NOWPAP MERRAC

Northwest Pacific Action Plan
Marine Environmental Emergency Preparedness and Response
Regional Activity Centre

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Understanding of floating marine litter distribution in the NOWPAP region

Regional Seas

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PREFACE

Recently, the NOWPAP members recognized the seriousness of marine litter causing environmental, economic, health and aesthetic problems including possible distribution of toxic substances, destruction of marine habitats and biodiversity and transfer of invasive species. Marine litter can reach and cause serious problems even to the remote corners of the world by ocean currents and affect other countries.

In order to prevent and minimize the problems of marine litter in the NOWPAP region, the NOWPAP members took cooperative actions in line with the global efforts on marine litter. MERRAC started to implement activities related to sea-based marine litter under the MALITA (marine Litter Activity) project (2006-2007). The overall objective of the MALITA project was to promote the environmental protection and sustainable development of the NOWPAP region through the formulation and implementation of the NOWPAP Regional Action Plan on marine litter.

Since 2008, MERRAC has continued implementing marine litter activities under the NOWPAP Regional Action Plan on Marine Litter (RAP MALI) in close cooperation with nominated marine litter national experts of the four NOWPAP member states (People's Republic of China, Japan, Republic of Korea and Russian Federation). Many activities were carried out under the RAP MALI project and many achievements have been made. Several guidelines, brochures and regional reports on marine litter monitoring and management in different sectors were published as listed below:

- Guidelines for Monitoring Marine Litter on the Seabed in the Northwest Pacific Region (2007)
- Guidelines for Providing and Improving Port Reception Facilities and Services for Ship-Generated Marine Litter in the Northwest Pacific Region (2007)
- Sectoral Guidelines for Marine Litter Management: Fishing, Commercial Shipping, Recreational Activities, Passenger Ships (2007)
- Brochure on Sea-Based Marine Litter: Problem & Solution (2007)
- Regional Report on Sea-Based Marine Litter (2008)
- Marine Litter Management: The Approach of Incheon City, Korea (2008)
- Port Reception Facilities in the NOWPAP Region (2009)

- Report on the Technologies and Research Outcomes on Prevention, Collection and Treatment of Marine Litter in the NOWPAP Region (2010)
- Negative Impacts of Marine Litter in the NOWPAP Region: Case Studies (2013)
- Best Practices in dealing with Marine Litter in Fisheries, Aquaculture and Shipping sectors in the NOWPAP region (2015)

This publication aims to gather information on the distribution of the floating marine litter in the NOWPAP region. The main objective is to understand the current status of floating marine litter in order to identify prospects for effective management and find solution to floating marine litter problems, by analyzing the marine litter distribution by amounts, types and sources (origins) and also by mapping hotspots in the NOWPAP region.

I strongly believe that this publication would provide essential information and framework for reduction and prevention of floating marine litter in the NOWPAP region and the global community. It also aims to trigger actions to build a stronger regional cooperation among the NOWPAP members. I would like to take this opportunity to express my sincere gratitude to all NOWPAP MERRAC Focal Points, Marine litter Focal Points and national experts for their support and contributions to the MERRAC activities.

Dr. Seong-Gil Kang
Director of NOWPAP MERRAC

Acknowledgments

This report has been prepared by the Marine Environmental Emergency Preparedness and Response Regional Activity Centre (MERRAC) of the Northwest Pacific Action Plan (NOWPAP) with inputs from the national experts of the NOWPAP members as agreed at 18th NOWPAP Intergovernmental Meeting (IGM) and the 16th MERRAC Focal Points Meeting in 2013. This study has been conducted as a part of activities within the framework of the NOWPAP Regional Action Plan on Marine Litter (RAP MALI), inter alia, upon the RAP MALI workplan for 2014-2015 biennium. The following nominated national experts of the NOWPAP members contributed in the report: Dr. An Lihui (Chinese Research Academy for Environment Sciences, China), Dr. Atsuhiko Isobe (Research Institute for Applied Mechanics Kyushu University, Japan) and Ms. Maria Vysotskaya (Institute of Sea Protection and Shelf Development, Russia). The MERRAC staffs (Ms. Yoon Young Back, Dr. Seong Gil Kang, Dr. Jeong Hwan Oh and Mr. Bo-Sik Kang) and external experts (Prof. Yong Hoon Kim (West Chester University, USA) and Dr. Young Gyu Park (Korea Institute of Ocean Science & Technology, Korea)) also contributed in the production of the report. This report was also finalized with technical supports of the MERRAC Focal Points, NOWPAP Marine Litter Focal Points, and NOWPAP Regional Coordinating Unit (RCU).

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Chapter 1. Introduction

Marine litter is human-created waste that has deliberately or accidently been released in a lake, sea, ocean or waterway [1]. It is considered as one of the major pollutants that destroy the marine environment and its negative impacts on the environment as well as economics cannot be emphasized enough.

No matter how marine litter enters into the ocean (whether it is deliberately disposed or naturally drifted in the ocean), it can travel large distances by ocean currents and winds to land on beaches irrespective the political maritime boundaries or to accumulate on open oceans. As such, it can lead to a serious transboundary issue, causing diverse problems for both wildlife and humans (Coe and Rogers, 1997). Thus, marine litter is not a problem limited to a certain nation but a global one. Cooperative efforts and activities among the neighboring countries are needed to protect coastal and ocean areas from marine litter (Morrison 1999).

In 2008, the aggravating problem of marine litter in the NOWPAP region inspired the NOWPAP members to take cooperative actions to implement the NOWPAP Regional Action Plan on Marine Litter (RAP MALI). The Marine Environmental Emergency Preparedness and Response Regional Activity Center (MERRAC), being in charge of preparedness and response for sea-based marine pollution in the NOWPAP region, has conducted various activities for the reduction and management of sea-based marine litter in cooperation with other NOWPAP Regional Activity Centers and published several regional reports, technical guidelines and brochures on the impacts of sea-based marine litter in the NOWPAP region, best practices of marine litter management in fisheries, aquaculture and shipping sectors in the NOWPAP region, etc. The publications of relevant MERRAC activities are available at the MERRAC website: http://merrac.nowpap.org/.

Especially, upon the approval of the RAP MALI workplan (2014-2015) at the 18th NOWPAP IGM (2013), MERRAC initiated a project entitled ‘Understanding of Floating Marine Litter Distribution and Its Impact in the NOWPAP Region’ to be implemented during the 2014-2015 biennium.

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1 https://en.wikipedia.org/wiki/Marine_debris

The main objective of the project is to understand the current status and seriousness of floating marine litter in the NOWPAP region by analyzing the marine litter distribution by amounts, types, and sources (origins), and mapping ambulation hotspots. The possible routes of the marine litter migration in the NOWPAP region are also reviewed. This report describes the results of this project, especially focusing on understanding of trajectories of floating marine litter in the region, by describing the regional current behavior and other physical oceanographic factors.

The MERRAC RAP MALI project on floating marine litter will be continued during 2016-2017 biennium with a project entitled ‘Review and analysis on existing floating marine litter prediction models in the NOWPAP region’ in which the current status and results of the floating marine litter prediction models carried out in the NOWPAP region will be overviewed and analyzed more in detail using numerical model. This project will help the NOWPAP members to identify prospects for better management and solution to the floating marine litter problems and to stress the importance of regional cooperation to respond effectively and efficiently to our common marine and coastal environmental problems related to marine litter in the NOWPAP region.

Chapter 2. Marine Litter as a Global Environmental Problem

2.1. Floating Marine Litter

In order to manage the problems caused by marine litter, it is important to identify the origin and destination of litter, and then initiate regional and/or international cooperative activities (Morrison, 1999).

Marine litter originates from land-based and sea-based activities. The land-based activities include landfills, rivers and floodwaters, industrial outfalls, discharge from storm water drains, sewerage and littering of beaches. The sea-based activities include fishing industry, shipping, illegal dumping at sea and discarded fishing gears, etc. It is estimated that approximately 80% of marine litter is caused by land-based activities[2] whereas the marine-based activities account for only 20%. Once entered the ocean, marine litter sinks to the bottom or floats on the ocean surface depending on its density.

Primarily surface currents and secondarily winds depending on the shape and the area exposed above the sea water determine the trajectories of floating marine litter (Dohan and Maximenko, 2010).

Many studies have been carried out to assess the trajectories of floating marine litter regionally and globally. Marine litter could travel long distance either to reach a shoreline or the convergent zones in subtropical oceans where airflows or ocean currents meet (Fig. 1).

[2] http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm

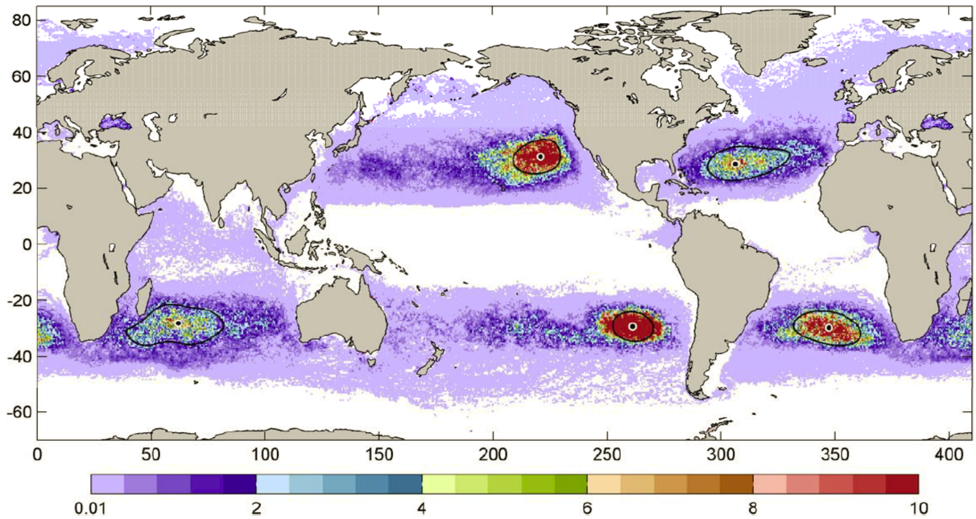


Figure 1. Convergent zones for surface tracers (Dohan and Maximenko, 2010).

The 'Great Pacific Garbage Patch', as described in Fig. 1, that is, a collection of marine debris in the North Pacific Ocean, is an example of the convergent zones. It is also known as the Pacific trash vortex where a huge cluster of floating plastic litter is formed in the middle of the subtropical North Pacific Ocean by converging Ekman currents (Dohan and Maximenko, 2010).

It is estimated that about 80% of the debris in the Great Pacific Garbage Patch comes from land-based activities in North America and Asia and the remaining 20% from sea-based activities, boaters, offshore oil rigs and large cargo ships that dump and lose debris directly into the water [3].

There is another small convergent zone in the subtropical North Pacific southwest of Japan due to the Kuroshio recirculation gyre called as the Western Garbage Patch (WGP) (Fig. 2). This WGP is connected to the Eastern Garbage Patch (EGP), which is another name of the 'Great Pacific Garbage Patch', and by a transition zone [4].

The Great Tohoku tsunami of 2011 devastated the east coast of Japan and resulted in thousands of human casualties washed an unparalleled amount of debris into the

[3] http://nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/

[4] https://pifsc-www.irc.noaa.gov/do/annualreport2011/marine_habitats_and_ecosystems.php

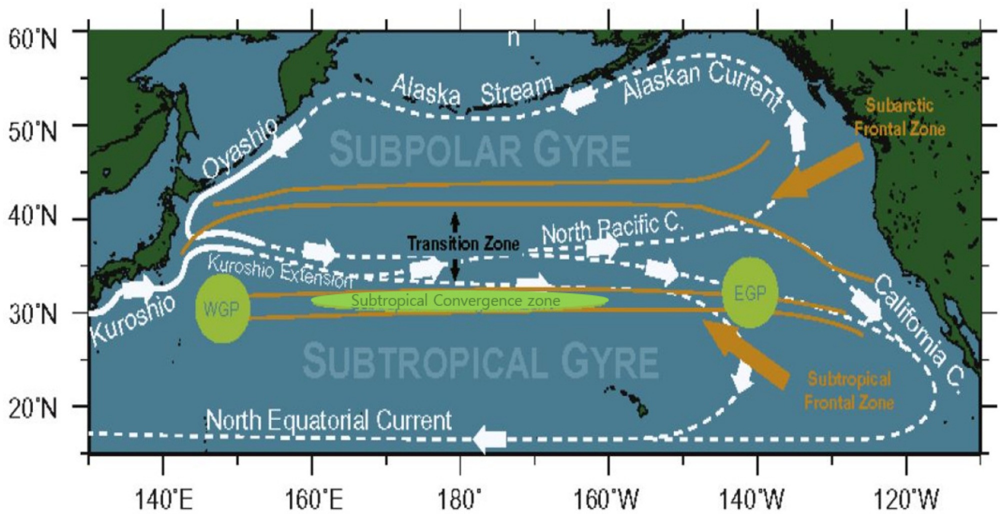


Figure 2. Marine litter concentrations in the North Pacific (Howell et al., 2012).

Pacific Ocean. International researches were carried out to study the transport and distribution of the tsunami debris, and concluded that this tsunami debris, departing from the tsunami area, would travel and accumulate in the North Pacific Ocean subtropical gyre due to the ocean currents and increase the debris concentration in the 'Great Garbage Patch' (Lebreton and Borrero, 2013).

2.2. Major Ocean Currents in the NOWPAP Region

The four NOWPAP members (People's Republic of China, Japan, Republic of Korea and Russian Federation) are geographically contiguous with the geographical scope from about 121°E to 145° E longitude and from approximately 33° N to 55°N latitude (Fig. 3; the geographical scope for NOWPAP). This NOWPAP region is highly urbanized and there are many cities known to be the most populated in the world (NOWPAP POMRAC, 2015) along the coastline. In addition, many economic activities such as coastal industries, energy development, fisheries, maritime trade and tourism are occurring along the coastal regions.

