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Addressing Marine Plastics
A Systemic Approach

Addressing marine plastics:

A systemic approach

Stocktaking report

Acknowledgements

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Acronyms

10YFP	10 Year Framework of Programmes on Sustainable Consumption and Production
ABTA	Association of British Travel Agents
ADUPI	Association of Recyclers in Indonesia
ALDFG	Abandoned, lost or otherwise discarded fishing gear
ASEAN	The Association of Southeast Asian Nations
CBD	Convention on Biological Diversity
CEMPRE	Compromisso Empresarial Para Reciclagem
CMS	Convention on the Conservation of Migratory Species of Wild Animals
EDC	Endocrine disruptor chemical
EPR	Extended producer responsibility
EPRO	European Association of Plastics Recycling and Recovery Organisations
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
G7	Group of Seven
G20	Group of Twenty
GEF	Global Environment Facility
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GGGI	Global Green Growth Insitiute
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities
GPML	Global Partnership on Marine Litter
HELCOM	Helsinki Commission
HELCOM MONAS	Helsinki Commission Monitoring and Assessment Group
ICC	International Coastal Cleanup
IMO	International Maritime Organization

IUCN	International Union for Conservation of Nature
MARPOL	International Convention for the Prevention of Pollution from Ships
MSFD	EU Marine Strategy Framework Directive
NGO	Non-governmental organisation
NOAA	National Oceanic and Atmospheric Administration
NPO	Not-for-profit
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, bioaccumulative and toxic substance
PETCO	PET Recycling Company
PoM	Programme of Measures
POP	Persistent Organic Pollutant
PRO	Producer Responsibility Organisation
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SAICM	Strategic Approach to International Chemicals Management
SCBD	Secretariat of the Convention on Biological Diversity
SDGs	Sustainable Development Goals
UN	United Nations
UN DESA	United Nations Department of Economic and Social Affairs
UNCLOS	United Nations Convention on the Law of the Sea
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UV	Ultraviolet
WWF	World Wildlife Fund

Types of plastics

PET	Polyethylene terephthalate (Resin code 1)
HDPE	High-density polyethylene (Resin code 2)
PVC	Polyvinyl chloride (Resin code 3)
LDPE	Low-density polyethylene (Resin code 4)
PP	Polypropylene (Resin code 5)
PS	Polystyrene (Resin code 6)
EPS	Expanded polystyrene
PE	Polyethylene
PMMA	Poly (methyl methacrylate)
PUR	Polyurethane
PP&A	Polyester, polyamide and acrylic

Plastic-related chemicals

BPA	Bisphenol A
BPP	Butyl benzyl phthalate
DEHP	Di(2-ethylhexyl) phthalate
DIDP	Diisodecyl phthalate
DINP	Diisononyl phthalate
HBCDD	Hexabromocyclododecane
PBDE	Polybrominated diphenyl ethers
PCB	Polychlorinated biphenyl
PCN	Polychlorinated naphthalene
TBBPA	Tetrabromobisphenol A

Executive summary

From cigarette butts and plastic packaging to microfibers arising from artificial textiles, the issue of plastics and microplastics polluting the world's oceans is gaining global prominence. This is a large and complex environmental and social problem that requires a collaborative response. Raising awareness of and seeking ways to address this environmental challenge is fast emerging as one of the key issues of our time.

This report takes stock of the extent of knowledge on plastics in the marine environment.[1] It provides a high-level summary of the available literature on the key sources and locations of these plastics, along with an analysis of the problem products and polymers making up marine plastics and microplastics. It also looks at what is currently being done to address the problem of marine plastics and summarises existing policy responses in order to lay the groundwork for future action.

The information for this report has been gathered partly through a review of the available literature, and partly through expert input.

The sources of plastic in the marine environment

Approximately 6,300 million tonnes of plastics are estimated to have reached end-of-life since the start of mass production in the 1950s. With only around 9% of global plastic waste recycled and 12% incinerated, and the fact that plastic is extremely durable, the majority of these plastics are accumulating, either in landfills or in the environment.

To date, relatively few studies have quantified the flow of plastics into the marine environment. And existing studies tend to use the same underlying data on plastic waste generation in their calculations, resulting in similar findings and ranges.

Based on this limited data, the majority of plastics appear to enter the ocean directly from maritime activities and coastal communities, or from inland water catchments via major river systems. Where plastics come from depends on the characteristics of the region. For example, in regions with high fishing and shipping activities, such as the North Sea, sampling studies find marine activities make up a large share of the plastics collected. The degree to which land-based sources are a significant component of marine plastics in a region depends on the propensity for plastics to find their way into rivers and coastal waters. This largely depends on the amount of littered and mismanaged plastics at end-of-life, which in turn depends on such factors as the coastal population density, the plastic consumption habits of the population and local waste management practices (or lack thereof).

The type of land-based plastic products entering the oceans vary and can mostly be linked directly to the major source of plastic litter in the region. Nonetheless, it is clear that single-use and short-lived products (such as bottles, plastic bags and straws) are the key contributors to marine plastics across the globe. This is due to the sheer volumes in which they are consumed. Packaging and other short-lived consumer goods make up around half of global plastics production.

Marine plastics tend to be most highly concentrated on shorelines. However, the relatively small footprint

1. This stocktaking report is prepared under Component 3 of the Global Environment Facility (GEF) funded project: Addressing Marine Plastics – A Systemic Approach.

of coastal shorelines means that plastics collecting on shorelines accounts for only around 5% of the total mass of plastics in the oceans. Floating plastics are thought to sink within a few months of entering the marine environment, and it is estimated that only around 1% of marine plastics are floating on the open-ocean surface. This means that in excess of 90% of the total mass of plastics in the oceans is potentially on the seafloor.

There is still much to be understood around the fate of plastics in the marine environment. There is up to three times less plastic mass observed in the ocean than the mass of plastics calculated to be in the ocean (using estimates of land-based plastic flows into the ocean). To understand why there is this large disparity between observed and calculated plastic flows requires improving our understanding of the mechanisms through which plastics are "removed" from the ocean (for example, sinking, fragmentation and ingestion by marine life), representative sampling of the marine environment (for example, through developing standardised sampling procedures) and through more accurate estimates of plastic flows into the oceans. The latter requires better data on per capita plastics consumption and on plastics mismanaged at end-of-life, as well as better models on the fate of mismanaged plastic waste flows (i.e. understanding the pathways through which plastics accumulate in terrestrial environments and/or enter the oceans).

The impacts of plastics in the marine environment

The impacts of marine plastic are broad and include environmental impacts, as well as impacts on marine industries and on the livelihoods of communities that rely on them.

Environmental impacts range from short-term impacts, such as the entanglement of animals, to longer-term impacts, such as the bioaccumulation of toxic compounds in the food chain. Over 500 species are known to be affected by ingestion, entanglement and ghost fishing, with over 800 species affected if dispersal by rafting and habitat effects are included. Research has also indicated impacts on smaller species, such as zooplankton.

Industries such as shipping, tourism and fishing that operate in the marine environment can also be severely impacted by plastic pollution. This has knock on effects on the individuals and communities relying on these industries as a source of food or income.

Significant gaps exist in knowledge on the possible effects of smaller microplastics[2] and nanoplastics on seafood safety. With the information currently available, the FAO puts the health risk to humans through ingesting seafood contaminated with plastic as negligible, but there are currently no methods to reliably observe and quantify these potential effects.

Key products and polymers making up marine plastics

Cigarette butts (cellulose acetate) are consistently the most commonly occurring item in coastal cleanup data, while the biggest contributor of larger plastic items in the marine environment (macroplastics) is packaging. Both coastal cleanup data and production data point consistently to this. Polymers used widely in packaging (HDPE/high-density polyethylene, LDPE/low-density polyethylene, PP/polypropylene and PET/polyethylene terephthalate) can thus be expected to be dominant in marine plastics too. Buoyant plastics, especially bottles and products made from Styrofoam (polystyrene) have a high propensity for washing up on beaches. Polystyrene (PS) is thus identified as a polymer of concern in marine plastics, despite accounting for a relatively small share of polymers used in packaging.

Single-use consumer products and fishing gear are also indicated in coastal cleanup data to be significant sources of plastics in the ocean. These products are made from a variety of polymers.

2. The general convention that microplastics are plastic particles < 5 mm in size is followed in this report. Primary microplastics are plastics manufactured at this micro particle size, whilst secondary microplastics are micro particles of plastic formed from the fragmentation and weathering of larger plastic particles. In this report the distinction is made between *land-based* secondary microplastics (such as those arising from washing textiles and the abrasion of tyres), and *marine-based* secondary microplastics, formed from the fragmentation and weathering of plastic items already in the marine environment.

The polymers with the highest toxicological concerns are polystyrene (PS), polyvinyl chloride (PVC) and those incorporating flame-retardant chemicals. These polymers are primarily used in electronics, transport and building and construction products. These longer-lived products are not found to be prevalent in marine plastics, but their potential presence is of concern because of their high toxicity.

Macroplastics degrade constantly within the ocean due to wave action, sunlight, biological action and other processes to form secondary microplastics. Additionally, primary microplastics, such as microbeads found in personal care products and cosmetics, and accidental losses of pellets from plastic production and recycling industries, have found their way into the marine environment. Pellet losses occurring in production and transport spills tend to be of the polymers used most widely by industry (PE/polyethylene and PP/polypropylene).

Land-based secondary microplastics are postulated in top-down modelling studies to be the greatest source of microplastics in the ocean. Fibres released during the washing of artificial textiles and particles from the abrasion of tyres are the largest potential sources of microplastic flows to the oceans. Other potential sources include particles from the application, abrasion and disposal of marine coatings (primarily polyurethane and vinyl), and particles from the abrasion of various objects and infrastructure (so called city dust), which include a wide mix of polymers.

Data from field studies confirm that microfibers from artificial textiles are the largest source of observed microplastics in the ocean. This is consistent with modelling studies that relate potential microplastic flows to the washing of artificial textiles, although dolly ropes and fishing nets are also indicated to be sources of microfibers in the oceans. Polymers from tyre losses are not evident in field studies, most likely due to limitations in detecting particles in the nano size range rather than their not being present.

The top-down modelling studies indicate industrial pellets and microbeads to be only minor sources of microplastics. However, the fact that industrial pellets and microbeads are visible to the naked eye (whilst fibre losses are visible only under microscope and tyre dust is below current detection limits), and are commonly found items in beach cleanups, means that they tend to get more attention from the public and policy makers, particularly since these sources are relatively easy to take action on.

Actors and initiative addressing marine plastics

The remarkable global profile of marine plastics is thanks in part to an increasing number of actions being taken at all levels of society. A range of different actors, including inter-governmental agencies, industry alliances, foundations and non-governmental organisations (NGOs) are driving initiatives to stem the flow of plastics into the oceans. These include **knowledge-oriented initiatives** that aim to add to the knowledge base on marine plastic flows and impacts and to identify potential solutions, and **action-oriented initiatives** that aim to change the status quo, for example, through raising awareness and promoting the sustainable use of plastics. The focus of industry and government initiatives tends to be around minimising waste, especially promoting recycling and better waste management, while the focus of foundations and not-for-profits is broader, with a ground-swell of campaigns working to reduce plastic consumption, especially of single-use plastics.

Measures and policies addressing marine plastics

Marine plastic is now firmly on the global environmental agenda for action. Marine plastic litter and microplastics have been the subject of resolutions at United Nations Environment Assembly (UNEA)-1, -2 and -3. Sustainable Development Goal 14 of the 2030 Agenda for Sustainable Development (Conserve and sustainably use the oceans, seas and marine resources) sets targets specifically on marine litter. Five of the Group of Seven (G7) nations have agreed to an Ocean Plastics Charter that commits the leaders of Canada, France, Germany, Italy, the United Kingdom and the European Union to take action toward "a resource-efficient lifecycle management approach to plastics in the economy".

The most encompassing legislation on marine plastic is the **United Nations Convention on the Law of the Sea (UNCLOS)**. It is the only binding policy that requires nations to minimise pollution from both marine and land based sources that may enter the marine environment.

The **Regional Seas Conventions and Action Plans** are of direct relevance to reducing marine plastic pollution. The action plans target key activities and sources of plastic waste in 18 separate regions and set binding and non-binding legislation to reduce these sources.

The **European Union (EU) Marine Strategy Framework Directive** (MSFD) is the first European Union legislative instrument related to the protection of marine biodiversity and ecosystems through managing human activities that have an impact on the marine environment. The Marine Strategy Framework Directive requires member states to develop a marine litter strategy, thus most member countries have implemented - or are in the process of developing - National Marine Strategies. Other countries with strategies or action plans on marine litter include Japan, the USA and Australia.

The **European Strategy for Plastics in a Circular Economy** is a global leader in describing the vision for a revised and sustainable plastics economy. This document includes aspects on: improving the economics and quality of recycling, preventing waste and littering, increasing investment and innovation in circular solutions and increasing global action.

More than 60 countries have introduced measures to curb single-use plastic waste. After the prominence of World Environment Day 2018, the number of government, industry and consumer led actions continue to rise. Plastic bags and, to a lesser extent, foamed plastic products have been the main focus of government action so far. Bans on single-use plastic bags have been especially evident in developing countries, particularly Africa and Asia, with restrictions and other disincentives (taxes or levies) motivated primarily by waste management and litter concerns. Most European Union member countries have taken some form of action on plastic bags, but unlike in developing countries, economic instruments and public-private agreements have been more prevalent than bans. The limited information that is available on restrictions and bans of single-use plastics indicate that policies and legislation can only be successful with sufficient monitoring and enforcement. The availability of alternatives is also an important success factor. Furthermore, taxes can be ineffective if not pitched at the correct level and point of application in the value chain.

Next steps

The studies reviewed in this report highlight that while much work has been done on the issue of marine plastics, much is still to be understood, particularly around the fate of plastics in the marine environment, and the potential for impacts at the nano scale, including impacts on seafood safety.

There are several positive steps that have been taken and opportunities to capitalise on. The benefits of a circular plastics model in particular and the potential to avoid plastics waste extend beyond improving marine ecosystems, with clear co-benefits of improved human health and livelihoods. There are also economic benefits, with significant opportunities for innovation in new materials and product systems. The challenges ahead will lie in catalysing the innovation required and creating the environment and partnerships for sustainable business models to flourish.

The next steps are to elaborate on the gaps that need to be addressed and identify opportunities to continue to move forward in addressing marine plastics. A subsequent report in this project will analyse the gaps, barriers and opportunities and provide recommendations for action.

1

Introduction

This stocktaking report is prepared under Component 3 of the Global Environment Facility (GEF) funded project: Addressing Marine Plastics – A Systemic Approach. It provides a high-level summary of the available literature on the key sources and residing locations for plastic in the marine environment, along with the major problem products and polymers comprising marine plastics and microplastics. The stocktaking exercise then looks at what is already being done to address the problem of marine plastics, including who is addressing the problem (the various key actors and their respective initiatives to address marine plastics and microplastics), as well international governance frameworks. Regional and national policies are discussed to establish what legislation is currently in place to address marine plastics in key regions. The conclusions of the report look forward to the next steps, which are to identify opportunities that can address the gaps in knowledge and action identified through the stocktaking.

1.1. Methodology

The information for the stocktaking report has been gathered partly through a review of the available literature, and partly through obtaining expert input. The desk-based literature review looked particularly at the large consolidation-type reports and studies of, amongst others, United Nations Environment Programme, Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), Secretariat of the Convention on Biological Diversity (SCBD), Ocean Conservancy and Ellen MacArthur Foundation, as well as the recent scientific literature. Expert input was obtained through a multi-stakeholder consultation workshop on a systemic approach to marine plastics, convened by UN Environment in Paris on 15 and 16 February 2018. The workshop included 40 participants across a range of nationalities and stakeholders, including industry, academia, non-governmental organisations (NGOs), not-for-profits (NPOs), regional and national government and intergovernmental organisations from a marine litter background and from a life cycle/circular economy plastics background.

1.2. Context to the study

Marine litter and microplastics has been a cause of concern for a number of decades, with the first reports of marine plastics and microplastics occurring during the 1960s and 1970s, respectively (Barnes et al., 2009). However, marine plastics has become a “hot topic” recently due to various studies highlighting both the very large volumes of plastics entering the oceans annually and the potential long-term impact of this pollution, with the most oft-quoted statistic being that if significant action is not taken, there may be more plastic than fish in the ocean, by weight, by 2050 (World Economic Forum et al., 2016). A major cause for concern is the non-biodegradability of plastic and the fact that is it nearly impossible to remove from the marine environment, resulting in a constant build-up of plastics within the world's oceans. This, compounded with the visible nature of plastics washing up on beaches, has resulted in a number of policies coming into effect to address this problem (UNEP, 2016a). However, the current status quo is not sustainable and different response options to better address marine plastics, including microplastics, are being discussed under the UN Environment Assembly, along with initiatives to prevent the situation from worsening (UN Environment, 2017a).

The marine plastics problem is however a vast and complex one, and one that cannot be easily addressed through a single policy or framework. This is due to the variable nature of the sources, the timing of inputs, and sizes of the particles, amongst numerous other factors. Size variability of plastic particles in the marine environment and the very wide range of sources, as represented in Table 1, illustrate the considerable difficulty in designing policies and interventions that can deal with the entire spectrum of plastics entering the ocean. This difficulty is compounded when other variables are considered, such as the time variability of the input. This time variability is demonstrated by considering one off events, such as the 2011 tsunami in Japan, which deposited an estimated 5 million tonnes of debris into the ocean (NOAA, 2015).

Table 1: Illustrative sizes and examples of plastics commonly found in the marine environment[1] (ten Brink et al., 2016)

Size class	Nano	Micro	Meso	Macro	Mega
Particle size	< 1 µm	< 5 mm	< 3 cm	< 1 m	> 1 m
Examples of plastic particles	■ Nanofibres from clothing ■ Rubber tyre dust ■ Nanoparticles in products and pharmaceuticals	■ Microbeads from personal care products ■ Fragments of larger plastic products ■ Polystyrene fragments ■ Blasting plastic from shipyards ■ Incineration particulates	■ Bottle caps ■ Plastic pellets ■ Fragments of larger plastic products	■ Beverage bottles ■ Plastic bags ■ Disposable tableware and cutlery ■ Take-away containers and disposable cups (including those of Styrofoam/ polystyrene) ■ Polystyrene packaging (sheets and chips) ■ Beer ties ■ Fishing lines, floats and buoys ■ Tyres ■ Pipes ■ Balloons and toys ■ Textiles	■ Fishing nets and traps ■ Rope ■ Boats ■ Plastic film ■ Construction PVC

1. Adapted from ten Brink et al. (2016).

Whilst the current momentum on marine plastics has seen a number of impactful studies being published in recent years, there is still a lack of consistent data and firm knowledge on the sources, quantities, pathways and impacts of marine plastics. Current estimates are based on a limited number of studies, which are often inconsistent, limited in their regional coverage, often based on relatively easy-to-access beach litter, and/ or rely on many assumptions for modelling (Eunomia Research & Consulting Ltd., 2016a, UN Environment, 2017a, UNEP, 2016b). Numerous studies continue to fill these gaps; nevertheless it is clear that, whilst the magnitude of the problem is increasingly clear, the many gaps in the knowledge base on marine plastic make it difficult to design policies and interventions to effectively tackle the problem. In particular, a systemic understanding of the multi-faceted problem is needed; understanding the quantities, behaviour and impact of plastics once in the ocean so as to design effective cleanup interventions, the sources and main channels of plastic entering the ocean so as to design interventions to prevent their entry, and finally understanding the types and demand for plastic products so as to design alternatives and strategies to mitigate their demand. This report therefore aims to summarise the current state of knowledge and to identify gaps in the knowledge that need to be filled, so as to ensure future initiatives and policy making is based on a sound knowledge base.

2

Plastics in the marine environment

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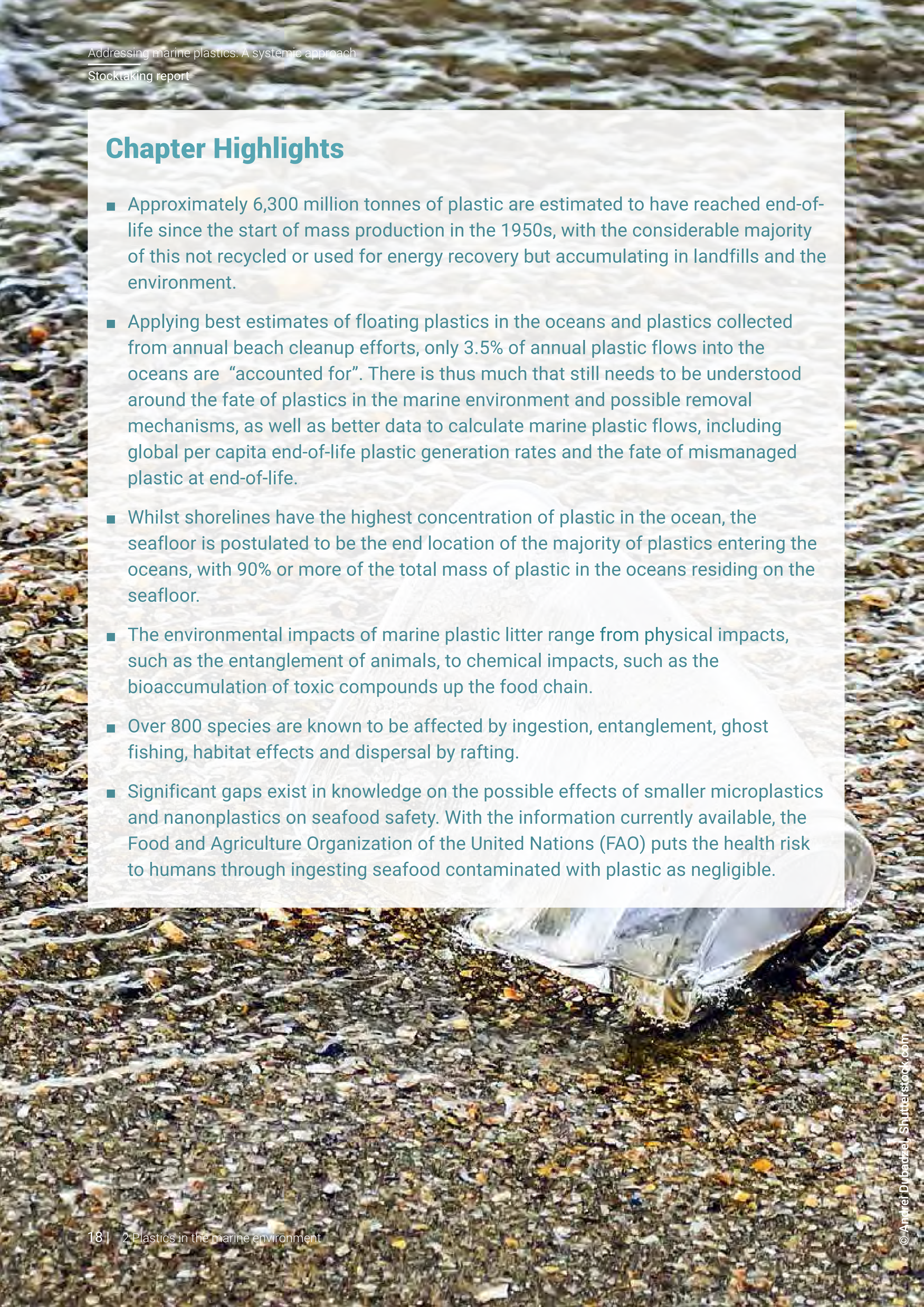


Chapter Highlights

- Approximately 6,300 million tonnes of plastic are estimated to have reached end-of-life since the start of mass production in the 1950s, with the considerable majority of this not recycled or used for energy recovery but accumulating in landfills and the environment.
- Applying best estimates of floating plastics in the oceans and plastics collected from annual beach cleanup efforts, only 3.5% of annual plastic flows into the oceans are "accounted for". There is thus much that still needs to be understood around the fate of plastics in the marine environment and possible removal mechanisms, as well as better data to calculate marine plastic flows, including global per capita end-of-life plastic generation rates and the fate of mismanaged plastic at end-of-life.
- Whilst shorelines have the highest concentration of plastic in the ocean, the seafloor is postulated to be the end location of the majority of plastics entering the oceans, with 90% or more of the total mass of plastic in the oceans residing on the seafloor.
- The environmental impacts of marine plastic litter range from physical impacts, such as the entanglement of animals, to chemical impacts, such as the bioaccumulation of toxic compounds up the food chain.
- Over 800 species are known to be affected by ingestion, entanglement, ghost fishing, habitat effects and dispersal by rafting.
- Significant gaps exist in knowledge on the possible effects of smaller microplastics and nanonplastics on seafood safety. With the information currently available, the Food and Agriculture Organization of the United Nations (FAO) puts the health risk to humans through ingesting seafood contaminated with plastic as negligible.

