12. JAPAN

Summary of research topics: *Japan's research effort on marine plastics is notable for its early start in 2001 and its breadth across research topics covering most aspects of pollution by plastics. Some of the research requires a more technical understanding and advanced research material (i.e. plastic as a transport vector, and plastic adsorption/desorption experiments). All environs are also being investigated, including a few studies on the deep seafloor and deep-sea organisms. More than half of the articles published seek to quantify the presence and abundance of marine plastic debris. The second most common research focus is ecological and environmental impacts, with a primary interest in ingestion of macro- and microplastics by various marine life, including seabirds, fish, and shellfish.*

Summary of understanding at national level: *For most of the microplastics studies published, the studies distinguish the types of plastic polymers and the shapes of plastics (i.e. fragments, microbeads, pellets, etc.), as well as specific ecological and environmental impacts. However, there is limited polymer-specific research investigating the extent of polymer-types fragmentation and degradation in the marine environment. Nearly one-third of the papers focus on marine plastics as a pathway for pollution by other organic substances or by inorganic contaminants (e.g. POPs and heavy metals). Dominant sources of marine plastics appear to be ALDFGs, rivers, land runoffs and untreated sewers. Other sources mentioned are the unintentional release to the environment of resin pellets during manufacturing and transport, as well as plastic fragments from nearby large ocean basins. No investigation on plastic transfer through the food chain has been found, nor article on the physical impacts of macroplastics on marine life such as endangered migratory species (e.g. whales, sea turtles and seabirds).*

Keywords/research fields: *National approach; solid waste; trade of plastic waste; research foci; marine environs; laws and administrative measures; public outreach; beach clean-up; waste management; surveys and monitoring; methodology for the monitoring and assessment of marine litter; source differentiation; contribution from fisheries; ALDFG; contribution from rivers; accumulation zones; hotspots; fragmentation and degradation; ecological and environmental impact; movement of plastics; adsorption-desorption of contaminants; organic contaminants; inorganic contaminants; plastics as transport vector; plastic additives; main players*

12.1 Context

12.1.1 National approach to plastic waste and its management

Japan has adopted a Packaging Waste Recycling Act (covering PET since 1997, and others since 2000), and promotes domestic packaging waste recycling to reduce the burden of waste disposal of municipalities (Terazono, 2019).

In addition, there are strict plastic separation regulations for households, as well as a good plastic collection system in place at the national level. The Plastic Waste Management Institute (PWMI), originally founded in 1971, now has the objective of surveying and researching the recycling of plastic waste and helping plastic-related industries expand their business soundly in Japan (PWMI, 2019: available https://www.pwmi.or.jp/ei/about.pdf).

Based on studies from PWMI Japan, the country has good recycling capabilities, with a high 86% plastic 'recycling' rate in 2017 (PWMI Japan, 2019; Figure 1.2.13.1). Approximately 58% would be credited to incinerated plastic through 'thermal recycling' to recover energy, while the remaining 28% is equally split between actual plastic recycling within the country, and exported plastic waste to other countries, respectively.