Lately, most countries surrounding the NOWPAP region have undergone rapid economic development and change in life style, which resulted in increase in the consumption of products made from plastic (Andrady, 2003). Slow introduction of

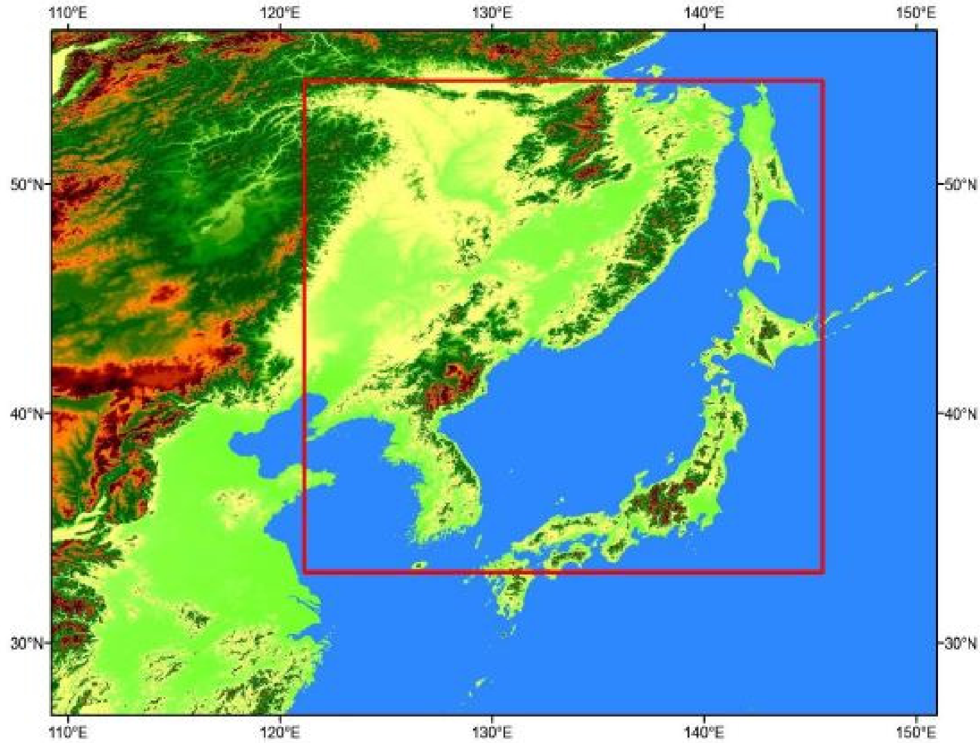


Figure 3. Geographical scope of the NOWPAP region.

recycling and poor management of waste in these rapidly developing countries have resulted in the accumulation of considerable quantities of plastic litter contaminating coastlines through rivers, sewage, storm water or wind. As a consequence, litter accumulated on these beaches and reduced their aesthetic appeal as well as caused harm to the marine environment including wildlife that may either ingest the litter or become entangled in it. Nonetheless, there has been no enough means of estimating the total quantity of litter over beaches as well as oceans in the NOWPAP region.

Marine litter heavier than the seawater sinks to the bottom, while those lighter and floating would be transported to remote areas through ocean currents and winds. Floating marine litters eventually land on coastline or transported to open water outside of the NOWPAP region since there is no known convergent zone of marine litter within the region. The ocean currents are not limited by territories, so does the transport of marine litters.

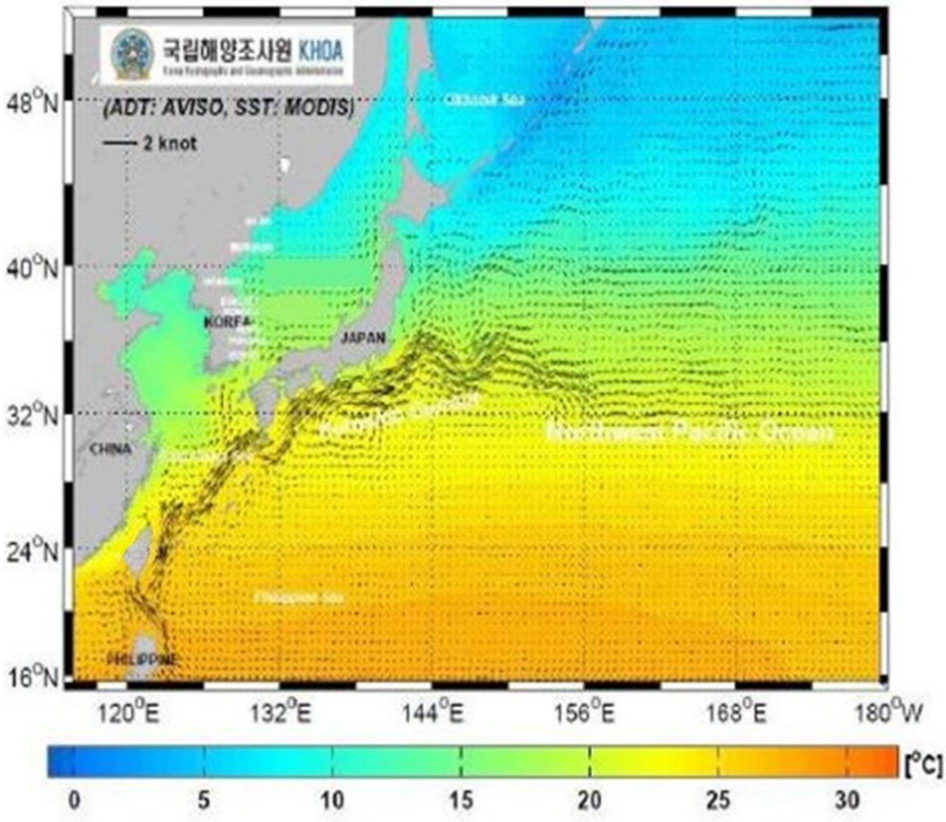


Figure 4. Surface currents in the NOWPAP region from 1993-2013 (KHOA, 2016).

In Figure 4, the surface ocean currents over the NOWPAP region averaged between 1993 and 2013 (21 years) estimated from satellite altimetry data (Archiving, Validation and Interpretation of Satellite Oceanographic data; AVISO) are shown (this particular estimate was conducted by Korea Hydrographic and Oceanographic Agency, KHOA). The most prominent flow is the Kuroshio Current dominantly moving clockwise along the western boundary of the North Pacific from the east coasts of Philippines to Japan.

Except Japan, the NOWPAP states are not directly affected by the Kuroshio, but the major ocean currents found in this region shown in Figure 5 are strongly influenced by the Kuroshio.

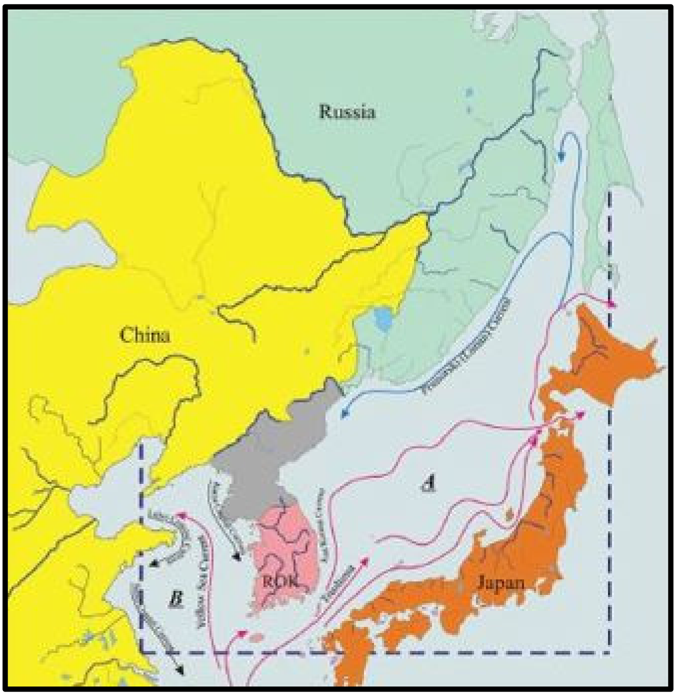


Figure 5. The NOWPAP region with main ocean currents (NOWPAP POMRAC, 2014).

With a geographical viewpoint, the NOWPAP region can be divided into two parts: the sea areas “A” and “B”. The area “A” is surrounded the Japanese Islands and Sakhalin Island to the east, and the Russia mainland and the Korean peninsula to the west. The water circulation is dominated by the Tsushima current, the main part of which is from the Kuroshio, entering the area through the south through the straight between Korea and Japan. Upon entering the area the current is divided into two or three branches. One of the branches follows the east coast of Korea, while another one west coast of Japan, About 70 % of the current leave area A to the north Pacific through the Tsugaru Strait, and the remaining 30 % through the Soya Strait. The northward current moving along the west coast of Sakhalin reverses at the Tartar Straight and moves towards south as a cold Primorsky (Liman) current (NOWPAP POMRAC, 2014).

The sea area “B” is located between China to the west and the Korea peninsular to the east. The water circulation is characterized by the Kuroshio branch: a northward Yellow Sea current with two crosswind currents running along the coasts of the Korean and Shandong peninsulas of China (Fig. 5). Significant tidal currents can also be found in the west coast of Korea with direct influences of large Chinese rivers such as Huaihe, Huanhe, Haihe and Liaohe (NOWPAP POMRAC, 2014).

The neighboring NOWPAP countries could affect each other through the ocean currents. In other words, the influence of one produced at one region is not limited to the generation area. The migration of marine litter can be assessed by analyzing the distribution pattern of marine litter and main ocean currents. In order to prepare appropriate action plans to be taken at regional levels, such analysis and monitoring is conducted in a consistent manner (Lebreton et al., 2013).

The NOWPAP member countries have been monitoring the distribution of marine litter in their respective territories as well as studies on the trajectories of marine litter. The results of monitoring and analysis are provided in the following chapter.

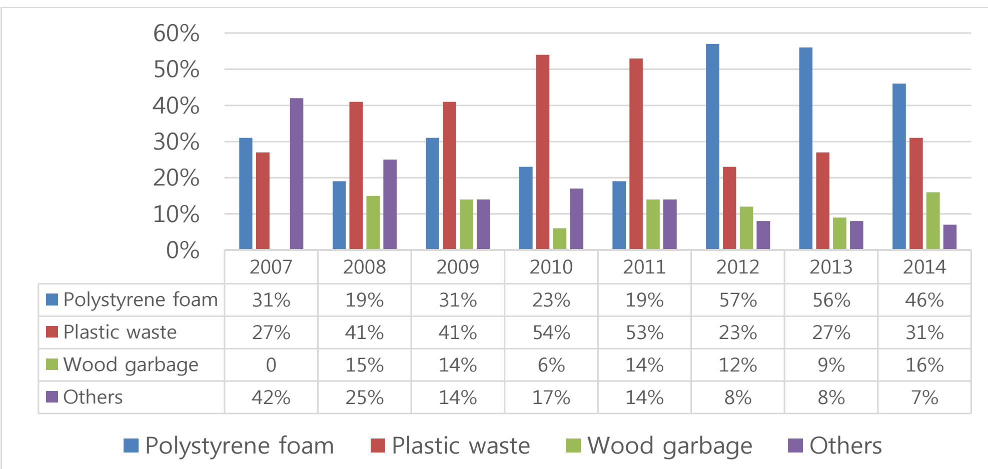
Chapter 3. Floating Marine Litter Distribution in the NOWPAP Region

3.1. People's Republic of China

The State Oceanic Administration (SOA), People's Republic of China, performed a monitoring program since 2007 to monitor the floating marine litter in some of the key areas of China, including sea surface, beach and seabed. Marine litter is distributed mainly in the coastal recreational areas, fishery areas and the shipping areas.

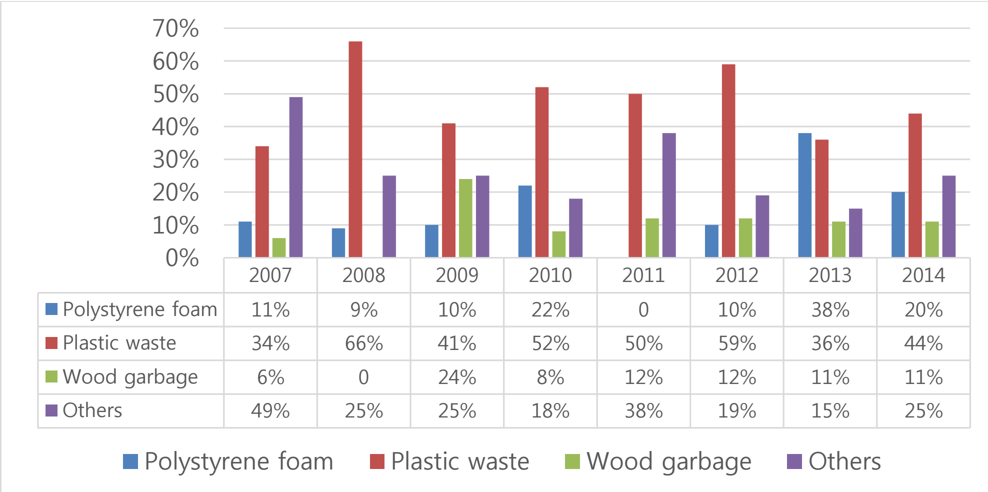
According to the data collected from 2007 to 2014 (Fig. 6), the majority of floating marine litter was plastic waste accounting for 37%, closely followed by polystyrene foam with 35% and wood garbage with 12%. The average number of the pieces was 23.5 pieces /km^2 for the large size litter and 2,992 pieces /km^2 for the medium and small size litter, with an average weight of 13kg /km^2.

It was also estimated that the main composition of plastic litter included plastic bags, and bottles, and about 80% of the floating litter is discharged from land and the remaining 20% originates from various marine activities.



	2007	2008	2009	2010	2011	2012	2013	2014
Polystyrene foam	31%	19%	31%	23%	19%	57%	56%	46%
Plastic waste	27%	41%	41%	54%	53%	23%	27%	31%
Wood garbage	0	15%	14%	6%	14%	12%	9%	16%
Others	42%	25%	14%	17%	14%	8%	8%	7%

Figure 6. Composition ratio of the number of floating marine litter in China.

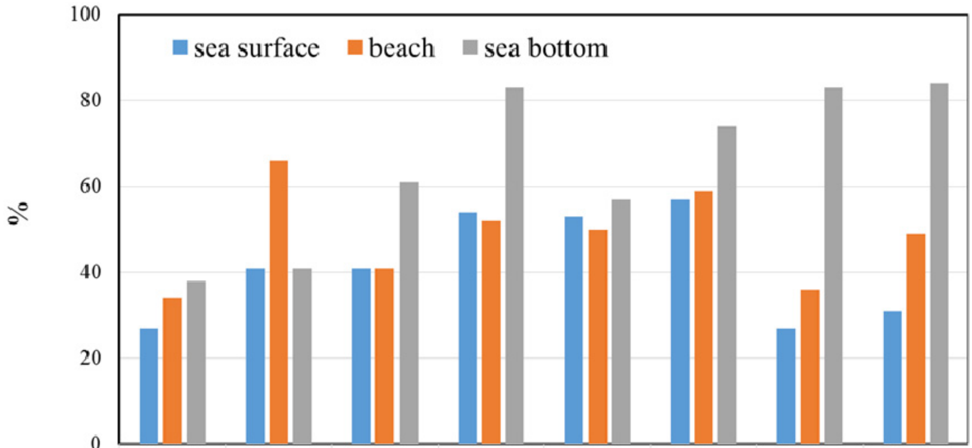


	2007	2008	2009	2010	2011	2012	2013	2014
Polystyrene foam	11%	9%	10%	22%	0	10%	38%	20%
Plastic waste	34%	66%	41%	52%	50%	59%	36%	44%
Wood garbage	6%	0	24%	8%	12%	12%	11%	11%
Others	49%	25%	25%	18%	38%	19%	15%	25%

Figure 7. Composition ratio of the number of litter on beach in China.

For the litter found on beach (Fig. 7), it was identified that the majority of litter was also comprised of plastic waste accounting for 48%, followed by polystyrene foam with 17% and wood garbage with 12% on average. The average number of the pieces was 43,207 pieces /km^2, with the average weight of 1,265kg /km^2. The main composition of plastic litter included plastic bags, bottles as well as plates and ropes.