Global plastic polymer production (the building blocks of plastic products) amounted to some 335 million tonnes in 2016 (Plastics Europe, 2017), with Geyer et al. (2017) estimating that 8,300 million tonnes of virgin plastics have been produced to date since the start of mass production in the 1950s. This has resulted in approximately 6,300 million tonnes of plastic at end-of-life as of 2015 (Geyer et al., 2017). The considerable majority of plastics are derived from fossil fuels and are not biodegradable. Of high concern is thus the accumulation of plastic at end-of-life in the environment, with only around 9% of global plastic waste recycled and 12% incinerated, the majority of plastic at end-of-life is assumed to be accumulating in landfills (Geyer et al., 2017). However, the portion of accumulated end-of-life plastic that has made its way into the oceans is very difficult to estimate, as it requires knowledge on waste disposal practices in coastal areas and along inland watercourses, as well as models on the fate of littered and mismanaged plastic at end-of-life. Table 2 summarises some the studies that have estimated flows of plastic into the ocean and plastic accumulation in the ocean. The high uncertainty ranges given by the authors for their results is indicative of the difficulty in making these estimates.

Plastics of all forms, sizes and types enter the marine environment from a number of sources and through a number of different channels. An accessible review of plastic in the marine environment is available in Law (2017) *Plastics in the Marine Environment*, and also in UNEP and GRID-Arendal (2016) *Marine Litter Vital Graphics*.

Table 2: Estimates of annual plastic flows into the oceans

Study	Reference	Estimated annual input from coastal areas (million tonnes per year)	Estimated annual input from inland areas (million tonnes per year)	Estimated annual input from marine sources (million tonnes per year)	Estimated annual input of microplastics (million tonnes per year)
Plastic waste inputs from land into the ocean	(Jambeck et al., 2015)	4.8 – 12.7			
River plastic emissions to the world's oceans	(Lebreton et al., 2017)		1.15 – 2.41		
Export of Plastic Debris by Rivers into the Sea	(Schmidt et al., 2017)		0.41 – 4.00		
Marine litter vital graphics	(UNEP and GRID-Arendal, 2016)			0.05	
Plastics in the Marine Environment	(Eunomia Research & Consulting Ltd., 2016a)		0.075 – 1.1	0.3 – 3.25	0.5 – 1.4
Primary[1] microplastics in the oceans: a global evaluation of sources	(Boucher and Friot, 2017)				0.8 – 2.5

[1] Under the definition applied in this report, the plastic flows of Boucher and Friot (2017) include primary microplastics and land-based secondary microplastics.

2.1. Terminology

The term *plastic* is applied in this report to the range of materials that soften on heating and can be moulded into a wide range of solid objects (thermoplastic materials), as well as cross-linked materials that cannot be remoulded (thermosets, such as polyurethane (PUR) foams and epoxy resins). Plastics are made from polymers[3], which are molecules that have long chain-like molecular structures. The resins from which plastic polymers are made are typically blends, with chemicals added to enhance the performance of the material, including fillers, plasticisers, colourants and stabilisers.

3. The term resin is sometimes used inter-changeably with polymer, but in terms of chemistry, resins are mixtures of organic compounds, whilst polymers are macromolecules. Resins are solid or viscous materials that give rise to polymers during polymerization or curing.

Plastics in the marine environment are typically differentiated into macroplastics and microplastics. A more rigorous definition of plastic pieces has been to refer to nano-, micro-, meso-, macro- and mega-size ranges (GESAMP, 2015, UNEP and GRID-Arendal, 2016). These size classes have not yet been formally adopted by the international research community, and, at present, the lack of an agreed nomenclature, together with practical difficulties of sampling different size ranges in the field, has led to the widespread adoption of microplastics as a generic term for small pieces of plastic (generally defined to include plastic particles less than 5 mm in size) (GESAMP, 2015). In this report, macroplastic is applied to refer to plastic that is greater than 5 mm in size (i.e. plastic that is above the micro size range, but not limited to any particular size class).

In addition, it is worth noting while looking into the definition of marine plastic classes that macroplastics fragment through physical methods, ultraviolet (UV) degradation and biological action into microplastics over time. Therefore, once they are in the ocean, it is not possible to consider plastic that entered the ocean as micro particles independently from large plastic particles that have degraded into micro particles (Barnes et al., 2009, Boucher and Friot, 2017, Eunomia Research & Consulting Ltd., 2016b). Under the definition of the *Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection* (GESAMP, 2015), macroplastics that have degraded into microplastics are termed secondary microplastics to distinguish them from plastics that were manufactured at the micro particle size, e.g. microplastics in cosmetics (termed primary microplastics). However, different definitions of primary microplastics and secondary microplastics have been applied in the literature (Lassen et al., 2015). In their study Boucher and Friot (2017) apply the definition that primary microplastics are plastics released to the marine environment in the form of micro particles, regardless of whether they are manufactured at that size of are abraded from larger items outside of the marine environment; and secondary microplastics as microplastics originating from the breakdown of larger plastic items once exposed to the marine environment. For example, under the GESAMP definition tyre abrasion particles would be defined as secondary microplastics, whilst under the definition of Boucher and Friot (2017) they would be defined as primary microplastics.

The importance of a distinction between land-based "wear and tear" sources of microplastics and microplastics formed in the sea is recognised for life cycle and material flow type studies, but that different non-conflicting terms need to be agreed upon. In this report, the following definitions are applied:

- **Primary microplastics** are plastics manufactured at a micro particle size (typically less < 5mm);
- **Land-based secondary microplastics** are micro particles of plastic formed from the fragmentation and weathering of larger plastic items before entering the marine environment, such as from textiles, paint and tyres.
- **Marine-based secondary microplastics** are micro particles of plastic formed from the fragmentation and weathering of larger plastic items *within the marine environmen*t due to wave action, UV exposure etc.

2.2. Sources of plastics in the marine environment

The landmark study by Jambeck et al. (2015) *Plastic waste inputs from land into the ocean*, provides the most often quoted estimate of plastic entering the oceans - 4.8 to 12.7 million tonnes in 2010 - equivalent to dumping the contents of one garbage truck into the ocean every minute (World Economic Forum et al., 2016). The estimate calculated by Jambeck et al. (2015) is based on estimates of per capita plastic waste generation in 192 countries with populations living within 50 km of the coast, and estimates of the percentage of plastic waste that is mismanaged and ends up in the oceans, i.e. an estimate of the percentage of plastic waste that is littered or inadequately disposed of that enters the marine environment. The accuracy of this approach is dependent on the accuracy of the per capita waste generation rates and waste composition data applied in the model, which are poor and/or lacking for many countries (Hoornweg and Bhada-Tata, 2012), and the accuracy of the conversion rate of plastic mismanaged at end-of-life into marine plastics. For the latter Jambeck et al. (2015) explore three rates: low (15%), mid (25%) and high (40%), leading to the uncertainty range given in the results.

Recent studies by Lebreton et al. (2017) *River plastic emissions to the world's oceans* and Schmidt et al. (2017) *Export of Plastic Debris by Rivers into the Sea* build on that of Jambeck et al. (2015), in that they similarly use per capita plastic waste generation and estimates of mismanaged waste to estimate potential plastic flows, but calibrate their models using data on plastic concentrations in the water columns of a number of global rivers. Lebreton et al. (2017), Schmidt et al. (2017) and Eunomia Research & Consulting Ltd. (2016b) come up with similar ranges of plastic flows from river catchments into the ocean (see Table 2), which is to be expected given that the studies use similar approaches, and much of the underlying waste and river plastic data on which the models are based are common. It is, however, interesting to note that the estimated plastic flows of Lebreton et al. (2017) and Schmidt et al. (2017) are substantially lower than that of Jambeck et al. (2015), despite their models being based on global catchment areas covering much larger areas than the 50 km coastal zone considered in Jambeck et al. (2015). The river-based studies do acknowledge their estimates to be conservative due to the river data including only buoyant plastic of a size greater than the mesh size of the sampling nets. The river-based studies also do not account for the potential for plastic litter to enter the oceans via other mechanisms active in coastal areas, such as direct littering on beaches.

Global flows of microplastics entering into the oceans have been estimated by Boucher and Friot (2017) in the International Union for Conservation of Nature (IUCN) study *Primary microplastics in the oceans: a global evaluation of sources* and Eunomia Research & Consulting Ltd. (2016b) *Study to support the development of measures to combat a range of marine litter sources*. These studies both take top-down modelling approaches to estimating microplastic flows, and as such, show fairly similar results (Table 2). Both of the studies consider primary and land-based secondary sources of microplastics, estimating intentional and unintentional losses from seven potential sources; tyres, textiles, pellet losses, cosmetics, marine coatings, road markings and city dust. Tiny particles are washed into wastewater and storm water systems, from where they ultimately make their way into the oceans, with the quantity released dependent on the level of wastewater treatment received. Abrasion of synthetic textiles and tyres are estimated to account for two-thirds of the releases of primary microplastics, although the magnitude of the losses from these sources vary considerably by world region, with India & South Asia and China dominating textile-related releases, and North America and Europe dominating tyre-related releases (Boucher and Friot, 2017). Microplastic losses from both these sources enter river and marine environments through wastewater systems or road runoff, and consequently could be minimised, if not eliminated, if correct filtering could be achieved on these wastewater streams (Boucher and Friot, 2017, GESAMP, 2015) (or alternatively they could be decreased or eliminated upstream through changing consumption and production patterns of synthetic fabrics and tyres).

The majority of microplastics are released as result of unintentional losses, with the exception of particles from personal care and cosmetic products[4] (Boucher and Friot, 2017). These products can be classed as "wash-off" or "leave-on" products, where the former includes products such as shampoos, scrubs and toothpastes, and the latter includes products such as lipsticks, hair sprays and sun cream. Both classes of products contain plastics, with the "wash-off" products containing up to 10 weight% of microbeads for abrasion and the "leave-on" products containing up to 99% plastics as a form of filler (Eunomia Research & Consulting Ltd., 2016b).

The estimates of plastic flows given in Table 2 are all based on top-down material flow models that look at the volume of plastic waste that has been produced, its likely end-of-life fate (e.g. incineration, landfill, recycling, dumping or littering), and the potential fraction that could have ended up in the ocean; and in the case of microplastics, the potential loss of plastic during a plastic products' use life that could end up in the ocean. As there have been relatively few studies on the fate of plastics in the environment, both terrestrial and marine, the study authors recognise the need for calibration of their models but cite the lack of necessary data to do so (Jambeck et al., 2015, Boucher and Friot, 2017). However, the top-down approach is necessitated by the near impossibility of representative sampling of the marine environment, which would require sampling of all compartments (surface, water column, floor and shoreline) across all regions so as to build a bottom-up estimate of marine plastic. Table 4 in Section 2.3 provides literature estimates of marine plastic stocks.

The major pathways for plastics to enter the ocean are directly from maritime activities and coastal communities, and via transport to the ocean in major river systems. Transport pathways of marine plastic litter are well illustrated in UNEP and GRID-Arendal (2016) *Marine Litter Vital Graphics*, with sources of macro- and microplastic covered in a number of reports (UNEP, 2016b, Thevenon et al., 2014, Ocean Conservancy, 2015, ten Brink et al., 2016, GESAMP, 2016). Direct dumping of waste by the shipping industry was formerly the largest source of sea-based macroplastics. Under current policies this has been significantly reduced, and fishing gear accidentally lost or deliberately left behind, aquaculture gear lost to sea and shipping accidents now accounts for the highest shares of sea-based plastic litter (UNEP, 2016b, ten Brink et al., 2016, GESAMP, 2016, Ocean Conservancy, 2015, Eunomia Research & Consulting Ltd., 2016b, UN Environment, 2017).

It is widely cited that 80% of marine debris originates from land, although the origin of this figure is not well substantiated (Jambeck et al., 2015), and is, at best, outdated (Eunomia Research & Consulting Ltd., 2016b). The recent review paper, *Plastics in the Marine Environment* (Law, 2017) states that the mass of plastics that enters the ocean from maritime activities or catastrophic events is not known, with the only estimates available dating back to 1975. Analysing data primarily from the Ocean Conservancy's International Coastal Cleanup (Ocean Conservancy, 2012), (Eunomia Research & Consulting Ltd., 2016b) suggest that sea-based sources are potentially being underestimated, and in their study estimate a range of 10 to 30% of marine litter from sea-based sources globally, with a higher range estimated for Europe (20 to 40%) (Eunomia Research & Consulting Ltd., 2016b). This is supported by recent findings quoted in (Ocean Conservancy, 2018) where nearly half of all the large debris accumulating in the North Pacific Subtropical Gyre is lost or abandoned fishing gear (Ocean Conservancy, 2018).

Sources of marine plastics, both macro- and micro-, vary greatly from region to region and depend on various factors and the transport routes present to deliver plastics into the ocean. The percentage of plastic attributed to sea-based sources is dependent on the amount of fishing and shipping occurring within the vicinity of sampling, along with the sampling method employed. Studies utilising beach data only

4. The microplastics in these products are considered intentional losses because they are designed to be used once and subsequently lost to the environment (e.g. an exfoliant in a face wash or an application of lipstick), as opposed to a durable product, such as tyres, textiles or paints, where the loss is due to wear and tear over the products life.

are likely to be skewed towards land-based litter entering the ocean from recreational beach users and from coastal communities through river systems (UNEP and GRID-Arendal, 2016, Eunomia Research & Consulting Ltd., 2016b).

Land-based plastic products entering the oceans vary by region and can mostly be linked directly to the major source of plastic litter in the region. Nonetheless, from available coastal cleanup data it is clear that single-use[5] and short-lived products are problematic across the globe due to the sheer volumes in which they are consumed and ease with which they can enter the marine environment (see section 3.1.1) for a listing of the top ten marine plastic items from global coastal cleanup data). While these products are a problem globally, the degree to which they enter the marine environment is directly linked to how widespread and used they are in a given country, to the behaviours of the users and to the state of local solid waste management. The dependency of river plastic litter loads on local waste infrastructure is well demonstrated by two recent articles with similar findings, with Lebreton et al. (2017) estimating that 67% of the total river plastic comes from just 20 rivers mostly located in Asia, and Schmidt et al. (2017) estimating that between 88% and 94% of the global river plastic load originates from just 10 river catchments. The quantity of microplastics entering the marine environment similarly depends directly on the products design, user behaviours and the state of local wastewater infrastructure and treatment (Boucher and Friot, 2017, GESAMP, 2016).

Sea-based sources on the other hand are problematic in regions with significant fishing industries or near major shipping lanes (HELCOM MONAS, 2014, UNEP and GRID-Arendal, 2016, UNEP, 2016b, ten Brink et al., 2016, GESAMP, 2016, European Commission, 2010). The situation is further complicated by one-off events, such as shipping accidents, which release large volumes of a particular product into a region (European Commission, 2010, Boucher and Friot, 2017). Whilst many regional studies on marine plastics estimate a breakdown by whether the plastic source is land-based or sea-based (Ioakeimidis et al., 2014, Sheavly, 2010, Ocean Conservancy, 2015), the sectorial breakdown of the EU's 4 Seas programme (European Commission, 2010) is interesting as it highlights the variability in marine litter sources across different regions. As shown in Table 3, no one sector of origin comes in the top three for all four regions.

The main sources of plastics entering the oceans, in terms of the products and sectors from which these plastic flows arise, are discussed in Section 3.

Table 3: Top three probable marine litter[6] sources in four different regional seas in Europe (Source: EU's 4 Seas programme (European Commission, 2010))

Sector of origin[1]	North Sea	Mediterranean Sea	Baltic Sea	Black Sea
Coastal/ beach tourism	26%	32%	25%	
Fishing	12%			
Recreational boating	10%			10%
Toilet/ sanitary		26%	29%	
General household		11%	12%	20%
Recreational fishing				46%

[1] Top three sectors shown for each case study, with other categories shown for interest. Categories do not sum to 100% as only the top three are listed.

5. Single-use plastics include items intended to be used only once before they are thrown away or recycled. Single-use plastics include most packaging items (e.g. bottles, containers etc.), but also include numerous other disposable consumer goods, such as straws, grocery bags, cups, cutlery, ear buds etc.

6. Marine litter, as defined in the EU "4 Seas" pilot project, can be any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. It consists of items that have been made or used by people and deliberately discarded or unintentionally lost into the sea and on beaches, including such materials transported into the marine environment from land by rivers, draining or sewage systems or winds. For example, marine litter consists of plastics, wood, metals, glass, rubber, clothing or paper.

2.3. Stocks of plastics in the marine environment

Plastics in the marine environment are not evenly dispersed and great variability in concentration has been observed depending on the region and the sampling method, particularly the location, timing and period of the sampling. This is because the movement and concentrations of plastic observed are dependent on various factors, including (Barnes et al., 2009, UNEP, 2016b, Thevenon et al., 2014, Niaounakis, 2017):

- The size and demographics of the local populations, including the total population and rural/urban split;
- The speed and direction of the local currents;
- The speed and direction of the wind;
- The occurrence of extreme natural events, such as hurricanes, floods and tsunamis; and
- The nature of the marine coastline, with relatively enclosed areas (such as bays, the Mediterranean Sea and the Caribbean Sea) entrapping plastic in the local environment.

Accurate concentrations of plastic within a region are difficult to predict, even with extensive modelling. A thorough review of the issues and available data can be found in Galgani et al. (2015) *Global distribution, composition and abundance of marine litter.* Estimates of plastic stocks in the ocean from the literature are shown in Table 4. These estimates, even though highly uncertain, point to where more sampling needs to occur to gain a better understanding of the total mass of plastics in the ocean. The sources, residing locations and quantities of plastic in the ocean are the subject of a 5-year research project, funded through European Research Council. The goal of the TOPIOS (Tracking of Plastic in Our Seas) project is to vastly improve understanding of the way plastic litter moves through the ocean (see Figure 1).

Table 4: Reported stocks of plastics in the oceans (million tonnes)

Study	Reference	Shoreline	Sea floor	Floating	Coastal and open ocean waters	Estimated total plastic in ocean
A global inventory of small floating plastic debris	(Van Sebille et al., 2015)			0.093 – 0.236		
More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea	(Eriksen et al., 2014)			0.25		
Plastics in the Marine Environment[1]	(Eunomia Research & Consulting Ltd., 2016a)	1.4	25.3 – 65	0.27		27 – 66.7
Marine litter vital graphics[2]	(UNEP and GRID-Arendal, 2016)	included with sea floor	29	0.21 – 0.439	57	86

[1] Range determined from sampling data of the different compartments by various studies: Floating (Eriksen et al., 2014, Cozar et al., 2014), Beach (Ocean Conservancy, 2012, Ryan et al., 2014, Smith and Markic, 2013), and Sea floor (Pham et al., 2014).

[2] GRID-Arendal own calculations using various sources. Total plastic calculated as 1.4% of all the plastics produced since the 1950s.

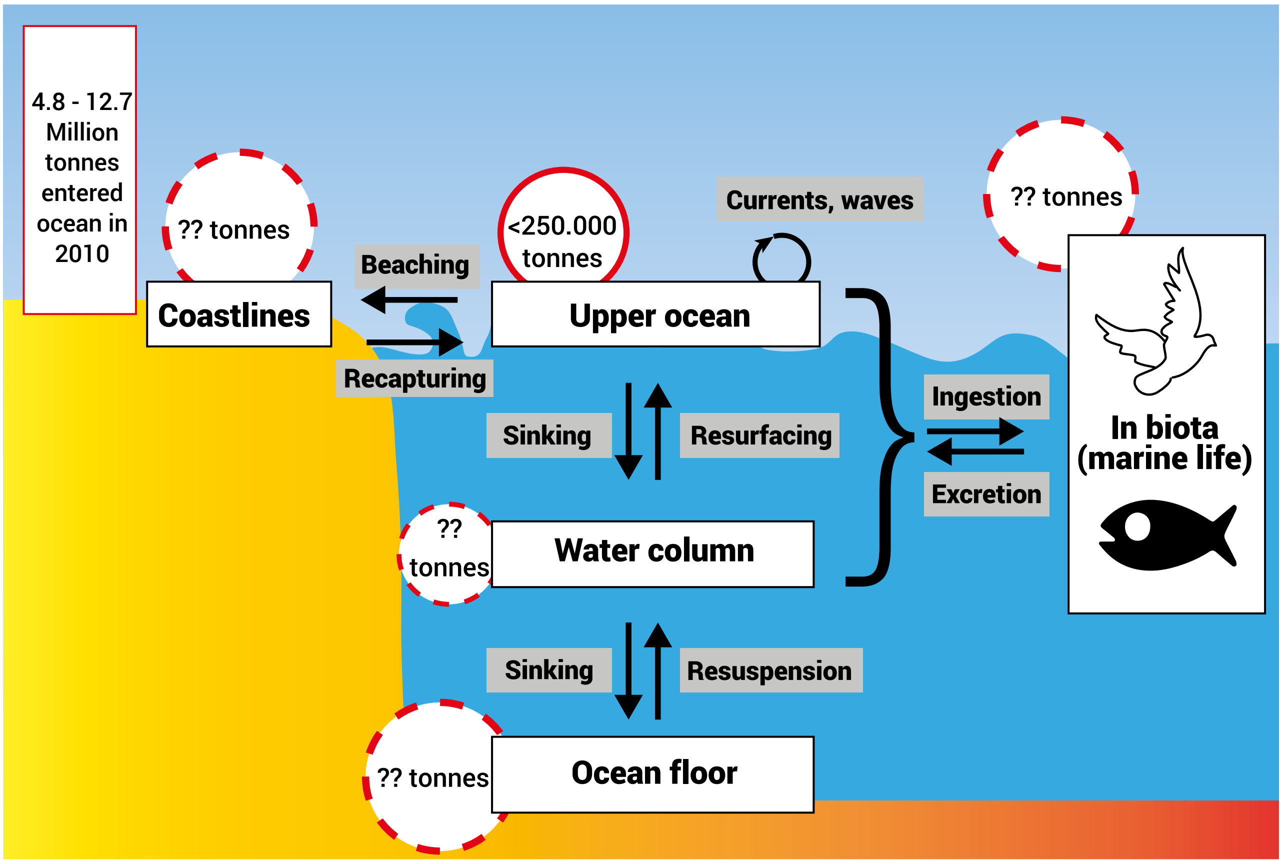


Figure 1: Pathways and locations of plastics in the marine environment.
Figure reproduced from source: {TOPIOS, 2018 #1170}

Plastics collecting on beaches and along the shoreline are the most visible form of marine plastics. The nature of water movements and the shoreline being the entry point of land based sources of plastic mean that shorelines have the highest concentration of plastics in the ocean (Barnes et al., 2009, UNEP, 2016b, Eunomia Research & Consulting Ltd., 2016a, Ocean Conservancy, 2015). Current estimates suggest that for every kilometre of shoreline there may be over 1,000 kg (approximately 2,000 kg/km^2) of plastics visible and more than 100 kg of buried plastics (Eunomia Research & Consulting Ltd., 2016a). However, the relatively small footprint of coastal shorelines means that shoreline plastics are estimated to only account for around 5% of the total mass of plastics currently residing in the ocean (Eunomia Research & Consulting Ltd., 2016a, Ocean Conservancy, 2015). Furthermore, shoreline plastics in a region consist of floating plastics or plastics that have entered the marine environment in the near vicinity, either through land-based sources (littering and poor waste management) or through coastal fishing. This indicates that studies focusing only on beach plastic data cannot fully capture the marine plastics problem, and offer only a limited understanding of the sources and extent of the problem (Eunomia Research & Consulting Ltd., 2016b, ten Brink et al., 2016, HELCOM MONAS, 2014, UNEP, 2016b).

Plastics floating in the open-ocean are also relatively visible, and consist of floating plastic items, such as bottles or items made from low-density polymers, such as polypropylene (PP), polyethylene (PE) or similar. Plastics in the open-ocean consist of a mixture of plastics discarded or lost at sea and land based sources of plastic that have floated out to sea (Ioakeimidis et al., 2014, UNEP, 2016b, Eunomia Research & Consulting Ltd., 2016b, UNEP and GRID-Arendal, 2016, Niaounakis, 2017). These items may remain floating for only a relatively short period after entering the marine environment, as fouling increases their density and is thought to result in their sinking within a few months (Galgani et al., 2015, Pham et al., 2014, Kaiser et al., 2017, Fazey, 2015). The maximum observed concentration of floating plastics is therefore only 18 kg/km^2 in the North Pacific gyre, with a global average predicted to be in the region of 1 kg/km^2 (Eunomia Research & Consulting Ltd., 2016a)[7]. It is therefore estimated that only around 1% of marine plastics occur on the open-ocean surface (Eunomia Research & Consulting Ltd., 2016a).

Plastics collecting below the surface and on the seafloor are the least visible form of marine plastics and are also the least studied, due to the complicated nature and expense of these studies (Galgani et al., 2015, MAP and UNEP, 2016, Eunomia Research & Consulting Ltd., 2016b). However, the seafloor is potentially the end location of the majority of plastics entering the ocean (Koelmans et al., 2017) and studies have shown that the average concentration could be in the region of 70 kg/km^2 (Eunomia Research & Consulting Ltd., 2016a). Overall this would mean that as much as 94% of marine plastics currently reside on the ocean floor (Eunomia Research & Consulting Ltd., 2016a). A 'whole ocean' mass balance model developed by (Koelmans et al., 2017) put this figure even higher, with an estimate that 99.8% of the plastics that have entered the ocean since 1950 had settled below the ocean surface layer by 2016.