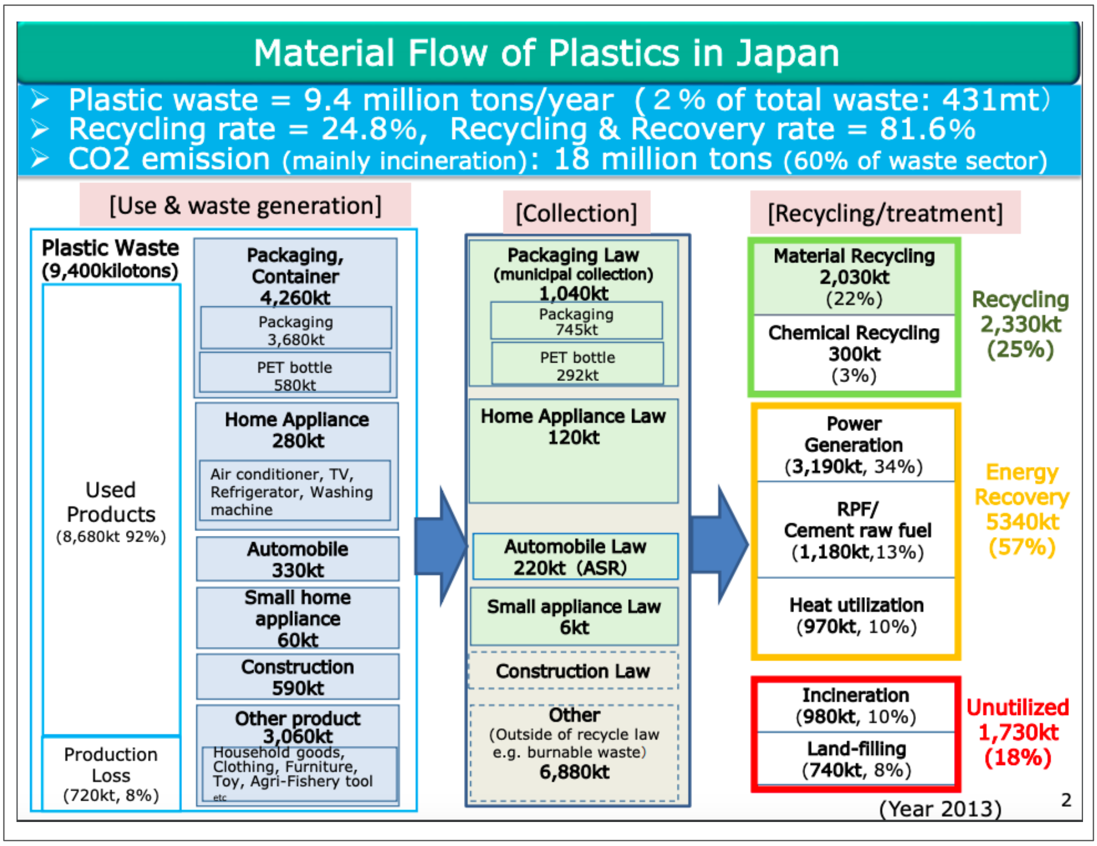

Figure 1.2.13.1. Plastic resource flow in Japan (source: Ministry of the Environment, Japan).

In June 2018, the Ministry of the Environment considered a plastic resource recycling strategy due to interest in marine plastics (Terazono, 2019). The 'Plastic Resources Circular Strategy (Draft)' was adapted in March 2019 and submitted to the Minister of the Environment. The current strategy proposes '3R + Renewable' as a basic principle. Specifically, restrictions on use (Reduce), thorough separation and recycling (Recycle), bioplastics introduction, marine plastic countermeasures, etc. are included. Japan also has various regulations in place, such as the Containers and Packaging Recycling Law which adopts concepts of EPR to hold businesses responsible for their plastic usage. However, a challenge for Japan appears to be the existing long-term emphasis on waste incineration and energy recovery, with limited demand for recycled plastics.

On reducing plastic waste, Japan targets to reduce single-use plastic by 25% by 2030. At the recent G20 Osaka Summit meeting, Japan launched the 'Osaka Blue Ocean Vision' (available: https://www.mofa.go.jp/files/000493728.pdf), which aims to reduce additional pollution by marine plastic litter to zero by 2050.

In November 2019, a joint-panel of Japan's industry and environment ministries agreed to require all retailers nation-wide to place charges on plastic bags, regardless of sizes, in effect from July 2020 (Channels News Asia, 2019: available https://www.channelnewsasia.com/news/asia/japan-retailers-charge-plastic-bags-2020-12055412) . This move was said to be a leading step to the then-upcoming 2020 Tokyo Olympics and Paralympics (before the onset of the COVID-19 pandemic), which had undertaken the UN Sports for Climate Action framework pledge (https://www.olympic.org/news/tokyo-2020-sustainable-games-for-a-sustainable-society).

12.1.2 Plastics as a proportion of solid waste

In 2016, the MSW (excluding disaster waste such as debris from the tsunami) was estimated at 44.6 million tonnes, and with a projection of reaching 45 million tonnes in 2030, but with a decline to 43.3 million tonnes in 2050 as population declines (Kaza et al., 2018).