The percentage of plastic waste litter in sea surface increased from 2007 (27%) to 2010 (54%), and then decreased from 2011 (53%) to 2014 (31%) (Fig. 8). A similar phenomenon happened to the beach litter: the percentage of plastic litter generally increased from 2007 (34 %) to 2012 (59%) and then decreased in 2013 down to 36%. However, the percentage of plastic waste litter in seabed increased from 2007 (38%) to recent years (about 73%). If the polystyrene foam litter is also regarded as plastic waste, more than 50%, or even to 80%, of the floating marine litter belongs to the plastic waste. Compared with the data published in the international journals such as *Science*, and *Marine Pollution Bulletin*, the average number of floating litter in China was similar to that of in the North Atlantic coast, while the average weight was significantly lower (about 2 orders of magnitude) than that of the Gulf Stream Area in North Atlantic.



	2007	2008	2009	2010	2011	2012	2013	2014
sea surface	27	41	41	54	53	57	27	31
beach	34	66	41	52	50	59	36	49
sea bottom	38	41	61	83	57	74	83	84

Figure 8. Percentage of the plastic litter from 2007 to 2014 (SOA).

The floating marine litters were distributed in the tourist, port and fishing areas, which are the main industrial areas and recreational areas along the coast in China.

3.2. Japan

The Ministry of Environment (MoE) of Japan conducted a survey to estimate the total quantity of marine debris accumulate on the entire Japanese beaches [5]. The estimate is based on the results of the beach surveys and cleanup campaigns conducted by the MoE, local authorities, NGOs, and voluntary activities which were conducted in years 2009 (number of beach surveys unknown), 2010 (2,878 beaches), 2011 (3,879 beaches), 2012 (1,781 beaches), and 2013 (6,484 beaches) around the entire Japanese coast.

[5] http://www.env.go.jp/water/marine_litter/umigomi/all_01.pdf; hereinafter referred to as "Japan MoE report"

a) Total quantity of marine debris

Each year, the total weights (in tons) of marine debris retrieved on multiple surveys on each beach were divided by survey times in order to normalize the weight data irrespective of survey efforts. These weight data provide a “snapshot” weight of the marine debris on each beach in each year.

Second, by multiplying these snapshot quantities by ratios of un-surveyed beach length to surveyed one, a snapshot estimate of marine debris that might be accumulated on the un-surveyed beaches in Japan is obtained.

Lastly, by summing the snapshot weights of marine debris on both surveyed and un-surveyed beaches, an estimate of the total weight of marine debris weights washed ashore on the entire beach of Japan is conducted, as if the beach surveys were conducted on the entire beaches of the Japanese coast simultaneously (Note: In the definition of marine debris, driftwoods as well as anthropogenic marine debris in the surveys are included).

Table 1 summarizes the total weight of marine debris during years 2009 through 2013. The weight ranges between upper and lower limits. When estimating the lower limit, a factor (0.5) is multiplied to the weight of marine debris on un-surveyed beaches. On the average, the total weight varied from 230 to 590 kilotons [6].

Table 1. Total weight of marine debris littered on the entire Japanese beaches

Years	Lower limits (Kt)	Upper limits (Kt)
2009	230	460
2010	290	590
2011	300	570
2012	280	580
2013	310	580

[6] These data are obtained from Table 1.4-4 in the Japan MoE report

b) Materials of the marine debris

In order to analyze the composition of marine debris, seven beaches around the Japan Islands were specifically selected: A) Ishikawa, B) Yamaguchi, C) Nagasaki, D) Kagoshima, E) Okinawa, F) Hyogo and G) Ibaraki (Fig. 9). The surveys were conducted 1 to 3 times in each year from 2010 through 2014 within a 50m radius of the beaches.

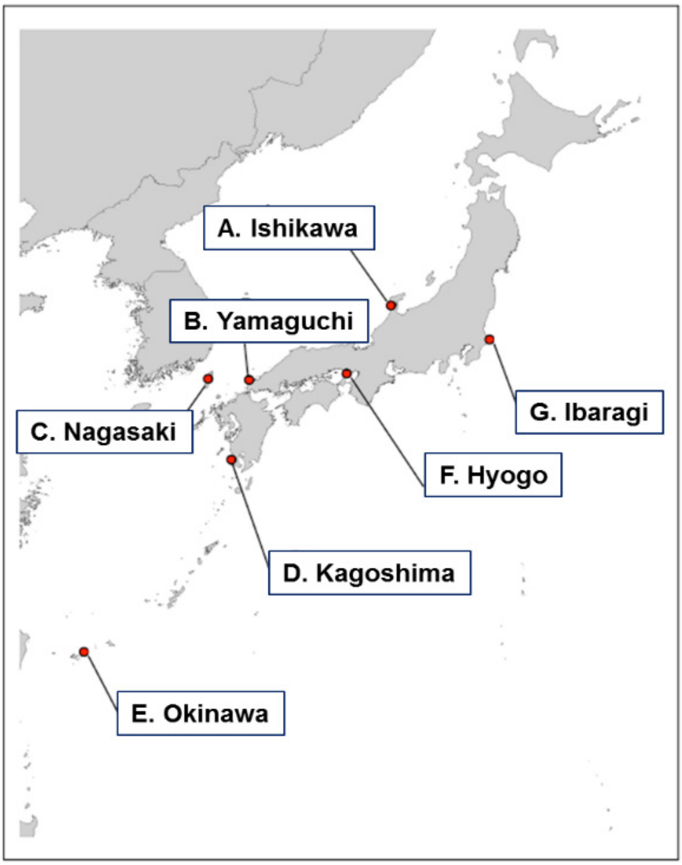
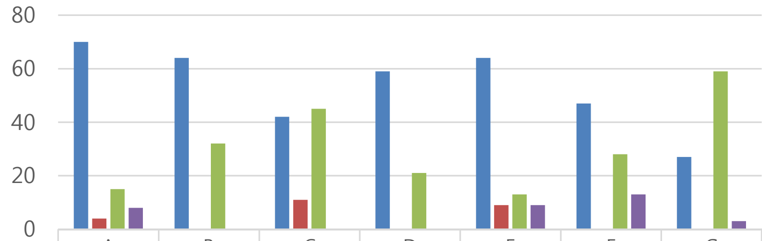


Figure 9. Seven selected beaches to analyze the composition of marine debris around the Japan Islands under the Japan MoE monitoring program (For details, see the text).



	A	B	C	D	E	F	G
Plastic	70	64	42	59	64	47	27
Expanded polystyrene	4	0	11	0	9	0	0
Lumber	15	32	45	21	13	28	59
Others	8	0	0	0	9	13	3

Plastic Expanded polystyrene Lumber Others

Figure 10. Material ratios (%) of weight of marine litter in beaches A-G.

Figure 10 shows the 5 year averaged percentage of weight (volume) of the materials found on the beaches. Plastic debris occupied the main part of marine debris accumulated on beaches, accounting for 53(62)% of the total weight (volume) averaged on the seven beaches [7].

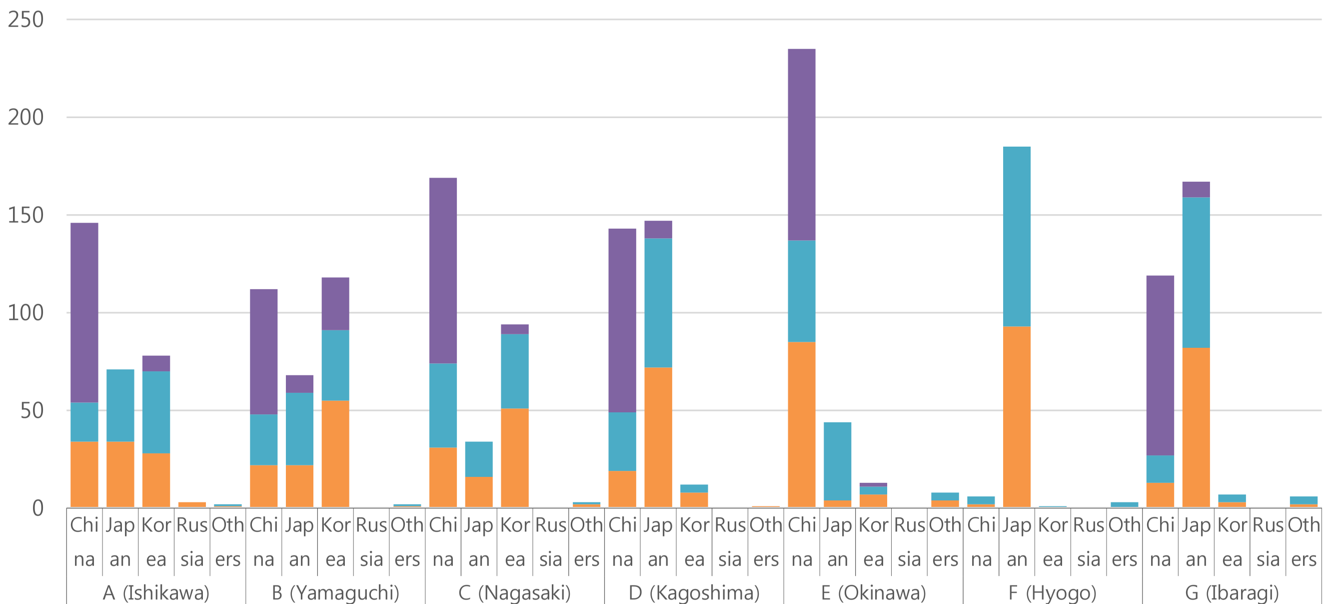
c) Sources of the marine debris

Subsequently, the possible source countries of marine litter have been investigated [8]. PET bottles (influenced by both ocean currents and winds), disposal lighters (mainly carried by ocean currents), and fishery float (typical ocean-based items) were selected. The sources were mostly identified by reading the legible textual information found on the surface of debris.

According to the collected data, a comparable amount of PET bottles and disposal lighters originated from Japan, China and Korea in the beaches A-C and mostly from Japan in the beaches D-G. It was also found that most of the fishery floats originated from China in all of the seven beaches (Fig. 11).

[7] The data is obtained from Figures 2.3-44 and 45 in the Japan MoE report. Only the major materials are listed and the mark* means negligibly small ratios.

[8] The data is obtained from the Figures. 2-6.1, 2-6.3 and 2-6.13 in the Japan MoE report.



A (Ishikawa)	China	Japan	Korea	Russia	Others
fishery floats	92	0	8	0	0
lighter	20	37	42	0	1
PET	34	34	28	3	1

B (Yamaguchi)	China	Japan	Korea	Russia	Others
fishery floats	64	9	27	0	0
lighter	26	37	36	0	1
PET	22	22	55	0	1

C (Nagasaki)	China	Japan	Korea	Russia	Others
fishery floats	95	0	5	0	0
lighter	43	18	38	0	1
PET	31	16	51	0	2

D (Kagoshima)	China	Japan	Korea	Russia	Others
fishery floats	94	9	0	0	0
lighter	30	66	4	0	0
PET	19	72	8	0	1

E (Okinawa)	China	Japan	Korea	Russia	Others
fishery floats	98	0	2	0	0
lighter	52	40	4	0	4
PET	85	4	7	0	4

F (Hyogo)	China	Japan	Korea	Russia	Others
fishery floats					
lighter	4	92	1	0	3
PET	2	93	0	0	0

G (Ibaragi)	China	Japan	Korea	Russia	Others
fishery floats	92	8	0	0	0
lighter	14	77	4	0	4
PET	13	82	3	0	2

Figure 11. Cumulative ratios of foreign-originated floating marine litters collected at surveyed beaches of Japan.

It is mostly likely that the sources of the floating litter are influenced by the direction of the currents (Fig. 12): the beach A, B and C are located in the eastern NOWPAP sea area influenced by the Tsushima Current flowing from southwest to the northeast, and the beach D, E, and G are located in the seas influenced by northeastward Kuroshio Current (although the areas are not located in the mainstream of the currents).

The beach F is located in the Seto Inland Sea, which is relatively isolated from the outer oceans therefore the majority of the litter found in the beach F was from Japan.

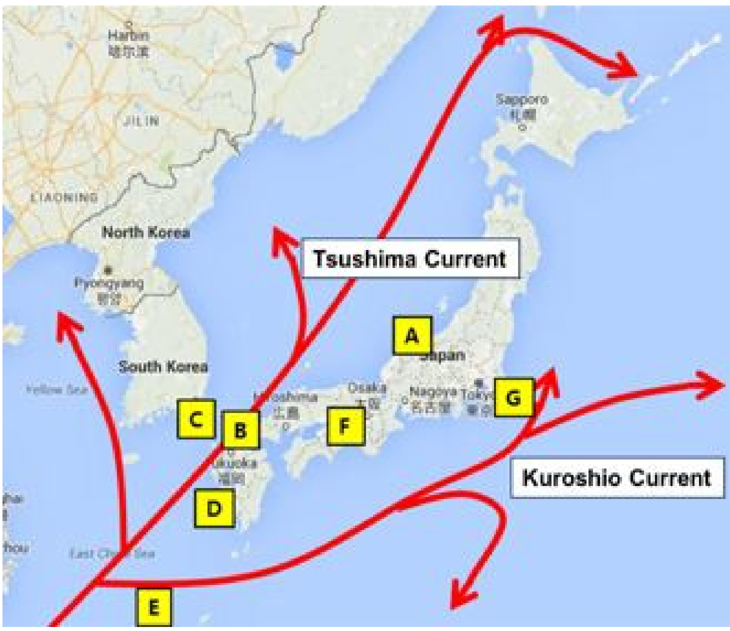


Figure 12. Direction of Tsushima and Kuroshio Current which affect directly the movement of marine litter in the NOWPAP region.

d) Quantity and properties of marine debris littered on a specific beach

In addition to the comprehensive but relatively rough estimates of the quantity and sources of marine litter, a beach survey project was implemented to accurately investigate the quantity and properties (i.e., materials, polymer types of plastic debris, and potential source countries) of marine debris ashore on a specific beach.

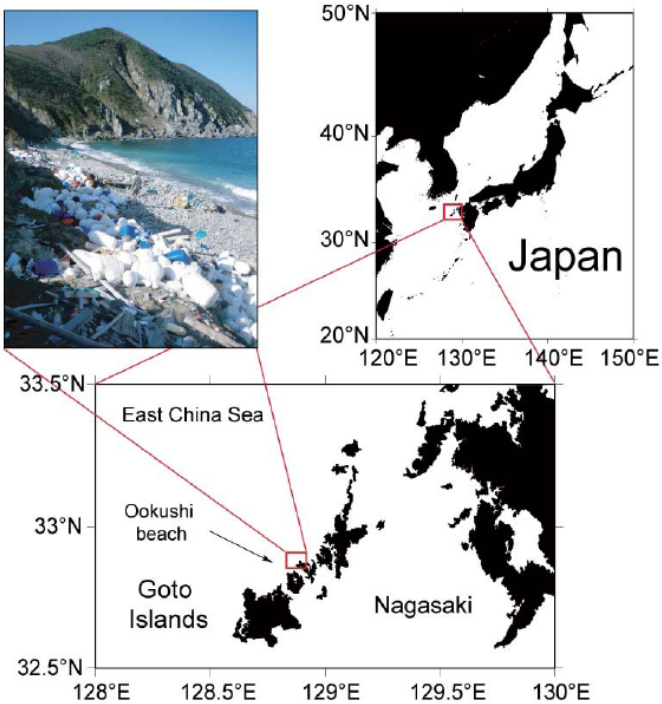


Figure 13. Location of the Ookushi beach, Goto Islands, where beach survey on marine litter have been investigated by Japan in 2009-2011 [9].