A high degree of disparity is evident between the estimates of plastic flows into the ocean (Table 2) and plastic stocks in the ocean (Table 4). Jambeck et al. (2015) report in their article that their estimate of plastic entering the ocean is "one to three orders of magnitude" greater than the estimated global mass of plastic floating in the oceans (Jambeck et al., 2015). Similarly, Eunomia Research & Consulting Ltd. (2016b) calculate that the total cumulative plastics from terrestrial sources[8] to be one thousand times the magnitude found by sampling the surface waters of global oceans, and does not even take into account sea-based sources of plastic, which would push the disparity even higher. This is consistent with the findings of Van Sebille et al. (2015), who find that the accumulated weight of microplastic particles floating in the oceans is only approximately 1% of the global plastic flows estimated to enter the ocean in the year 2010. Using a slightly higher estimate of floating plastic in the oceans (Eriksen et al., 2014), and adding the some 6,000 tonnes of plastic from annual beach cleanup efforts, raises the estimate of "accounted for" plastic in the oceans to 3.5% of annual plastic flows into the oceans (Ocean Conservancy, 2015).

UNEP and GRID-Arendal (2016) list a number of theories as to why there is such a disparity between the amounts of plastic detected in the ocean and the amounts estimated to be entering the ocean, including transfer mechanisms that are hard to measure (e.g. shoreline deposition, decreased buoyancy due to fouling, uptake by biota and excretion through sinking faecal pellets), degradation, and high-energy oceanographic events leading to massive transportation from surface coastal areas to the deep open ocean. UNEP and GRID-Arendal (2016) Also point out limitations in sampling methods, leading to the largest and smallest items avoiding capture, and resulting in underestimates of the concentration of plastics in the ocean. The theory that the total microplastic load in the ocean is underestimated is supported by a study on microplastic fluxes in river catchments in northwest England (Hurley et al., 2018)

Notwithstanding the above, the high disparity between stocks and flows also suggests an over-estimation of waste leaked to the ocean and a higher degree of accumulation of plastic on land than anticipated in Jambeck et al. (2015). This is shown to be the case in South Africa, where a consideration of plastic flows at end-of-life, especially including the informal waste economy, results in lower estimates of plastic leaked into the environment than in Jambeck et al. (2015) (Chitaka et al., 2017).

7. Derived from the study by the 5 Gyres Institute (Eriksen et al., 2014) that collected samples using surface-towed trawls, with plastic samples ranging from 0.33 mm to larger than 200 mm.
8. Based on the estimate of marine litter for 2010 by Jambeck et al. (2015) and global plastic production data for that year.

2.4. Impacts of plastics in the marine environment

Marine plastics have significant impacts on the environment, on the socio-economics of local communities and even potentially on human health. The short-term impacts are mostly well known and documented, however the longer-term effects are relatively unknown and could be more severe than currently felt (Browne et al., 2013, Gilbert et al., 2016, GESAMP, 2015, ten Brink et al., 2016). The intention of this section is to provide an indication of the breadth of potential impacts of marine plastics, with key references provided for a reader requiring a thorough exploration of the issues.

Environmental impacts

The environmental impacts of marine plastic litter range from short-term impacts, such as the entanglement of animals, to long-term impacts, such as the bioaccumulation of toxic compounds up the food chain. In many cases the full impacts, especially the long-term impacts and those involving particles in the nano size range, are not yet known. Good overviews are available in UNEP and GRID-Arendal (2016) *Marine Litter Vital Graphics* and UNEP (2016b) *Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change.* A detailed technical coverage and inclusion of all new research since 2012 is available in SCBD (2016) *Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity.*

Plastics of almost all sizes create an entanglement issue and present a choking hazard for marine species, with the species affected determined by the size of the plastic. This problem is most visible in large species, such as whales entangled in fishing lines, fish caught in 'ghost nets', birds found with stomachs full of plastic and turtles choked on plastic bags. A recent update on the state of knowledge of the impacts of marine plastics by the Secretariat of the Convention on Biological Diversity (SCBD) puts the total number of species known to be affected by marine plastics at over 500, which increases to over 800 if dispersal by rafting and habitat effects are included along with ingestion, entanglement and ghost fishing (SCBD, 2016). Research has also indicated impacts in smaller species, such as zooplankton (GESAMP, 2016, Ioakeimidis et al., 2014, SCBD, 2016). Many of these smaller species are filter feeders and this technique makes them particularly likely to ingest microplastic particles (Wright et al., 2013).

The impacts of plastics are not limited to the physical effects they have on the environment and on marine life. Plastics contain chemicals added during manufacture (so-called additives, such as bisphenols), many of which cause adverse effects in animals and could potentially leach into the food chain once ingested. Furthermore, research has shown that plastic particles sorb (adsorb and absorb) persistent, bio-accumulative and toxic contaminants (so-called PBTs) from the environment, thereby providing a mechanism for PBTs to accumulate in the food chain (GESAMP, 2016). However, adverse effects of ingestion of microplastics have only been observed under laboratory conditions, usually at exposure concentrations that exceed present environmental concentrations by several orders of magnitude. At present there is no evidence that microplastics ingestion has negative effects on populations of aquatic organisms in the ocean, although further research is needed (Lusher et al., 2017).

Other indirect impacts of marine plastics are that they are a potential vector for disease, providing a novel habitat for unique microbial communities (Lusher et al., 2017, Lamb et al., 2018), in addition to macroplastic items causing smothering of seafloor species, damaging coral reefs and facilitating the transfer of alien species on floating debris (UNEP, 2016b, GESAMP, 2016, Ioakeimidis et al., 2014, ten Brink et al., 2016, Lusher et al., 2017).

Socio-economic impacts

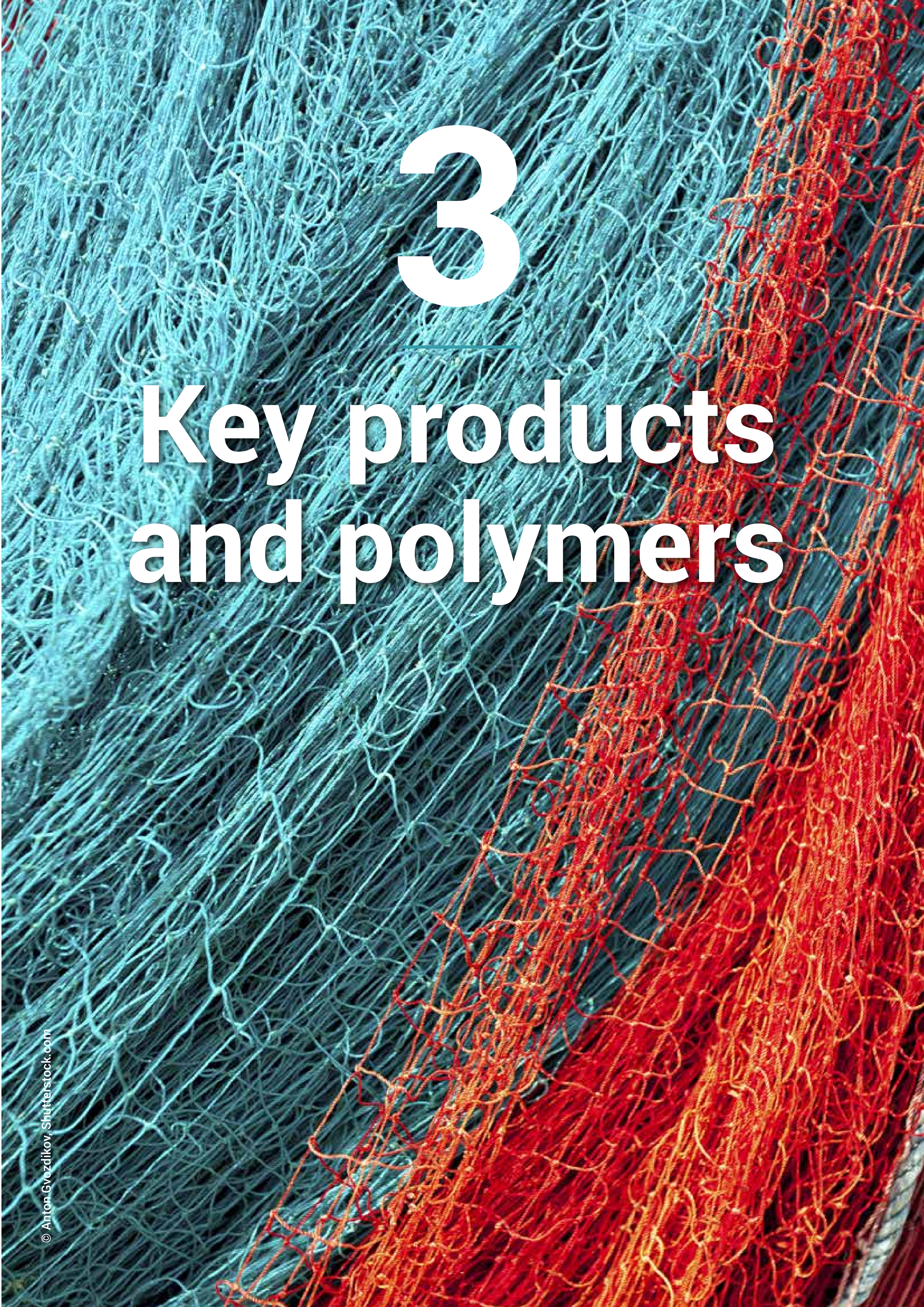
The socio-economic impacts of marine plastics are less well researched than the environmental impacts, with knowledge gaps particularly on the social impacts (UNEP, 2016b). Plastics in the ocean impacts on any industry operating in the marine environment and consequently has knock on effects to the individuals and communities relying on the marine environment as a source of food or income. Perhaps most concerning is the effect that marine plastics are having and could continue to have on the fishing industry (Ioakeimidis et al., 2014, UNEP and GRID-Arendal, 2016, UNEP, 2016b, GESAMP, 2016). The fishing industry currently supplies 17% of the world's protein and is relied on as the main source of protein in many low-income areas worldwide (FAO, 2014). The effects of ingestion and entanglement of plastics negatively impact fish stocks worldwide, while the operation of fishing boats is affected by the fouling of motors by plastics, which leads to significant downtimes and repair costs (ten Brink et al., 2016, GESAMP, 2016). These fouling issues are demonstrated by plastic waste costing the EU shipping fleet an estimated € 61.7 million, and the UK shipping industry between € 0.83 and € 2.2 million during 2008, due to fouled propellers and other plastics related incidents (ten Brink et al., 2016). Furthermore, 9% of Korean shipping incidents are attributed to marine litter (ten Brink et al., 2016). Together these factors may impact worldwide food security and particularly food security in regions relying heavily on fish as a protein source.

Economic impacts of plastics in the oceans also extend to other industries, such as tourism, which rely on the appeal of the marine environment. The poor appeal of beaches covered in plastics and negative publicity of the state of the world's oceans have already impacted coastal tourism, as demonstrate by studies based on Sweden (Fanshawe and Everard, 2002, Olin et al., 1995), and could reduce income in regions relying on coastal tourism (ten Brink et al., 2016). These impacts can be reduced to a certain extent by beach-clean ups, however these exercises are costly, with worldwide beach cleanup efforts estimated to cost € 50 billion, costing coastal municipalities the loss of vital income and resources (ten Brink et al., 2016). An upstream effort, engaging the tourism communities is also essential.

Human health impacts

Human health impacts from plastics can occur both from reduced food security, as discussed above, and from the contamination of the human food chain with toxic chemicals (UNEP, 2016b, GESAMP, 2016). A recent FAO report *Microplastics in fisheries and aquaculture: Status of knowledge on their occurrence and implications for aquatic organisms and food safety* (Lusher et al., 2017) provides a thorough overview of the potential human health issue and a review of research in this area.

An average European shellfish consumer could ingest up to 11,000 pieces of microplastic per year by eating mussels and oysters (ten Brink et al., 2016). Nonetheless, the FAO puts the health risk to humans through chemical exposure to PBTs and plastic additives by ingesting seafood as negligible (Lusher et al., 2017). However, the FAO does raise significant gaps in knowledge on the possible effects of smaller microplastics and nanoplastics on seafood safety, but there are currently no methods to observe and quantify these potential effects (Lusher et al., 2017).



3

Key products and polymers

Chapter highlights

- Key products and polymers are discerned through looking at coastal cleanup data and modelled plastic flows using plastic production data according to product sector and polymer type.
- In terms of **macroplastics**, both cleanup data and plastics production data are consistent in pointing to **packaging as the sector with the highest contribution to marine plastics.**
- Packaging products are also well documented as a source of entanglement and ingestion by marine life (making the link that PE, PET and PP found in microplastics are largely from the degradation of macroplastics).
- **Fishing gear** is identified as key contributor to entanglement impacts (particularly nets, lines and ropes), and also as a source of artificial textiles (microplastics) and chemical toxicity (EPS floats).
- **Plastics incorporating flame retardants** (such as those used in electronic goods), as well as plastics used in the building & construction and transportation sectors, are of concern due to their high use of potentially harmful chemicals, despite having lower production data and counts in marine sampling and coastal cleanup data (due to their being primarily longer-lived products).
- **Land-based secondary microplastics** are determined to be the highest source of microplastic in top-down modelling studies, primarily **fibres released during the washing of artificial textiles** (predominantly PET) and **particles from the abrasion of tyres (natural and synthetic rubbers).**
- Data from field studies show a range of polymers across different marine compartments, but confirm that **microfibers from artificial textiles are the largest source of observed microplastics in the ocean**.

A first step towards understanding the most impactful plastics in the ocean is understanding the most prevalent types of plastics in the ocean, with impact being a function of both the quantity of a particular type of plastic and its potential impact (e.g. for environmental impact this can be physical, such as entanglement, or toxicological; whilst for socio-economic this can be physical (e.g. damage to fishing vessels), visibility (e.g. impact on tourism activities) or related to environmental impacts (e.g. impact on fishing stocks). Two approaches to discerning the most prevalent types of plastics in the ocean are seen in the literature; 1) analysing data on plastics collected in marine sampling studies and coastal cleanups, and 2) modelling plastic flows using plastic waste and/or plastics production data. The insights gained from these two approaches as to the most prevalent plastic products and polymers are discussed below. This is then extended to a discussion of key products and polymers in terms of their potential impacts, which together with the analysis on products with the highest presence, leads to the identification of certain sectors warranting particular attention.

3.1. Key products and polymers in terms of flows

Plastics entering the ocean occur across the product life cycle - during production, transport, use and end-of-life - with the quantity a function of such regional factors as the population density, economic activity, consumption trends and state of solid waste and wastewater management (Boucher and Friot, 2017, GESAMP, 2016). This section looks at plastics entering the ocean from a product perspective as a link back to both the life cycle stages at which the plastic loss is generated, as well as to the polymer from which it is made.

Table 5: Top ten items found in international coastal cleanups (counts) (Ocean Conservancy, 2011, Ocean Conservancy, 2017)

	Ranking in 2018	% in 2018	Ranking over 25 years	% over 25 years (1985-2010)
Cigarette butts	1	12%	1	32%
Food wrappers	2	8%	2	9%, category also includes containers
Plastic beverage bottles	3	8%	5	6%
Plastic bottle caps	4	5%	3	8%, category also includes lids
Plastic grocery bags	5	4%	6	5%
Other plastic bags	6	4%		included with grocery bags
Straws, stirrers	7	3%	9	4%
Take out/ away containers	8	3%	4	6%, category includes cups, plates, forks, knives, spoons
Plastic lids	9	3%		included with caps
Foam take out/away containers	10	3%		not split from other take-away containers
Glass beverage bottles			7	4%
Beverage cans	-	-	8	4%
Rope	-		10	2%
Top 10 items as % of total items collected		52%		80%

Plastics in coastal cleanup data

Most coastal cleanup and sampling studies characterise the debris[9] according to the type of product from which it is derived. Extrapolating from these product types is thus an expedient approach to estimating the polymer loads in the ocean. Cleanup and sampling data are most often in item counts rather than mass of plastic, thus knowing the mass of the item and its composition is required for extrapolating to polymer. Sampling and cleanup data also tends to capture only the lager plastic

9. Data from cleanups and sampling studies are generally of marine debris (also termed marine litter) and not of plastic items only, i.e. they include items of glass, metal, wood etc.

items (macroplastics), as well as favour a particular plastics fraction (i.e. buoyant plastics). Nonetheless, coastal cleanup data provides the largest and most accessible source of data on the composition of marine plastics. A sample of data from the annual International Coastal Cleanup (ICC) is shown in Table 5, where for the first time (in 2017), all ten of the items making up the top ten (in terms of number of items/counts) contain plastic (Ocean Conservancy, 2018).

Modelled plastic flows

Sampling studies and beach cleanups are unable to provide a complete picture of marine plastics due to the near impossibility of obtaining representative samples. An alternative is thus to model plastic flows to the ocean based on either plastic in waste data or plastic production data.

Coastal and riverine plastic loads have been predicted based on modelling plastic in solid waste and its propensity to end up in the environment (Lebreton et al., 2017, Schmidt et al., 2017, Jambeck et al., 2015). The studies do not differentiate the plastic loads they identify into product or polymer types. Polymer breakdown of plastic in municipal solid waste could perhaps be used as a proxy for polymer loads in such sources of marine plastics but waste characterisation data is inherently variable and mostly of poor quality (Hoornweg and Bhada-Tata, 2012). The polymer composition of end-of-life plastic flows are modelled in a study by Geyer et al. (2017). However, due to the general lack of waste data, Geyer et al. (2017) model the composition of end-of-life plastic flows from production data and product lifetimes.

The insights from this Geyer et al. (2017) on the composition of plastics end-of-life flows are shown in Figure 2, where the left-hand side gives a breakdown in primary plastics production according to the polymer type, whilst the right-hand side gives a breakdown in plastic end-of-life flows according to polymer type. Polymers used in packaging and other short-lived products (i.e. high-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP) and polyethylene terephthalate (PET)) show higher percentages at end-of-life than at production, whilst polymers used in products with long lifetimes, such as polyvinyl chloride (PVC) and polyurethane (PUR), have lower shares at end-of-life than in production. These trends in polymer composition at end-of-life is explained by looking at the sectors in which the products are used (see Figure 3). For example, building and construction products account for 16% of global plastics production but due to their long product lifetimes, they account for only 4% of plastics at end-of-life.

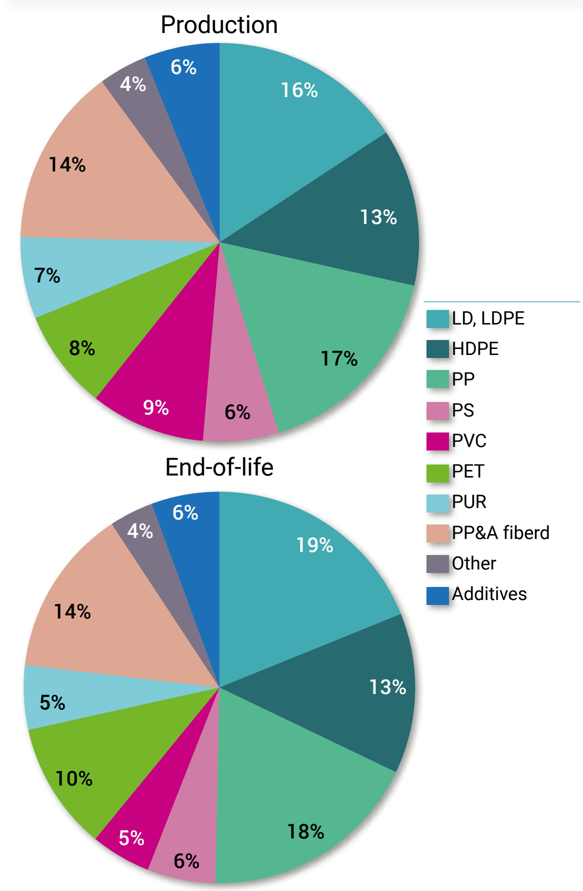


Figure 2: Global primary plastics production and end-of-life flows according to polymer type/additive (in million metric tons in 2015) (Geyer et al., 2017)

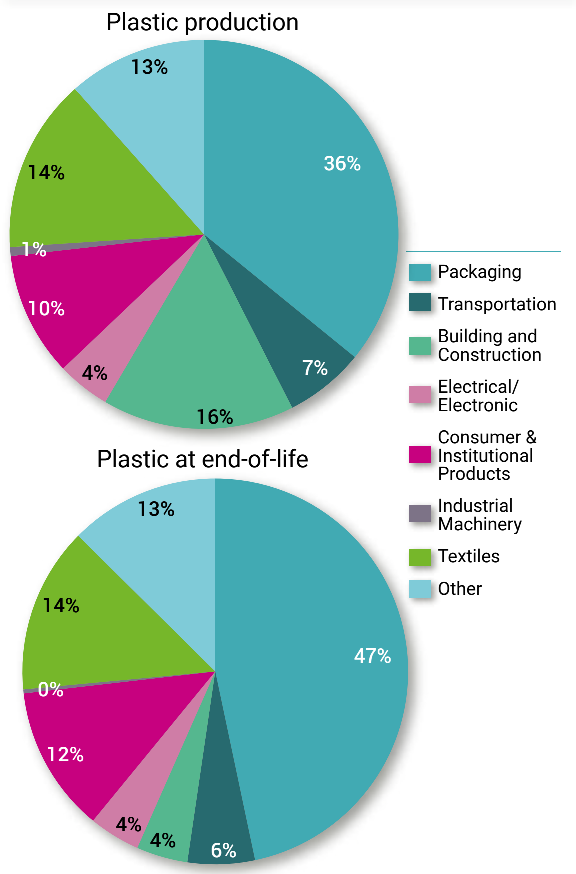


Figure 3: Global primary plastics production and end-of-life flows according to industrial use sector (in million metric tons in 2015) (Geyer et al., 2017)

A limitation of modelled plastic flows at end-of-life is that models on the fate of plastics in the environment are lacking, i.e. a waste/end-of-life composition approach is currently not able to capture the fact that leaked or littered waste is likely to have a higher concentration of small and lightweight plastic items that easily escape treatment systems and are easily transportable by wind and water. They also are applicable only to marine plastics arising at end-of-life (i.e. associated with disposal) and do not encompass plastics entering the ocean during the manufacturing or use phases (e.g. transport losses, production spills and "wear and tear" losses). Use phase losses are associated primarily with land-based secondary microplastics, and are covered separately in section 3.4.

3.2. Key products and polymers in terms of impacts

The physical impacts of plastics on marine life through entanglement are well documented (SCBD, 2016), with fishing line, fishing nets and rope identified to be top offenders, followed by packaging products, especially 6-pack holders and plastic bags (Ocean Conservancy, 2011). Buoyant plastics, especially bottles and Styrofoam (polystyrene (PS)) cups, containers etc. have a high propensity for washing up on beaches and thus have the highest socio-economic impacts in terms of tourism losses and cleanup costs.

The impacts of microplastics are less able to be readily linked to a particular product or sector. The impacts of ingestion on marine life are extensively documented (Andrady, 2011), but the wide range of polymers found in fish and bird stomachs (Luscher et al., 2013, Yamashita et al., 2011), suggests that, at least for the physical impacts of ingestion, a wide range of sources of microplastics (as discussed in Section 3.4) are responsible. However, potentially more significant than the physical impacts of microplastic ingestion, are chemical impacts. Chemical impacts occur through the transfer of chemicals associated with microplastics, including persistent organic pollutants (POPs) and endocrine disruptor chemicals (EDCs) (SCBD, 2016, Gallo et al., 2018).

The potentially hazardous chemicals found in marine plastics originate from four categories (Gallo et al., 2018):

1. Chemicals (additives) intentionally added during production processes, such as flame retardants, plasticizers, antioxidants, UV stabilisers, and pigments;
2. Chemicals arising unintentionally during from the production processes, such as catalysts

and monomers (e.g. vinyl chloride, BPA, etc.) (degradation of the plastic is also a possible source of these chemicals);

3. Chemicals arising from the recycling of plastics; and
4. Hydrophobic chemicals adsorbed onto the surface of the plastics from environmental pollution.

Chemical additives can to some degree be linked to particular plastic products or sectors. For example, polybrominated diphenyl ethers (PBDEs) and chlorinated paraffins are used as flame retardants in plastics, polyurethane foams and textiles; tetrabromobisphenol A (TBBPA) is used as flame retardant in epoxy, vinyl esters and polycarbonate resins; hexabromocyclododecane (HBCDD) is used in polystyrene foam (Gallo et al., 2018). Such plastics are used particularly in the electronics, transport and building and construction sectors. Polystyrene foam is also used as floats in fishing gear and in aquaculture.

Other widely used plastic additives are more difficult to link with a particular product sector. For example, plasticizers, such as phthalate esters (e.g. di(2-ethylhexyl) phthalate (DEHP), diisodecyl phthalate (DIDP), diisononyl phthalate (DINP) and butyl benzyl phthalate (BPP)) are widely used to increase the flexibility, transparency or longevity of plastic products (Gallo et al., 2018). Alkylphenols (octylphenol and nonylphenol) are used mainly as antioxidants, and bisphenol A (BPA), is present in polycarbonate plastics as trace monomers.