Reports emphasise an obsession of Japanese people with hygiene and their pride in 'omotenashi' or customer service, which would dictate that everything should be wrapped with multiple layers of plastic packaging. It was estimated that every person in Japan uses around 300 or 400 plastic bags annually, which is equivalent to more than 40 billion for the entire nation. (Washington Post, 2019, available: https://www.washingtonpost.com/world/asia_pacific/japan-wraps-everything-in-plastic-now-it-wants-to-fight-against-plastic-pollution/2019/06/18/463fa73c-7298-11e9-9331-30bc5836f48e_story.html).

By contrast, the government reports very high recycling rates. Estimates from 1986 indicate that plastics accounted for 7% to 20% of total solid waste across the various major cities in Japan (Sakai, 1996). A more recent estimate by Jambeck et al. (2015) suggests that the national average for Japan would be 10%, and interestingly, 0% of mismanaged waste.

However, Harada (2015) surmised that several major rivers in Japan are sinks of marine litter. For instance, the Kansai Wide Area Union estimated about 3 million plastic bags and 6.1 million plastic pieces on the seafloor of Osaka Bay, suggesting possible leakages into river systems (The Sankei News, 2019: available https://www.sankei.com/west/news/190612/wst1906120024-n1.html).

12.1.3 Illegal trade of plastic waste

Prior to the 2018 China ban on imported plastic waste, Japan was exporting up to 1.5 million tonnes of plastic waste into China annually. Following the ban, Japan redirected its plastic waste to alternative countries in the Southeast Asia region (Greenpeace, 2019). Specifically, Japan redirected its plastic waste primarily to Malaysia, Thailand and Vietnam, and sent much smaller shipments to Myanmar, the Philippines, Singapore, Lao PDR, and Cambodia (Trademap, 2019 from Greenpeace, 2019). In 2018 alone, Japan exported 430,064 tonnes to ASEAN, making it one of the top exporters of plastic waste in this region.

12.2 Research review of pollution from marine plastic

12.2.1 Research overview

Research on marine plastics in Japan is in progress, with a moderate number of published peer-reviewed articles (n=30). Although the number of publications may not be comparable to that of some countries reviewed here (e.g. China, Indonesia, the RO KOREA and Malaysia), there is a high level of awareness of marine plastics among the scientific community, with notable researchers leading scientific research.

A non-academic association, the Plastic Waste Management Institute (PWMI) Japan was founded in December 1971 to oversee research and develop technology for the optimal processing and effective use of plastic waste, as well as to publicise their findings. More recently, PWMI's objectives were newly re-established in April 2013 as "surveying and researching the recycling of plastic waste and contributing to a reduction in environmental load by the total recycling of plastic, and helping plastic-related industries to expand their business soundly and contributing to the creation of a society capable of sustainable growth." Two publications are available in English: An Introduction to Plastic Recycling 2016 (https://www.pwmi.or.jp/ei/plastic_recycling_2016.pdf) and Plastic Products, Plastic Waste and Resource Recovery 2017 (https://www.pwmi.or.jp/ei/siryo/ei/ei_pdf/ei48.pdf).