The beach surveys were carried out three times on October 22, 2009, July 31, 2010, and March 5, 2011 on Ookushi beach at the Goto Islands, Nagaski, Japan (Fig. 13) [10]. The Goto Islands were an imperative location to conduct the surveys since they are located at a “crossroads” of the ocean currents (Kuroshio, Taiwan, and Tsushima Currents) [11].

An aerial photography using a balloon-equipped digital camera was conducted in conjunction with in-situ beach surveys to estimate the total quantities of the macro-debris ashore on the beach.

[9] The upper left panel shows a photo taken on October 22, 2009

[10] The result in the first survey has been already published in Nakashima et al. (2011), which provides the detailed descriptions on procedures, results, and discussions that are partly skipped in this report.

[11] Isobe, 2008 for an ocean current map of the East Asian marginal seas

The first step was to photograph the beach using a remote-controlled digital camera suspended from a balloon filled with helium gas (Fig. 14) [12]. The locations of 20 markers ($1m^2$ size blue panels) were placed randomly on the beach and recorded using a global positioning system. The markers were used as a geo-reference in calculating the area covered by litter as shown later. Figure 15 is a photograph of the beach taken from the camera [13] and it shows that the beach is covered by a large amount of litter, including fishing floats and expanded polystyrene.

Once the photographs were taken, they were converted into images where the line of sight was perpendicular to the locations of the markers for geo-referencing; otherwise, the distorted original photographs taken at the oblique angle could lead to wrong estimates for the litter-covered area.

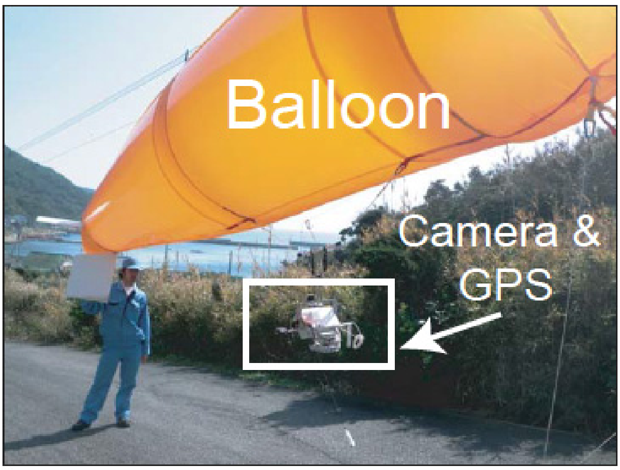


Figure 14. Balloon photography system to monitor distribution of marine litter in Japan.

[12] Nakashima et al., 2011

[13] Nakashima et al., 2011

Figure 15. A photograph taken by the balloon photography, showing the severe accumulation of marine litter at the beach.

The second step was to estimate the area of the beach covered by litter using these converted photographs, the lightness value was calculated at each pixel as a function of red, green and blue values (the RGB values) in different color coordination. The prevalence of white expanded polystyrene buoys, which were common on this beach (Figs. 13 and 15), enabled to calculate the area covered by beach litter by counting the number of pixels that were lighter than the defined threshold value: 90 was chosen for the value through a trial-and-error process where the actual photographs were compared with various lightness maps. The total area covered by beach litter was then calculated by multiplying the number of white pixels by the area of a single pixel (10×10 cm).

Third, the beach litter mass per unit area (hereafter referred to as "density of litter") was estimated in order to calculate the total litter mass on the beach. The density of litter (kg/m^2) was multiplied by the total area covered by litter (m^2; as calculated from the aerial photographs). Measurements of the density of beach litter were carried out the day after the aerial photographs were taken. 10 square boxes, each with an area of $4m^2$ and completely covered by litter, were randomly chosen. All litter except plastic fragments smaller than $1cm^2$ was collected and weighed. The density of litter within each of these 10 boxes was calculated by dividing the mass of litter within each box by the area in the box ($4m^2$).

In addition to the in-situ beach survey described above, random samples of litter from each square box on the Ookushi beach were collected and categorized according to both their original function and components. To measure the mass of each type of material, all collected litter samples were transported to the laboratory and classified per categories used by Ribic et al. (1992): plastic, multiple material products (i.e., beach sandals), expanded polystyrene, man-made wood, metal, glass, rubber, fabric, paper, vinyl and others.

In order to assist in determining the origin of the litter, any legible textual information (indicating the country of origin or product names) was also recorded. Plastic samples were investigated using a near-infrared spectrometer for plastics [14] and a Fourier transform infrared spectrophotometer [15] to identify the type of polymer. The most common types of polymer found on the Ookushi beach were polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), acrylonitrile-butadiene-styrene (ABS), acrylonitrile-styrene (AS), polyamide (PA) and polyurethane (PUR).

In the case of the surveys conducted on 22 October 2009, the total area covered by beach litter was found to be 123.5 m^2. The density of litter within the 10 boxes placed on the Ookushi beach ranged from 2.6 to 12.6 kg/m^2 with an average of 5.8 kg/m^2. Multiplying the total litter-covered area (123.5 m^2) by the average density of litter gives an approximate total litter mass for the entire beach of 716 kg.

In addition, the standard deviation (2.8 kg/m^2) was used to calculate the margin of error for the density. Hence, the margin of error for the total litter mass was calculated to be ±259 kg by multiplying the margin of error (±2.1 kg/m^2) and by calculating the total litter-covered area on the beach (123.5m^2).

The litter quantities based on three surveys are listed in Table 2 [16]. The difference of the total mass of the surveys are likely to be controlled by wind directions over the beach as it was monitored by a webcam system set on the Ookushi beach [17].

14 Plascan-SH, OPT Research Inc. Tokyo, Japan

15 FT-IR, ALPHA, Bruker Optics

16 The values in 2009 have already shown in Nakashima et al., 2011

17 Kako et al., 2010

Table 2. Quantities of macro-litter on the Ookushi beach

	Areas covered by litter (m2)	mass per unit area (kg/m2)	total mass (kg)
22 October 2009	123.5	5.8±2.1	716±259
31 July 2010	490.8	8.2±2.6	4,025±1276
5 March 2011	248.0	11.5±2.7	2,852±670

Table 2 shows that the quantity of marine debris washed ashore on the Ookushi beach (approx. 500m length) were 0.7~4.0 tons during the survey periods. If the entire beaches around the Japan Islands (approx. 35,000 km) are occupied by beach litter similar to the photos in Figure. 13 and 15, the total quantities of marine debris found around the Japan Islands reaches about 50 (=0.7 tons*35000km/0.5km) to 280 Kt, which are significantly smaller than the weights stipulated in Table 1.

The beaches around the Japan Islands are not always covered by litter like the Ookushi beach therefore 50~280 Kt could be regarded as the upper limit of the litter quantities around the Japanese coasts. It is therefore suggested that the values in Table 1 might be overestimated for marine debris littered on the Japanese coasts. Probably this overestimation was derived from the difficulty of estimating litter quantities deduced for beaches in the absence of actual beach surveys. Repeated surveys and/or an improvement of estimate procedures are further required to accurately estimate the quantities of marine litter.

Next, Figure 16 describes the detailed properties of marine litter collected on the Ookushi beach during the 2009 survey. As estimated in the MoE report, plastics were the most common type of materials found in the samples of litter collected from the Ookushi beach. The plastics, even without including micro-plastics[18], accounted for 74% (i.e., 530±201 kg) of all materials on this beach. Other common categories of materials were expanded polystyrene (9%) and multiple material products (13%) such as beach sandals, and shoes. Wood, metal, glass, rubber, fabric, paper and

[18] defined as small fragment smaller than 5 mm; Andrady, 2011; Cole et al., 2011

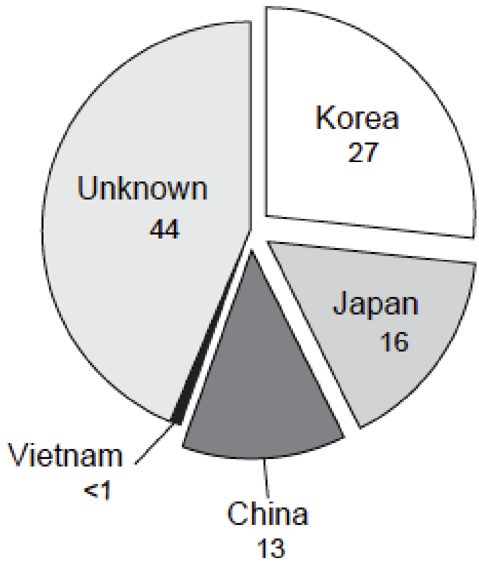


Figure 16. Origins of the PET bottles collected on the Ookushi beach in 2009.

vinyl accounted for less than 1% each. Roughly 20% (by mass) of items such as plastic bottles/caps and fishing gears had Korean, Chinese, or Japanese characters while the origin of the other item was unknown. The suggested origins for PET bottles are shown in Figure. 16.

Among the marine litter collected during the 2009 survey, detailed analysis on plastic was conducted as plastic is the most predominant litter. Figure 17(a) indicates that 39% of plastic litter items had fragmented to such an extent that the original products could not be identified. Nevertheless, bottles/caps and fishing gears comprised more than half of all plastic litter on the Ookushi beach. Most plastic litter (as well as these major items) was made from three main types of polymers: polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET) (Fig. 17(b)). PET in particular is used mostly for plastic juice and water bottles. Approximately half of the buoyant fishing gears were made of polystyrene (PS) and polyvinyl chloride (PVC). Acrylonitrile-butadiene-styrene (ABS) and acrylonitrile-styrene (AS) were the most commonly seen in fragments, bottle/caps and fishing gear. AS and polyamide (PA) were found mostly in disposable lighters. Plastic products made from relatively lightweight polymers (especially, PE, PP, and PET (as plastic bottles)) are more likely to become marine litter than others are.

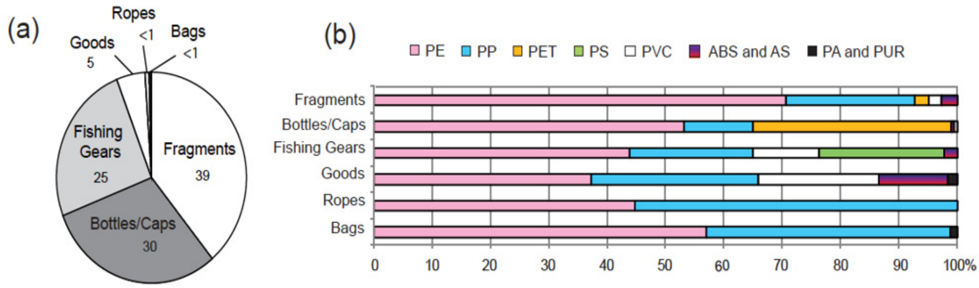


Figure 17. Mass ratios (%) of items of plastic litter collected from 10 boxes on the Ookushi beach, and (b) the type of polymer of each item identified in (a). (Nakashima et al., 2011).

Figure 18. PVC fishery floats with high concentration of Pb.

Lastly, it was also noted that toxic metals such as chromium, cadmium, tin, antimony and lead (Pb) were detected in plastic litter collected during the beach surveys (Nakashima et al., 2012). A specific type of PVC fishing float (Fig. 18) contained the highest quantity of Pb.

e) Floating marine litter distribution on sea surface

Plastic marine debris accounts for more than half of all debris littered on beaches around the Japan Islands. In the case of the Ookushi beach on which intense surveys were conducted to accurately measure the debris quantities, plastic debris occupied more than 70% of the total quantities on beach litter. This percentage is comparable with various estimates on beaches around the world (Derraik, 2002).

Thus, the problem of marine debris can be mostly recognized as the problem of “marine plastic pollution”. However, different from beach surveys, it is a difficult task to survey floating plastic debris in the actual oceans, because floating objects are too small to be detected by airplanes/satellites, because observers on vessels may pass over the floating debris during surveys, and because opportunities to meet floating objects are greatly reduced under the wavy condition. Nevertheless, the Japan Meteorological Agency (JMA) has carried visual counting surveys for floating marine plastic debris from research vessels from 1976 to the present, and opened the survey data on their website [19]. Their floating plastic debris data (shown as “floating pollutant data” on their website) provides a useful dataset to evaluate the plastic pollution around the NOWPAP region.

The visual counting of floating plastic debris (including expanded polystyrene) is conducted along with other hydrographic observations during the daytime. Positions, distances along which the visual counting was conducted (transect length), and plastic debris numbers counted from the vessels, were all recorded. The numbers are converted to those along 100-km transect distance. Figure 19 summarizes the surveys during the period 1981 through 2010.

[19] http://www.data.jma.go.jp/gmd/kaiyou/db/vessel_obs/data-report/html/ship/ship_e.php

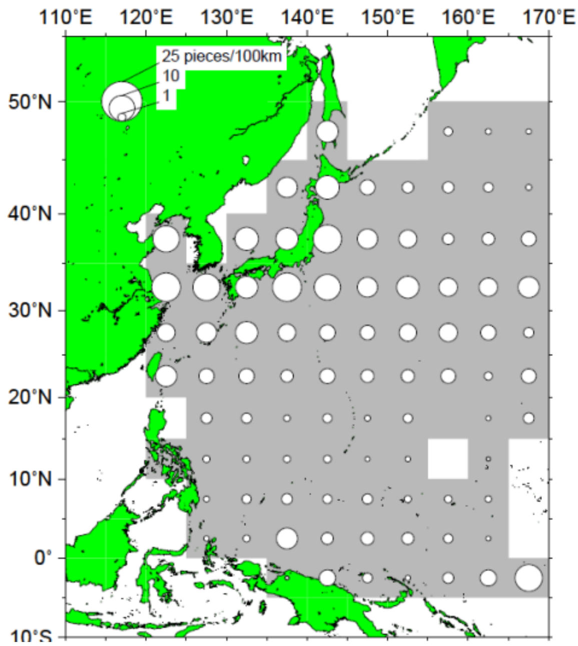


Figure 19. Number of floating plastic debris along 100-km transect line. This map is depicted based on the visual counting from 1981 to 2010 [20].

Then the above 100-km data was converted into numbers of plastic debris floating in the unit area (drift density; d) in line with the density estimation method given by Randriarilala et al. (2014) as follows:

$$d = N / (2 e L) \qquad (1)$$

where N denotes the numbers of the floating plastic debris detected along each transect, e the “effective search half width”, and L the transect length for each survey. The values except for e can be downloaded from the JMA website. The effective search half width is introduced to deduce the floating object numbers, which usually reduce exponentially in distance from the vessels because of passing over during the visual counting. Although the value e should be determined statistically based on the visual survey data, we here chose the width of 20m for simplicity in line with Randiarilala et al., 2014 (Tab. 3) and a recent estimate opened on the MoE website (http://www.env.go.jp/water/marine_litter/umigomi/all_02.pdf; Table II-3.18).

[20] Data obtained from http://www.data.jma.go.jp/kaiyou/shindan/sougou/html_vol2/3_1_vol2.html

Table 3. Drift density (number of plastic debris per km2) averaged over the period 2009 through 2013

Spring	2.3
Summer	3.2
Autumn	1.6
Winter	1.0
Annual average	2.0

Table 3 summarizes the drift density of plastic marine debris by seasons and its annual average. We computed the drift density using the recent five years from 2009 to 2013. The surveys in spring (April to mid-June), summer (mid-June to September), autumn (October to December), and winter (January to March) were conducted 257, 564, 335, 471 times, respectively, in the course of these five years.