PVC is associated with a number of potentially hazardous chemicals: DEHP is used in PVC, whilst polychlorinated biphenyls (PCBs) and polychlorinated naphthalenes (PCNs) are included in PVC coatings/paints, whilst organotin compounds, such as tributyltin, are used as stabilizing additives in some PVC polymers (Gallo et al., 2018). PVC is used widely across a number of product sectors, including transport, packaging and consumer goods, although its highest use share is in the building and construction sector (with over 60% of Western Europe's annual PVC production for the building and construction sector).

3.3. Key sectors

Both the sampling and modelling approaches give valuable insights into the quantity and composition of marine plastics, although neither is able to give the complete picture and they are best interpreted together. Considering data on the environmental and socio-economic consequences of marine plastics gives further insights into the products and sectors most responsible for impacts, although data are limited, and in many cases, environmental damages are not able to be clearly linked to specific products or polymers. Nonetheless, the discussion above shows packaging and other short-lived products to be clearly implicated both in terms of quantity of flows and impacts as key contributors to marine impacts. Fishing gear is also identified as a key product sector, particularly in terms of impacts on marine life.

Packaging and single-use plastics

The prevalence of packaging and single-use consumer products in marine litter is clearly indicated both by modelled plastic end-of-life flows (as shown in the right-hand side of Figure 3), as well as in coastal cleanup data. Table 5 shows that plastic packaging and single-use consumer product have consistently made up 7seven out of the top ten items found globally on beaches, with this proportion increasing to all of the top ten items containing plastic in the most recent year for which data are available (2017).

Packaging includes a wide variety of items consumed in large numbers by the retail, commercial, household and tourism sector. These plastic items are typically small, light and can easily enter the marine environment if littered, dumped or poorly treated in the waste management systems (UNEP and GRID-Arendal, 2016, UNEP, 2016b, ten Brink et al., 2016). The packaging sector accounts for around 26% of the world's total plastic use (World Economic Forum et al., 2016), with higher rates evident in many countries (e.g. 40% in Europe (Plastics

Europe, 2017) and 53% in South Africa (Plastics SA, 2016a)). Not only is packaging the largest application of plastics in most countries, but its small size, short service life and low residual value also makes it especially prone to finding its way into the environment. This is borne out by the fact that plastic packaging comprises more than 62% of all items (including non-plastics but excluding cigarette butts) collected in international coastal cleanup operations (World Economic Forum et al., 2016). Many of these packaging items, such as polyethylene terephthalate (PET) bottles and polystyrene (PS) food containers (Styrofoam), are particularly visible due to their buoyant nature and thus their common occurrence on beaches (UNEP and GRID-Arendal, 2016, Ocean Conservancy, 2015).

A breakdown in polymer types used in the manufacture of common plastics packaging items is given in Table 6. Whilst global packaging polymer consumption might be useful as a proxy for the composition of marine litter, it does not take into account the likely higher concentrations of light, smaller items easily littered and transported to water bodies. On the other hand, data on beach and floating marine litter tends to preferentially capture buoyant items, potentially overestimating the overall polymer share of such items.

Thin film products, such as plastic wrap and shopping bags, are a particular subset of packaging items that are frequently littered. These items are extremely light and mostly enter the marine environment through wind transfer into oceans or rivers when incorrectly or poorly disposed of (GESAMP, 2016, Barnes et al., 2009). Thin film products are primarily made of polyethylene (PE, consisting of both LDPE and HDPE), with a smaller contribution from polyvinyl chloride (PVC) and polypropylene (PP) (Plastics SA, 2015, Mudgal and Lyons, 2011, Plastics Europe, 2016).

Table 6: Packaging polymer breakdown and typical products

Polymer	Example of products	Percentage of packaging in Europe	Percentage of packaging in USA	Percentage of packaging in South Africa
PET	Bottles and "clam-shell" packaging	17%	27%	23%
HDPE	Larger bottles and containers	15%	26%	17%
PVC	Bottles, thin flexible packaging and cling wrap	2%	3%	2%
LDPE	Thin film packaging, squeeze bottles and cling wrap	36%	26%	31%
PP	"Inner" packaging bags, bottle tops, containers and chip bags	20%	12%	20%
PS	Take-away container, drinking cups and foam packaging	7%	4%	5%
Other – including multi-layered)	Pouches, wrappers and chip bags	3%	3%	1%
Reference	(Hopewell et al., 2009, Plastics SA, 2016b, Sharobem, 2010)	(Plastics Europe, 2016)	(USEPA, 2016)	(Plastics SA, 2016a)

Single-use plastics include items intended to be used only once before they are thrown away or recycled. Single-use plastics include most packaging items (e.g. bottles, grocery bags, containers etc.), but also include numerous other disposable consumer goods, such as straws, cups, cutlery and ear buds. Short-lived products (other than packaging) that have been implicated in coastal cleanup and marine impact data worldwide include (ten Brink et al., 2016, Ocean Conservancy, 2011, Niaounakis, 2017):

- Disposable cutlery and take-away food containers, typically manufactured from polystyrene (such as Styrofoam);
- Straws, typically manufactured from polypropylene;
- Balloons, typically manufactured from latex;
- Cigarette butts, containing cellulose acetate.

Recreational and tourism activities are primarily the source of these items.

Another prevalent source of single-use consumer plastics encountered in the marine environment is sanitary items. Sanitary products, such as ear buds, tampons, and absorbent items, have been estimated to account for in excess of 20% of plastics in riverine systems (Morritt et al., 2014). The accumulation of these items in the marine environment is due to poor wastewater treatment or direct dumping of household waste into rivers (MAP and UNEP, 2016, HELCOM MONAS, 2014, UNEP, 2016b, Eunomia Research & Consulting Ltd., 2016b).

Fishing gear

Fishing gear is highly prevalent in coastal cleanup data, with International Coastal Cleanup data over 25 years showing fishing line, fishing nets and rope to be the biggest offenders in terms of wildlife entanglement, as well as being in the top 20 items counts (top 10 in the case of rope) (Ocean Conservancy, 2011). Furthermore, the widespread use of polystyrene floats is associated with potentially endocrine disrupting chemicals (Gallo et al., 2018).

Fishing operations lose gear, including ropes, nets, lines, floats and cords, due to a combination of entanglement, abandonment and loss. These items pose a significant threat to marine ecosystems due to the high chance of entanglement and the "ghost net" effect, which can result in large volumes of fish being accidentally caught. The high environmental impacts of abandoned and lost fishing gear make fishing gear a particularly visible marine litter sector, which is further enhanced by the visible nature of certain items, such as floats (Galgani et al., 2015, UNEP, 2016b, ten Brink et al., 2016, Eunomia Research & Consulting Ltd., 2016b).

Nets, lines, cords and gillnets are typically made from polyethylene terephthalate (PET) and polyethylene (PE), whilst floats are primarily made from polystyrene, although floats can also be made from hollow spheres manufactured from a number of polymers, including acrylonitrile butadiene styrene (ABS) (Niaounakis, 2017).

Electronics, transport and building & construction

Marine sampling and coastal cleanup data shows short-lived products, such as packaging and single-use consumer goods, along with fishing gear, to be the predominant product types in marine plastics. Nonetheless, it is important to keep in mind that some of the product sectors with longer-lived products are those with potentially the highest toxicity impacts. This particularly includes plastics with flame-retardants added, prevalent especially in electronics (eWaste), but also in the transport, building & construction and consumer goods sectors. PVC, used primarily in the building & construction sector, but also in packaging, transport and consumer goods, is also associated with potentially hazardous additives.

3.4. Microplastics

Extrapolating from product type to polymer is generally not applicable to microplastics sampled in the ocean, and analysis of plastic samples is the only approach to knowing the polymer types making up microplastic particles. Examples of field studies providing samples of microplastics by polymer type in various ocean compartments is shown in Table 7. A alternative approach is to model potential polymer loads based on plastic production data and loss estimates, as in Boucher and Friot (2017) *Primary microplastics in the oceans: a global evaluation of sources.*

The products and polymers identified above as key sources of macroplastics are also relevant to microplastics, as the formation of secondary microplastics occurs constantly within the ocean due to wave action, sunlight, biological action and other degradation processes (ten Brink et al., 2016, Boucher and Friot, 2017, GESAMP, 2016, Eunomia Research & Consulting Ltd., 2016b). The dominant polymers in packaging and short-lived consumer goods (i.e. PE, PET and PP) are thus also found to be prevalent in microplastics (see Table 7).

Table 7: Polymer breakdown of microplastic particles (adapted from GESAMP, 2015)

Location in marine environment	Particle size	Polymer composition	Reference
Beach sediment	< 1 mm	PES (58%); AC (23%); PP (7%); PE (6%); PA (3%)	(Browne et al., 2011)
Sediment at sewage disposal site	< 1 mm	PES (78%); AC (22%)	(Browne et al., 2011)
Estuary sediment	< 1 mm	PES (35%); PVC (26%); PA (18%); AC; PP; PE; EPS	(Browne et al., 2010)
Sediment in inter- and sub-tidal region	0.03 – 0.5 mm	PE (48.4%); PP (34.1%); PP+PE (5.2%); PES (3.6%); PAN (2.6%); PS (3.5%); AKD (1.4%); PVS (0.5%); PVA (0.4%); PA (0.3%)	(Vianello et al., 2013)
Beach sediment	1 – 5 mm pellets	PE (54-78 %); PP (10-32%)	(Karapanagioti et al., 2011)
Coastal water surface	< 1 mm	AKD (75%); PSA (20%); PP+PE (2%); PE, PET, EPS	(Song et al., 2014)
Effluent water from sewage treatment plant	< 1 mm	PES (67%); AC (17%); PA (16%)	(Browne et al., 2011)
Fish stomachs	0.13 – 14.3 mm	PA (35.6%); PES (5.1%); PS (0.9%); LDPE (0.3%); AC (0.3%); Rayon (57.8%)	(Luscher et al., 2013)
Bird stomachs	-	PE (50.5%); PP (22.8%); PC and ABS (3.4%); PS (0.6%); Other (22.8%)	(Yamashita et al., 2011)

PES – Polyester; AC – Acrylic; PP – Polypropylene; PE - Polyethylene; PA – Nylon; PVC – Polyvinyl chloride; EPS – Expanded polystyrene; PAN – Polyacrylonitrile; PS – Polystyrene; AKD – Alkyd; PVA – Polyvinyl alcohol; PSA – Polystyrene acrylate; Rayon – Semi synthetic compound produced from cellulose; PC – Polycarbonate; ABS – Acrylonitrile butadiene styrene

Polyester, polyamide and acrylic (PP&A) fibres, attributed to artificial textiles, show a high share in production and end-of-life plastic flows (see Figure 3 and Table 7). Textile fabrics are not indicated in coastal cleanup data, likely due to them not being easily transported by wind or water, as well as their tendency to disintegrate (leading to microplastic losses rather than macroplastic losses). However, fibres released during the washing of artificial textiles are identified as one of the top sources of land-based secondary microplastics in modelling studies (Boucher and Friot, 2017). This is consistent with artificial fibres (predominantly polyesters, but also acrylic, nylon and rayon) being found in high concentrations in sampling studies (see Table 7). Fishing gear, such as ropes and nets, are also typically make of artificial fibres. The abrasion of fishing gear, particularly dolly ropes, is thus also likely to be a key source of artificial fibres in the marine environment.

Unlike macroplastics, where the majority of products entering the ocean are at end-of-life, the majority of primary microplastics and land-based secondary micro-plastics enter the ocean during the product use phase. The major sources of primary microplastics entering the oceans are losses from plastic production and recycling industries. Although on a global level, modelling studies show plastic pellet loss to be a relatively small source of microplastics (Boucher and Friot, 2017), they have been shown to the dominant source of mesoplastics[10] (2 mm -25 mm) on a local scale (Ryan et al., 2018). Industrial pellets can be of any polymer, but tend to be of those polymers used most widely in the plastics industry (i.e. PE, PET and PP).

Land-based secondary microplastics arise through product "wear and tear", with natural and synthetic rubber losses from abrasion of tyres during driving the other most significant source identified in modelling studies (along side fibre losses during washing of textiles) (Boucher and Friot, 2017). However, whilst microfibers from artificial textiles as a large source of microplastics in the ocean is confirmed by marine sampling studies, polymer from tyre losses are not evident in field studies. However, it is possible that this is due to limitations in detecting particles in the nano size range rather than their not being present. Limits in sampling and detection, particularly in the nano size range, mean that the key sources of microplastics identified by studies employing top-down modelling approaches (tyre abrasion, city dust, road markings etc.) cannot be calibrated against concentrations of

10. Mesoplastics are taken to be particles in the 2 mm to 25 mm size range in the study by Ryan et al. (2018).

polymer in the marine environment. Conversely, the top-down modelling studies put plastic pellets and microbeads as low sources of microplastics, even through these sources are high in terms of their profile, with many countries taking action against microbeads (see Section 5.2.2), and "citizen science", finding high evidence of plastic pellets (for example, the "great nurdle hunt" in the UK[11]). However, this can perhaps be attributed to the visibility of microbeads and industrial pellets (being as they are at the top end of the microplastic range) and the relative ease with which it is possible to take action against them. Voluntary industry action against releases of industrial pellets has already been shown to be reducing ingestion impacts (Ryan et al., 2018).

11. https://www.nurdlehunt.org.uk/take-part/nurdle-map.html

4

Initiatives addressing marine plastics

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Chapter highlights

- A large number of initiatives have grown out of the high global focus on marine plastic. These can be broadly classified into knowledge-oriented initiatives (aiming to add to the knowledge base on marine plastic flows, impacts and potential solutions) or action-oriented initiatives (aiming to change the status quo, for example, eliminating single-use plastics).
- Initiatives are convened by a range of different actors, including inter-governmental agencies, industry alliances, foundations and NGOs, and range in scale from global multi-stakeholder alliances to local non-profit organisations.
- The focus of industry and government initiatives tends to be around minimising waste, especially promoting recycling and better waste management.
- The focus of foundations, NGOs and not-for-profits is broader, with a ground-swell of campaigns working to reduce plastic consumption, especially of single-use plastics.

Plastic pollution of the world's oceans has in recent years become a headline environmental issue. This can be seen in plastic pollution being the theme for both Earth Day (*End Plastic Pollution*[12]) and World Environment day (*Beat Plastic Pollution*[13]) in 2018. A very large number of initiatives and organisations addressing plastic pollution have grown out of this high media attention. This section aims to capture the range of different initiatives, from inter-governmental, to industry alliances to non-profit organisations, active in different areas of the plastic value chain and across different geographies.

To provide a summary representation of the initiatives a classification scheme was developed that indicates its primary aim, i.e. whether it aims to add to the knowledge base (knowledge-oriented) or whether it aims to change the status quo (action-oriented), and where in the plastics value chain its primary focus lies. With regards to the latter, an initiative is identified as:

- Addressing marine plastic "**in the ocean**" if its primary focus is on cleaning up and/or mitigating the impacts of plastic already in the oceans, or researching the impacts, quantities, residing locations etc. of plastic in the oceans;
- Addressing marine plastic "**entering the ocean**" if its primary focus is on managing plastic end-of-life flows so that they do not end up in the oceans. This includes anti-littering measures and waste management initiatives, such as sound disposal practices and increased recycling;
- Addressing plastic "**production and use**" indicates initiatives focussing upstream in the plastic value chain that aim to reduce and/or eliminate plastic

12. https://www.earthday.org/
13. http://worldenvironmentday.global/

end-of-life flows through changes in consumer behaviour and developing new products, materials and business models.

It is acknowledged that many initiatives cover more than one of the focus areas (possibly with different degrees of focus), and larger initiatives may be both knowledge- and action- oriented.

The actors and initiatives identified in this research were sorted into the following categories: inter-governmental agencies, government initiatives (regional, national and local), funders, campaigns, partnerships and alliances, NGOs/NPOs and industry initiatives. Campaigns are run by organisations, and thus the categorisation results in duplication in places, but as the campaigns are often better known than the organisation, initiatives are listed by the campaign rather than the organisation where this makes sense to do so.

The following tables give examples of actors and initiatives identified in the categories identified. The actors and initiatives were identified in a fairly ad hoc process through desk-based research (literature and media articles) and through consultation with experts working in the area. The actors and initiatives listed in the tables in this Chapter are selected to show a range of aims and focus areas, but do not aim at representing a comprehensive listing.

The marine plastic issue has been elevated to its headline status on the back of decades of scientific research. Academics and scientists from a very wide range of universities, research organisations, consultancies and NGOs have contributed, and continue to contribute, to the body of knowledge on the impact of marine litter, and to research ways to mitigate these impacts. The list of universities and research groups involved in primary marine litter research is too extensive to include here but can be inferred from the academic affiliations of authors cited in reviews of the scientific literature, such as that found in Law (2017). A good database of European marine researchers can be found in the EurOcean Marine Knowledge Gate[14], which provides an inventory of European and nationally funded marine science projects, including details on the organisations involved. Of the 6,307 projects listed on the register, involving 1,484 institutions over 134 countries, 507 are listed under the topic Marine Litter.

With the increasing concern and attention placed on marine plastic impacts, so has the number of initiatives to address marine plastic litter and the associated causes grown. As would be expected with an environmental issue of this magnitude, all of the major international agencies (e.g. UN Environment, Word Economic Forum, FAO) and large NGOs (e.g. WWF, IUCN, Greenpeace) are involved in campaigns addressing plastic pollution. However, a large number of community and grass roots organisations have also emerged in the fight again plastic pollution. This can perhaps be attributed to the fact that plastic litter is a particularly visible problem, but also that it is an issue where ordinary people feel they can take action (e.g. through beach clean ups and changing consumption habits). An example is the large number of campaigns against plastic straws found across the globe: The Last Plastic Straw (USA), Staws suck! (South Africa), One Less Straw (USA), The Last Staw (Australia), No Straw thanks (Hong Kong), For a Strawless Ocean (USA), DeStraw (UK)[15].

Of the action-oriented initiatives identified in this research, just over one-third are aimed upstream at addressing plastic consumption and production (i.e. at catalysing a more systemic change), with the majority aimed at addressing plastic in and/or entering the ocean (i.e. ocean cleanups and plastic litter awareness campaigns). Whilst this indicates a growing appreciation of the need for systemic change to address plastic marine litter, the focus, particularly from industry and government initiatives is still primarily around minimising waste, especially promoting recycling and better waste management.

14. http://kg.eurocean.org/

15. https://thelastplasticstraw.org; https://www.aquarium.co.za/blog/entry/straws-suck; https://onelessstraw.org/; http://www.laststraw.com.au/; https://www.opcf.org.hk/en/nostrawcampaign; www.strawlessocean.org; https://www.plasticfreepledge.com/

Table 8: Inter-governmental initiatives addressing marine plastics litter (Lighter shading denotes secondary focus)

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
APEC Virtual Working Group on marine debris						The APEC Chemical Dialogue approved the formation of a Virtual Working Group in collaboration with the Oceans and Fisheries Working Group to promote innovative solutions to the issue of marine debris particularly through a focus on sustainable land-based waste management. http://mddb.apec.org/Documents/2015/OFWG/OFWG2/15_ofwg2_025.pdf
Community of Ocean Action on Marine Pollution (UN Department of Economic and Social Affairs)						The Community of Ocean Action, aims to support its members in implementing marine pollution-related voluntary commitments by exchanging progress reports, experiences, lessons learned and good practices. https://oceanconference.un.org/coa/MarinePollution
FAO voluntary guidelines to mark fishing gear						Countries have agreed on a set of draft Voluntary Guidelines on Marking Fishing Gear. The guidelines are expected to receive final endorsement by FAO's Committee on Fisheries (COFI) in July 2018.
Global Partnership on Marine Litter (UN Environment)						The UN Environment Global Partnership on Marine Litter (GPML) is one of the three global multi-stakeholder partnerships of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA), and brings together various international agencies, NGOs, private sector entities, governments, academia, civil society and individuals in a bid to reduce and manage marine litter. http://web.unep.org/gpa/what-we-do/global-partnership-marine-litter
G20 Action Plan on Marine Litter						The G20 Action Plan on Marine Litter aims to reduce marine litter, especially land-based sources of single-use plastic and microplastics, and its associated impacts by 2025. http://www.mofa.go.jp/mofaj/files/000272290.pdf
Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (UN)						GESAMP advises the United Nations on the scientific aspects of marine protection, and provides a large amount of research into the sources, quantities and impacts of plastic within the marine environment, which can be used to guide interventions and policy decisions. http://www.gesamp.org/
OECD RE-CIRCLE project						The Organisation for Economic Co-operation and Development (OECD) RE-CIRCLE project provides policy guidance on resource efficiency and the transition to a circular economy and aims to identify and quantify the impact of policies to guide stakeholders in OECD member countries and emerging market economies. http://www.oecd.org/environment/waste/recircle.htm
Regional Seas Programme (UN Environment)						UN Environment coordinates the Regional Seas Programme, in which 143 countries have joined of 18 Regional Seas Conventions and Action Plans that aim to address the degradation of the world's oceans and coastal areas by engaging neighbouring countries in comprehensive and specific actions to protect their common marine environment. http://web.unep.org/regionalseas/who-we-are/regional-seas-programmes

Table 9: Initiatves involving local government addressing marine plastics litter (Lighter shading denotes secondary focus)

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
Fishing for litter (KIMO)						KIMO's (Local Authorities International Environmental Organisation) Fishing For Litter is an imaginative yet simple initiative that aims to reduce marine litter by involving one of the key stakeholders, the fishing industry. The project is designed to reduce the amount of marine litter in our seas by physically removing it and to highlight the importance of good waste management amongst the fleet. Participating vessels are given hardwearing bags to collect marine litter that is caught in their nets during their normal fishing activities. Filled bags are deposited in participating harbours on the quayside. http://www.kimointernational.org/fishing-for-litter/

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
Green Deals						Green Deals in the Netherlands is an accessible way for companies, other stakeholder organizations, local and regional government and interest groups to work with Central Government on green growth and social issues. The aim is to remove barriers to help sustainable initiatives get off the ground and to accelerate this process where possible. http://www.greendeals.nl
Makassar city administration / Garbage banks						Makassar city administration aims to have 333 garbage banks in its 143 sub districts. At least 230 garbage banks have emerged across the city, accommodating a total of about 6,000 suppliers. Some banks not only buys trash from people, but also offers credit programs, such as selling rice by instalment and providing loans.
WRAP						Working with industry, local authorities and government to help households across the UK benefit from improved recycling collections, innovation in resource re-use and an overall reduction in waste. http://www.wrap.org.uk/
Zero waste Cities (Zero Waste Europe)						Zero Waste Europe brings together and represents the European municipalities that have openly committed to the goal of continuously reducing waste generation and improving waste separate collection and hence redesigning the relationship between people and waste. https://zerowasteeurope.eu
Zero Waste Scotland						Zero Waste Scotland's mission is to influence and enable change – from gathering evidence and informing policy, to motivating practical behaviour change in individuals and organisations. They also make direct interventions to affect change, commonly in the form of finance, business support, technical advice, training and competence development or communications support. https://www.zerowastescotland.org.uk

Table 10: Funders of projects and initiatives addressing marine plastics litter (Lighter shading denotes secondary focus)

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
Closed loop oceans (Trash free Seas Alliance)						Closed Loop Ocean funds waste infrastructure solutions in Southeast Asia, with a focus on investments to improve collection, sorting and recycling markets, particularly across the plastic value chain (partnership with the Ocean conservancy) http://www.closedlooppartners.com/ocean/
Global Environment Facility (GEF)						The Global Environment Facility (GEF) Trust Fund was established on the eve of the 1992 Rio Earth Summit, to help tackle our planet's most pressing environmental problems. GEF funding to support the projects is contributed by donor countries. GEF funds are available to developing countries and countries with economies in transition to meet the objectives of the international environmental conventions and agreements. https://www.thegef.org/
Global Green Growth Institute (GGGI)						The GGGI delivery model combines technical assistance to governments through embedded country teams, and helps to mobilize finance. http://gggi.org/
MAVA						The Sustainable Economy Programme of the MAVA Foundation supports the development of the circular economy and redesign of plastics in collaboration with the New Plastics Economy Initiative. Also supporting research on the toxicity effects of plastic. http://en.mava-foundation.org/oaps/
New Plastics Economy Innovation Prize (Ellen MacArthur Foundation)						The New Plastics Economy Innovation Prize calls on designers, entrepreneurs, academics and scientists to rethink the plastics system and eliminate plastics packaging waste. The Prize is led by the Ellen MacArthur Foundation and was launched in collaboration with HRH The Prince of Wales's International Sustainability Unit, and is funded by Wendy Schmidt. https://newplasticseconomy.org/projects/innovation-prize

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
Plastic Solutions Fund						The Plastic Solutions Fund is a funders collaborative focused on reducing single-use disposable plastics with a goal of phasing out all non-essential uses by 2035. It focuses on countries most vulnerable to pollution, seeking to build a global movement to eliminate plastic packaging waste and stem the flow into the world's oceans. Partners: Oak Foundation, Overbrook Foundation, GRACE Communications Foundation, MAVA Foundation, Oceans 5, Adessium Foundation, Kristian Gerhard Jebsen Foundation, Marisla Foundation, Paul M. Angell Family Foundation. http://plasticsolution.org/
Summit Foundation						The Summit Foundation, a private family foundation, seeks to promote the health and well-being of the planet – its people and its natural environment – by achieving gender equality, protecting the earth's biodiversity and making cities livable. http://www.summitfdn.org