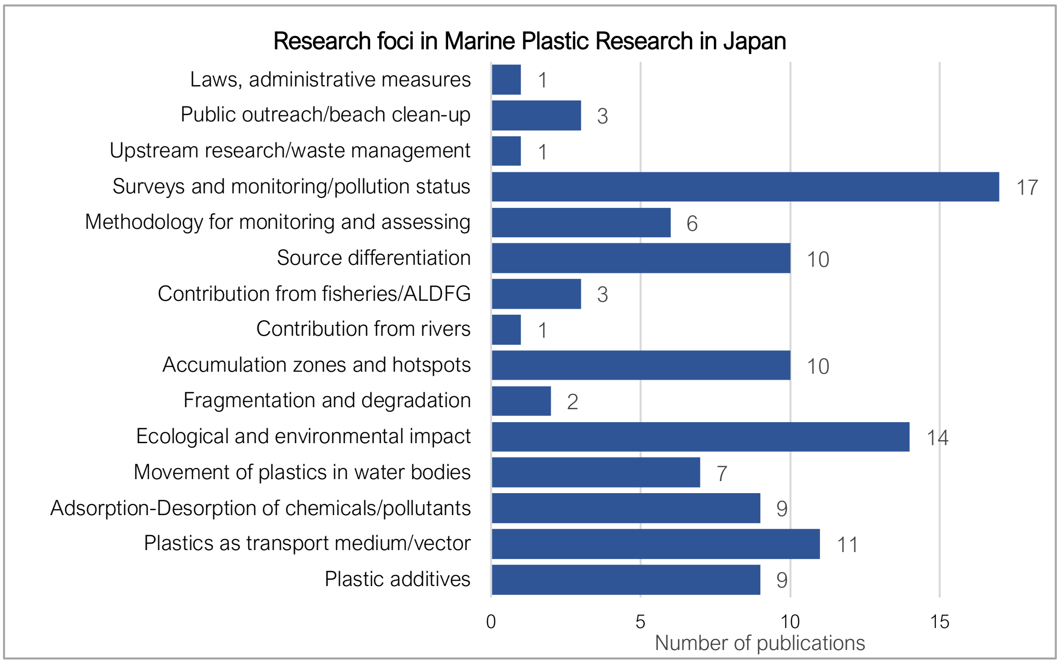

Figure 1.2.12.2. Research foci of marine plastic research conducted in Japan.

The 30 studies reviewed were conducted in different decades; three studies in 2001, 2003, and 2005 respectively, and 27 studies between 2011 and 2019, which geographically cover the entire shoreline of island Japan. No studies have been found for the Ryukyu Archipelago (Okinawa), south of the main island.

In 2019 alone, seven studies were published, the highest yearly count. This suggests an increased interest in the field of marine plastics. In general, these studies cover a wide range of research topics and provide useful insights to various issues surrounding marine plastics in Japan.

Looking at the research foci in more detail (Figure 1.2.12.2), Japan research efforts show a balanced interest in nine research foci. The majority of studies focus on survey and monitoring to understand pollution status (n=17), followed by ecological and environmental impact (n=14), plastics as transport vector (n=11), source differentiation (n=10) and accumulation zones and hotspots (n=10). Other major interests include the adsorption-desorption of chemicals and pollutants by plastic debris, and the impacts and interactions of plastic additives with plastic debris.

12.2.2 Types of research conducted

Types of plastics research foci

Studies examining microplastics focus either on their presence/absence in marine biota (Tanaka and Takada, 2016; Jamieson et al., 2019) or in coastal environs such as sediments (Matsuguma et al., 2017) or coastal waters (Hirai et al., 2011; Isobe et al., 2014, 2015; Isobe, 2016; Sagawa et al., 2018); on hydrodynamic modelling of how microplastics move with ocean currents (Iwasaki et al., 2017; Isobe et al., 2019; Amamiya et al., 2019); or on contamination of microplastics with other pollutants (Mato et al., 2011; Hirai et al., 2011), typically associated with marine biota such as seabirds (Yamashita et al., 2011; Tanaka et al., 2013, 2015, 2019) and mussels (Endo et al., 2005). There was also an experimental study that looked at the ingestion and egestion of size-dependent microplastics by mussels (Kinjo et al., 2019).

Macroplastics studies also focus on different research areas, which include abundance surveys (Kusui and Noda, 2003; Goto and Shibata, 2015; Chiba et al., 2018); heavy metal contamination of macro-debris (Yamashita et al., 2011; Nakashima et al., 2012; Tanaka et al., 2013, 2015; Nakashima et al., 2016); methods to detect and quantify macroplastic debris (Kako et al., 2011; Kataoka et al., 2012, 2013); hydrodynamic modelling of how macroplastics move with ocean currents (Isobe et al., 2014; Kataoka et al., 2015; Kataoka and Hinata, 2015; Maximenko et al., 2018); and policy regarding plastic waste management (Terazono, 2019). Apart from PVC (Nakashima et al., 2012, 2016), no other polymer type was identified for the macroplastic studies.

Studies that look at both micro- and macro-plastics can be divided into two groups: one that looks at impacts of contaminated (PCB and PBDE) plastics on seabirds (Yamashita et al., 2011; Tanaka et al., 2013, 2015), and the other that looks at survey and transport of plastics in coastal waters (Isobe et al., 2014, 2015; Iwasaki et al., 2017).

