturer manual for fishers	MOF (KOEM)

4.3.2. Strengthening the capacity for collecting and treating marine litter

Removal of existing marine litter is being actively implemented in Korea. The information on the amount collected through various programs is open to the public (www.marlic.or.kr).

Table 4.4. Removing existing marine litter and its disposal in Korea

Name of program or action	Contents	Notes
Land-based		
Collection and disposal of disaster litter	Collection and disposal of marine litter after disasters (typhoon, flood, etc.)	MOF (KOEM)
Sea-based		
Sea-bed litter cleanup	Retrieval of sunken litter from ports and designated areas for marine conservation	MOF (KOEM)
Ports cleanup	Management of floating and sunken litter in port area	MOF (KOEM, FIPA)
Coastal cleanup	Cleanup in beaches and seashores	MOF (Local government)
Fishing ground cleanup	Cleanup in fishing grounds including Buy Back program, retrieval of illegal fishing gears	MOF (FIPA)

Source: NOWPAP (2020)

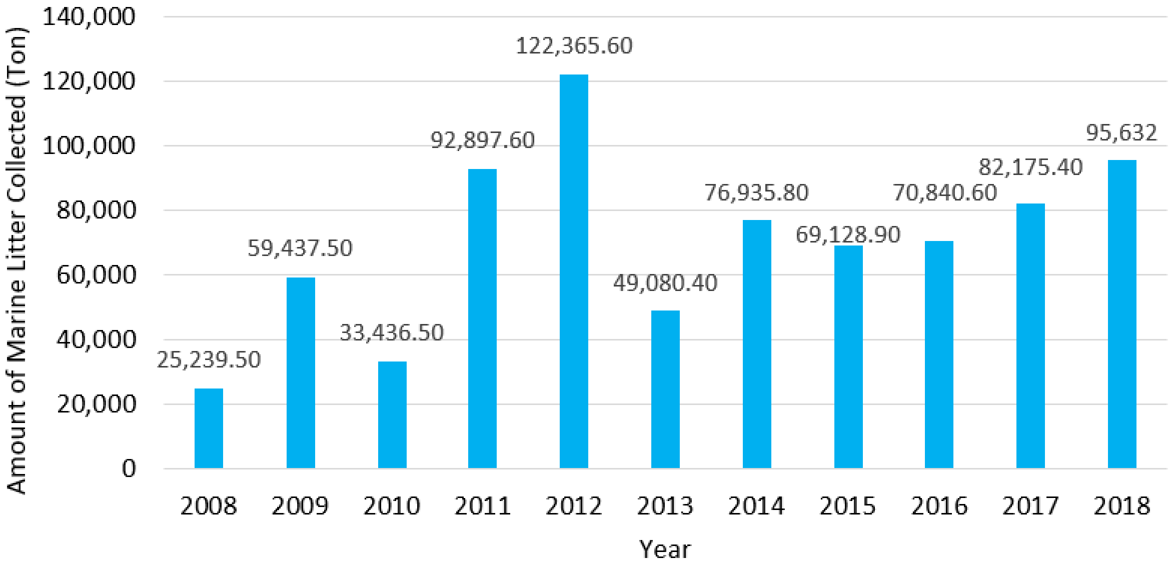


Figure 4.1. Amount of collected marine litter through various removal programs in Korea (www.malic.or.kr)