Table 11: Campaigns and initiatives addressing marine plastics litter (Lighter shading denotes secondary focus)

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
#breakfreefromplastic						The #breakfreefromplastic movement includes 1,060 groups and organisations from around the world, which aim to reduce plastic usage and poor plastic waste management. The movement targets improvements to the entire plastics value chain, including design, manufacture, use and end-of-life. https://www.breakfreefromplastic.org/
Beat the microbead						International campaign against microplastic ingredients in cosmetics. Supported by 94 NGOs from 39 countries and regions. www.beatthemicrobead.org
clean seas - turn the tide on plastic (UN Environment)						The UN Environment run #CleanSeas campaign targets marine litter by engaging with governments, the public and role players in the plastics value chain. Aims to transform production practices, consumer habits, standards and policies to reduce the amount of litter entering the marine environment, specifically focusing on the production and consumption of non-recoverable and single-use plastics. http://www.cleanseas.org/
Precious Plastic						The Precious Plastic campaign aims to promote recycling of plastics worldwide through education, knowledge sharing and the redesign of equipment. https://preciousplastic.com/
Rise Above Plastics						Surfrider Foundation initiative to raise awareness of plastic pollution and associated impacts and encourage people to recycle and stop using single-use products http://www.surfrider.org/programs/rise-above-plastics
Trash Free Seas / International Coastal Cleanup (Ocean Conservancy)						Trash Free Seas is an initiative run by the Ocean Conservancy to reduce and better understand plastic in the oceans, and stop the flow of plastic to oceans. The International Coastal Cleanup utilises people around the world to collect debris off beaches, recording, collating and publishing the results to improve understanding of marine plastics. https://oceanconservancy.org/trash-free-seas/
Plastics Pact (New Plastics Economy)						The Plastics Pacts are national or regional implementation initiatives of the New Plastics Economy, and bring together businesses from across the plastics value chain with governments and NGOs to tackle plastic waste. The UK Plastics Pact, led by the UK charity WRAP, was launched in April 2018 (http://www.wrap.org.uk/content/the-uk-plastics-pact). A second pact is being developed in Chile, led by TriCiclos.
World Aquariums against Marine Litter						Launched by EU Commissioner for Environment, Maritime Affairs and Fisheries in July 2017, participating aquariums are provided with material giving key facts on the issue and proposing actions to citizens to prevent and fight against marine litter. https://ourocean2017.org/campaigns/world-aquariums-against-marine-litter

Table 12: Partnerships and alliances addressing marine plastics litter (Lighter shading denotes secondary focus)

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
Cascading Material Vision (WWF)	○	●		●	○	World Wildlife Fund (WWF), in partnership with leading companies, developed the Cascading Materials Vision: a common framework of guiding principles for industry and other stakeholders that will help businesses source secondary materials that protect their profits, the environment and future wealth of our natural resources. https://www.worldwildlife.org/projects/cascading-materials-extending-the-life-of-our-natural-resources
Coast Watch Europe	●		●			Coastwatch Europe (CWE) is an international network of environmental groups, universities and other educational institutions, who in turn work with local groups and individuals around the coast of Europe. http://coastwatch.org
Food packaging Forum	●			○	●	FPF is leading a multi-partner research project on "Hazardous chemicals in plastic packaging: State of the art, prioritization, and assessment." The aim of the project is to compile current scientific information and make it accessible to all stakeholders. https://www.foodpackagingforum.org/
The New Plastics Economy (Ellen MacArthur Foundation)	●	●		○	●	The New Plastics Economy, launched by the Ellen MacArthur Foundation, is a three-year initiative to build momentum towards a plastics system that works, applying the principles of the circular economy and bringing together key stakeholders to rethink and redesign the future of plastics, starting with packaging. https://newplasticseconomy.org/
Parley	○	●	●	●	●	A collaboration space for creators, leaders and thinkers to create awareness for the beauty and fragility of the Oceans and to start and manage collaborations that can end their destruction. https://lea-stepken-qgx5.squarespace.com/#fortheoceans
Plastic Pollution Coalition		●		○	●	The Plastic Pollution Coalition is a group of more than 500 organisations and numerous individuals that seek to spread a common message about the effects of plastic pollution on the environment. The overall themes communicated include: minimising the use of single-use plastics, reducing overall consumption and the reuse and recycling of plastics http://www.plasticpollutioncoalition.org/
Trash Free Seas Alliance (Ocean Conservancy)	●	●		○	●	Trash Free Seas Alliance unites industry, science and conservation leaders who share a common goal for a healthy ocean free of trash, and provides a constructive forum focused on identifying opportunities for cross-sector solutions that drive action and foster innovation. https://oceanconservancy.org/trash-free-seas/plastics-in-the-ocean/trash-free-seas-alliance/

Table13: Organisations addressing marine plastics litter (Lighter shading denotes secondary focus)

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
Clean Oceans International		●	●			The Ocean Cleanup is a project to develop and produce a system to extract plastic litter from the oceans within the major gyres. https://www.theoceancleanup.com/
5 Gyres Institute	●	○	●		○	The Five Gyres Institute improves understanding of plastics in the ocean through scientific research and the use of this knowledge to empower action against marine plastics. https://www.5gyres.org/
IUCN Oceans and Plastics Platform	●	○	●	●		The Ocean and Plastics Platform is part of the International Union for Conservation of Nature's Marine and Polar Programme, which aims to report the facts and impacts of plastics within the marine environment and propose solutions to help solve this issue. http://oceansandplastics.info/
Net Works		●	●			Net-Works redesigns global supply chains to create sustainable and scalable solutions that reduce marine plastic, increase fish stocks and improve the lives of marginalised coastal communities. Operations in 36 communities in the Philippines and Cameroon, with expansion to Indonesia underway. http://net-works.com

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
Ocean Recovery Alliance						Ocean Recovery Alliance brings together new ways of thinking, technologies, creativity and collaborations in order to introduce innovative projects and initiatives that will help improve our ocean environment. Projects include the Plastic Disclosure Project, and the Global Alert platform. http://www.oceanrecov.org
Plastic bank						Plastic Bank aims to provide large scale sustainable premiums in every recycling community around the world. Plastic Bank Rewards are distributed and authenticated through the Plastic Bank app that uses Blockchain technology. https://www.plasticbank.org
Plastic 4 Change						Plasticforchange aims to change the social and environmental impacts of plastics by making profitable for companies to transition away from virgin plastics and start sourcing recycled. They create livelihoods and reduce plastic pollution by accelerating the development of recycling infrastructure by creating markets for the waste. http://www.plasticsforchange.org/
Plastic Oceans						The Plastic Oceans Foundation's mission is to change the world's attitude toward plastic within one generation, primarily through media (film) and education campaigns. https://www.plasticoceans.org/
Plastic Soup Foundation						Dutch Foundation and advocacy group to tackle plastic pollution.' "We do not get plastic out of the water. We want to put an end to the increasing pollution of the seas and oceans with plastics. We want to prevent even more plastics entering the sea in the future." https://www.plasticsoupfoundation.org/en/
Project Aware						Project Aware work with businesses, NGOs and governments to advocate for long-term solutions and influence waste management policies. Their citizen science program, Dive Against Debris® is focused on scuba divers reporting types and quantities of debris found on the ocean floor, helping bridge the gap in knowledge and build convincing arguments to lead to change. https://www.projectaware.org
Race for Water						The Race for Water Foundation is dedicated to the preservation of water. Their mission is to prevent plastic waste from reaching rivers by developing social and economic models that add value to plastic waste. http://www.raceforwater.com/
SEED4com						Sustainable Energy and Enterprise Development for Communities (SEED4Com) focuses on clean energy solutions, capacity building and rural entrepreneurship as key enablers of rural community development (including ecobricks made from plastic). http://www.seed4com.org/
Surfers Against Sewage						The Wasteland campaign brings to life concerns about plastic in the marine environment. Plastic Free Coastlines asks people to sign up and download their Individual Action Plans to reducing their plastic use. In a Bottle campaign calls for the introduction of a UK-wide Deposit Return Scheme (DRS) on plastic bottles. https://www.sas.org.uk
Surfrider						Activist network consisting of 80 chapters and 70 youth clubs that collaborate on the local and national level with regional staff and issue experts to carry out campaigns, programs and educational initiatives in their local communities. https://www.surfrider.org
Think Beyond Plastics Innovation Centre						Think Beyond Plastics runs a centre and annual challenge in a bid to develop and commercialise bio-based materials that can replace plastics. It also assists in the development of manufacturing and the design of packaging using these materials. https://www.thinkbeyondplastic.com/innovation-center
WeTap						WeTap improves awareness, access and use of public drinking fountains, reducing dependence on single-use plastic, while improving public health. http://wetap.org/
Waste Free Oceans						Waste Free Oceans collects plastic from the marine environment and produces new products in collaboration with recyclers, converters and brands. The collection method includes specific ocean trash collectors and utilising nets attached to fishing boats https://www.wastefreeoceans.org/

Table 14: Industry initiatives addressing marine plastics litter (Lighter shading denotes secondary focus)

Initiative	Knowledge	Action	In the ocean	Entering the ocean	Production and use	About
ABTA		■		■		Association of British Travel Agents (ABTA) is the UK's largest travel association, offering advice and guidance to the travelling public, as well as promoting responsible tourism. https://abta.com
ADUPI		■		■		Association of Recyclers in Indonesia adupi.org
EPRO	■	■		■		European Association of Plastics Recycling and Recovery Organisations (EPRO) is a partnership of specialist organisations working to develop and deliver efficient solutions for the sustainable management of plastics resources, includes 14 European countries plus South Africa and Canada. http://www.epro-plasticsrecycling.org/
Cambridge Institute of Sustainability Leadership	■			■		The Future of Plastic Packaging aims to inform UK policy and help companies across the soft drinks supply chain get on the front foot and work towards eliminating all avoidable plastic waste well in advance of the Government's 2042 target. https://www.cisl.cam.ac.uk/
CEFlex	■			■		CEFLEX is consortium of European companies and associations representing the entire value chain of flexible packaging. Their mission is to make flexible packaging more relevant to the circular economy by advancing better system design solutions. https://ceflex.eu/
CEMPRE		■		■		Compromisso Empresarial Para Reciclagem (CEMPRE) is an association dedicated to promoting recycling within the concept of integrated waste management. Cempre is maintained by private companies from various sectors. http://www.cempre.org.br/
Marine Litter Solutions		■		■		The Global Plastics Alliance is a collaboration among plastics and allied industry associations. 75 world plastics organizations in 40 countries have signed the Declaration for Solutions on Marine Litter committing to adopt additional improvements to reduce the effects of ocean pollution. https://www.marinelittersolutions.com
NextWave		■		■		Originally convened by Dell, the members of NextWave commit to decreasing the volume of plastic and nylon waste before it enters the ocean and to demonstrating the commercial viability and advantages of integrating ocean-bound plastics into their supply chains. https://www.nextwaveplastics.org/
Operation clean sweep		■		■		Plastic industry-led campaign, with the goal is to help every plastic resin handling operation implement good housekeeping and pellet, flake, and powder containment practices to work towards achieving zero pellet, flake, and powder loss. https://opcleansweep.org

5

Measures and policies for addressing marine plastics

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Chapter highlights

- UNEA resolutions and Goal 14 “Conserve and sustainably use the oceans, seas and marine resources” of the UN 2030 Agenda for Sustainable Development and Sustainable Development Goals (SDGs) setting targets specifically on marine litter, sets marine plastic firmly on the global environmental agenda for action.
- The most encompassing legislation on marine plastic is the **United Nations Convention on the Law of the Sea (UNCLOS)**. It is the only binding policy that compels nations to minimise pollution from both marine and land based sources that may enter the marine environment.
- The **Regional Seas Conventions and Action Plans** are the most directly relevant to reducing plastic pollution from land-based activities. The action plans target key activities and sources of plastic waste in 18 separate regions and set down binding and non-binding legislation to reduce these sources.
- The **EU Marine Strategy Framework Directive** (MSFD) is the first EU legislative instrument related to the protection of marine biodiversity and ecosystems through managing human activities that have an impact on the marine environment. The MFSD requires member states to develop a marine litter strategy, thus most member countries have implemented - or are in the process of developing - National Marine Strategies.
- Lightweight plastic carrier bags have been the subject of the greatest number of legislative interventions; most EU member countries have taken some form of action on plastic bags, either bans or taxes, or voluntary actions, whilst a number of developing countries have also placed bans, restrictions and other disincentives (taxes) on plastic bags (and some other plastic products). These actions in developing countries have been motivated primarily by waste management and litter concerns.
- The limited information that is available on restrictions and bans of single-use plastics indicate that policies and legislation can only be successful with sufficient monitoring and enforcement. Also, that taxes can be ineffective if not pitched at the correct level and point in the value chain.

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Plastic has been detected in all major marine habitats across the world's oceans (Law, 2017), with increasing evidence of significant adverse impacts on coastal and marine biodiversity (SCBD, 2016) and on livelihoods depending on the sea (ten Brink et al., 2016). The predicted high rate of increase in plastics consumption and production, together with the ubiquity of marine plastic, has led to increasing policy and legislative focus on plastics consumption, production and waste management.

The United National Environment Assembly (UNEA) has drawn attention to the issue of marine plastic since its first Session (UNEA-1) in 2014, and marine plastic has been the subject of a number of resolutions. An overview of international, regional and sub-regional responses is given in Section 5.1, with a comprehensive review available in *Combating marine plastic litter and microplastics: An assessment of the effectiveness of relevant international, regional and subregional governance strategies and approaches* (UNEP, 2017b). National strategies and responses are discussed in Section 5.2, together with the policies and measures applied.

Given the steep predicted increase in plastics production, and the fact that even in economies with good waste management practices there is an inevitable leakage/litter fraction, concerted abatement efforts to reduce the flow of plastic into the ocean, will result in the mass of plastic in the ocean stabilising rather than declining. This implies abatement efforts need to be coupled with a longer-term systemic solution (Ocean Conservancy, 2015). Measures to achieve more sustainable consumption and production of plastic products have tended to focus on administrative and economic instruments (product bans and taxes), with examples given in Section 5.2.2. Systemic solutions to marine plastics are those avoiding the consumption and production of plastic in the first place are largely lacking, for example, through innovative business models allowing reusable products, or through substantial redesign of plastic products so that they are resource efficiency and do not become waste (i.e. producing products with high residual material value). Extended Producer Responsibility (EPR) has been the most widely applied measure to move industry towards such business models, particularly those geared toward increased recycling, with examples given in Section 5.2.3.

Whilst eliminating plastic waste is the long-term goal, the current evidence that as much as 60% of the total flow of plastic leaked to the oceans is from just five countries (Jambeck et al., 2015) puts the urgent short-term need on measures to address inadequate waste management in these and other developing nations. Section 5.2.3 thus looks at waste management policies in developing economies.

5.1. International, regional and sub-regional responses

Global multilateral agreements, initiatives and frameworks

The UN **2030 Agenda for Sustainable Development and Sustainable Development Goals (SDGs)**, adopted by world leaders in September 2015, has a strong call to action on marine litter in **Goal 14: Conserve and sustainably use the oceans, seas and marine resources.** Goal 14 includes the following targets:

- **14.1:** By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution;
- **14.2**: By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans;
- **14.7**: By 2030, increase the economic benefits to Small Island developing States and least

developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism;

- **14.a**: Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries;
- **14.c**: Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want.

A number of the other SDG targets, whilst not directly aimed at protecting marine resources, will have beneficial effects on marine plastics and microplastics, in particular under Goal 12 on Sustainable Consumption and Production. These targets include (UNEP, 2016b):

- **6.3**: By 2030, the proportion of untreated wastewater should be halved;
- **11.6**: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management;
- **12.1**: Implement the 10-year framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries;
- **12.2**: By 2030, achieve the sustainable management and efficient use of natural resources;
- **12.4**: By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment;
- **12.5**: By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse;
- **12.8**: By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature;
- **12.a**: Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production;
- **12.b**: Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products; and
- **15.5**: Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

Governments are expected to establish national frameworks for the achievement of the Goals. Reviewing progress will require quality, accessible and timely data collection, although implementation and monitoring responsibility remains primarily with the countries (UN Environment, 2017a, UN, 2015).

Five of the G7 nations have agreed to an **Ocean Plastics Charter**. The charter presents the commitment of the leaders of Canada, France, Germany, Italy and the United Kingdom to move toward a more resource-efficient and sustainable approach to the management of plastics. The Leaders resolve to "take a lifecycle approach to plastics stewardship on land and at sea, which aims to avoid unnecessary use of plastics and prevent waste, and to ensure that plastics are designed for recovery, reuse, recycling and end-of-life management to prevent waste through various policy measures". Commitments include working toward making 100% of plastics reusable, recyclable or recoverable (where viable alternatives do not exist) by 2030; reducing single-use plastics (whilst taking into account the full environmental impacts of alternatives); working with industry and other levels of government to recycle and reuse at least 55% of plastic packaging by 2030 and recover 100% of all plastics by 2040; and promoting the use of recycled plastic. In the Charter, the Leaders also pledge to build recycling infrastructure and innovate around more sustainable technologies, as well as foster sustainable lifestyles and education (G7, 2018).

The commitment of the United Nations Environment Assembly to combating marine plastics and microplastics are evident in the **UNEA Resolution 2/11**, which resulted in the report "Combating marine plastic litter and microplastics: An assessment of the effectiveness of relevant international, regional and sub-regional governance strategies and approaches". Most recently UNEA-3 provides commitments to:

- Strengthening the United Nations Environment Programme's contribution to the Global Partnership on Marine Litter;
- Providing advice on the prioritizing of activities upon request based on best available scientific knowledge, and the most environmentally sound and cost-effective measures to prevent and reduce marine litter and microplastics, according to the UNEA resolutions 1/6, 2/11 and this resolution;
- Facilitating the establishment and implementation of regional and national action plans to prevent and reduce litter and microplastics in the marine environment, as requested by Member States;
- Supporting countries, upon request, in collaboration with other international organisations and relevant stakeholders, in closing data gaps and improving the availability of accessible data on sources and extent of marine litter and microplastics in the environment; and
- Closely liaising with other UN agencies to encourage them to support programmes to achieve marine litter and microplastic reduction.

The strong focus of The United Nations Environment Assembly on marine plastic litter is evident in the number of resolutions and decisions taken on measures to reduce marine plastic litter and microplastics[16], and, earlier, in the establishment of **The Global Partnership on Marine Litter (GPML)** under The **Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA)**. The GPA is the only global intergovernmental mechanism directly addressing the connectivity between terrestrial, freshwater, coastal and marine ecosystems, and encouraging collaboration between parties (UN Environment, 2017a, UNEP, 2016b). The GPML is one of the three global multi-stakeholder partnerships of the GPA, and brings together various international agencies, NGOs, private sector entities, governments, academia, civil society and individuals in a bid to reduce and manage marine litter. The major objectives of this partnership are (UNEP, 2018):

- Preventing and managing marine litter;
- Reduction of the impacts of marine litter;
- Promoting resource efficiency to reduce waste;
- Knowledge management and education on marine litter; and
- Assessing emerging issues associated with marine litter

A significant objective of the GPML is enhancing international cooperation and coordination through the promotion and implementation of the **Honolulu Strategy: A global framework for the prevention and management of marine debris** developed by UNEP

16. Resolutions 1/6 "Marine plastic debris and microplastics" and 2/11 "Marine plastic litter and microplastics"

and National Oceanic and Atmospheric Administration (NOAA) following the Honolulu Commitment (a multi-stakeholder pledge endorsed at the fifth International Marine Debris Conference) (NOAA and UNEP, 2011). The goals of the Honolulu Strategy are:

- Reduced amount and impact of land-based sources of marine debris introduced into the sea;
- Reduced amount and impact of sea-based sources of marine debris, including solid waste; lost cargo; abandoned, lost or otherwise discarded fishing gear (ALDFG); and abandoned vessels, introduced into the sea; and
- Reduced amount and impact of accumulated marine debris on shorelines, in benthic habitats, and in pelagic waters.

The Honolulu strategy acknowledges the needs for research, monitoring, collaboration and the development of new technologies to achieve a reduction in marine litter. The strategy is however non-binding and does not provide any firm targets or deadlines (UN Environment, 2017a).

Also part of the Global Programme of Action and hosted by UN Environment, the **Global Wastewater Initiative** has relevance to microplastic losses to the ocean. Established in 2013, the Global Wastewater Initiative is a voluntary multi-stakeholder partnership working to address wastewater-related issues, prompt coordination and encourage investments in wastewater management. The Initiative is also working towards having wastewater viewed as a valuable resource instead of a waste product (United Nations Environment Programme, 2017).

The most encompassing legislation on marine plastic is the **United Nations Convention on the Law of the Sea (UNCLOS)**, which is the legal framework governing all marine activities and activities that may cause marine pollution. As such, it is the only binding policy that compels nations to minimise pollution from both marine and land based sources that may enter the marine environment (UN Environment, 2017a, UN, 1994). The **Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (United Nations Fish Stocks Agreement)** includes requirements for states to minimise pollution and the loss of gear from ships. This agreement is principally implemented through regional fisheries bodies, which typically implement their own policies to minimise plastic pollution and lost gear (UN Environment, 2017a).

The **International Convention for the Prevention of Pollution from Ships (MARPOL)** is the major International Maritime Organization (IMO) convention dealing with pollution from ships. This convention legally prevents the disposal of any form of plastic from ships and requires all ships, including fishing boats, to do there upmost to prevent the loss of plastic items overboard during operation. Larger vessels are also required to develop garbage management plans and/or garbage record plans to ensure ship based pollution is minimised (UN Environment, 2017a, UNEP, 2016b).

The **Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters (London Convention)** and the **London Protocol** similarly prevent parties from dumping plastics or similar synthetic materials into the marine environment (UN Environment, 2017a, UNEP, 2016b).

The **FAO Code of Conduct for Responsible Fisheries** sets out standard for fishing vessels to ensure that garbage is stored on-board and discharged effectively at port and that the loss of fishing gear is minimised. This code of conduct is merely a standard and as such is not legally binding (UN Environment, 2017a, UNEP, 2016b).

The **Food and Agriculture Organisation of the United Nations (FAO)** is proposing a roadmap to tackle the issue of ALDFG. The roadmap will be developed through the following activities, working closely with fisheries management bodies and the fishing industry (SCBD, 2016):

- Awareness-raising programmes involving national fisheries authorities, regional fisheries bodies and the fishing industry;
- Improving port reception facilities for derelict gear, marking fishing gear and encouraging that ALDFG is part of the licensing conditions;
- Encouraging the reporting of lost gear using a no-penalty approach;
- Incentivizing gear clean up and gear removal;
- Reviews of legal frameworks in relevant countries; and
- Public-private partnerships for ALDFG removal that involve fishers and offer rewards for social and environmental responsibility.

A number of other conventions and frameworks have bearing on marine plastic, even if that is not their primary focus. These are summarised in Table 15.

Table 15: Global multilateral conventions and frameworks with relevance to marine plastics (UN Environment, 2017a, UNEP, 2016b)

Convention / Framework	Comment
Convention on Biological Diversity (CBD)	Includes targets to ensure pollution does not cause a detrimental effect on natural environments and that the pressures on coral reefs and other vulnerable systems are minimised. Some of the Aichi Biodiversity Targets included in the convention which impact marine plastic are: ▪ 6.a: Develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes which shall reflect, inter alia, the measures set out in this Convention relevant to the Contracting Party concerned; ▪ 6.b: Integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies; ▪ 8.d: Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings; ▪ 8.e: Promote environmentally sound and sustainable development in areas adjacent to protected areas with a view to furthering protection of these areas; and ▪ 8.f: Rehabilitate and restore degraded ecosystems and promote the recovery of threatened species, inter alia, through the development and implementation of plans or other management strategies Additional decisions also aim to reduce marine plastic and request nations to adjust legislation in a bid to combat marine plastics across the entire plastics value chain. The additional decisions are however non-binding.
Convention on the Conservation of Migratory Species of Wild Animals (CMS)	Includes action plans to address the impact of marine plastics on turtle, dolphin and whale species; strategic plans to reduce the detrimental effects of marine pollution; and resolutions that parties are encouraged to undertake. The resolutions include addressing gaps in our understanding of the impacts of marine plastics, identification of best practice for marine vessels and the implementation of awareness campaigns.
Convention on the Law of Non-Navigational Uses of International Watercourses	Requires parties to prevent harm to rivers and other water bodies shared with other states. It does not specifically mention plastics, however it does require the prevention, reduction and control of all pollution
Convention on the Transboundary Movements of Hazardous Wastes and Their Disposal (Basel Convention)	The Basel Convention requires all persons involved in the management of plastic waste to prevent pollution of the environment and minimise the impact of the pollution on humans and the environment when pollution does occur. This Convention addresses both land- and sea-based sources of waste and also requires parties to minimise the generation of plastics and ensure sufficient disposal facilities for the effective management of produced waste. Recent decisions have also highlighted the need to further address plastic waste and marine plastics and regional centres were encouraged to address the impact of plastics.
Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention)	Targets specific persistent organic pollutants (POPs), that were used as additives within plastic and are known to absorb into plastics, and regulates the use and disposal of these compounds. It further includes measures to reduce and eliminate wastes containing these POPs
Strategic Approach to International Chemicals Management (SAICM)	Voluntary policy framework aiming to ensure the sustainability of chemicals throughout their life cycle. It targets how chemicals are produced, used and disposed; however it does not specifically refer to plastics
10 Year Framework of Programmes on Sustainable Consumption and Production (10YFP)	Adopted at RIO+20, the 10YFP supports the shift to sustainable consumption and production patterns.