Also shown in Figure 20 are the maps of the drift density in the seas around the Japan Islands. When depicting the drift density map, we averaged the drift density within each box with 1-degree lengths in both latitude and longitude. If the survey numbers were less than three, the box for mapping the density has been omitted.
In addition to the maps in Figure 20, the readers can find a recent report issued by the MoE (http://www3.nhk.or.jp/news/html/20150719/k10010158821000.html) on the floating marine debris observed during 2014 surveys. Using the annual average of 2.0 pieces/km^2 in Table 3, and the areas of Japan territorial waters and EEZ (4,470,000 km^2), the total numbers of floating plastic debris in the oceans surrounding the Japan Islands is evaluated to be about 9 million.

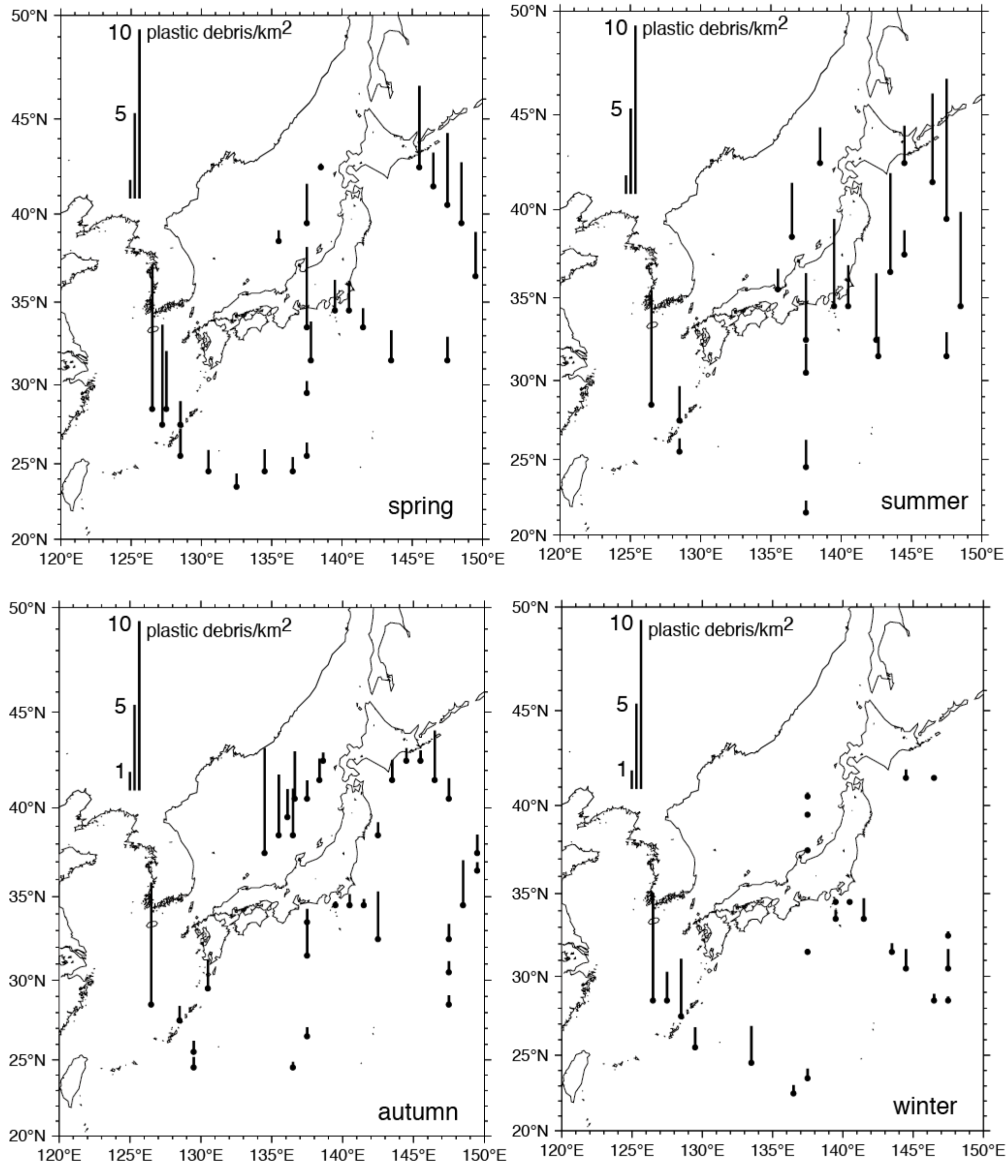


Figure 20. Maps of floating plastic debris density in each season in the NOWPAP region.

3.3. Republic of Korea

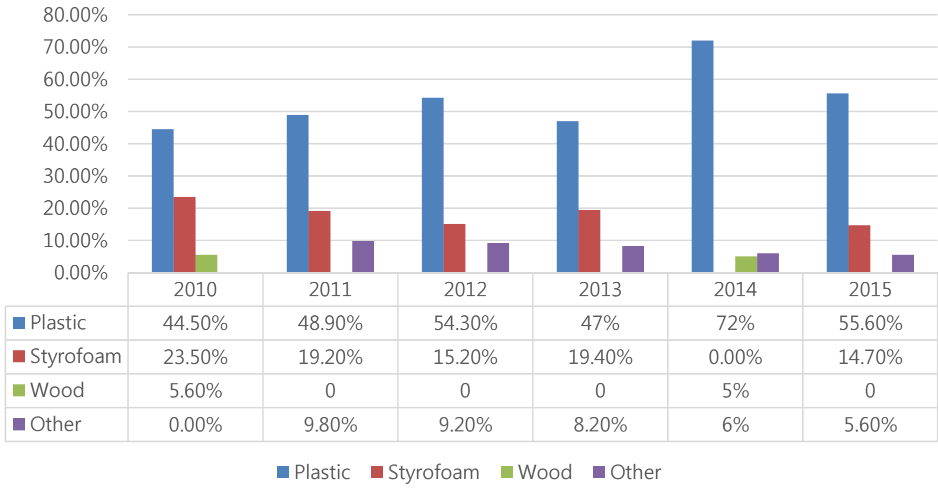
The Ministry of Oceans and Fisheries (MOF) of Republic of Korea has been implementing the Korean National Marine Debris Monitoring Programs since 2008 to monitor the marine litter distribution and its impacts to the environment.

The main objectives of the monitoring program were to 1) find grounds to decide investment priorities and allocate resources for setting up policies; 2) set criteria to review the effectiveness of the existing policies, and 3) find science-based countermeasures against floating marine litter by analyzing the occurrence characteristics of the foreign originated marine litter and its trend of deviation (hotspots, types, quantity, seasons, etc.).

The following paragraphs provide a summary of the results of the monitoring conducted over the period 2010 through 2015 by MOF of Republic of Korea and the information is selected from the national reports on marine litter monitoring of Republic of Korea.

a) Number and types of marine litter

Figure 21 shows the total number of collected marine litter and its composition ratios during 2010 to 2015. It can be observed that the number of marine litter decreased from the year 2010 (64,406) to 2014 (33,600), and increased sharply in 2015 up to 72,399 which can be explained by the expansion of the number of monitoring sites in 2015 (20 to 40 sites). As such, there was a steady decrease since 2010 and was no peculiar change in terms of the total number of marine litter.



	2010	2011	2012	2013	2014	2015
Plastic	44.50%	48.90%	54.30%	47%	72%	55.60%
Styrofoam	23.50%	19.20%	15.20%	19.40%	0.00%	14.70%
Wood	5.60%	0	0	0	5%	0
Other	0.00%	9.80%	9.20%	8.20%	6%	5.60%

Figure 21. Total number of collected marine litter and its composition ratios (%) during 2010-2015 in Korea.

In most of the years, plastic waste and Styrofoam took the first and second place with plastic waste taking almost (or more than) half of the marine litter, except the year 2014 where other was ranked the second highest. The third highest was mostly occupied by wood, glass, cigarettes or foreign-originated marine litter.

Among the total amount of the collected marine litter between 2010 and 2015, around 20-30% (slightly varying depending on the year) of them was found to be fishery-related waste such as Styrofoam/plastic buoys or ropes (Fig. 22). On the other hand, the rest (around 70-80%) of marine litter originated from land-based activities (MOF, Korea, 2015).

Figure 22. Example of Fishery-related marine litter in Korea (MOF, Korea, 2015).

b) Seasonal characteristics

In general, the quantity of marine litter tends to increase during the summer seasons in Korea and it is probably due to the geographical location and also heavy rains and typhoons during the summer season (June and July) in the Northeast Asia which in turn increase the waste generation and marine litter (MOF, 2013).

c) Hotspots

The number of the collected marine litter was generally higher in the southern coast (i.e., Tongyoung, Masan and Jeju). In terms of volume and weight of marine litter, on the other hand, it was higher in the western coast (i.e., Buan and Jindo) and it is due to the occurrence of voluminous and heavy wastes such as buoys in the western coast of Korea (MOF, 2014).

e) Foreign-originated marine litter

The ratio of the number of marine litter of foreign origin varied from 3.2 up to 8.2, and there was no considerable change in the ratio except in 2013 when the ratio had more than doubled than the previous year 2012 (Tab. 4).

Most of the marine litter of foreign origin was found in Jeju, Jindo, Sinan and Buan which are located in the southwestern coast of Korea (Fig. 23). Among them, plastic beverage bottles and plastic buoys were the most commonly found items, and generally originated from China. The sources have been presumed from the language of the labels attached on the items found.

Table 4. Ratio (%) of foreign-originated marine litter collected in Korea

Year	Number	Weight	Volume
2010	5.9	3.1	3.5
2011	3.6	8.4	8.3
2012	3.2	2.3	4.3
2013	8.2	9.4	8.4
2014	5.3	5.8	5.9
2015	4.7	2.9	5.4

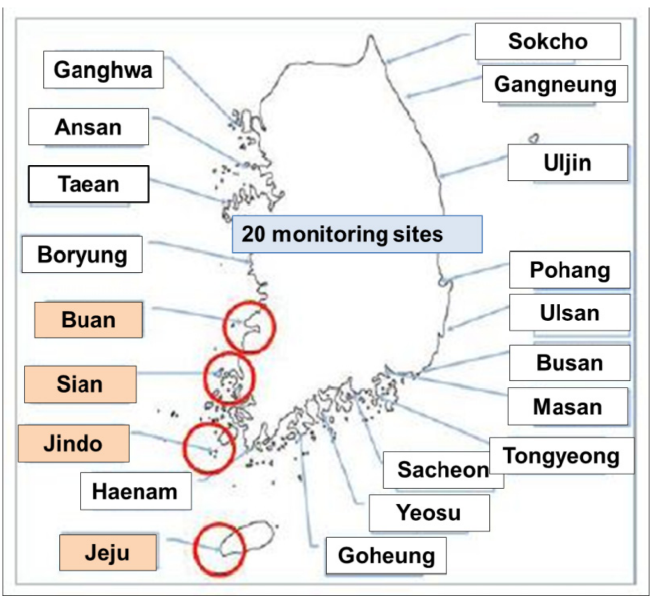


Figure 23. Hotspots of foreign-originated marine litter in Korea (MOF, Korea, 2014).

The national monitoring programs are generally conducted by non-experts therefore, it has been difficult to identify the source countries of the foreign-originated marine litter. Thus, special monitoring has been carried out and numerical modellings have been conducted to understand the possible trajectories of floating marine litter (Fig. 24; MOF, Korea, 2010b).

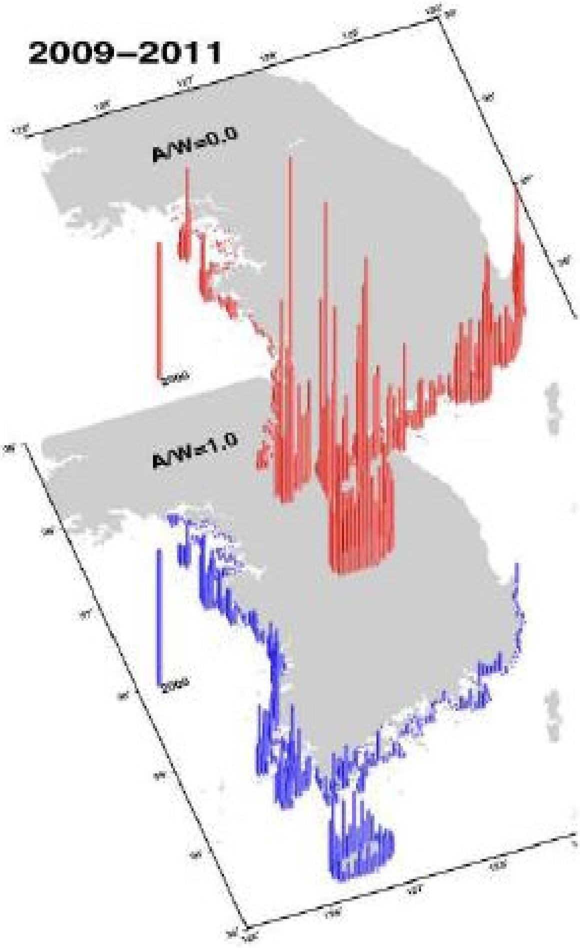


Figure 24. Distribution of the China-originated marine litter in Korea (MOF, Korea, 2010b).

Unlike the total number of marine litter which tends to increase during summer seasons and decrease during winter seasons, the quantity of the foreign-originated marine litter increased in winter (January) due to the occurrence of voluminous waste in the west coast of Korea such as buoys, which seem to have derived from foreign countries (MOF, Korea, 2014).

According to recent data collected in 2015 (MOF, Korea, 2015), the foreign-originated marine litter found in Korea were originated from China (2,070 items, 89%) and Japan (68 items, 2.9%).

Figure 25. Foreign-originated plastic buoys found in Korea (MOF, Korea, 2015).

Chapter 4. Possible Trajectory of the Floating Marine Litter in the NOWPAP Region

4.1. Japan

Generally, it is not easy to accurately detect marine litter floating on the ocean by satellite and aerial photography. The behavior of marine litter in the ocean is also difficult to be deduced precisely.

However, recently, Japan was able to use ocean reanalysis products, which are computational results of a numerical ocean circulation model assimilating ocean observed data derived from satellites and Argo floats. An ocean reanalysis product, DREAMS (Hirose et al., 2013), has been used to reproduce the surface ocean currents carrying marine litter.

In addition, satellite-derived wind vectors (ASCAT data, Kako et al., 2011a) were used for computing the influence of drag directly exerted by winds (i.e., leeway drift), which is also a driving force that carries marine debris in the ocean.

The movement of marine litter has been expressed by a particle tracking model (PTM) using DREAMS and ASCAT data. When the original (unprocessed) ocean currents and winds are used for the PTM experiments, the particles in the model reproduced the behavior and fate of the marine debris (forward tracking). Further, when the ocean currents and winds, reversed in signs are used, the particles returned to their original position, which suggests the origins of the marine debris (backward tracking). Such experiments have been conducted in Kako et al. (2011b) and Kako et al. (2014) in the NOWPAP area.