4.4. The 3rd National Action Plan

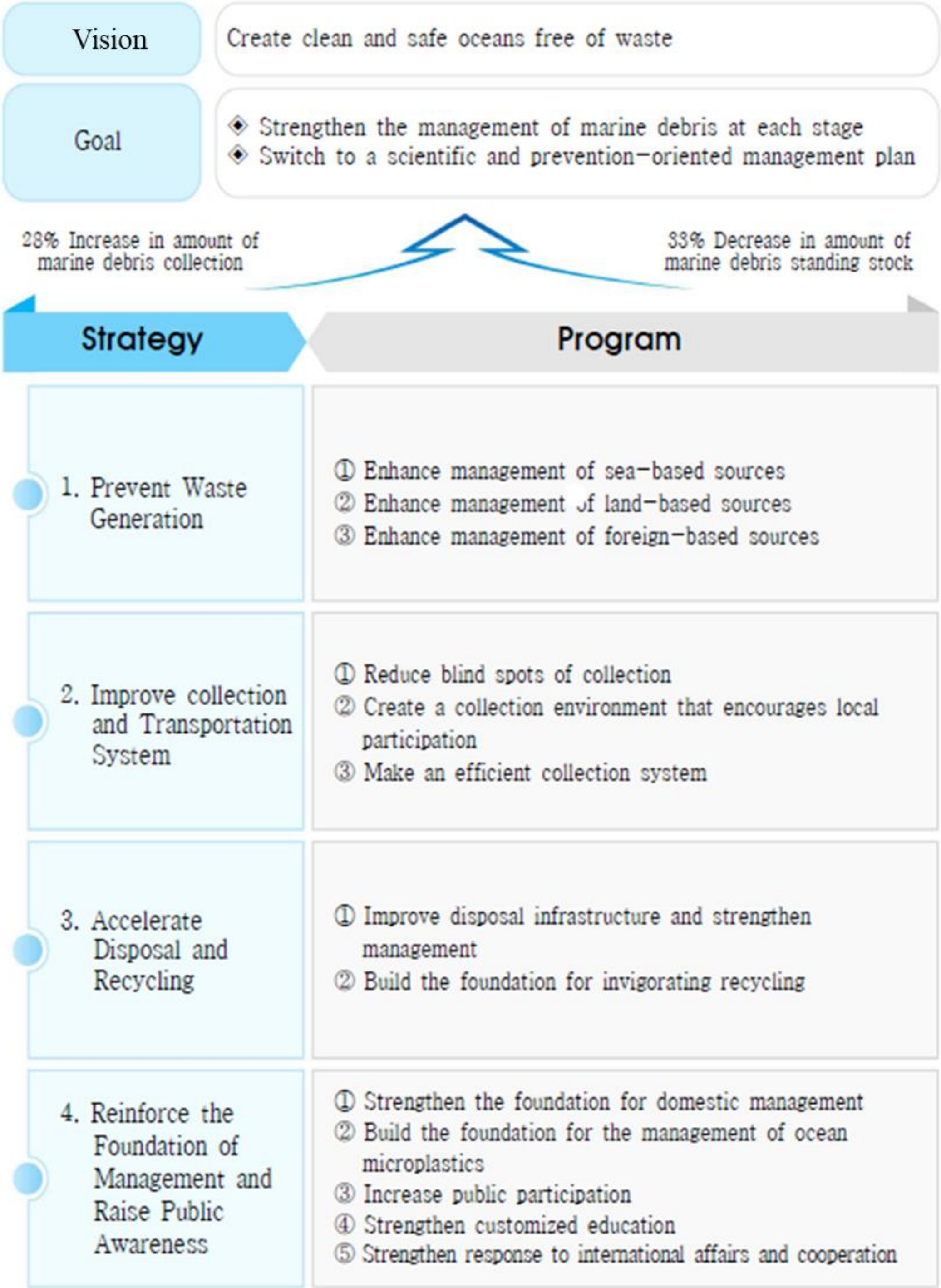
The Korean Government has published 'The 3rd National Action Plan on Marine Litter (2019~2023)' in 2019. It is an inter-ministerial action plan jointly established by the Ministry of Oceans and Fisheries (MOF), the Ministry of Environment (MOE), and the Korea Coast Guard (KCG).

The legal base of the plan is 'the Marine Environment Management Act (article 24)'. The article identifies the obligation of the Ministry of Oceans and Fisheries (MOF) to establish Marine Litter Management Plan.

The vision of the plan is to create clean and safe oceans free of waste. The goals are to strengthen the management of marine debris at each stage, and to make a shift to a scientific and prevention-oriented management. The strategies include 1) prevent waste generation, 2) improve collection and transportation system, 3) accelerate disposal and recycling, and 4) reinforce the foundation of management and raise public awareness.