Coverage of marine environs

Of the 30 studies examined (Figure 1.2.13.4), the shoreline environment appears to have benefited from the most attention (Mato et al., 2001; Kusui and Noda, 2003; Endo et al., 2005; Hirai et al., 2011; Kako et al., 2011; Nakashima et al., 2012; Kataoka et al., 2012, 2013, 2015; Kataoka and Hinata, 2015; Sagawa et al., 2018; Amamiya et al., 2019). This is followed by coastal waters (Hirai et al., 2011; Isobe et al., 2014, 2015, 2016; Nakashima et al., 2016; Iwasaki et al., 2017; Sagawa et al., 2018; Maximenko et al., 2018; Isobe et al., 2019; Amamiya et al., 2019).

The other studies examined impacts of marine plastics on marine organisms, such as Japanese anchovy (*Engraulis japonicus*) (Tanaka and Takada, 2016), Mediterranean mussel (*Mytilus* *galloprovincialis*) (Endo et al., 2005; Kinjo et al., 2019), few species of seabirds (Yamashita et al., 2011; Tanaka et al., 2013, 2015, 2019), and deep sea Lysianassoidea amphipods (Jamieson et al., 2019). Few studies have examined the occurrence of macroplastics in sediment cores (Matsuguma et al., 2017) and on or in the deep seabed (Goto and Shibata, 2015; Chiba et al., 2018).

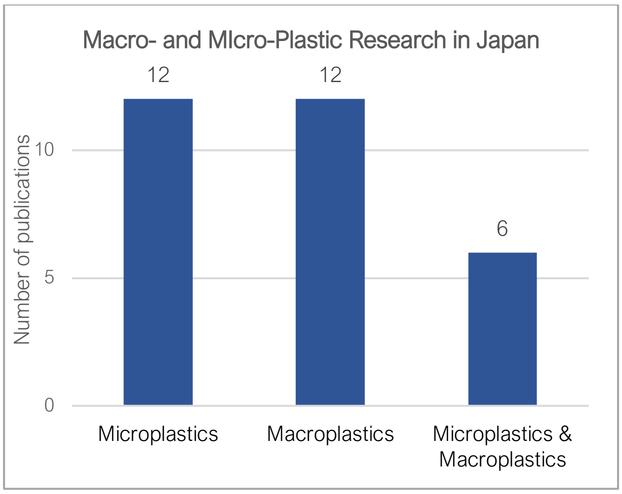

Figure 1.2.12.3. Marine micro-/macro-plastics researched in marine plastic research in Japan.

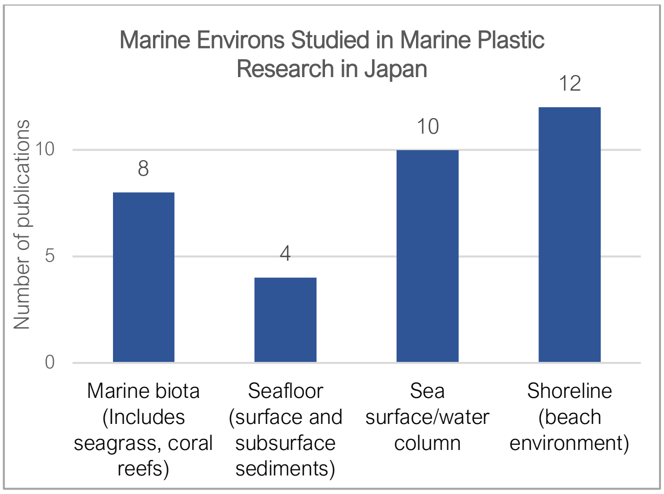

Figure 1.2.12.4. Distribution of marine environs researched in Japan.

12.2.3 Survey and monitoring

More than half of the published articles conducted surveys and monitoring in various marine environs, but the methods used to study distribution and abundance are varied. Some studies attempted to quantify marine plastics in beaches (Kusui and Noda, 2003; Isobe et al., 2015), the deep-sea (Goto and Shibata, 2015; Chiba et al., 2018), sediment cores (Matsuguma et al., 2017), and coastal waters (Isobe, 2016). A paper by Sagawa et al. (2018) also examined microplastics in three areas: bottom sediments, beach sediments, surface waters.