Regional responses

Regional multilateral agreements with relevance to marine plastic are listed in Table 16. The most directly relevant to reducing plastic pollution from land-based activities are the **Regional Seas Conventions and Action Plans.** These are 18 separate bodies that encourage cooperation between countries sharing the same marine environment. The plans are administered either directly by, or in collaboration with, **UN Environment**, or independently by the regional bodies, and are based on the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) principals. As such, the conventions and action plans target key activities and sources of plastic waste entering each region and set down binding and non-binding legislation to reduce these sources (UN Environment, 2017a, UNEP, 2016a, UNEP, 2016b). 14 of the Programmes include legally binding policies.

The overall aim of the Regional Seas Programmes is to stop the sources of, and more recently the activities causing, marine litter, while the newest policies also include requirements to eliminate litter already occurring within the marine environment. A wide range of implementation measures, and also requirements for monitoring and reporting are included within these Programmes (UN Environment, 2017a, UNEP, 2016b).

Table 16: Regional multilateral agreements and initiatives with relevance to marine plastics (United Nations Environment Programme, 2017)

Region	Convention / Framework
Africa	Revised African convention on the conservation of nature and natural resources (adopted March 2017)
	Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa (1991)
	Convention for Cooperation in the Protection, Management and Development of the Marine and Coastal Environment of the Atlantic Coast of the West, Central and Southern Africa Region (Abidjan Convention) and the Additional Protocol to the Abidjan Convention Concerning Cooperation in the Protection and Development of Marine and Coastal Environment from Land-based Sources and Activities in the Western, Central and Southern African Region (LSBA Protocol - 2012)
	Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region (Nairobi Convention) and its Protocol Concerning Co-operation in Combating Marine Pollution in Cases of Emergency in the Eastern African Region
	Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (Jeddah Convention) and Protocol Concerning the Conservation of Biological Diversity and the Establishment of Network of Protected Areas in the Red Sea and Gulf of Aden (2005), Protocol Concerning the Protection of the Marine Environment from Land-Based Activities in the Red Sea and Gulf of Aden (2005), and Protocol Concerning Technical Cooperation to Borrow and Transfer Experts, Technicians, Equipment and Materials in Cases of Emergency (2009)
Asia	Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement of Hazardous Wastes within the South Pacific Region (Waigaini Convention) (1995)
	Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978) and Protocol concerning Regional Cooperation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency (1978)
	The Action Plan for the South Asian Seas Programme (1995)
	Action Plan for the Protection and Sustainable Development of the Marine and Coastal Areas of the East Asian Region (1994)
	The Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region (1994)
Europe	The Barcelona Convention for the Protection of the Mediterranean Sea against Pollution (1976) and its Protocols: ▪ Protocol for the Prevention and Elimination of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea (1995) ▪ Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea (2002), which replaced the Protocol ▪ Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities (1996) ▪ Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean (1995) ▪ Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil (1994) ▪ Hazardous Wastes Protocol: Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal (1996) ▪ Protocol on Integrated Coastal Zone Management in the Mediterranean (2008)
	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) (1992)
	Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) (1992)
	River Basin Conventions: Danube (1994), Elbe (1990), Oder (1996), Rhine (1999)

Region	Convention / Framework
	The Convention on the Protection of the Black Sea Against Pollution (Bucharest Convention) and its Protocols: ■ Protocol on Protection of the Black Sea Marine Environment Against Pollution from Land Based Sources (1992), ■ Protocol on Cooperation in Combating Pollution of the Black Sea Marine Environment by Oil and other Harmful Substances in Emergency Situations; and ■ Protocol on the Protection of the Black Sea Marine Environment Against Pollution by Dumping
	Framework Convention for the Protection of the Marine Environment of the Caspian Sea (Tehran Convention) and the and the Protocol for the Protection of the Caspian Sea against Pollution from Land-based Sources and Activities (2012)
Latin America and the Caribbean	Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (Cartagena Convention) (1983) covers the marine environment of the Gulf of Mexico, the Caribbean Sea and the areas of the Atlantic Ocean, and calls on Parties to take appropriate measures to control pollution of the wider Caribbean Sea region from land based sources, ships, dumping, sea bed activities, and airborne sources: ■ Protocol Concerning Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean Region (1990). ■ Protocol Concerning Pollution from Land-Based Sources and Activities (1999)
	Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific (1981) (Lima Convention) obligates Parties to take measures to prevent, reduce and control pollution of the marine environment and coastal area of the South-East Pacific and to ensure appropriate environmental management of natural resources
	Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the Northeast Pacific (Antigua Convention) and Plan of Action for the Protection and Sustainable Development of the Marine and Coastal Environment of the North-East Pacific
Antarctic	Protocol on Environmental Protection to the Antarctic Treaty (1991)
	Convention on the Conservation of Antarctic Marine Living Resources (1980) (CCAMLR)
Arctic	Arctic Contaminants Action Program (ACAP) mandated to prevent adverse effects from, reduce, and ultimately eliminate pollution of the Arctic environment
	Arctic Monitoring and Assessment Programme (AMAP) mandated to provide reliable and sufficient information on the status of, and threats to, the Arctic environment, including scientific advice on actions to be taken to support Arctic governments in their efforts to take remedial and preventive actions relating to contaminants
	Conservation of Arctic Flora and Fauna (CAFF) mandated to develop common responses on issues of importance for the Arctic ecosystem, including responses on conservation opportunities and political commitments
	Emergency Prevention, Preparedness and Response (EPPR) mandated to contribute to the protection of the Arctic environment from the threat or impact that may result from an accidental release of pollutants or radionuclides
	Protection of the Arctic Marine Environment (PAME) mandated to address policy and non-emergency pollution prevention and control measures for the protection of the Arctic marine environment from both land and sea-based sources
	Sustainable Development Working Group (SDWG) incorporates activities to prevent and control disease and injuries by monitoring the impact of pollution and climate change on health and Sustainable Development of the people living in the Arctic

Sub-regional responses: the example of the European Union.

The **EU Marine Strategy Framework Directive** (MSFD) is the first EU legislative instrument related to the protection of marine biodiversity and ecosystems through managing human activities that have an impact on the marine environment (SCBD, 2016). The MFSD requires states to develop a marine litter strategy that includes an assessment of the current marine state, establish a "Good Environmental Status" for their waters, set targets and associated indicators and develop a Programme of Measures (PoM) to achieve these targets (UNEP, 2016a, European Commission, 2017b). "Good Environmental Status" is defined as the "Properties and quantities of marine litter do not cause harm to the coastal and marine environment" (European Commission, 2017a). A summary of various states interpretation of this and their policies can be found in Arroyo Schnell et al. (2017).

The EU Marine Strategy Framework Directive (MSFD) is translated into national legislation using such instruments as a **National Marine Strategy**. Thus most member countries have implemented, or are in the process of developing, National Marine Strategies. Many countries (**Belgium, Bulgaria, Croatia, Cyprus, Denmark, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Malta, the Netherlands, Slovenia, Spain and the United Kingdom**) have targets for marine litter in their National Marine Strategies. A few countries have indicated that they have or plan to develop **Action plans or Strategies specifically for Marine Litter**. **Scotland** and **Northern Ireland** both have a Marine Litter Strategy and **England** has a National Litter Strategy that includes marine litter. Countries planning to develop action or management plans for marine litter include **Estonia** (for managing marine litter in harbours), **Cyprus, Croatia, Slovenia** (implementing the Mediterranean action plan) and the Flemish region of **Belgium** (Arroyo Schnell et al., 2017).

The MSFD is one of a series of EU Directives with relevance to marine litter prevention and management, with 13 Directives having relevance and potential for adaptation in order to develop a more effective and integrated EU marine litter policy (Van Acoleyen et al., 2013). Of these, the most relevant are the **Packaging and Packaging Waste Directive**, the **Water Framework Directive**, the **Micro-and Nano-Plastics in Cosmetics Directive**, the **Port Facilities Directive** and the **Waste Framework Directive**.

The **EU Circular Economy Action Plan** focuses on sustainable production, use, reuse and disposal of products in a way that maximises resources and minimises wastes (European Commission, 2018b). Included in this plan is a target to reduce beach litter and lost fishing gear by 30% until 2020 (European Commission, 2017).

The recently released **European Strategy for Plastics in a Circular Economy** further describes the vision for a revised and sustainable plastics economy in Europe. This document includes aspects on: improving the economics and quality of recycling, preventing waste and littering, increasing investment and innovation in circular solutions and increasing global action (European Commission, 2018a).

5.2. National responses

Strategies, policies and action plans

Country level strategies and action plans are mostly focusing on Circular Economy, Sustainable Consumption and Production, and Marine Litter, but mostly do not specifically focus on plastics.

China has developed a Circular Economy action plan. The **12th Five Year Plan** calls for the development of a Circular Economy, as detailed in the **Circular Economy Development Strategies and Action Plan**. These plans call for government, society and industry to work together to produce a sustainable production model.

Countries that have policies specifically addressing marine plastics include:

- In **Japan** the **Law for the Promotion of Marine Litter Disposal** mandates the central Government to formulate a marine litter policy, which led to the creation of the Basic Policy for Comprehensively and Effectively Promoting Measures against Marine Litter (adopted in 2010). The law also mandates the prefectural governments to formulate regional plans and establish councils to undertake their mandated activities (UNEP, 2016a).
- In the **USA** the **Marine Plastic Pollution Research and Control Act** requires the study of the sources, amounts and effect of plastics in the marine environment, and the **Marine Debris Research, Prevention and Reduction Act** requires the establishment of methods to reduce the sources, amounts and effects of these plastics (UNEP, 2016a).
- **Nigeria** has a proposal to develop a national action plan on marine litter management through collaboration between UNEP-GPA and the Nigerian Maritime Administration and Safety Agency. Nigeria is also implementing Annex V of MARPOL through the adequate provision of waste reception facilities by Nigeria Ports Authority and their subsequent regulation by relevant government agencies (SCBD, 2016).
- In **Australia**, the **Threat Abatement Plan for the Impacts of Marine Debris on Vertebrate Life (TAP)** aims to monitor and remove existing marine debris, while ensuring the prevention of further release of marine debris (UNEP, 2016a).

Whilst the above indicates countries are developing strategies and policies specifically aimed at marine plastic, most national strategies on water and waste are partially addressing marine plastic and microplastics, with waste strategies generally targeting increased waste recovery and recycling. For example, in the **USA** the **Clean Water Act**, with implementation through the Water Resource Control Boards, has led to structural controls to capture plastics and other debris before it reaches rivers and the marine environment (SCBD, 2016). Strategies addressing biodiversity and environmental protection also have relevance to marine plastics in many instances, For example, in **China**, The **Environmental Protection Law** includes improved protection to the marine environment by ensuring that discharge and dumping of wastes into the sea is reduced and to guard against environmental damage (China Dialogue, 2014). However, these examples are only pieces of a larger need for national strategies and related policies to systemically addressing marine plastics, in a comprehensive manner, focusing on the simultaneous efforts needed from different stakeholders at different stages of the value chain.

Nations across the world use a variety of instruments to dis-incentivise the use of certain products and materials, to encourage product redesign or to encourage recovery and recycling. Legislative instruments can be broadly categorised into **administrative and economic** (OECD, 2001, OECD, 2016, Sanz et al., 2015, Hennlock et al., 2014). **Administrative or regulatory** instruments, include measures such as product bans or restrictions, landfill bans, landfill diversion targets, ban on landfilling source separated materials, incineration bans, waste prevention targets, recycling targets, recovery targets, minimum recycled content requirements, material restrictions, and source separation requirements. **Economic** instruments, include measures such as landfill taxes, incineration taxes, deposit-refund schemes, material taxes, input taxes, product taxes, pay as you throw, advance recycling fees, and upstream combination taxes/subsidies. Some legislative instruments, such as extended producer responsibility, producer take-back requirements, and waste-to-energy as renewable energy source include both. administrative and economic aspects.

In combination with the regulatory and economic instruments, nations have at their disposal **voluntary** and **information-based** measures. Information-based tools, such as ecolabels, are intended to provide knowledge on the performance of products in a standardised manner so that stakeholders, such as consumers, can make informed choices. Other information-based/education measures include government training programmes and consumer advice centres/portals. Voluntary instruments cover such aspect as voluntary programmes, industry commitments and negotiated agreements (UN Environment, 2015).

The following two sections are focusing on measures addressing the production and consumption phases of plastics value chain (5.2.2) and measures addressing the end-of-life phase of the plastics value chain (5.2.3).

Measures addressing the production and consumption phases of the plastics value chain

Regulatory and economic instruments: Bans, taxes and deposit schemes.

Taxes, deposit refund schemes and material bans are instruments that can be applied prior to the use phase to either limit or eliminate consumption or increase the return of materials by consumers after use. Material taxes increase the cost of materials, such as virgin polymer, whereas input taxes increase the cost of products, such as packaging. Such taxes are specifically aimed at problem materials or products and aim to minimise product usage and promote the selection of different, more environmentally attractive alternatives (OECD, 2016). Combination tax/subsidies and advance recycling fees are similar in that they involve producers paying a tax on designated products, however here the tax is utilised to promote recycling activities and collect money to cover downstream collection and recycling operations (OECD, 2016). A final option considered in the category of upstream interventions is the complete ban of certain problem materials that lead to excessive volumes of waste or waste streams that are difficult to treat (OECD, 2016).

Product taxes are commonly applied to packaging, with the Netherlands, Austria, Denmark, France, Italy and Norway all having taxes on all packaging, whilst Belgium, Finland and Sweden have taxes on beverage containers (Hennlock et al., 2014, Sanz et al., 2015).

Deposit-refund scheme that involve the payment of an additional fee for products that is then refunded on return of the packaging to designated collectors are relatively common worldwide for beverage cans and glass bottles, however some European countries also apply deposit schemes to plastic packaging (Hennlock et al., 2014), with Denmark, Sweden and Lithuania having deposit systems for plastic bottles (Arroyo Schnell et al., 2017).

More than 60 countries have introduced **bans** and **levies** to curb single-use plastic waste. Plastic bags and, to a lessor extent, foamed plastic products like Styrofoam have been the main focus of government action so far (UN Environment, 2018). The EU Directive on packaging and packaging waste refers to the reduction of the consumption of lightweight **plastic carrier bags**, thus most EU member countries have taken some form of action on plastic bags, either bans or taxes, as detailed above, or voluntary actions (discussed below) (Arroyo Schnell et al., 2017). There are also international commitments, such as the coalition promoted by France and other EU Member States including Sweden and Italy, aiming at the elimination of single-use plastic bags in all participating countries (Arroyo Schnell et al., 2017). A number of developing countries have also placed bans, restrictions and other disincentives (taxes) on plastic bags (and some other plastic products) motivated primarily by waste management and litter concerns. A review and detailed chronology of global plastic bag policy interventions is available in Xanthos and Walker (2017), whilst (UN Environment, 2018) *Single-Use plastics: A Roadmap for Sustainability* provides case studies across Europe, Africa, Asia and America.

Countries that have effected bans on plastic bags include:

- **Bangladesh** was the first country to ban plastic bags (in 2002), with the ban applying to all bags or containers for purchasing, selling, keeping or carrying another item manufactured from polyethylene, polypropylene or a mixture thereof (UNEP, 2016a). Manufacturers contravening this legislation faced a potential 10-year jail sentence and/or a fine, while persons selling, distributing or using the bags faced a potential 6-month jail sentence and/or a fine (green page, 2013). The ban initially worked, with plastic bag use stopping for more than a year (Irin, 2011, Prothom Alo, 2014). However, a lack of enforcement, with few fines handed out since 2006, and a lack of cost-effective alternatives has meant that plastic bag use has resumed (green page, 2013, Irin, 2011, Prothom Alo, 2014).
- **Eritrea** banned all plastic bags in 2005, with heavy fines for producers and distributors (News 24, 2005, fikrejesus, 2017). Individuals caught with plastic bags do not receive a fine, however they are required to tell authorities where they obtained the bags, so that the appropriate producer/distributor can be fined (News 24, 2005). Currently it appears that the ban has worked, with Eritreans using cloth, nylon and straw bags as alternatives (fikrejesus, 2017).
- **Tanzania** banned the use of plastic bags thinner than 30 microns in 2006, before extending this ban to plastic bags thinner than 50 microns in 2015 (Mtulya, 2016, Ubwani, 2018). This ban has also been reported as a ban on any bags thinner than 100 microns (UNEP, 2016a). In recent years Tanzania has also announced a ban on all plastic bags, although this legislation has not come into effect due to concerns around the economic effect it will have on the plastic bag industry (Xinhua Net, 2017, Ubwani, 2018, Mushi, 2015). This lack of implementation has resulted in continued plastic bag use within the country (Mushi, 2015).
- **Rwanda** banned the use of all non-biodegradable plastic bags in 2008, along with the manufacture or import of any such bags (UNEP, 2016a, Clavel, 2014). This ban has been strictly enforced, with heavy fines and jail time for offenders, and has largely been successful in stopping the use of

plastic bags (Freytas-Tamura, 2017, Fullerton, 2018, Clavel, 2014). However, a black-market for plastic bags imported from neighbouring countries developed itself. Rwandan border officials attempt to prevent these imports through constant searches and heavy penalties, including fines and extended jail time for offenders (Freytas-Tamura, 2017, Fullerton, 2018).

- **Haiti** banned the import, manufacture and marketing of black polyethylene bags in 2012, although white plastic bags and plastic bags used to transport water were exempt from the ban (ENS, 2012, Charles and Morgan, 2012). Due to lack of alternatives and lack of enforcement the ban was not applied (Daniel, 2012). Haiti published a second decree aimed at making alternative materials available; however it is reported that plastic bag use continues (HGW, 2013).
- **Kenya** banned the manufacture, selling or carrying of plastic bags in 2017. This ban includes the toughest sanctions for offenders in the world, with large fines or jail time of up to four years (Reuters, 2017, Oniang'o, 2017). Due to the recent nature of this ban it is not possible to establish its effectiveness yet.
- **Macedonia** banned the use of plastic bags with a capacity of below 5 kg and implemented a fee for plastic bags with a capacity of over 5 kg In 2009 (MINA, 2008, MIA, 2013). This ban was meant to be enforced with a fine, however this has not occurred and plastic bags are widely used throughout the country (MIA, 2013, Health4earth, 2015).
- 18 states/Union Territories in **India** have banned plastic bags, with partial bans in many of the other states/Union territories (CPCB, 2017). However, it has been observed that plastic bags are stocked, sold and used indiscriminately in States/UTs that have imposed bans on the use and sale of plastic carry bags (CPCB, 2017, Johari, 2018).
- **France** ended the supply of single-use plastic bags as of July 2016 and ended the provision of bags intended for the packaging of goods from January 2017 (Arroyo Schnell et al., 2017).
- **China** banned the production, use and sale of plastic bags less than 25 microns in thickness in 2008 (UNEP, 2016a). However, the ultra-thin bags can be found throughout China. Reasons identified for this failure include: lack of consultation between government and stakeholders prior to implementation, retailers pursuit of profit, the difficulty in changing consumer habits and lack of enforcement (Feng, 2017).
- **Botswana** banned the manufacture or import of plastic bags less than 24 microns in thickness in 2007 (Dikgang and Visser, 2010). However, the legislation has not resulted in positive or sustainable results according to the Botswana government and they are currently looking at implementing a complete ban on plastic bags to address the problem (Botswana Daily Mail, 2018).
- **Ethiopia** banned the use of plastic bags less than 33 microns in thickness In 2008 (UNEP, 2016a). The Ethiopian government has attempted to enforce this legislation and has recently closed down three factories that were producing thinner plastic bags. However, illegally thin bags can still be found, especially in markets (Beyene, 2018, Xinhua, 2017b).

Many countries have employed taxes, often coupled with thickness regulations, as an alternative to outright bans on plastic bags. Countries that have implemented taxes include:

- **Ireland** implemented a levy on all disposable plastic bags in 2002 in a bid to reduce consumer consumption of these bags. This levy was only implemented after the government obtained support from key stakeholders. The levies collected are supplied to the Environment Fund, where they are used, along with other environmental purposes, to fund recycling facilities and enforce waste management legislation. Since inception, this levy has reduced plastic bag consumption by 90%, reduced the per capita bag usage in Ireland, raised revenue for the Environment Fund and reduced the plastic fraction in Ireland's litter (UNEP, 2016a).

- **South Africa** implemented a levy for bags in 2003. However, despite an initial decrease in the use of bags, over time the effectiveness of the levy has diminished and the use of bags remain widespread, despite its comprehensive application at checkout points. This has been attributed to the levy charge being too small (Dikgang et al., 2012). The levy also largely failed in its mandate to promote plastic recovery and recycling in South Africa, with the money never ring-fenced by Treasury and the programme set up to promote waste minimisation, create awareness, expand collector networks and support rural collection eventually collapsing (Dikgang et al., 2012). Furthermore, despite regulations on the specification of carry bags intended to promote their recyclability, including a minimum thickness of 30 μm and restrictions on the type of ink and coverage of printing, high use of calcium carbonate filler by the industry has rendered carry bags in South Africa essentially non-recyclable (Department of Environmental Affairs, 2017).

- **Belgium** implemented a tax on single-use plastic bags and other single-use plastics in 2007. This tax was removed in 2015 as it was felt that the tax had achieved its objectives of reducing consumer demand for single-use plastics. However, the success of this tax in reducing plastic bag usage is difficult to establish, as use was already decreasing prior to 2007 and the tax was only effectively implemented in larger retail outlets. Collected taxes were retained by national government and were not specifically earmarked for environmental programmes.(Card, 2016).

- **Denmark** implemented a tax on plastic carrier bags above five litres in volume in 1994. This tax has reduced consumer consumption by over 50%, although it is acknowledged that an increase in the tax rate is required to further change consumer behaviour. The tax is also limited to bags that have the capacity to handle at least 5 litres and can reasonably be replaced by cloth bags, carrier net and the like,(DEC, 2015b, DEC, 2015a).

Other plastic products that have been subject to bans and/or taxes include **expanded polystyrene**, **multilayer plastics and plastic film**. For example, in addition to black polyethylene bags, **Haiti** banned the use of expanded polystyrene containers, including cups and plates, in 2012 (Charles and Morgan, 2012, ENS, 2012). As with plastic bags, the lack of enforcement and alternative products has meant that the use and sale of expanded polystyrene containers has continued (Daniel, 2012, HGW, 2013). In 2010 **Vanuatu** banned the import or manufacture of any extruded polystyrene foam, polystyrene board stock or thermoformed plastic packaging (such as supermarket meat trays, fast-food containers, disposable cups and plates etc.) made using ozone depleting substances (UNEP, 2016a, Republic of Vanuatu, 2010). Since February 2018 the use of polystyrene takeaway containers of any form has been banned (Graue and Livingstone, 2018, VINM, 2018). **Belgium** implemented a tax on plastic films in 2007, with the tax subsequently withdrawn in 2015 (UNEP, 2016a, Card, 2016, All About Bags, 2012). However, it does not appear that the tax reduced consumer consumption and it has been suggested that the taxation level was too low to alter consumer behaviour (Card, 2016).

In 2016 **India** released a Rule that stated all non-recyclable multilayer plastics must be phased out within two years (Government of India, 2016). This ban should be coming into force currently, but enforcement remains a challenge and political will needs to be demonstrated (Johari, 2018, RaboResearch, 2018).

France has plans, in addition to policies on plastic bags and microplastics in cosmetic products, to limit the avail- ability of **disposable plastic cups and plates** (unless they are compostable in domestic compost and made from bio-materials) and to end the placing on the market of plastic cotton swabs made for household use by January 2020 (Arroyo Schnell et al., 2017).

Microplastics in personal care products (microbeads) have received increasing global attention, and since

2014 there has been a rapid proliferation in policies to reduce the use of intentionally added microbeads (Xanthos and Walker, 2017). The **USA** banned the manufacture of rinse-off cosmetics containing plastic microbeads in 2015, phased in from July 2017 (manufacture) and Jan 2018 (sale). Over-the-counter cosmetics containing plastic microbeads have an additional year to become compliant with these bans (UNEP, 2016a). Various states have also implemented their own legislation to this effect (UNEP, 2016a, Xanthos and Walker, 2017). In all states, other than California, the legislation allows for biodegradable microbeads. **Canada** banned the manufacture and sale of toiletries containing plastic microbeads in 2017, to be phased in during 2018. Natural health products and non-prescription drugs have until July 2018 and July 2019 to become compliant with the manufacturing and sales bans respectively (Government of Canada, 2018).