Marine Environment Management Act (article 24)

The Minister of Oceans and Fisheries shall formulate and implement an ocean waste collection and disposal plan, as prescribed by Presidential Decree, in order to effectively collect and dispose of wastes (including wastes generated at sea; hereafter the same shall apply in this Article) discharged or flowing into the sea. In such cases, Mayors/Governors shall formulate and implement detailed action plans in accordance with the ocean waste collection and disposal plan.



Vision	Create clean and safe oceans free of waste
Goal	◆ Strengthen the management of marine debris at each stage ◆ Switch to a scientific and prevention-oriented management plan

28% Increase in amount of marine debris collection

33% Decrease in amount of marine debris standing stock

Strategy	Program
1. Prevent Waste Generation	① Enhance management of sea-based sources ② Enhance management of land-based sources ③ Enhance management of foreign-based sources
2. Improve collection and Transportation System	① Reduce blind spots of collection ② Create a collection environment that encourages local participation ③ Make an efficient collection system
3. Accelerate Disposal and Recycling	① Improve disposal infrastructure and strengthen management ② Build the foundation for invigorating recycling
4. Reinforce the Foundation of Management and Raise Public Awareness	① Strengthen the foundation for domestic management ② Build the foundation for the management of ocean microplastics ③ Increase public participation ④ Strengthen customized education ⑤ Strengthen response to international affairs and cooperation

Figure 4.2. Vision, goal, and strategies of the 3rd National Action Plan (MOF *et al*., 2019)

The strategies of the plan specify their own implementation tasks for implementation of the plan to achieve the goals of the plan (Table 4.4).

Table 4.5. Strategies and tasks of the 3rd National Action Plan on Marine Litter of Korea ((MOF *et al*., 2019)

Strategy	Implementation Tasks	Specific tasks
1. Prevent Waste Generation	Enhance management of sea-based sources	1-1. Introduce a deposit system for fishing gear and buoys
		1-2. Strengthen management of derelict fishing gear
		1-3. Strengthen management of waste Styrofoam buoys
		1-4. Reinforce guidance and crackdown on ship-originated waste
	Enhance management of land-based sources	1-5. Reduce inflow of land-based waste into oceans
		1-6. Total Waste Load Management on rivers and estuaries
	Enhance management of foreign-based sources	1-7. Improve management and response of foreign-based waste
2.Improve collection and Transportation System	Reduce blind spots of collection	2-1. Strengthen waste management on islands
		2-2. Strengthen collection at vulnerable sea areas
		2-3. Expand existing collection projects (fishing grounds)
		2-4. Expand existing collection projects (sea areas other than fishing grounds)
		2-5. Establish collection and transport system for derelict fishing gear at regional level
	Create a collection environment that encourages local participation	2-6. Create a collection environment that encourages local participation
	Make an efficient collection system	2-7. Make an efficient collection system

Strategy	Implementation Tasks	Specific Tasks
3. Accelerate Disposal and Recycling	Improve disposal infrastructure and strengthen management	3-1. Distribute resource recovery facilities of marine debris
		3-2. Strengthen management of private disposal companies
		3-3. Install collection facilities of marine debris
	Build the foundation for invigorating recycling	3-4. Increase the application of Extended Producer Responsibility (EPR)
		3-5. Expand the demand of recycled products
		3-6. Develop technology for recycling and resource recovery
		3-7. Project for creating a pilot village for turning marine debris into energy
4. Reinforce the Foundation of Management and Raise Public Awareness	Strengthen the foundation for domestic management	4-1. Provide a foundation for management
	Build the foundation for the management of ocean microplastics	4-2. Build the foundation for the management of ocean microplastics
	Increase public participation	4-3. Increase public participation
		4-4. Boost public relations
	Strengthen customized education	4-5. Invigorate customized education per subject
	Strengthen response to international affairs and cooperation	4-6. Strengthen response to international affairs and cooperation