In the present PTM application, the particle location [$\mathbf{X}$ = (x, y)] at the time t+Δt, where Δt (= 600 s) is the time increment of the PTM and is computed as

$$\mathbf{X}^{t+\Delta t} = \mathbf{X}^{t} + \mathbf{U}\Delta t + \frac{1}{2}\left(\mathbf{U}\cdot\nabla_{H}\mathbf{U} + \frac{\partial \mathbf{U}}{\partial t}\right)\Delta t^{2} + R\sqrt{2K_{h}\Delta t}(\mathbf{i},\mathbf{j}) \qquad (2)$$

where **U** [= (u, v)] and K_h are the current vector and diffusivity, and **i** and **j** denote the unit vectors in the zonal (x) and meridional (y) directions, while R represents a random number generated at each time step with the average and standard-deviation of 0.0 and 1.0, respectively. The DREAMS is used to provide ocean surface current data, which are used to compute drifting marine-debris behavior and the diffusivity in Eq. (2). See http://dreams-i.riam.kyushu-u.ac.jp/vwp/ for more thorough description of DREAMS.

In computing the motion of beach debris drifting on the ocean surface, the leeway drift should be added to the ambient currents in PTMs. We used Richardson's (1997) relationship between the wind speed (W) and leeway drift (V) to incorporate the leeway drift into the PTM algorithm as follows:

$$V = \sqrt{\frac{\rho_a}{\rho_w}\frac{Cd_a}{Cd_w}\frac{A_a}{A_w}}W \qquad (3)$$

where ρ_a (ρ_w) is the air (seawater) density, Cd_a (Cd_w) is the drag coefficient for the debris in the air (seawater), respectively, and $A_a(A_w)$ denotes the horizontally projected area of the debris. We used $\rho_a / \rho_w = 1.15 \times 10^{-3}$ and $Cd_a / Cd_w = 1.0$ in the present application, assuming that Reynolds' numbers in both air and water are less than the critical values at which the drag coefficient suddenly decreases. However, constant A_a / A_w values are unlikely to be appropriate for expressing the various statuses of drifting beach litter in the actual ocean. In the present model, the ratio (A_a / A_w) randomly changes from $1/300$ to 1, although the choice of the denominator 300 is somewhat arbitrary; 300 was used to express the situation in which drifting objects are unlikely to constantly sink beneath the sea surface while moving stochastically in time. The present PTM does not account for the motion of marine-debris mostly determined by wind speeds (i.e., A_a / A_w is larger than 1.0). This was done because wind-induced motion is about ten times faster than motion mainly determined by ocean currents, and because such wind-borne debris on the ocean surface takes much less than one month to move across the basin (we will show monthly maps). The daily averaged wind vectors observed by ASCAT were employed after being gridded with an optimum interpolation method (Kako et al., 2011a). The surface currents derived from DREAMS and leeway drifts computed using ASCAT are interpolated linearly for the spatial and temporal resolutions of the present PTM.

In this report, ocean currents and winds, reversed in signs, were used to find possible routes and origins of marine litter. The Goto Islands of Japan (Fig. 13) were chosen as the starting point from which the particles were released in backward tracking. The monthly maps (Fig. 26) show that the particles representing the marine litter washed ashore at the Goto Islands in March returned to their source candidates.

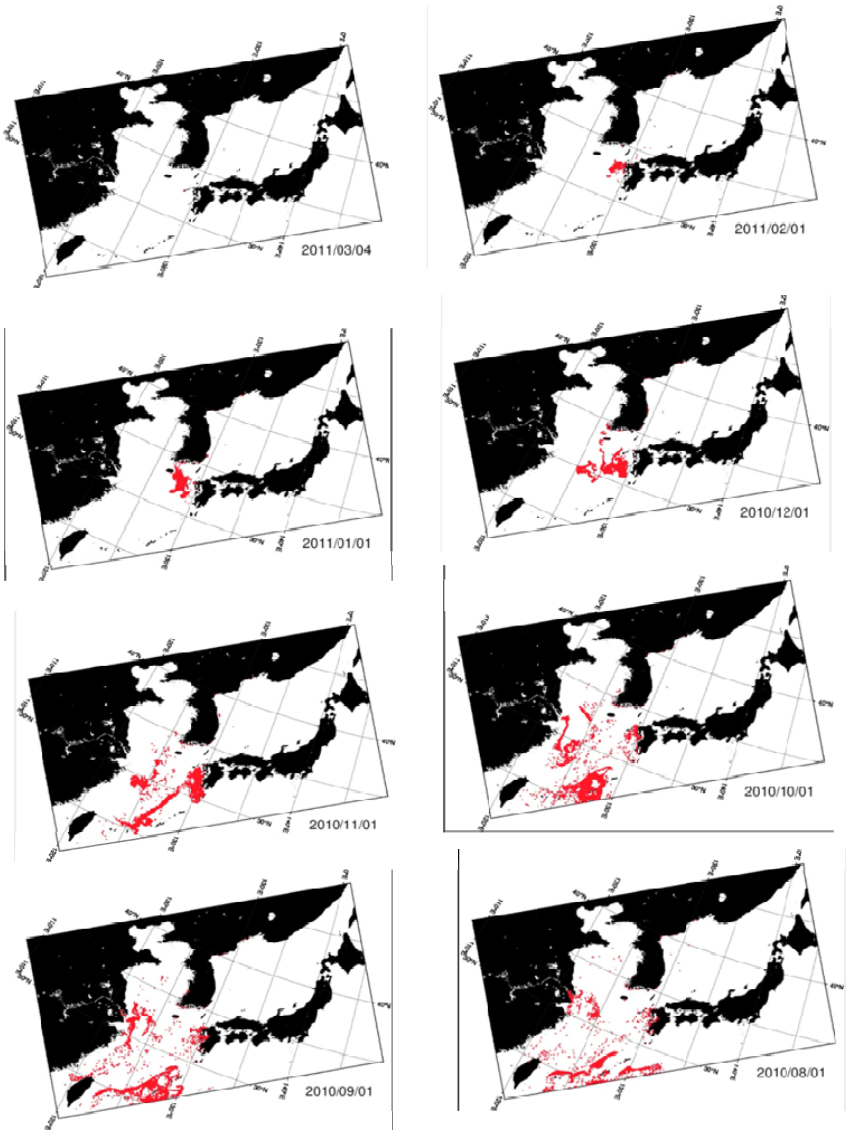


Figure 26. Backward tracking of marine debris at the Goto Islands from March 2011 (the year/month/date are shown in the lower right of each map).

The particles returned to the west as time went back, and mostly disappeared towards the Kuroshio upstream. However, it is interesting to see that a non-negligible fraction of particles returned to the Changjiang river mouth from October to August. This may suggest that the debris released from the Changjiang river spread widely over the seas around the Japan Islands. The inverse estimation conducted by Kako et al. (2011b) also pointed out the importance of Changjiang river mouth as well as southern coasts of the Chinese mainland as the sources of marine debris littered on beaches at the Goto Islands.

4.2. Russian Federation

The main source of marine litter in the Far East of Russian Federation is considered to be the recreational activities. As of now, the issue of floating marine litter is not as urgent as in other countries of the NOWPAP region but is certainly an issue of a growing concern.

In Russia, litter management is governed by the regulatory and legal framework. Thus, the rules for preventing pollution by litter from ships completely ban dumping of any type of plastic into the sea, including synthetic materials. However, a considerable amount of plastics is continuously threatening the marine environment.

The Russian sector of the NOWPAP coastal zone is no exception. On the other hand, unlike in other NOWPAP member countries the floating litter was concentrated in the hydrodynamic shadow areas where litter is being transported by winds and currents.

The following water areas in the Russian part of the NOWPAP region are the possible sites of floating marine litter concentration (Fig. 27).

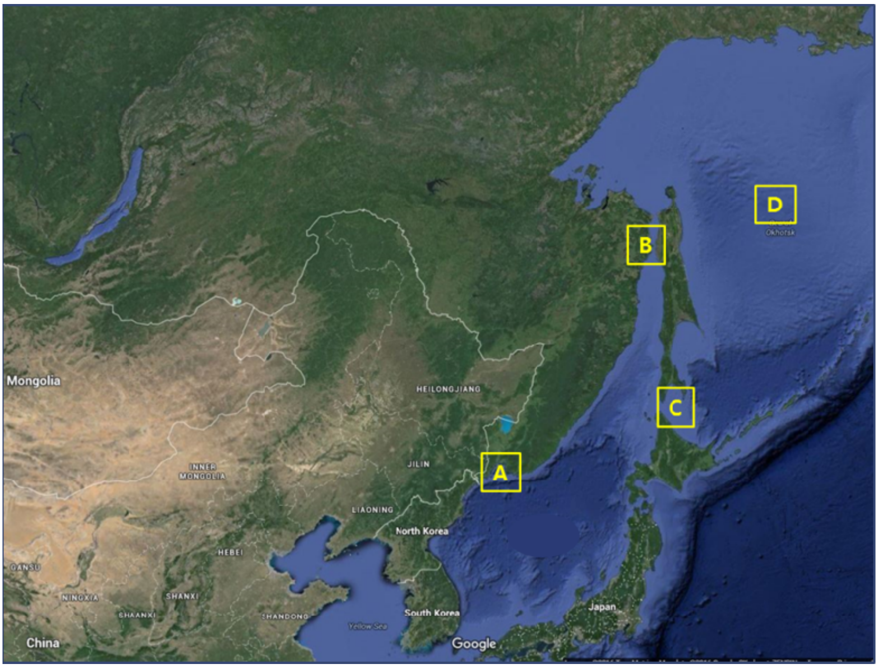


Figure 27. Possible sites of floating marine litter concentration in the Russian part of the NOWPAP region.

a) Primorsky region

The coastal marine area of Primorsky Krai is entirely included within the geographical scope of the NOWPAP region. The total coastline length is approximately 1,500km and the south of Primorsky Krai is characterized by typical shorelines and it is undergoing the heaviest economic growth.

The most noticeable area of floating marine litter distribution in Primorsky Krai is the Peter the Great Gulf. The surface currents allowed predicting the major litter migration routes and the spots of floating litter concentration.

The currents pattern was created under general circulation of in the Eastern NOWPAP sea area, monsoon winds and tides. The most prominent currents transporting the litter are the northward Tsushima current (a branch of warm Kuroshio Current) and the cold Primorskoye current streaming southward along the coast of Primorsky Krai.

Each of the currents consequently forms hydrodynamic flows providing circulation in bays of the gulf. River discharge and open sea water also result in the formation of local circulation forming circular currents in the Peter the Great Gulf.

In the Peter the Great Gulf (Fig. 28) the litter tends to travel from the southwestern part of the Primorsky Krai shores along the coast of the Khasan district towards the Amur Bay. The current setting from the head of the Amur Bay is also a litter migration route. As a result, the highest litter concentration in the offshore zones can be observed in the central part of the Amur Bay where the currents meet.

Wind amplitude characteristics allow determining the litter concentration zones. In the course of monitoring, a 300 to 500 m wide litter plumes emerged from the Razdolnaya River was discovered. At those windless regions litters tend to be accumulated for a long period of time, gradually shifting towards the nearshore waters, such as Peschanaya Bight and Melkovodnaya Bight.

The qualitative and quantitative characteristics of the offshore litter vary depending on the distance from the shoreline as they are governed by the currents' strength and rate, pollution source distribution, and some other factors.

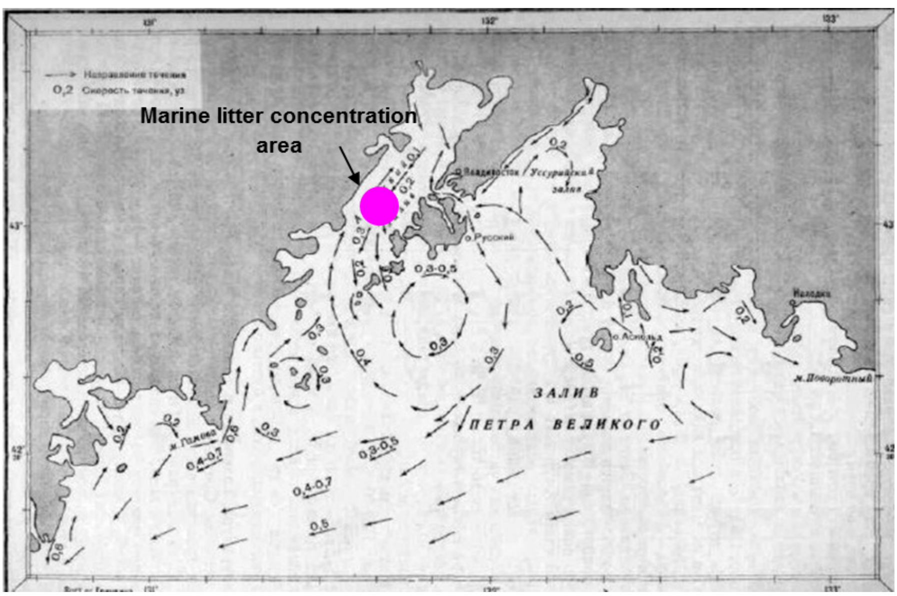


Figure 28. Surface currents in the Peter the Great Gulf.

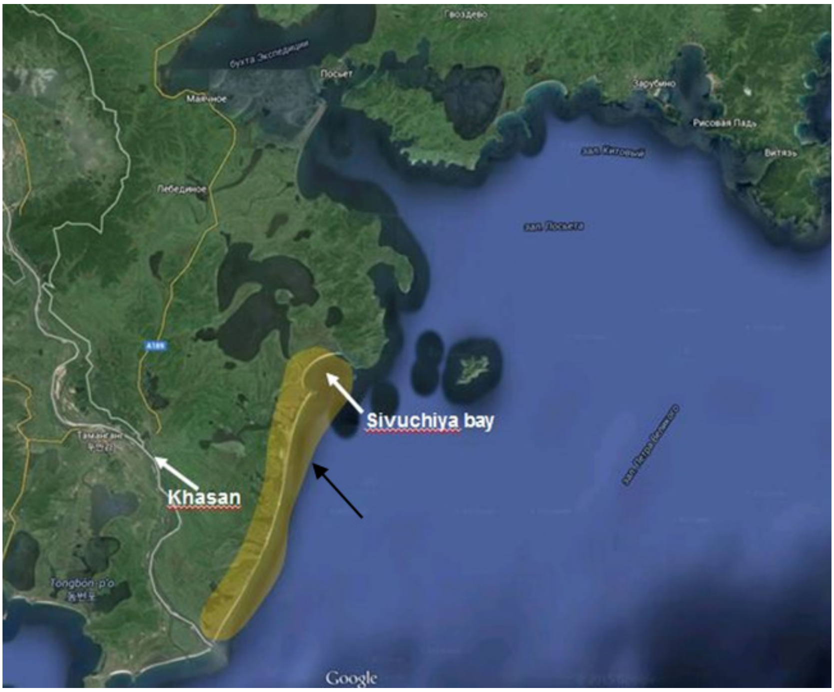


Figure 29. The Sivuchiya bay and Khasan seashore.

Based on the field research data, the marginal areas of the Gulf are the areas where the transboundary litter from other NOWPAP members accumulates. The most litter accumulated areas are the Sivuchiya Bay and Khasan seashore (Fig. 29).