With respect to marine biota, one paper focused on the presence/absence of plastics in seabirds (Yamashita et al., 2011; Tanaka et al., 2013, 2015, 2019) and another on Japanese anchovy (Tanaka and Takada, 2016). These studies typically quantified the abundance of plastics relative to an individual, for instance, the number of plastic fragments ingested per individual or total number of plastic fragments found in sampled individuals. Most of these studies identified the types of plastic polymers, such as PE, PP, PS. Generally, these studies sought to quantify abundance of plastics based on counts (e.g. number of litter items, concentration of litter in items per 100m^2, weight of debris, number of plastic pieces per kg).

Most of the studies also examined the types of microplastic polymers, and the types of macroplastics (e.g. fishing gear, household items, metals, glass, wood). Studies of microplastics mostly adhered to the definition of size <5 mm, and they also reported the shapes of microplastics (such as fibre, fragment, granule, film, foam, pellet). Among the microplastic studies conducted, the following plastic polymer types were identified: FPS, EVA, PE, PA, PP, PS, PEP, PET, PAK, PVA, PVC, PCL, PMMA, PEPD (Tanaka and Takada, 2016; Matsuguma et al., 2017; Sagawa et al., 2018; Tanaka et al., 2019; Amamiya et al., 2019; Jamieson et al., 2019).

New techniques were also being developed to assess distribution and quantity of marine plastic debris on beaches (Kataoka et al., 2012) and in the ocean (Isobe et al., 2014) on a large scale and with less human resources. Kataoka et al. (2012) also developed a technique to detect pixels of plastic debris monitored through time-series images, thus allowing users to compute the amount of beached plastic debris, and to remotely monitor the amount of plastic debris. Isobe et al. (2014) assessed the occurrence of small plastic fragments using field surveys and numerical particle-tracking model (i.e. hydrodynamic modelling) to understand plastics accumulation.

Other authors have surveyed the presence of toxic chemicals (Mato et al., 2001; Hirai et al., 2011; Yamashita et al., 2011; Tanaka et al., 2013, 2015, 2019) or heavy metals (Nakashima et al., 2012) on plastic debris, either on micro- or macroplastics.

12.2.4 Source differentiation and pathways

A substantial number of papers (n=10) examine or mention potential sources of plastics to the oceans. A dominant source of marine plastics in Japan's coastal waters appears to be derived from offshore fisheries and (derelict) fishing gear (Isobe et al., 2014; Goto and Shibata, 2015; Nakashima et al., 2016; Sagawa et al., 2018). The next common source would be derived from rivers (Isobe et al., 2014), land runoffs (Amamiya et al., 2019), and untreated sewers (Isobe, 2016; Tanaka and Takada, 2016).

Several papers also referred to the March 2011 Tohoku Earthquake and the large quantity of anthropogenic debris that seemed to have been transported by the tsunami into the ocean (Goto and Shibata, 2015; Maximenko et al., 2018). Other sources mentioned are the unintentional release to the environment of resin pellets during manufacturing and transport (Mato et al., 2001) as well as plastic fragments from nearby large ocean basins (i.e. Yellow Sea and East China Sea) that would contribute to marine plastics found in coastal waters of Japan (Isobe et al., 2015).

Notably, some papers were concerned with the adsorption-desorption of organic and inorganic contaminants associated with marine plastic debris whether as plastic additives or otherwise. For example, PP resin pellets were found to contain significant concentrations of PCBs and DDE (Mato et al., 2001; Endo et al., 2005), while plastic fragments may have had PCBs, PAHs, DDTs, PBDEs, NP, and BPA (Hirai et al., 2011). As demonstrated further in studies, these contaminated particles became potential vectors of chemicals and pollutants when consumed by marine life such as seabirds (Yamashita et al., 2011; Tanaka et al., 2013, 2015, 2019).

12.2.5 Movement of plastics, accumulation and hotspots

Studies examining the movement of plastics, accumulation and hotspots can broadly be categorised into two groups. The first category focuses on the seaward transport of plastic debris from the shoreline (beach) and via different circulation models (Kako et al., 2011; Kataoka et al., 2013, 2015; Kataoka and Hinata, 2015). The second category focuses on transport of plastic debris within coastal waters via numerical and particle-tracking modelling that also use currents and wind data (Isobe et al., 2014, 2019; Iwasaki et al., 2017). In particular, Maximenko et al. (2018) used numerical simulations to investigate the movement of macro-debris derived from the Great Japan Tsunami 2011.