4.5. Flow and stock of marine litter in Korea

4.5.1. Concept of flow and stock of marine litter

Estimation of annual flow and standing stock of marine litter in Korea was attempted under the “Study for Second National Action Plan on Marine Litter" in 2013 (KOEM, 2013). The inflow (input) of marine litter shows how much litter enters the sea during the year. The timeframe is a period of one year. Standing stock (existing quantities) represents how much marine litter is present within a given spatial range at a given point of time. In establishing the second action plan, the inflow was estimated based on a one-year period of 2013, and the standing stock was estimated at the end of 2012. Inflows were divided into the land-based and sea-based litter, and the standing stock was calculated by dividing into three spatial categories: coastal, floating, and sedimentary (submerged). In the study for the third action plan, the baseline of inflows was set for the one-year period of 2017, and the baseline of standing stock was estimated at the end of 2017.

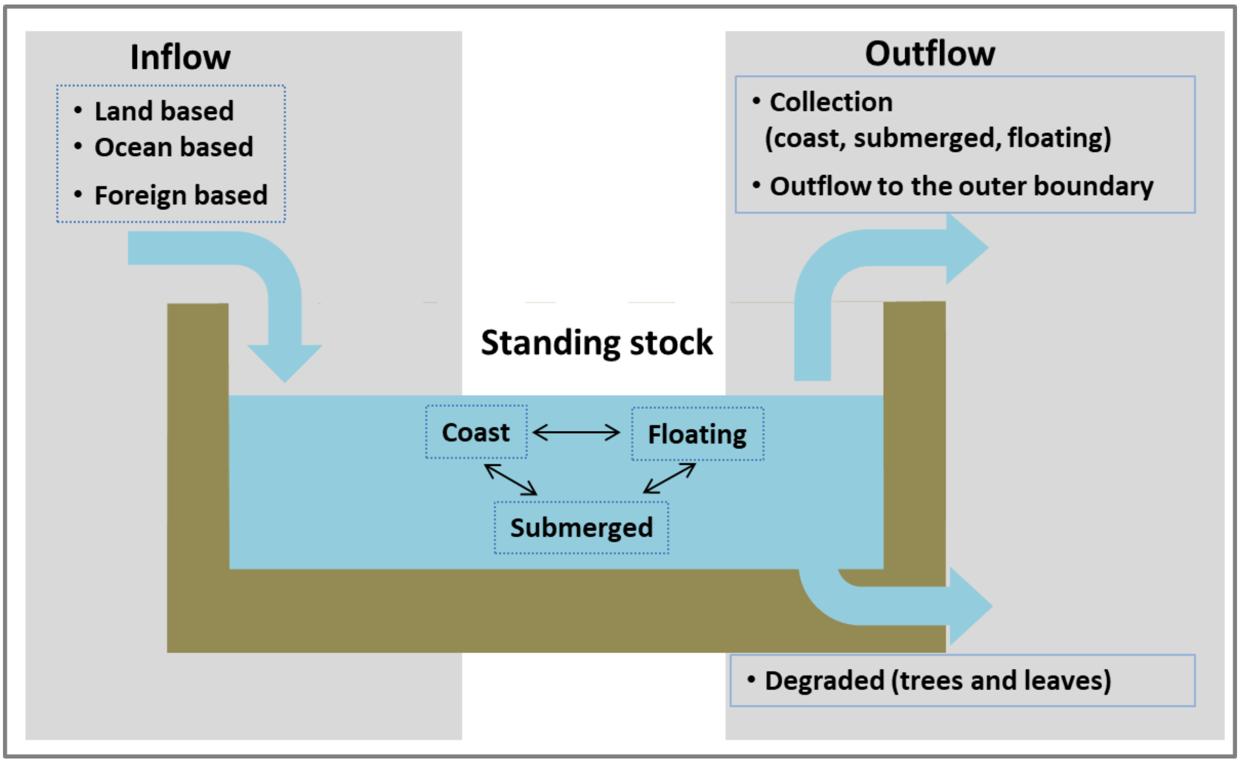


Figure 4.3. Conceptual diagram of flow and stock of marine litter

4.5.2. Inflow

The inflow rate of land-based marine litter was estimated as about 95,000 tons (about 34,000 tons excluding vegetation), which was about 23,000 tons lower compared to about 118,000 tons in the 2nd action plan. The most significant reason was the decrease in the amount of vegetation wastes during the last five years due to the decrease in the number of meteorological disasters accompanying heavy rains (2.8 → 2.0 times/year). Instead, the average stream waste and coastal waste flow increased slightly with population growth (from 49 million to 51 million).