Various European countries have also taken action on microbeads. Austria, Belgium, Sweden, The Netherlands, and Luxembourg issuing a joint statement to the Council of the European Union requesting a ban on microplastics in cosmetics and detergents (Council of the European Union, 2014). The EU Plastics Strategy included an announcement that the Commission has started the process to restrict intentionally added microplastics, to be implemented under the EU's main chemicals law Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (European Commission, 2018a). European countries that are in the process of banning microbeads include the **UK, Ireland**, **The Netherlands, France** and **Italy,** with number of countries making voluntary commitments at the UN Ocean Conference in New York in June 2017 to ban the placing on the market of microplastics in rinse-off cosmetic products (including Sweden, France, Finland, Ireland and Luxembourg).

While information is available on plastic bag bans, there are as yet no studies related to efficacy of bans of microbeads (Xanthos and Walker, 2017). The above country profiles do, however, indicate that policies and legislation can only be successful with sufficient monitoring and enforcement. A lack of alternatives on the market is also highlighted as a cause for the failure of bans. Furthermore, to be effective taxes need to be pitched at the correct level and point in the value chain (Dikgang et al., 2012). This is reinforced by the findings of (UN Environment, 2018), which finds that, although it is too early to draw robust conclusions on the environmental impact that bans and levies are having, of the countries that have reported little to no impact, the main problems appear to be a lack of enforcement and a lack of affordable alternatives. Nonetheless, only 20% of the country cases investigated in (UN Environment, 2018) reported little to no change, with 30% of the countries registering drastic drops in the consumption of plastic bags within the first year. In the remaining 50% of cases, information about the impact of bans and levies is lacking, partly because some countries have adopted them only recently and partly because monitoring is inadequate (UN Environment, 2018).

Information-based and voluntary measures

The Austrian Ministry of Agriculture, Forestry, Environment and Water Management, together with industry and NGOs has adopted a voluntary agreement on the reduction of carrier bags. The initiative, called "Farewell Plastic Carrier Bag", aims to reduce the number of plastic bags in Austria by 50% by 2019. Similarly, Finland has a Plastic Carrier Bag Agreement that was concluded by the Ministry of Environment and the Federation of Finnish Commerce to reduce the consumption of plastic carrier bags (Arroyo Schnell et al., 2017).

Microplastics in personal care products (microbeads) have also been subject to voluntary measures in The Netherlands, Austria and Germany (Arroyo Schnell et al., 2017). Austria has information-based instruments to help citizens make informed choices, such as the Austrian Ecolabel (awarded to cosmetic products if they do not contain microplastics). Germany has initiated a dialogue in 2014 with the cosmetic industry promoting a voluntary phasing out of the use of microbeads in rinse-off products.

Austria has an initiative with the Technical Association of the Austrian Chemical Industry to reduce the discharge of plastic granules into the environment. The "Zero Pellet Loss" initiative comprises a ten-point plan to address microplastic production losses. **Belgium** published a manual in 2015 aimed at helping different industry sectors to avoid emissions of microplastics into the environment (Arroyo Schnell et al., 2017).

Measures to curb **primary microplastics arising from production losses** and accidental spills have been implemented through voluntary action by the plastics industry. Operation Clean Sweep[17] implemented by the Plastics Industry Association and The Plastics Division of American Chemical Council is an international program designed to prevent resin pellets, flakes and powder loss and help keep pellets out of the marine environment. Furthermore, 47 plastics associations across the globe signed a declaration to combat the causes of marine litter. The *Declaration of the Global Plastics Associations for Solutions on Marine Litter* (Global Declaration) represents a public commitment by the global plastics industry to tackle plastic litter in the marine environment[18].

Measures addressing the end-of-life phase of the value chain

Recent studies have indicated that relatively few countries account for the considerable majority of land-based plastic entering the oceans (Jambeck et al., 2015, Lebreton et al., 2017, Schmidt et al., 2017). 80% of coastal land-based plastic leaked into the ocean is estimated to come from just 17 countries (Jambeck et al., 2015). All but two of these countries are middle-income countries, where economic growth is occurring but waste management infrastructure is lacking. This lack of waste infrastructure is evident in the fact that, on average, the mismanaged waste fraction across these countries is 68% (Jambeck et al., 2015). 12 of the top 20 marine-plastic generating countries are in Asia (Jambeck et al., 2015) Similar findings are evident in river plastic, with one study estimating that 8 the top 10 catchments delivering the highest loads to the ocean are located in Asia, mostly in middle-income countries (Schmidt et al., 2017), and another that the top 20 rivers feeding into the seas, mostly located in Asia, account for 67% of the global total (Lebreton et al., 2017). These findings indicate a logical focus on waste management in Asia, with analysis in (Ocean Conservancy, 2015) suggesting that coordinated interventions in just five Asian countries (China, Indonesia, the Philippines, Thailand, and Vietnam) could reduce the global leakage of plastic waste into the ocean by approximately 45% over the next ten years.

Regulatory instruments: Waste management legislation and its relevance to marine plastic

Plastic end-of-life management influences the volume of plastic entering the oceans and consequently waste management legislation and other policies influencing the end-of-life of plastic products play a role in the overall policy framework for marine plastics within a region (Schmidt et al., 2017, UNEP, 2016a, UNEP, 2016b). Landfill bans and closures of illegal landfills and landfills that do not meet requirements, prevention of leakage of plastic waste from waste transportation are some of the measures mentioned by EU member states regards preventing marine plastic (Bulgaria, Czech Republic, The Netherlands, Spain and France) (Arroyo Schnell et al., 2017). In addition, waste legislation plans such as National Waste Management Plans and programmes often consider plastics (Croatia, Greece, Denmark, Estonia, Germany, Finland, Ireland, Italy, Lithuania, Luxembourg, Malta, the Netherlands, Latvia, Slovakia, Spain, and the United Kingdom) (Arroyo Schnell et al., 2017).

17. https://opcleansweep.org/
18. The Global Declaration and list of signatories can be found at: www.marinelittersolutions.com

Table 18: Waste policy goals and strategies in ASEAN countries (Source: UN Environment, 2017a)

Country	Goals											
	Policy to reduce MSW	Plan/strategy to reduce MSW	Policy to increase recycling	Plan/strategy to increase recycling	Policy to green value chain	Plan/strategy to green value chain	Policy to address waste, especially plastics in marine environment	Plan/strategy to address waste, especially plastics in marine environment	Policy to implement EPR	Plan/strategy to implement EPR	Policy to improve resource efficiency and productivity	Plan/strategy to improve resource efficiency and productivity
Brunei Darussalam	X	X	X	X			X					
Cambodia							X					
Indonesia	X	X	X		X				X	X	X	X
Lao PDR		X		X			X					
Malaysia	X	X	X	X	X		X		X		X	
Myanmar	X		X		X	X						
Philippines	X	X	X		X	X	X					
Singapore	X	X	X	X	X	X	X	X			X	X
Thailand	X	X	X	X		X	X	X	X	X	X	X
Vietnam	X	X		X		X			X			

Waste management legislation in **The Association of Southeast Asian Nations (ASEAN)** countries is summarised in the UNEP *Waste Management in ASEAN Countries* summary report (UN Environment, 2017b). The report highlights that most of these countries have established policies and strategies, based on the waste hierarchy [19], to deal with waste management. However, there is often disharmony between government departments controlling different aspects of the waste chain and the policies often lack set strategies and goals (UN Environment, 2017b). Furthermore, even when detailed policies, strategies and targets have been developed, the level of adoption needs to be improved.

The national waste and environmental policy frameworks, including goals and associated strategies that directly deal with aspects relating to resource efficiency, waste minimisation and effective treatment of waste are summarised in Table 18 as an indication of the level of current legislation in South East Asia. This analysis provides further evidence that although the high-end policies, such as reducing MSW generation, are in place, the more targeted goals, such as policies directly addressing plastic waste and improving resource efficiency, are in a developmental stage.

19. The waste management hierarchy indicates an order of preference for sustainable waste management and demonstrates that first and foremost policy should take action on preventing waste generation. This is followed by reduction, recycling, recovery and lastly disposal. (UN Environment, 2015)

The comparison of these waste management policies indicates that the general principals, based on the waste hierarchy, are typically found in the legislation of both developing and developed nations. However, the number of specific goals included in these plans, along with the strategies developed and targets set, vary considerably between different nations and this impacts the effectiveness of these policies on combating marine plastic litter. Effective implementation of these policies is also often lacking, as demonstrated by only 68% of waste collected in India, of which more than 80% is disposed at open dump sites (Mani, 2016)+¯þ, and the difficulties of Chinese municipalities to deal with the vast volumes of waste collected other than through landfilling (Cheng, 2017, Rech, 2013). This trend is evident in ASEAN countries and world disposal figures, that indicate that developing countries rely on uncontrolled dumping and often poorly maintained landfills for the disposal of the majority of waste (World Bank, 2012). As such it is clear that waste management policies can only be successful with effective monitoring, enforcement and political will. A similar situation is evident in South Africa, with a wide disparity between waste legislation and implementation. South Africa has a National Waste Management Strategy based on the Waste Hierarchy and aimed at prioritising actions to ensure waste is minimised and well managed in the country (including targets of achieving 25% recycling rates, and that all metropolitan municipalities, secondary cities and large towns to have initiated separation at source programmes). However, at the same time, basic service delivery is lacking in many municipalities (with 87% of rural and 13.5% of urban households not receiving basic waste collection services) (Department of Environmental Affairs, 2017).

Information based and voluntary approaches:

Stemming the Tide: Land-based strategies for a plastic-free ocean (Ocean Conservancy, 2015) outlines a model that can be applied to countries that would benefit from improved waste management systems, based on case studies in five countries with especially high levels of plastic-waste leakage. Their analysis found the following levers to be most effective in reducing plastic litter:

- Closing leakage points within the collection system by optimizing transport systems to eliminate illegal dumping, and closing or improving dumpsites located near waterways.
- Increasing waste-collection rates by expanding collection service, as plastic waste is more than twice as likely to leak into the ocean if it remains uncollected.
- Using a variety of waste-to-fuel (e.g., gasification) or waste-to-energy (e.g., incineration with energy recovery) technologies to treat waste in areas with high waste density.
- Manually sorting high-value plastic waste and converting much of the remainder to refuse-derived fuel (RDF).

Stemming the Tide (Ocean Conservancy, 2015) also find six key areas for action, with a critical requirement being a multi-stakeholder approach bringing together local waste managers, secondary material markets, consumers, informal waste sector workers and producers of resin, packaging and consumer goods (brand owners). The key areas are: political leadership and commitment, local “proof of concept” for integrated waste management approaches, critical mass, public private partnerships to fund waste management projects, technology implementation support, and leadership and strategic focus (Ocean Conservancy, 2015).

- There are strong parallels between measures to address land-based secondary microplastics, such as losses from synthetic textiles in washing, and land-based macroplastic leakage, as in both cases, implementing effective infrastructure is a critical first measure. However, in the case of microplastics the need is for wastewater treatment infrastructure rather than for solid waste infrastructure.

The case of Extended Producer Responsibility:

Increased recycling is a target most national Waste Management Plans, but in order for recycling policies to be effective, all value chain actors involved in designing, producing, using and disposing of plastic products, and in handling the plastic waste must be involved. Such cooperation can be incentivised through various measures, most frequently **Extended Producer Responsibility (EPR).** EPR schemes require producers, manufacturers and importers of products to take responsibility and manage the waste produced from their products, and are designed to ensure producers design products to minimise waste and ease of recyclability. The rationale for EPR is that only by holding producers responsible for the full costs caused by their products, will the companies be incentivised to design products that are recycled or prepared for reuse more easily, and at a lower cost, thereby being littered less often. EPR is thus recognised as a useful policy tool for accelerating the circular economy (Zero Waste Euorpe, 2017), and a key mechanism in the recently released *Strategy for Plastics in a Circular Economy* (European Commission, 2018a).

EPR has been mandated for a variety of plastic products in various countries, with examples given in Table 19. Packaging has especially been subject to EPR regulations in many countries, with plastic packaging identified as a particularly prevalent source of marine plastic. The widespread use of EPR schemes is due to the fact that systems that target both the upstream producer and downstream management together typically result in the most effective change to waste production and management (Hennlock et al., 2014, OECD, 2001, OECD, 2016). This is particularly relevant to the recycling of plastic products, where the choice of polymer, use of additives, extent of printing, and choice of labels and closures have important implications for the products' recyclability. It is only when recyclers work with product designers and brand owners that effective material recovery systems can be realised.

EPR schemes can also be voluntary, with PET Recycling Company (PETCO) in South Africa an example of a scheme successfully run by a Producer Responsibility Organisation (PRO). PET bottle recycling in South Africa has attained a level of 52% (with 30% bottle to bottle recycling), with a funding model based on the voluntary contributions from producers. The funding model is focused on maintaining a robust plastics recycling value chain, providing funding to recyclers in the form of adjustable subsidies intended as a buffer against the price volatility and market fluctuations characteristic of the recycling industry. This continuity of operation is essential in a recycling value chain fed primarily by collectors in the informal sector.

Table 19: Examples of mandatory EPR programmes involving plastic products

Country	Plastic containing products included in EPR schemes	Reference
Australia	Packaging; electronics; PVC; micro-beads	(APC, 2017, Australian DEE, 2016)
Brazil	Packaging; electronics	(Alnuwairan, 2016, MoE, 2010, SINIR, 2015b, SINIR, 2015a)
China	Packaging; electronics; vehicles	(Xinhua, 2017a)
EU	Packaging; electronics; vehicles	(Sanz et al., 2015)
India	Multi-layer plastics; plastic films	(MEFCC, 2016)
Japan	Packaging; electronics	(PWMI, 2016)
Russia	Plastic bags, bottles, home ware, crockery and stationary; carpets; textiles; electronics	(Anoshka, 2016, Pravsky Consulting, 2016

5.3. Reflections on measures and policies addressing marine plastics

Figure 4 summarizes various international, regional and national strategies and action plans with bearing on marine plastic. The emphasis of marine strategies has tended to be on the prevention of litter entering the marine environment, with improved waste management, often through efforts to increase recycling, the focus of strategies to curb plastic litter.

Despite the focus of strategies on waste management and recycling, with only 14% of plastic packaging collected for recycling globally (less than 30% for Europe), and only 5% of material value retained for a subsequent use when additional value losses in sorting and reprocessing are factored in, it is increasingly clear that new approaches are needed. Recognition that "game-changing" strategies are required is seen from government in the European Strategy for Plastics in a Circular Economy (European Commission, 2018a) and from public-private partnerships in The New Plastic Economy (World Economic Forum et al., 2016).

The need to acknowledge the currently non-recyclable fraction of the plastic waste stream is important to targeting specific product-formats for redesign or alternative management options (such as bans, as with plastic bags, or public action, as with straws). Analysis in Stemming the Tide (Ocean Conservancy, 2015), which involved case studies in five Asian countries (China, Indonesia, the Philippines, Thailand, and Vietnam) suggests that about 80% of the plastic waste stream is too low in value to incentivize extraction. Similarly low recycling collection yields are found in South Africa, with between 70 and 90% of plastic in the waste stream of too low a value to find a market (Department of Environmental Affairs, 2017). Waste-to-energy options are shown to be a cost-effective option for these low value plastic streams, but waste to energy is not preferred from a sustainability perspective. This is because waste-to-energy has the potential to divert waste from options higher on the waste management hierarchy and "lock in" wasteful and unsustainable lifestyles. However, demand for recycled plastic is very low (accounting for only 6% of plastics demand in Europe) (European Commission, 2018a), and plastics that do get recycled are mostly recycled into lower-value applications that are not again recyclable after use (World Economic Forum et al., 2016). Building markets for recycled plastics is identified as a critical requirement to increasing plastics recycling in developing economies, especially high-value markets able to provide sustainable incomes for informal waste collectors (Department of Environmental Affairs, 2017, Ocean Conservancy, 2015).

Analysis by the World Economic Forum and Ellen MacArthur Foundation (2017) in *Catalysing Action* suggests that recycling can be an economically attractive option for 50% of plastic packaging, but only with concerted efforts on design and after-use systems (World Economic Forum and Ellen MacArthur Foundation, 2017)2017. Substantially increasing plastic recycling rates from their current low levels will require:

- Implementing design changes in plastic packaging to improve recycling quality and economics (e.g., choices of materials, additives and formats);
- Harmonising and adopting best practices for collection and sorting systems;
- Scaling up high-quality recycling processes;
- Exploring the potential of material markers to increase sorting yields and quality;
- Developing and deploying innovative sorting mechanisms for post-consumer flexible films;
- Boosting demand for recycled plastics through voluntary commitments or policy instruments, and exploring other policy measures to support recycling; and
- Deploying adequate collection and sorting infrastructure where it is not yet in place.
- (World Economic Forum and Ellen MacArthur Foundation, 2017)2017

Even with these measures and robust markets for recycled plastics, the World Economic Forum and Ellen MacArthur Foundation (2017) indicate that without fundamental redesign and innovation 30% of plastic packaging will never be reused or recycled (World Economic Forum and Ellen MacArthur Foundation, 2017)2017. Avoiding waste management options lower on the waste hierarchy for this plastics fraction, such as waste-to-energy, will require significant innovation

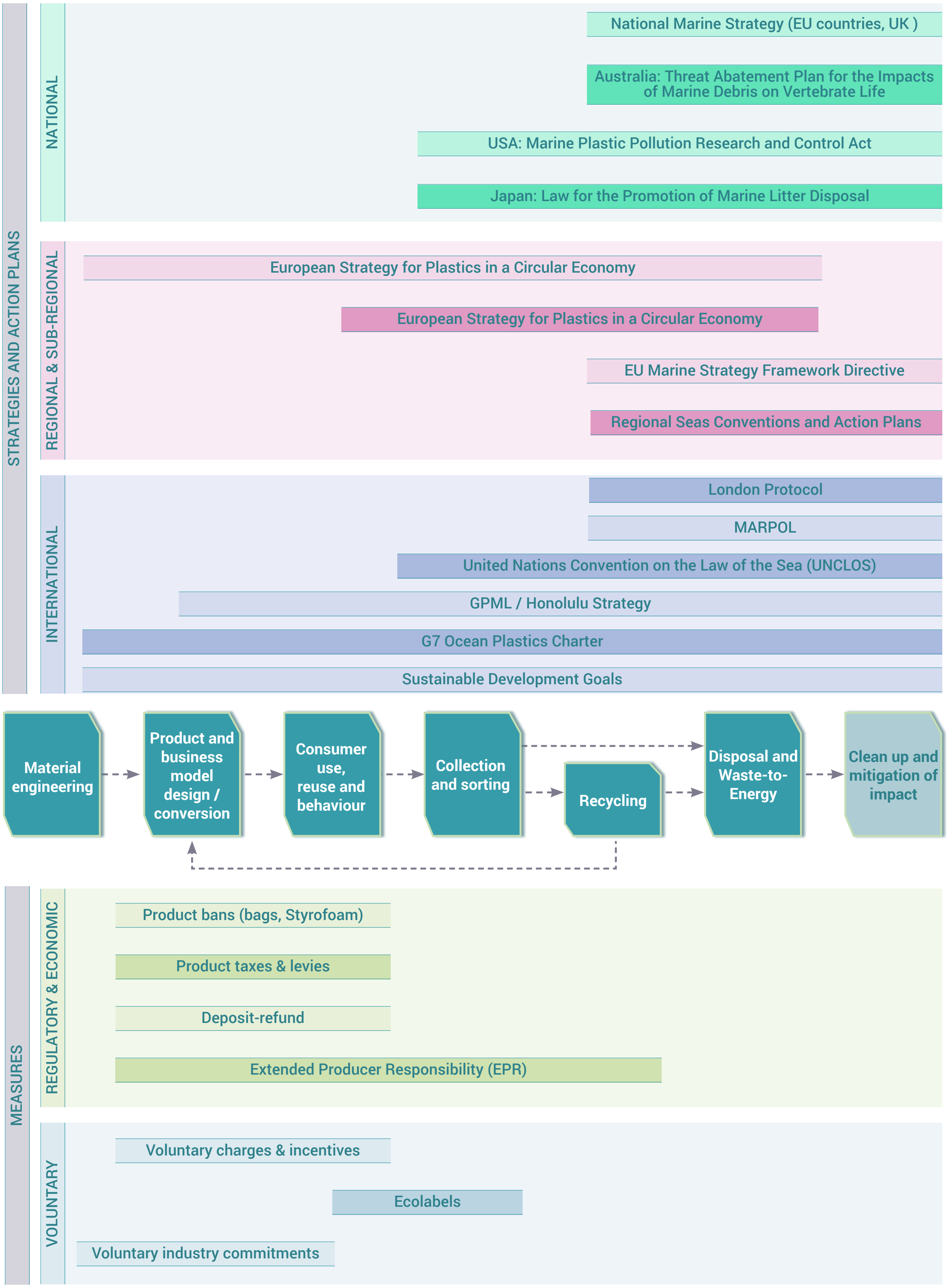

Figure 4: Strategies and Measures with bearing on marine plastics

and changes in consumer behaviour. Whilst reuse is at the top of the waste hierarchy, it provides an economically attractive opportunity for only about 20% of plastic packaging (World Economic Forum and Ellen MacArthur Foundation, 2017)2017. Successful implementation of reuse policies will require innovative business models and the involvement of brand managers, retailers and consumers. Education and consumer awareness campaigns will be essential to ensure consumer buy-in.

Bans and disincentives (primarily economic instruments in the form of levies) are increasingly being applied as measures to address problematic plastic wastes, with single-use plastics particularly targeted. As can be seen in Figure 5, this is especially a route being taken in African countries, where effective waste infrastructure is lacking. It is interesting to note from the data in Figure 5 that bans are the most-applied instrument to curb consumption of plastic bags in all continents other than Europe, which is also the only continent where private public agreements have been applied (UN Environment, 2018).

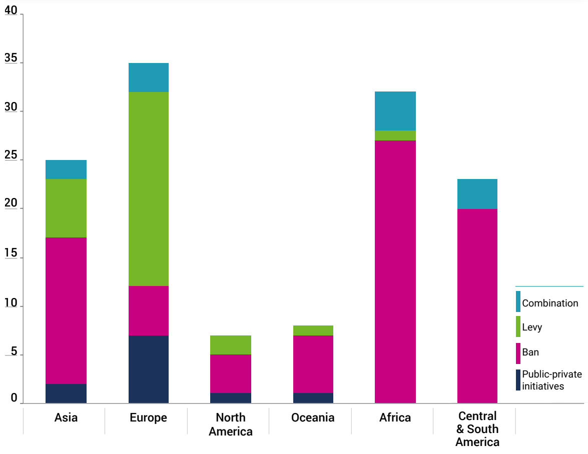

Figure 5: Types of national policies on plastic bags, by continent. Source: UN Environment (2018)

The constraints to recycling discussed above suggest that different mechanisms working together will be the most effective solution to curbing marine plastics. Bans and disincentive (taxes and levies) are increasingly being seen as a viable option for encouraging different business models, e.g. reusable shopping bags. Although in many cases these measures have been applied too recently for their long-term impacts to be determined. Preliminary evidence suggests that availability of alternatives and enforcement are critical factors for the success of product bans and restrictions (UN Environment, 2018).

Thus, for plastic products where recovery for recycling is proving problematic and where alternatives exist, restrictions or bans are possibly the most effective short-term option. However, for products without alternatives, significant innovation is required, such as development of new bio-benign materials. The latter are an important option in contaminated plastic streams, such as meat packaging and sanitary products, where the resources required (e.g. water and energy for cleaning the material) and the potential for contamination make recycling uneconomical and/or not environmentally preferred.

UN Environment (2018) present a 10-step roadmap to guide governments opting for a policy approach to managing single-use plastics, drawing upon the experiences of over 60 countries that have already implemented bans and levies on single-use plastics (primarily plastic bags and Styrofoam). The steps of the roadmap, and important factors to consider at each step are summarised in Table 19. Whilst particularly developed from experiences with measures addressing single-use plastics, the principles are equally relevant to disincentive measures on plastic products more broadly.