12.2.6 Ecological and environmental impacts

Studies that focused on ecological impacts include impacts on marine life via ingestion of plastic debris, with an apparent interest in seabirds (Endo et al., 2005; Yamashita et al., 2011; Tanaka et al., 2013, 2015, 2019). These studies on seabirds also discussed the uptake and possible transfer of contaminants (i.e. toxic chemicals and heavy metals) to the tissues of these seabirds. More recently, studies have examined the impacts of microplastics on fish (Tanaka and Takada, 2016) and invertebrates (Jamieson et al., 2019; Kinjo et al., 2019). Notably, the study by Jamieson et al (2029) was conducted in various marine environs, including the deep-sea.

With respect to environmental impacts, some studies briefly mentioned direct impacts on the environment, such as the way plastic debris affected the marine environment, but none in detail. Similarly, these studies were conducted in various marine environs, from the beach (Kako et al., 2011), sediment cores (Matsuguma et al., 2017), to deep-sea areas (Chiba et al., 2018).

Papers that looked at both ecological and environmental impacts only implyied potential risks to shorelines exposed to contaminated plastic debris (Mato et al., 2001; Hirai et al., 2011; Nakashima et al., 2012). They suggested that further studies are needed to characterise impacts.

Of note, no studies were found on the physical impacts of plastic debris on marine wildlife such as endangered migratory species known to come through Japan’s EEZ, except for one study on the ingestion of PCB-contaminated plastic debris by seabirds (e.g. Tanaka et al., 2013, 2015, 2019).

12.2.7 ALDFG

Few papers (three out of 30) specifically mention impacts of ALDFG in Japan, despite being highlighted as a potential dominant marine plastic source in oceans (see Part 1, Section 13.2.4).

In particular, two papers noted the presence of derelict fishing gear in deep-sea areas (Goto and Shibata, 2015; Chiba et al., 2018). Goto and Shibata (2015) noted that a major source of sea-based debris found post-tsunami 2011 was fishing gear and related items from adjacent fishing grounds.

Chiba et al. (2018) also found that ALDFGs cause entanglement with several deep-sea organisms.

Another paper by Sagawa et al. (2018) documented an indirect impact of ALDFG, whereby the foamed polystyrene (FPS) derived from oyster culture had been found to break down into small FPS microplastics (i.e. using digital microscopy, field emission scanning electron microscopy (FE-SEM) and X-ray computed tomography (X-ray CT) to deduce sinking and fragmentation process). As a result, these FPS microplastics could be found in both beach and bottom sediments off Hiroshima Bay.

12.2.8 Social perceptions and socio-economic impacts

There is no published peer-reviewed study on social perceptions, but possibly these data and information may exist in the form of unpublished reports, or were published in Japanese.

A single study strongly implied the socio-economic impacts of marine plastic pollution on a commercially-valuable fish, the Japanese anchovy (*Engraulis* sp.). The species is widely distributed around Japan and is a common food in the country. The study finds that >70% of sampled fish contain microplastics. Typically eaten without removal of their digestive tracts, the presence of microplastics in the guts of this fish means that human consumers and predators of this fish (such as other fish, birds and marine mammals) are directly exposed to ingestion of marine plastics. This study also pointed out that consuming fish that ingested contaminated plastics from the marine environment may pose health risks.

12.3 Main players in marine plastic research

More than 90% of marine plastic research conducted in Japan is carried out by locally-based researchers (n=28), with one study led by an international institution from RO KOREA and another one from the UK (Figure 1.2.13.5). Several Japanese researchers appear to have taken the lead of marine plastics research over different research foci.