The inflow of sea-based litter was about 50 kilo tons, 8 kilo tons less than that of the second action plan (58 kilo tons). First of all, the decrease in the number of fishing boats (from 75 kilo tons to 70 kilo tons) seems to have significantly contributed to reduction of sea-based marine litter. In the 2nd action plan, the inflow of waste from fishing boat was estimated with on the basis of the postal questionnaire survey answered by fishers nationwide. In the 3rd action plan, the estimation was based on the results of face to face interviews and focus group interviews with fishers carried out in the city of Busan and Jeollanamdo Province. Therefore, the reliability of estimation on waste from fishing boat in the 3rd action plan was higher than that of the second action plan. Aquaculture wastes increased by about 2 kilo tons compared to the 2nd action plan. The increase of the permit area of aquaculture farms (141 kilo ha → 1,161 kilo ha) contributed to this increase. In the second action plan, the inflow of aquaculture waste was only estimated with derelict EPS buoys based on interviews with a few fishers. In the 3rd action plan, derelict EPS buoys were estimated using the result of systematic nationwide survey. Furthermore, the inflow of auxiliary fishing gears waste from aquaculture was newly included in the 3rd action plan, which takes up a higher proportion than the waste buoys in the amount of sea-based marine litter. All of these contributed to increase of the estimation on aquaculture wastes in the 3rd action plan.

However, port waste was reduced by about 2,000 tons. This is thought to be due to the improvement of awareness of those involved in ship operations such as fishermen.

Table 4.6. Annual inflow of marine litter in Korea (MOF *et al*., 2019)

Sectors	**Details**	**The 2nd management plan**				**The 3rd management plan**			
		Exclude trees and leaves		**Include trees and leaves**		**Exclude trees and leaves**		**Include trees and leaves**	
		ton	**%**	**ton**	**%**	**ton**	**%**	**ton**	**%**
Land-based	River (excl. flood)	24,250	26.6	24,250	13.7	25,180	29.9	25,180	17.3
	River (incl. flood)	1,300	1.4	1,300	0.7	928	1.1	928	0.6
	Trees and leaves (incl. flood)	-	-	85,612	48.4	-	-	61,152	42.1
	Coast	7,275	8.0	7,275	4.1	7,554	9.0	7,554	5.2
	Subtotal	32,825	36.0	118,437	67.0	33,662	40.0	94,814	65.3
Ocean-based	Lost derelict fishing gear	44,081	48.3	44,081	24.9	38,105	45.3	38,105	26.2
	Household debris from ship	2,347	2.6	2,347	1.3	511	0.6	511	0.4
	Aquaculture debris	4,382	4.8	4,382	2.5	6,462	7.7	6,462	4.4
	Port debris	7,560	8.3	7,560	4.3	5,366	6.4	5,366	3.7
	Subtotal	58,370	64.0	58,370	33.0	50,444	60.0	50,444	34.7
Total		91,195	100.0	176,807	100.0	84,106	100.0	145,258	100.0

4.5.3. Outflow

Marine litter outflow consists of collected and degraded amount. The collected amount is the amount of litter collected by the central government, local governments, and maritime-related agencies and organizations. Degradation refers to the amount of vegetation (trees and leaves) that has not been collected, but flow ed into the ocean in a flood and but disappear immediately and thus not regarded as marine litter.