The litter in these areas is mostly originated from the sea-based activities (buoys, floats, nets etc.). Local circulation is created by winds and vortex flows generated by the Tumen River discharge. The hydrological studies confirmed that the Tumen River discharge is responsible for the distribution of litter transported along the southwestern coast of Primorsky Krai (Fig. 29). The hydrodynamic vortices formed within the area provide the transportation of the litter to its accumulation spot in the Sivuchiya Bay (Fig. 30).

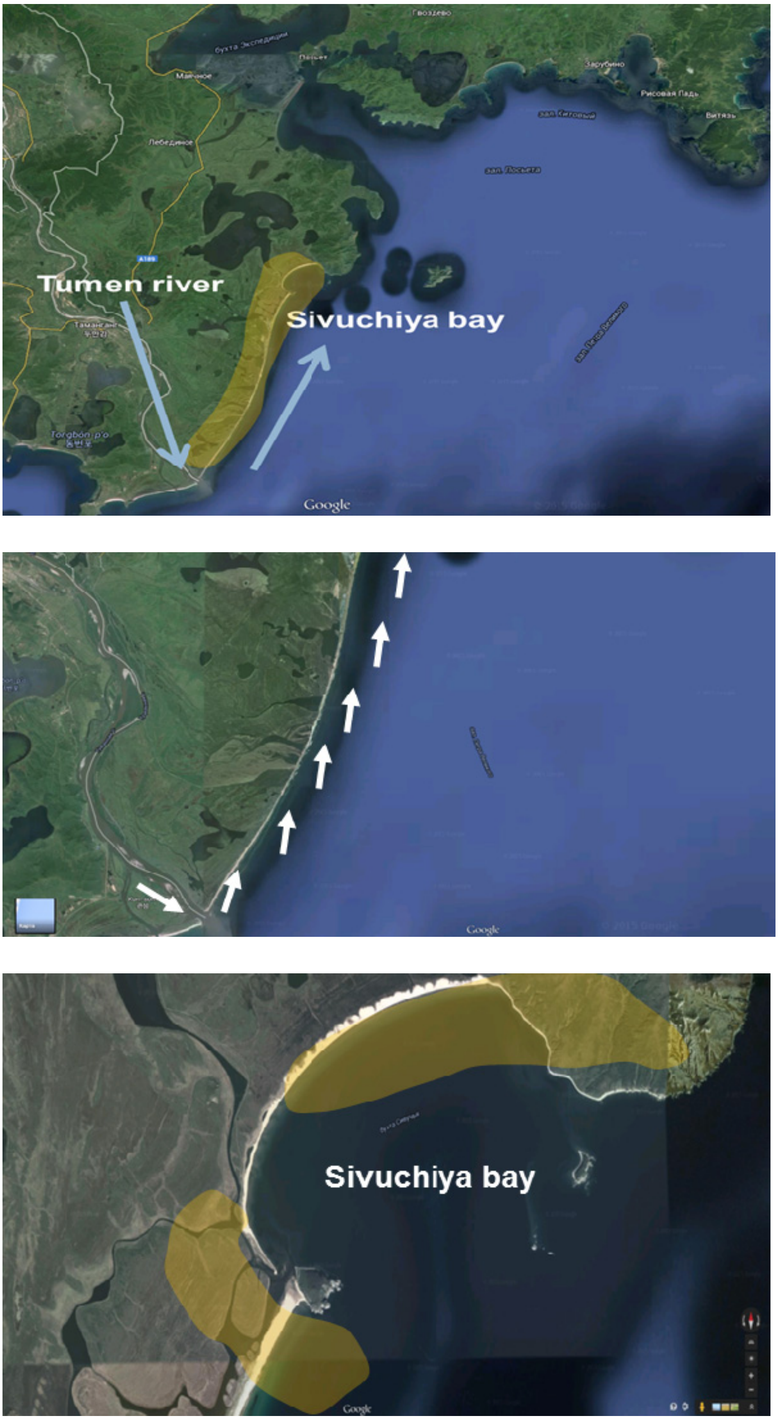


Figure 30. Movement of litter from the Tumen River mouth to the Sivuchiya Bay.

Numerous vortices and stream flows registered in the southwestern area of the Peter the Great Gulf show considerable impact on marine litter transportation.

Primorsky Krai Administration for Hydrometeorological and Environmental Monitoring reported that the superficial currents can change their direction during strong cyclones and typhoons. As far as no detailed surveys of these phenomena were carried out, it is impossible to define actual boundaries of the areas of floating marine litter concentration. This is the reason why all hydrodynamic shadows can be potential litter concentration areas. The activities of floating litter monitoring after storms and approval of theoretical spots of floating litter accumulation are planned to be carried out in the near future.

The probability of finding floating litter from water areas of the neighboring NOWPAP countries outside the Peter the Great Gulf is low, as other Far Eastern Russia currents are local. The natural litter concentration areas are semi-closed bays of northern Primorsky Krai. Studies carried out in 2012-2014 resulted in finding litter of mainly local origin (recreational) or coastal fishing litter. Among these bays are the Olga Bay, the Vladimir Bay, the Valentin Bay, and the Rudnaya Pristan Bay (Fig. 31).

Figure 31. Marine litter concentration area in eastern coastal water area.

b) Strait of Tartary

The Strait of Tartary stretches within the limits of the NOWPAP region up to 52°N. This place is a potential accumulation area of transboundary floating marine litter. Location of the floating litter concentration spots is determined by the prevailing current patterns. The Strait of Tartary lies at the northeast part of the NOWPAP region between the mainland coast (Khabarovsky Krai) and western coast of the Sakhalin Island. Both coasts are high, steep and flattened, and the depths are irregular.

The pattern of constant superficial currents was determined by water circulation within the sea (Fig. 32). There are two vortex currents located in the northern (shallow) and southern (deep) parts. The southern vortex is weaker; consequently, it is difficult to define floating marine litter concentration areas there. The probability of floating marine litter movement from the neighboring regions and its coastal accumulation would be minimal. The litter registered in the area is unevenly distributed and mainly of recreational and fishing origin.

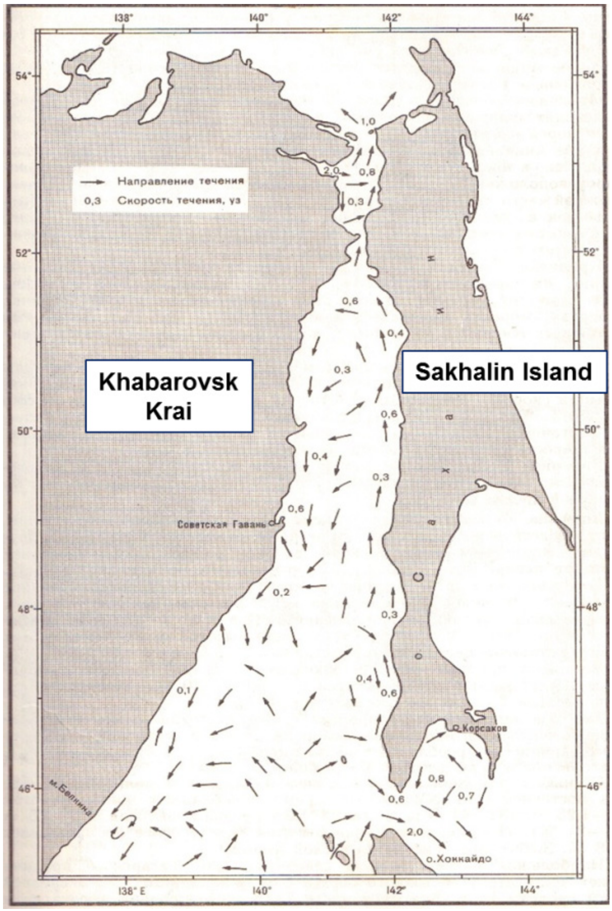


Figure 32. The pattern of constant superficial currents in the Strait of Tartary.

A peculiarity of currents in the Strait of Tartary is their proximity to the coasts. Along the western coast of the Sakhalin Island the current (a branch of the warm Tsushima Current) flows northward. Its speed ranges 0.8-1.0 knots. The following litter accumulation areas are singled out there: the southern coast of the Crillon Peninsula, the De Langle Bay, the Alexandrovsky Bay and the Nevelskoy Bay (Fig. 33). Local areas of distribution of transboundary floating marine litter belong merely to the southern coast of the Crillon Peninsula.

The probability of finding transboundary floating marine litter along the western coast of the Strait of Tartary is rather low and is solely natural for the Sovetskaya Gavan Bay (Fig. 33).

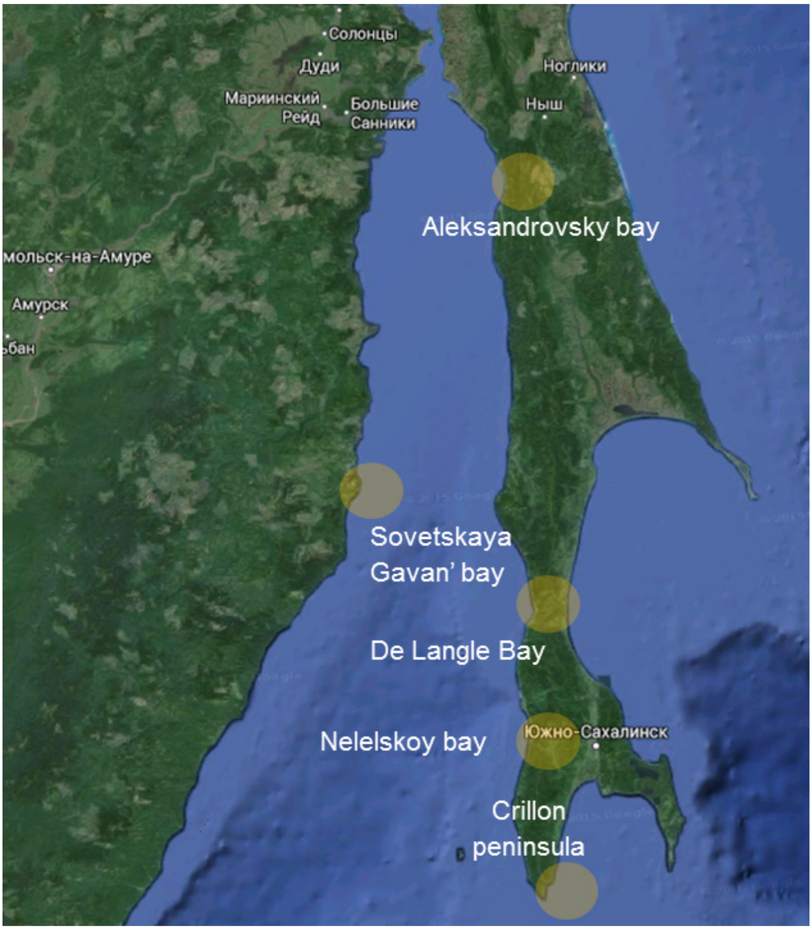


Figure 33. Marine litter concentration area in Tatarsky strait coastal water area.

c) Aniva Gulf

In Aniva Gulf, the pattern of currents is determined by the shoreline configuration, bottom relief, and tidal events. In La Perouse Strait, the Soya Current constantly flows southwest from the eastern NOWPAP sea area to the Sea of Okhotsk. The velocity of the constant currents along the Crillon Peninsula is about 0.6 knots, increasing to 0.8-2.0 knots from Cape Crillon to Cape Soya, and then decreasing to 0.8 knots southeast and to 0.4 knots east. Near the east end of Hokkaido, the current turns north and flows to Aniva Gulf (Fig. 34).

In Aniva Gulf, a constant weak current is registered (0.1-0.5 knots), directed mainly counterclockwise. The coast is of moderately irregular shape; the bench area within rocky bed is 700 m wide and the depth of the bench outer edge is 40 m. Considerable part of the bench dries out during the low tide. A considerable number of surface and hidden rocks are observed along the coast and some of these rocks are distanced to 1 mile from the coastline (from Morzh Bay to Korsakov port). This predetermines a possibility of inflow of transboundary marine litter to the east coast of the bay and its apex.

The marine litter concentration hot spots are located mainly along the Cape Aniva. The concentration of floating marine litter along the Tonino-Aniva Peninsula decreases northwards. Figure 35 shows marine litter hot spots in the Aniva Gulf.

The seasonal peculiarity of the Aniva Bay is determined by deep cyclones/typhoons crossing over the Japanese archipelago (Fig. 36). This increases the possibility of inflow of transboundary floating marine litter to the southern coast of Sakhalin.

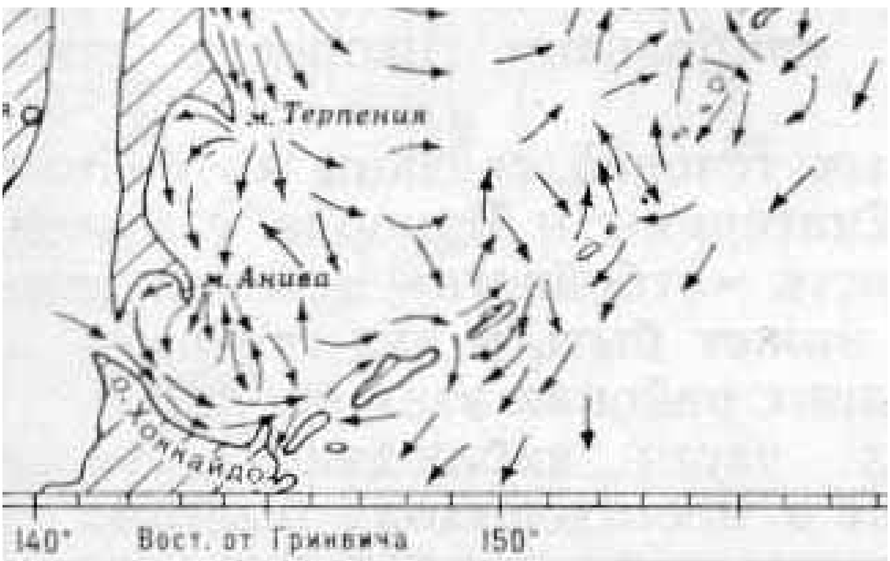


Figure 34. The pattern of constant superficial currents in the Laperuz Strait.

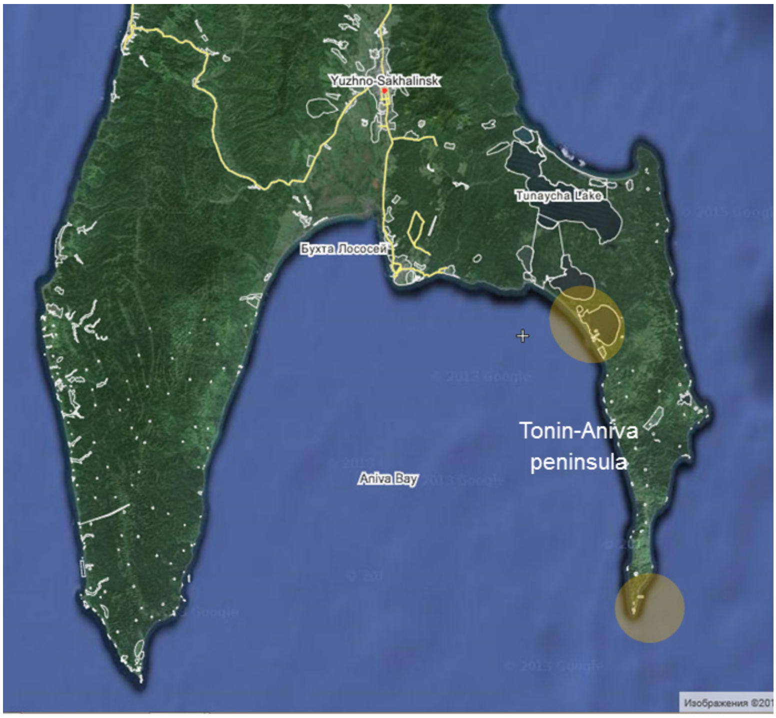


Figure 35. Marine litter concentration area in the Aniva gulf coastal water area.