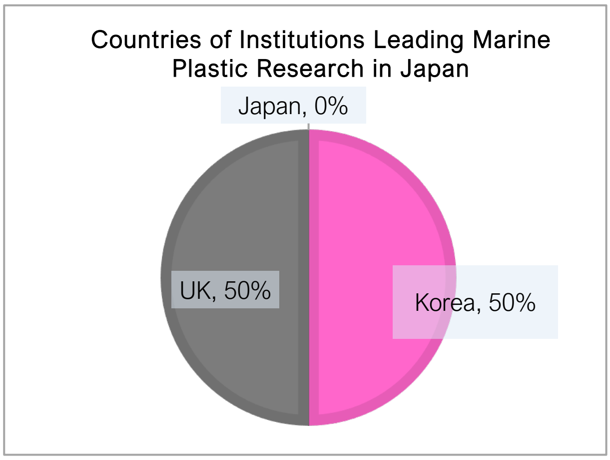

Figure 1.2.13.5. Composition of research efforts in Japan.

Takada, H. of Tokyo University of Agriculture and Technology has been conducting research since 2001 (Mato et al., 2001), with a specific focus on contaminants associated with marine plastic debris, particularly their impact on marine seabirds and other biota. Isobe, A. of Kyushu University also stands out as another lead researcher whose focus is on forecasting the quantity and movement of plastic debris around Japan waters. Other researchers, Hinata, A. of Ehime University and Kataoka, T. of the National Institute for Land and Infrastructure Management have worked closely together to examine accumulation zones and hotspots, and movement of plastics in water bodies.

12.4 Summary of understanding

Japan is an early pioneer in the publication of studies on the country's status of marine plastic pollution; the earliest article found was published in 2001. The interest of the scientific community has steadily increased since, with the highest number of articles found in 2019 alone. The research effort is also notable for its breadth across research topics covering most aspects of pollution by plastics. Some of this research requires a more technical understanding and advanced research material (i.e. plastic as a transport vector, and plastic adsorption/desorption experiments). All environs are also being investigated, including a few studies on the deep seafloor and deep-sea organisms – an environment not as well-studied in most other countries.

More than half of the articles published seek to quantify the presence and abundance of marine plastic debris. Across the studies, varied methodologies have been used in monitoring marine litter in marine biota and environments across Japan. This makes it difficult to do cross-comparisons. On closer examination, comparisons may be possible between studies conducted by the same researchers, as they attempt to streamline their protocols for their work (e.g. studies published by the team at Tokyo University of Agriculture and Technology).

For most of the microplastics studies published, papers distinguish the types of plastic polymers and the shapes of plastics (i.e. fragments, microbeads, pellets, etc.), as well as specific ecological and environmental impacts. However, there is limited polymer-specific research investigating the extent of polymer-types fragmentation and degradation in the marine environment. Of the studies examined for Japan, nearly one-third of them investigated how marine plastics can act as a pathway for pollution by other organic substances or by inorganic contaminants (e.g. POPs and heavy metals).

The second most common research focus is ecological and environmental impacts, with a primary interest in ingestion of macro- and microplastics by various marine life, including seabirds, fish, and shellfish. No investigation on plastic transfer through the food chain has been found so far. Interestingly, there is no peer-reviewed article on the physical impacts of macroplastics on marine life such as endangered migratory species (e.g. whales, sea turtles and seabirds).

Marine plastic research in Japan appears to be in at an advanced stage regionally, as studies are beginning to present evidence of a direct link between plastic pollution and marine wildlife health. The current research landscape also appears to be uniquely heterogenous, as overlaps in research interests seem to be minimal among lead researchers. As one of the leading countries in this research area in the region, it would be beneficial for Japanese researchers to engage the wider scientific community and conduct knowledge exchanges of their current techniques. In particular, some research groups have developed novel methodologies for monitoring and assessing marine litter more efficiently; these methodologies could be shared with the wider scientific community within the ASEAN+3 region.

Japan appears to have an elaborated regulation system in place for the management of public waste, including plastics. However, it seems that half of the reported (high) recycling rates goes to waste-to-energy incineration, and that plastic use remains very high within the country. Notably, there are articles suggesting pathways for the discharge of land-based plastic debris into the oceans via river systems. These pathways might be more numerous than what has been believed before.

There has been a conscious effort from the research community in Japan to investigate and differentiate sources and pathways of marine plastic debris, including offshore fisheries and derelict fishing gear, land-based sources (i.e. rivers, land runoffs, untreated sewers), and how marine plastics are transport vectors of chemicals and pollutants across the oceans. However, only a handful of articles have identified abandoned fishing gears and rivers as an important source of discharge of plastic waste at sea. More research in these two areas would therefore be useful.