Amount of marine litter collected increased by 1,000 tons, from 68,000 tons in the 2nd plan to 69,000 tons in the 3rd plan. The amount of coastal litter collected increased from 27,000 to 40,000 tons and floating litter collection from 4,000 to 21,000 tons, while submerged litter collection decreased from 11,000 to 4,000 tons. The data of the ‘Marine Litter Integrated Information (MALI) System', which calculates the amount of marine litter collected, has been improved in terms of completeness, thus improving data reliability. This was thought to have happened because local governments have continuously registered the data as the collected data registered in the MALI System, serving as an important evaluation basis in the ‘Municipal Marine Litter Management Evaluation Project’.

Vegetation collections in flood have been drastically reduced from 6,000 tons to 4,000 tons, but this cannot be interpreted as a reduction in the actual collection. At the time of the 2nd action plan, the ratio of the amount of flooded vegetation (trees and leaves) was arbitrarily set at 30%, while the 3rd plan applied 6% using the disaster litter collection data input to the MALI system. In other words, the 2nd plan may have overestimated the ratio of collected vegetation during the flood season.

Table 4.7. Annual outflow of marine litter in Korea (MOF *et al*., 2019)

Sectors	**Details**	**The 2nd plan**	**The 3rd plan**

		ton	**%**	**ton**	**%**
Collection	Coast	27,279	21.3	40,125	31.6
	Submerged	11,370	8.9	4,431	3.5
	Floating	3,946	3.1	21,159	16.7
	Trees and leaves when flooding	25,683	20.0	3,669	2.9
	Subtotal	68,278	53.3	69,384	54.7
Degradation	not collected trees and leaves when flooding	59,929	46.7	57,483	45.3
Total		**128,207**	**100.0**	**126,867**	**100.0**

4.5.4. Standing stock

The standing stock of marine litter is composed of the amount of coastal, floating and submerged litter (Table 4.8). The standing stock of coastal litter in the 3rd plan increased significantly with the addition of the amount of island litter, which has not been considered separately at the time of the 2nd action plan (from 12,000 to 2,800 tons). In the 2nd plan, the result from 'National Marine Debris Monitoring Program' was multiplied by the coastline length of Korea. In the 3rd plan, the results from 'Nationwide Survey of Marine Debris on Korean Coasts' was applied for natural coast. For the constructed coast and island, the result of 'Jeonnam Province Marine Litter Survey (Jeollanam-do, 2018)' was separately estimated and added to the standing stock of coastal litter.

The amount of submerged litter decreased to 115,000 tons in the 3rd plan compared to about 13,800 tons in the 2nd plan. In the 2nd plan, the results of one survey project, including sea areas and fisheries, were applied. However, in the 3rd plan, surveys on sea and aquaculture areas were presented as results of separate projects. However, it is important to note that the survey of the amount of litter in the aquaculture farm area uses the results from the sample surveys with a smaller number The amount of submerged litter under aquaculture areas should be investigated through further surveys to improve the reliability of the estimation.

The floating litter has increased to 6,000 tons in the 3rd plan, compared to 2,000 tons in the 2nd plan. In the 2nd plan, there were no domestic survey results, so the results of international surveys were used. However, the 3rd plan used the results of the field survey on Mokpo included in the ‘Jeonnam Marine Litter Survey (Jeonnam-Province, 2018)’. Since this is a survey of very limited area, there is a need to increase the reliability of the estimates through broader surveys of domestic floating litter.

Table 4.8. Standing stock of marine litter in Korea (MOF *et al*., 2019)

Sectors	**Details**	**The 2nd plan**		**The 3rd plan**	
		ton	**%**	**ton**	**%**
Coast	Natural coast on land	12,029	7.9	27,995	18.8
	Artificial coast on land				
	Islands				
	Subtotal	12,029	7.9	27,995	18.8
Submerged	Sea area	137,761	90.5	114,977	77.3
	Aquaculture field				
	Subtotal	137,761	90.5	114,977	77.3
Floating	Floating	2,451	1.6	5,749	3.9
Total		**152,241**	**100.0**	**148,721**	**100.0**

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