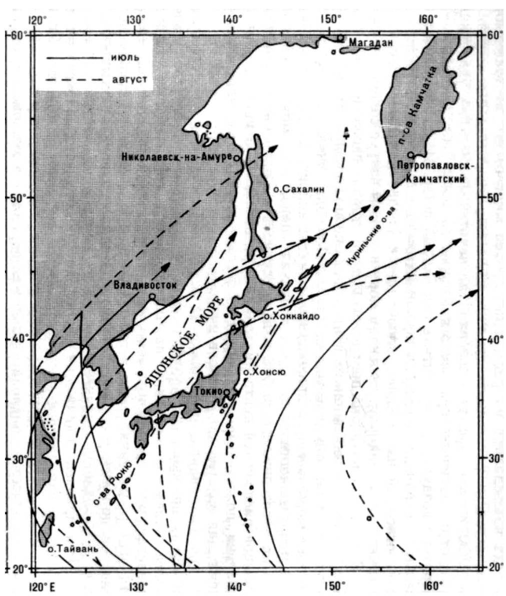


Figure 36. The most probable typhoon trajectories at the Far East.

d) Sea of Okhotsk

The impact of the transboundary marine litter on the coast of the Sea of Okhotsk is relatively low. Nevertheless, the combination of natural geographical factors does not exclude the possibility of finding marine litter on the eastern coast of Sakhalin. Figure 37 shows the northern boundary of the NOWPAP region, and it is evident that marine litter can be observed in this area.

Figure 37. The northern boundary of the NOWPAP region.

Figure 38. The pattern of constant superficial currents in the Sea of Okhotsk.

The general circulation in the Sea of Okhotsk is counter-clockwise (Fig. 38). In this regard, the transboundary marine litter can be registered only at the eastern coast of the Tonino-Aniva Peninsula.

Figure 39 shows the sites of the most possible locations of transboundary floating marine litter in the area.

Figure 39. Marine litter concentration area in the western coast of the Sea of Okhotsk.

e) Results of the field studies on the verification of the distribution areas of transboundary floating marine litter

In order to verify the theoretical calculations on the distribution of transboundary floating marine litter in the Russian parts of the NOWPAP region, a number of field studies were carried out along the southern coast of Primorsky Krai. Figures 40 and 41 show the observation areas.

All of the study sites were characterized by transboundary floating marine litter. As it was repeatedly noted at the NOWPAP meetings, the major part of the litter along the Russian coasts is generated locally (due to recreational activities) and the amount of foreign-originated litter is rather small.

Nevertheless, it is worth notifying that the transboundary floating marine litter was composed of consumer plastics and fishing gear (i.e., buoys, nets). Most of them were registered in the meeting points of Tsushima and Primorskoye currents, forming a complex hydrologic vortex delivering marine litter to the shore. Figure 42 shows the examples of litter found, supposedly of foreign origin.

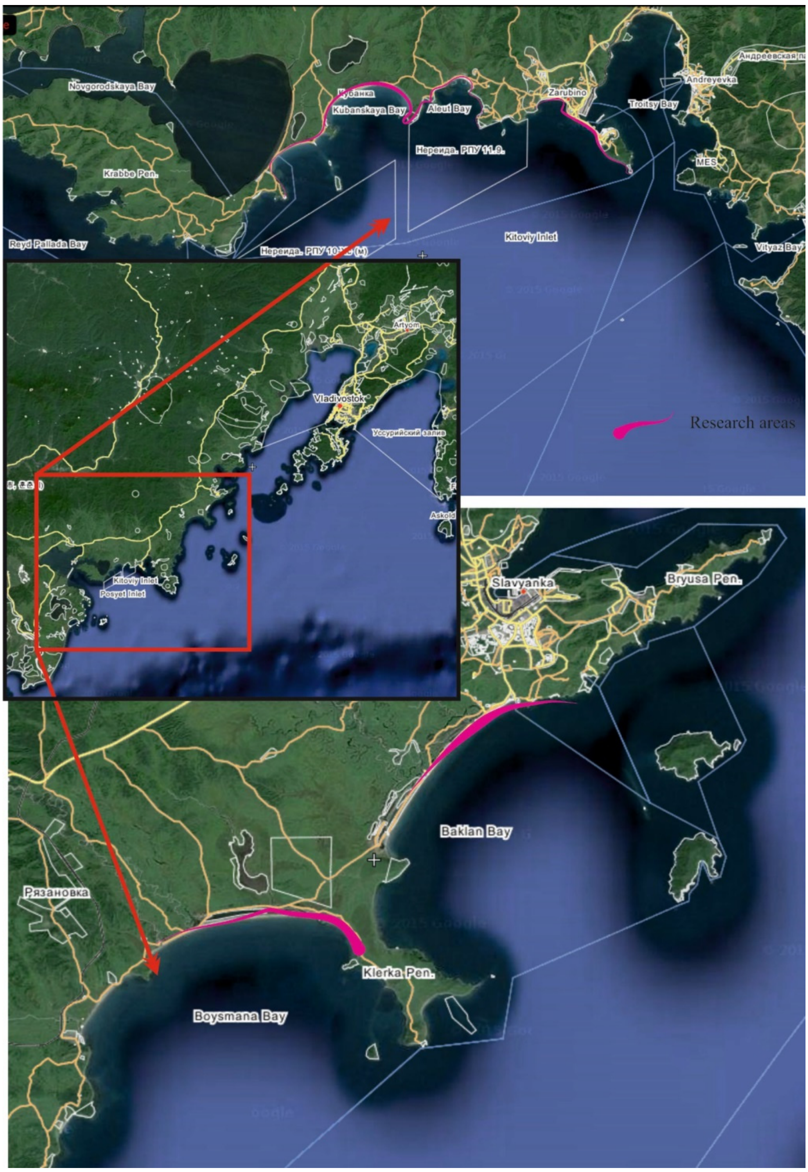


Figure 40. Research areas in the south-west part of Primorsky region.

Figure 41. Research areas in the south part of the Primorsky region.

Figure 42. Examples of foreign originated marine litter found.

Chapter 5. Conclusions and Recommendations

We cannot emphasize enough how many negative impacts marine litter give to the marine ecosystem, local tourism and economics, and the safety of the beach goers as well as the navigation. But unfortunately, due to the global economic development and increase in the consumption of products, the amount of marine litter is continuously increasing. Litter management and recycling systems have been introduced, but it seems they are not enough to mitigate the increase of the garbage produced.

Furthermore, marine litter problem is not confined to a single nation: they could travel without political boundaries, which causes transboundary issues and diplomatic discomfort. It requires international/regional cooperation to solve such marine litter problems.

In the spirit of international cooperation, since 2008, regional movements in the NOWPAP region have been successfully initiated to solve the transboundary marine litter issues under the NOWPAP RAP MALI and greater priority has been put on raising public awareness and strengthening the monitoring systems in the region. It was recognized that preventing marine litter is as important as (or more important than) collecting/ recycling marine litter in the region.

Scientific analyses for the identification of the quantity, causes (sources) and trajectory of floating marine litter are also required to establish appropriate preventative measures and effective response measures. Setting up continuous and regular monitoring programs is also a very important element as the marine litter issue will not be temporary but a long-term problem. It would also be useful for the verification of the effectiveness of the marine litter management policies.

The NOWPAP member states (Japan, People's Republic of China, Korea and Russian Federation) have individually been conducting monitoring and implementing different national policies and management systems. On the other hand, the NOWPAP region, where the four member states are located close to each other, needs to take more cooperative actions to solve the problem of marine litter because the transboundary issue of floating marine litter is significant in the region.

While this report has attempted to give a brief summary of the results of the national monitoring of the NOWPAP members on floating marine litter, the project on floating marine litter will be continued with the next MERRAC RAP MALI project on 'Review and analysis on existing floating marine litter prediction models in the NOWPAP region'.

If the current report was to understand the current situation and seriousness of floating marine litter in the NOWPAP region by conducting some qualitative analysis and overviewing the situation with a geographical viewpoint, the next project will be more concrete as it will overview the prediction model results in the NOWPAP region and analyze the trajectory of floating marine litter through more scientific analysis.

Application of numerical modelling is one of very important ways to predict the trajectories of marine litter and it also provides scientific basis for establishment of policies and regulations, and also for relevant international cooperation in the region. Instead of only monitoring and collecting the marine litter repeatedly at any specific area in the region, the results of numerical modelling provide scientific explanation on how, where and when the floating marine litter was washed ashore. However, such results should be used solely for understanding natural trajectory of floating marine litter, raising of public awareness and regional cooperation and not for blaming each other.

Furthermore, it is well known that the 80% of marine litter derived from land-based activities generally come through the river mouth and is transported by winds and currents. Conducting numerical modelling will allow tracing the source and trajectory of the land-sourced marine litter and also preventing the root of the problem in the NOWPAP region.

Recently, there are also public and scientific concerns on microplastics as small plastic fragments and their negative impacts on the marine environment are rapidly increasing in the NOWPAP region. Cooperative actions including special monitoring and prediction modelling should be conducted on micro plastics as well under the NOWPAP MALI framework.

References

Andrady L. A., “Common plastics materials”, in: Andrady, A. L. (Eds.), Plastic and the Environment. John Wiley & Sons, Inc., New Jersey, U.S.A., pp.77-121, 2003.

Andrady, L. A., 2011. “Microplastics in the marine environment.” Mar. Pollut. Bull., 62, 1596-1605., 2011.

Coe, J. M., and Rogers, D. B., “Marine Debris: sources, impacts and solutions”. Springer, New York, 1997, 432p.

Cole M., Lindeque, P., Halsband, C., Galloway, T. S., “ Microplastics as contaminants in the marine environment: A review.” Mar. Pollut. Bull., 62, 2588-2597, 2011.

Derraik, J. G. B. “The pollution of the marine environment by plastic debris: a review” Marine Pollution Bulletin, 44, 842-852, 2002.

Dohan, K., and Maximenko N. “Monitoring Ocean Currents with Satellite Sensors”, Oceanography 23(4): 94-103, 2010.

Evan A. Howell., Steven J. Bograd., Carey Morishige., Michael P. Seki., and Jeffrey J. Polovina “On north pacific circulation and associated marine debris concentration” Marine Pollution Bulletin 65 (2012) 16-22.

Hirose, N., Takayama, K., Jae-Hong Moon., T. Watanabe., and Nishida, Y. “Regional data assimilation system extended to the East Asian marginal seas”. Umi to Sora (Sea and Sky), 89(2), 43-51, 2013.

Isobe, A., “Recent advances in ocean circulation research on the Yellow and East China Sea Shelves”. J. Oceanogr. 64, 569-584, 2008.

Isobe, A., K. Kubo, Y. Tamura, S. Kako, E. Nakashima, and N. Fujii "Selective transport of microplastics and mesoplastics by drifting in coastal waters", Marine Pollution Bulletin, 89, 324-330, 2014.

Japan Meteorological Agency http://www.data.jma.go.jp/

Kako, S., A. Isobe, S. Magome "Seaquential monitoring of beach litter using webcams" Marine Pollution Bulletin, 60(5), 775-779, 2010.

Kako, S., A. Isobe, M. Kubota "High-resolution ASCAT wind vector data set gridded by applying an optimum interpolation method to the global ocean" Journal of Geophysical Research -Atmospheres, 116, D23107, doi:10.1029/2010JD015484, 2011a.

Kako, S., A. Isobe, S. Magome, H. Hinata, S. Seino, and A. Kozima "Establishment of numerical beach litter hindcast/forecast models: an application to Goto Islands, Japan" Marine Pollution Bulletin, 62(2), 293-302, 2011b.

Kako, S, A. Isobe, T. Kataoka, and H. Hinata "A decadal prediction of the quantity of plastic marine debris littered on beaches of the East Asian marginal seas", Marine Pollution Bulletin, 81, 174-184, 2014.

KHOA http://www.khoa.go.kr/koofs/eng/observation/obs_real.do

Lebreton, C.-M., and Borrero, J. C., “Modeling the Transport and Accumulation Floating Debris Generated by the 11 March 2011 Tohoku Tsumami”, 2013.

Ministry of Fishery of Republic of Korea, “National Marine Litter Monitoring Report”, 2010a.

Ministry of Fishery of Republic of Korea, “Special Monitoring on Foreign-Originated Marine Litter”, 2010b.

Ministry of Fishery of Republic of Korea, “National Marine Litter Monitoring Report”, 2011.

Ministry of Fishery of Republic of Korea, “National Marine Litter Monitoring Report”, 2012.

Ministry of Fishery of Republic of Korea, “National Marine Litter Monitoring Report”, 2013.

Ministry of Fishery of Republic of Korea, “National Marine Litter Monitoring Report”, 2014.

Ministry of Fishery of Republic of Korea, “National Marine Litter Monitoring Report”, 2015.

Morrison, R. J. “The regional approach to management of marine pollution in the South Pacific”. Ocean Coastal Management, 42, 503-521, 1999.

Nakashima, E., A. Isobe, S. Magome, S. Kako, and N. Deki "Using aerial photography and in-situ measurements to estimate the quantity of macro-litter on beaches" Marine Pollution Bulletin, 62(4), 762-769, 2011.

Nakashima, E., A. Isobe, S. Kako, T. Itai, S. Takahashi "Quantification of toxic metals derived from macroplastic litter on Ookushi beach, Japan", Environmental Science & Technology, 46, 10099-10105, 2012.

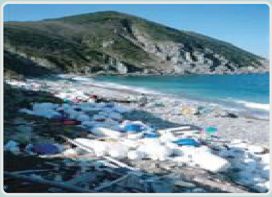
NOWPAP POMRAC. “State of the Marine Environment Report for the NOWPAP Region (SOMER-2). 2014

NOWPAP POMRAC. “Intergrated Coastal Planning and Ecosystem-Based Management in the Northwest Pacific Region”. 2015

Randriarilala, F., T. Kitakado, D. Shiode, M. Sakaguchi, T. Hayashi, and T. Tokai. “Density Estimation of the density of giant jellyfish Nemopilema nomurai around Japan using an alternative modified detection function to left truncation in a shipboard line transect survey”, Fish. Sci., 80, 261-271, 2014.

Ribic, C., Dixon, T.R., Vining, I., “Marine Debris Survey Manual” NOAA Technical Report, NMFS 108. US Department of Commerce, Washington, DC, USA, 100 p, 1992.

Richardson, P. L. “Drifting in the wind: leeway error in shipdrift data” Deep Sea Res, 44(11), 1878-1903, 1997.



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Regional Activity Centre

UNEP IMO

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