Table 19: Roadmap for policymakers: 10 steps to consider when introducing bans or levies on single-use plastics (UN Environment, 2018)

1	Know the baseline	■ Identify the most problematic single-use plastics ■ Assess current causes ■ Assess extent ■ Assess impacts ■ Evaluate consumers' willingness to pay
2	Evaluate possible actions	■ Regulatory ■ Voluntary ■ Economic ■ Combination
3	Assess impacts of preferred option	■ Social ■ Economic ■ Environmental
4	Engage stakeholders	■ Government (central and local) ■ Industry ■ Retailers ■ Waste management authority ■ Citizens ■ Tourism associations
5	Raise awareness	■ Education programmes ■ TV adverts ■ Campaigns to explain: ● Why is the policy being introduced? ● What are the expected benefits? ● Are there punitive measures?
6	Promote alternatives	■ Eco-friendly ■ Affordable ■ Fit for purpose
7	Incentivize industry	■ Allow enough time for the transition ■ Offer tax rebates ■ Keep certain eco-friendly materials tax-free
8	Ring-fence revenues	In order to support: ■ Waste minimization• ■ The recycling industry• ■ Environmental projects and to finance awareness initiatives
9	Enforce	■ Set roles and responsibilities ■ Ensure sufficient human-power for enforcement Communicate the enforcement process ■ Prosecute offenders in line with policy revisions
10	Monitor and adjust policy	■ Audits ■ Surveys ■ Studies and interviews ■ Keep the public updated on progress

6

Conclusions

Plastic pollution in the world's oceans is a headline environmental and social issue. As such, it is a fast-moving area, both in terms of increasing scientific knowledge over the sources, quantities and impacts of plastics in the oceans, as well as in the actions being taken to address the problem. Recent research studies have highlighted the scale of the problem, together with the potential for escalation in coming decades if prompt action is not taken. Research studies continue to shed light on the impacts that marine plastics are having on marine biodiversity, human health and coastal livelihoods. However, the studies also highlight that much is still to be understood, particularly around the fate of plastics in the marine environment, and the potential for impacts at the nano-scale, including impacts on seafood safety. With the wide diversity in marine environments and the considerable number of national and regional jurisdictions around the globe, the need for harmonised methods for monitoring of plastics and its impacts in the marine environment are a key requirement to better understanding the sources, stocks and impacts of marine plastics.

The evidence from marine sampling and beach cleanup data shows that short-lived consumer products disposed of from households, commercial activities and coastal tourism make up the bulk of larger marine plastics items (macroplastics). Changing consumer habits, together with developing innovative reusable business models and/or products with high material value at end-of-life, will be important strategies to addressing the plastic pollution of these product types. Such systemic strategies will go beyond merely addressing waste management deficiencies, which are nonetheless important in the short-term, given the urgency of the problem.

It is more difficult to trace microplastics in the ocean back to the product or sector responsible. Secondary microplastics form from the fragmentation of larger plastic items, and thus approaches addressing macroplastics will simultaneously address secondary microplastics. Primary microplastics, however, require a consumer education and legislative approach to their management. Significant action is already being taken by industry to prevent releases of industrial pellets, for example, and by governments to ban microbeads in consumer products. Land-based secondary microplastics (i.e. plastic particles from the wear and tear of plastic products during their use, such as textiles and car tyres) present a significant challenge. This is partly because the weight of evidence is still lacking, due to the very small sizes of the particles and current limits in detection, but also because the potential pathways from product to marine environment are diverse and not well characterised. Thus potential solutions are difficult to devise, although improving the coverage of wastewater treatment in countries where this is lacking is an urgent short-term measure. Further-reaching solutions require addressing the source of these micro-particles, requiring innovation in products and materials.

Global concern over the escalating problem of marine plastics is evident in multiple UNEA resolutions and that it is addressed in the UN's Sustainable Development Goals. The SDGs address marine plastics both directly (Goal 14: Conserve and sustainably use the oceans, seas and marine resources) and indirectly (Goals 6, 11 and 12). Improvements in wastewater treatment and solid waste management, as well as progress towards sustainable consumption and production, will have profound impacts on the quantity of plastics entering the marine environment. Consequently plastics are increasingly being addressed through regional, sub-regional and national responses. Notable in these responses is a shift away from addressing marine plastics purely as a waste management issue, towards recognising that plastic pollution requires life cycle approaches addressing the consumption and production of plastics. The EU's *European Strategy for Plastics in a Circular Economy* is a momentous example here, with its aims of improving the economics and quality of recycling, preventing waste and littering, increasing investment and innovation in circular solutions and increasing global action. The recent *Ocean Plastics Charter,* agreed to by five of the G7 nations, similarly recognises the need to take a lifecycle approach to plastics stewardship and to avoid unnecessary use of plastics and prevent waste, as well as to ensure that plastics are designed for recovery, reuse, recycling. This shift in the management of plastics is also noticeable in the more than 60 countries that have either banned or placed economic disincentives on the consumption of single-use plastics (predominantly plastic bags). However, the recent nature of most of these actions means that there has been insufficient time to study their effectiveness, and learning from the experiences of these early movers will be critical in replicating the successes and extending to a wider number of consumer products.

Plastic pollution has garnered significant media attention and a strong willingness to act is seen in the many campaigns and initiatives around the globe addressing marine plastics. There is thus a significant opportunity to capitalise on this ground swell of action, but coordination and leadership are required to ensure appropriate actions leading to sustainable solutions. Strategies and solutions need to be designed according to national and regional circumstances, identifying the most impactful products in the particular context, but in a globally consistent manner recognising the inter-connectedness of ocean systems and global value chains.

The benefits of a circular plastics model and avoiding plastics waste will go far beyond improving marine ecosystems, with clear co-benefits of improved human health and livelihoods. There are also clear economic benefits, with significant opportunities for innovation in new materials and product systems. The challenges ahead will lie in catalysing the innovation required and creating the environment and partnerships for sustainable business models to flourish.

The next steps are thus to elaborate on the gaps that need to be addressed to continue to move forward in addressing marine plastics, through which opportunities for action can be identified. A subsequent report in this project will analyse the gaps, barriers and opportunities and provide recommendations for action.

References

All About Bags (2012) Bags Around the World. Toronto, Canada: All About Bags. Available at: http://www.allaboutbags.ca/aroundtheworld.html (Accessed: 9 May 2018).

Alnuwairan, M. (2016) Role of Reverse Logistics in Waste Management. Doha, Qatar: EcoMENA. Available at: http://www.ecomena.org/tag/brazilian-national-solid-waste-policy/ (Accessed: 17 March 2017).

Andrady, A.L. (2011) Microplastics in the marine environment, *Marine Pollution Bulletin,* 62(8), pp. 1596-1605.

Anoshka, K. (2016) Development of Extended Producer Responsibility in Russia and Surrounding Countries. Brussels, Belgium: ENHESA Available at: http://www.enhesa.com/flash/development-extended-producer-responsibility-russia-and-surrounding-countries (Accessed: 22 March 2017).

APC (2017) Australian Packaging Covenant, Australian Packaging Covenant: Sydney, Australia. Available at: http://www.environment.gov.au/system/files/resources/936c31e6-749b-4298-a457-24808a76cc15/files/australian-packaging-covenant-2017.pdf (Accessed: March 2017).

Arroyo Schnell, A., Klein, N., Gomez Giron, E. and Sousa, J. (2017) National marine plastic litter policies in EU Member States: an overview, IUCN: Brussels, Belgium.

Australian DEE (2016) Outcomes of the Review of the Ozone Protection and Synthetic Greenhouse Gas Managment Programme, Australian Government Department of Environment and Energy: Canberra, Australia. Available at: https://www.environment.gov.au/system/files/resources/44f1ee26-0ccb-43b6-81b9-07fabe332a5e/files/factsheet-opsggm-review-outcomes.pdf (Accessed: December 2016).

Barnes, D.K., Galgani, F., Thompson, R.C. and Barlaz, M. (2009) Accumulation and fragmentation of plastic debris in global environments, *Philosophical Transactions of the Royal Society of London B: Biological Sciences,* 364(1526), pp. 1985-1998.

Beyene, D. (2018) Nation to ban plastic use. Ethiopia: The Ethiopian Herald. Available at: http://www.ethpress.gov.et/herald/index.php/news/national-news/item/10589-nation-to-ban-plastic-use (Accessed: 9 May 2018).

Botswana Daily Mail (2018) Botswana: Govt to Ban Plastic Bags. Gaborone, Botswana: Botswana Daily Mail. Available at: http://allafrica.com/stories/201803010520.html (Accessed: 9 May 2018).

Boucher, J. and Friot, D. (2017) Primary microplastics in the oceans: a global evaluation of sources, IUCN: Gland, Switzerland.

Browne, M., Crump, P., Niven, S., Teuten, E., Tonkin, A., Galloway, T. and Thompson, R. (2011) Accumulations of microplastic on shorelines worldwide: sources and sinks, *Environmental Science & Technology,* 45(21), pp. 9175-9179.

Browne, M., Galloway, T. and Thompson, R. (2010) Spatial Patterns of Plastic Debris along Esturine Shorelines, *Environmental Science & Technology,* 44(9), pp. 3404-3409.

Browne, M., Niven, S., Galloway, T., Rowland, S. and Thompson, R. (2013) Microplastic Moves Pollutants and Additives to Worms, Reducing Functions Linked to Health and Biodiversity, *Current Biology,* 23(23), pp. 2388-2392.

Card, D. (2016) Packaging taxes in Belgium, Eunomia for Institute for European Environmental Policy: Brussels, Belgium. Available at: https://ieep.eu/uploads/articles/attachments/750b4c86-75d6-4016-8e1b-da2e69d2ded9/BE Packaging Tax conference draft.pdf?v=63673818840 (Accessed: May 2018).

Charles, J. and Morgan, C. (2012) Haiti bans plastic bags, foam containers. Miami, USA: Miami Herald. Available at: http://www.miamiherald.com/news/local/community/article1943032.html (Accessed: 9 May 2018).

Cheng, Z. (2017) Study of policies and regulations for waste management in China and potential for application in the U.S. Earth Resources Engineering thesis, Columbia University, Columbia, USA Available at: http://www.seas.columbia.edu/earth/wtert/sofos/Kevin Cheng thesis.pdf (Accessed: February 2017).

China Dialogue (2014) Environmental Protection Law of the People's Republic of China. China: China Dialogue. Available at: https://www.chinadialogue.net/Environmental-Protection-Law-2014-eversion.pdf (Accessed: 9 February 2018).

Chitaka, T., Rodseth, C. and von Blottnitz, H. (2017) Estimating plastic leakage into the environment: the South African case, *African Marine Waste Conference*, Port Elizabeth, 9 – 13 July.

Clavel, E. (2014) Think you can't live without plastic bags? Consider this: Rwanda did it. United Kingdom: The Guardian. Available at: https://www.theguardian.com/commentisfree/2014/feb/15/rwanda-banned-plastic-bags-so-can-we (Accessed: 9 May 2018).

Council of the European Union (2014) Elimination of microplastics in products - an urgent need. In: Information From the Belgian, Dutch, Austrian and Swedish Delegations, Council of the European Union. Available at: http://register.consilium.europa.eu/doc/srv?l=EN&f=ST 16263 2014 INIT. (Accessed: May 2018).

Cozar, A., Echevarria, F., Gonzalez-Gordillo, J.I., Irigoien, X., Ubeda, B., Hernandez-Leon, S., Palma, A.T., Navarro, S., Garcia-de-Lomas, J., Ruiz, A., Fernandez-de-Puelles, M.L. and Duarte, C.M. (2014) Plastic debris in the open ocean, *Proc Natl Acad Sci U S A,* 111(28), pp. 10239-44.

CPCB (2017) Annual Report for the year 2015-16 on Implementation of Plastic Waste Management Rules, Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, Govt. of India: Parivesh Bhawan, East Arjun Nagar, Delhi-110032. Available at: http://cpcb.nic.in/displaypdf.php?id=cGxhc3RpY3dhc3RlL0FubnVhbF9SZXBvcnRfMjAxNS0xNl9QV00ucGRm (Accessed: May 2018).

Daniel, T. (2012) Haitians ignore gov't ban on plastic bags. Port-au-Prince, Haiti: Deseret News. Available at: https://www.deseretnews.com/article/765608417/Haitians-ignore-govt-ban-on-plastic-bags.html (Accessed: 9 May 2018).

DEC (2015a) The Danish Packaging Taxation: The Weight-based Tax, The Danish Ecological Counsil: Copenhagen, Denmark. Available at: http://www.ecocouncil.dk/documents/andet/1858-151111-the-danish-tax-on-packaging-weight (Accessed: May 2018).

DEC (2015b) Fact sheet: Tax on plastic bags, The Danish Ecological Counsil: Copenhagen, Denmark. Available at: http://www.ecocouncil.dk/documents/temasider/1776-150812-tax-on-plastic-bags (Accessed: May 2018).

Department of Environmental Affairs (2017) Plastics material flow and end of life management in South Africa, Department of Environmental Affairs: Pretoria, South Africa.

Dikgang, J., Leiman, A. and Visser, M. (2012) Analysis of the Plastic-bag Levy in South Africa, *Resources, Conservation and Recycling,* 66, pp. 59-65.

Dikgang, J. and Visser, M. (2010) Behavioral Response to Plastic Bag Legislation in Botswana, Environment for Development: South Africa. Available at: http://www.rff.org/files/sharepoint/WorkImages/Download/EfD-DP-10-13.pdf (Accessed: May 2018).

ENS (2012) Haiti Bans Plastic Bags and Foam Containers. Port-au-Prince, Haiti: Environmental News Service. Available at: http://ens-newswire.com/2012/10/03/haiti-bans-plastic-bags-and-foam-containers/ (Accessed: 9 May 2018).

Eriksen, M., Lebreton, L.C., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G. and Reisser, J. (2014) Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea, *PloS one,* 9(12), pp. e111913.

Eunomia Research & Consulting Ltd. (2016a) Plastics in the Marine Environment.

Eunomia Research & Consulting Ltd. (2016b) Study to support the development of measures to combat a range of marine litter sources: Report for European Commission DG Environment Eunomia Research & Consulting Ltd.: London, UK.

European Commission (2010) Pilot project '4 Seas'– plastic recycling cycle and marine environmental impact : Case studies on the plastic cycle and its loopholes in the four European regional seas areas, European Commission.

European Commission (2017) Descriptor 10: Marine Litter. Brusels, Belgium: European Commission: Environment. Available at: http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm (Accessed: 2 February 2018).

European Commission (2018a) A European Strategy for Plastics in a Circular Economy, European Commission: Brussels, Belgium. Available at: http://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy.pdf (Accessed: February 2018).

European Commission (2018b) Implementation of the Circular Economy Action Plan. Brussels, Belgium: European Commission: Environment. Available at: http://ec.europa.eu/environment/circular-economy/index_en.htm (Accessed: 2 February 2018).

Fanshawe, T. and Everard, M. (2002) The Impacts of Marine Litter, Marine Litter Task Team (MaLiTT) of the Marine Pollution Monitoring Management Group: Bristol, UK. Available at: http://www.gov.scot/Uploads/Documents/Impacts of Marine Litter.pdf (Accessed: February 2017).

FAO (2014) The State of World Fisheries and Aquaculture: Opportunities and Challenges, Food and Agricultural Organization of the United Nations: Rome, Italy. Available at: http://www.fao.org/3/a-i3720e.pdf.

Fazey, F. (2015) The role of buoyancy in the dispersal of marine plastic debris and the impact of biofouling: does size matter? MSc Conservation Biology, University of Cape Town, Cape Town, SA.

Feng, J. (2017) Nine Years Later, China's Plastic-Bag Ban Only Looks Good in Theory. China: SupChina. Available at: https://supchina.com/2017/06/13/nine-years-later-chinas-plastic-bag-ban-looks-good-theory-chinas-latest-society-culture-news/ (Accessed: 9 May 2018).

fikrejesus (2017) Banning Plastic Bags - The Case of Eritrea. Asmara, Eritrea: Fikre - Worldpress. Available at: https://fiqre4eri.wordpress.com/2017/08/29/banning-plastic-bags-the-case-of-eritrea/ (Accessed: 9 May 2018).

Freytas-Tamura, d. (2017) Public Shaming and Even Prison for Plastic Bag Use in Rwands. Gisenyi, Rwanda: The New York Times. Available at: https://www.nytimes.com/2017/10/28/world/africa/rwanda-plastic-bags-banned.html (Accessed: 9 May 2018).

Fullerton, K. (2018) Reflecting on Rwanda's Plastic Bag Ban. Sydney, Australia: Sense and Sustainability. Available at: http://www.senseandsustainability.net/2018/03/01/reflecting-on-rwandas-plastic-bag-ban/ (Accessed: 9 May 2018).

G7 (2018) Charlevoix Blueprint for Healthy Oceans, Seas and Resilient Coastal Communities. Available at: https://g7.gc.ca/wp-content/uploads/2018/06/HealthyOceansSeasResilientCoastalCommunities.pdf (Accessed: August 2018).

Galgani, F., Hanke, G. and Maes, T. (2015) Global distribution, composition and abundance of marine litter, *Marine anthropogenic litter*. Springer, pp. 29-56.

Gallo, F., Fossi, C., Weber, R., Santillo, D., Sousa, J., Ingram, I., Nadal, A. and Romano, D. (2018) Marine litter plastics and microplastics and their toxic chemicals components: the need for urgent preventive measures, *Environmental Sciences Europe,* 30(1), pp. 13.

GESAMP (2015) Sources, fate and effects of microplastics in the marine environment: A global assessment, IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection.

GESAMP (2016) Sources, fate and effects of microplastics in the marine environment: part 2 of a global assessment (Kershaw, P.J., and Rochman, C.M., eds), IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

Geyer, R., Jambeck, J.R. and Law, K.L. (2017) Production, use, and fate of all plastics ever made, *Science advances,* 3(7), pp. e1700782.

Gilbert, J., Reichelt-Brushett, A., Bowling, A. and Christidis, L. (2016) Plastic Ingestion in Marine and Coastal Bird Species of Southeastern Australia, *Marine Ornithology,* 44, pp. 21-26.

Government of Canada (2018) Microbeads in Toiletries Regulations: frequently asked questions. Canada: Government of Canada. Available at: https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/microbeads-toiletries-regulations-frequently-asked-questions.html (Accessed: 9 May 2018).

Government of India (2016) Plastic Waste Managament Rules, 2016, Government of India: New Delhi, India. Available at: http://www.moef.gov.in/sites/default/files/PWM Rules%2C 2016.pdf (Accessed: May 2018).

Graue, C. and Livingstone, N. (2018) Vanuatu bans non-biodegradable plastic to protect ocean life. Vanuatu: ABC Pacifi Beat. Available at: http://www.abc.net.au/news/2018-01-04/vanuatu-bans-non-biodegradable-plastic/9303348 (Accessed: 9 May 2018).

green page (2013) Bangladesh: world leader in banning the plastic bag. Bangladesh: green page. Available at: http://greenpagebd.net/bangladesh-world-leader-in-banning-the-plastic-bag/ - .WvKwxdOFPVo (Accessed: 9 May 2018).

Health4earth (2015) Macedonia has Not banned Plastic Bags: Health4earth. Available at: https://health4earth.com/2015/11/02/macedonia-has-not-banned-plastic-bags/ (Accessed: 9 May 2018).

HELCOM MONAS (2014) Marine Litter in the Baltic Sea: sources, monitoring approaches, possible common indicators and first lines of thinking on measures., Baltic Marine Environment Protection Commission Oslo, Norway.

Hennlock, M., Castell-Rudenhausen, M., Wahlstrom, M., Kjaer, B., Milios, L., Vea, E., Watson, D., Hansse, O., Frane, A., Stenmarck, A. and Tekie, H. (2014) Economic Policy Instruments for Plastic Waste - A review with Nordic perspectives, Nordic Council of Ministers: Copenhagen, Denmark. Available at: http://norden.diva-portal.org/smash/get/diva2:791794/FULLTEXT02.pdf (Accessed: March 2017).

HGW (2013) After Two Bans, Plastic Trash Still Plagues Haiti. Port-au-Prince: Haiti Grassroots Watch. Available at: http://haiti-liberte.com/archives/volume7-5/After Two Bans.asp (Accessed: 9 May 2018).

Hoornweg, D. and Bhada-Tata, P. (2012) What a Waste: A Global Review of Solid Waste Management, Urban Development & Local Government Unit, World Bank: Washington DC.

Hopewell, J., Dvorak, R. and Kosior, E. (2009) Plastics recycling: challenges and opportunities, *Philosophical Transactions of the Royal Society,* 364, pp. 2115-2126.

Hurley, R., Woodward, J. and Rothwell, J.J. (2018) Microplastic contamination of river beds significantly reduced by catchment-wide flooding, *Nature Geoscience,* 11(4), pp. 251-257.

Ioakeimidis, C., Zeri, C., Kaberi, H., Galatchi, M., Antoniadis, K., Streftaris, N., Galgani, F., Papathanassiou, E. and Papatheodorou, G. (2014) A comparative study of marine litter on the seafloor of coastal areas in the Eastern Mediterranean and Black Seas, *Marine pollution bulletin,* 89(1), pp. 296-304.

Irin (2011) Plastics proliferate despite ban. Dhaka, Bangladesh: Irin News. Available at: http://www.irinnews.org/report/92072/bangladesh-plastics-proliferate-despite-ban (Accessed: 9 May 2018).

Jambeck, J., Geyer, R., Wilcox, C., Siegler, T., Perrymna, M., Andrady, A., Narayan, R. and law, K. (2015) Plastic waste inputs from land into the ocean, *Science,* 347(6223), pp. 768-771.

Johari, A. (2018) Why have laws to completely ban plastic bags failed in India? India: Scroll.in Green Report. Available at: https://scroll.in/article/872612/why-have-laws-to-completely-ban-plastic-bags-failed-in-india (Accessed: 9 May 2018).

Kaiser, D., Kowalski, N. and Waniek, J. (2017) Effects of biofouling on the sinking behaviour of microplastics, *Environmental Research Letters,* 12, pp. 124003.

Karapanagioti, H., Endo, S., Ogata, Y. and Takuda, H. (2011) Diffuse pollution by persistent organic pollutants as measured in plastic pellets sampled from various beaches in Greece, *Marine Pollution Bulletin,* 62(2), pp. 312-317.

Koelmans, A.A., Kooi, M., Law, K.L. and van Sebille, E. (2017) All is not lost: deriving a top-down mass budget of plastic at sea, *Environmental Research Letters,* 12(11), pp. 114028.

Lamb, J.B., Willis, B.L., Fiorenza, E.A., Couch, C.S., Howard, R., Rader, D.N., True, J.D., Kelly, L.A., Ahmad, A., Jompa, J. and Harvell, C.D. (2018) Plastic waste associated with disease on coral reefs, *Science 26 Jan 2018:,* 359(6374), pp. 2.

Lassen, C., Hansen, S.F., Magnusson, K., Hartmann, N.B., Rehne Jensen, P., Nielsen, T.G. and Brinch, A. (2015) Microplastics: Occurrence, effects and sources of releases to the environment in Denmark, Copenhagen K: Danish Environmental Protection Agency.

Law, K.L. (2017) Plastics in the Marine Environment, *Annual Review of Marine Science,* 9(1), pp. 205-229.

Lebreton, L.C., van der Zwet, J., Damsteeg, J.-W., Slat, B., Andrady, A. and Reisser, J. (2017) River plastic emissions to the world's oceans, *Nature communications,* 8, pp. 15611.

Luscher, A., McHugh, M. and Thompson, R. (2013) Occurence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel, *Marine Pollution Bulletin,* 67(1-2), pp. 94-99.

Lusher, A.L., Hollman, P.C.H. and Mendoza-Hill, J.J. (2017) Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms and food safety, FAO Fisheries and Aquaculture Technical Paper. No. 615 Rome, Italy.

Mani, S. (2016) Waste Management: Politics, Issues, Challenges and Way Forward, National Institute of Urban Affairs: New Delhi, India. Available at: http://www.cseindia.org/userfiles/ShyamalaMani.pdf (Accessed: February 2018).

MAP and UNEP (2016) Marine Litter Assessment in the Mediterranean-2015.

MEFCC (2016) Plastic Waste Management Rules, 2016, Ministry of Environment, Forest and Climate Change: New Delhi, India. Available at: http://www.moef.gov.in/sites/default/files/PWM Rules%2C 2016.pdf (Accessed: March 2017).

MIA (2013) Plastic bags pose a threat to the environment. Macedonia: Macedonia Information Agency. Available at: https://www.mia.mk/en/Inside/RenderSingleNews/324/131974653 (Accessed: 9 May 2018).

MINA (2008) Plastic bags, what plastic bags? Macedonia: MINA - Macedonia Online. Available at: http://macedoniaonline.eu/content/view/3761/48/ (Accessed: 9 May 2018).

MoE (2010) Context and Main Aspects - National Solid Waste Policy. Brasilia, Brazil: Ministry of Environment. Available at: http://www.mma.gov.br/cidades-sustentaveis/residuos-solidos/politica-nacional-de-residuos-solidos/contextos-e-principais-aspectos (Accessed: 17 March 2017).

Morritt, D., Stefanoudis, P.V., Pearce, D., Crimmen, O.A. and Clark, P.F. (2014) Plastic in the Thames: a river runs through it, *Mar Pollut Bull,* 78(1-2), pp. 196-200.

Mtulya, A. (2016) Plastic bags ban still Jan 1, says govt. Dodoma, Tanzania: The Citizen. Available at: http://www.thecitizen.co.tz/News/Business/Plastic-bags-ban-still-Jan-1--says-govt/1840414-3426148-lo34j0z/index.html (Accessed: 9 May 2018).

Mudgal, S. and Lyons, L. (2011) Plastic waste in the environment, AEA Energy and Environment for European Commission: Paris. Available at: http://ec.europa.eu/environment/waste/studies/pdf/plastics.pdf (Accessed: December 2016).

Mushi, D. (2015) Tanzania: Plastic Bags Still Used Despite Ban, Who Is To Blame? Dar es Salaam, Tanzania: All Africa. Available at: http://allafrica.com/stories/201504201865.html (Accessed: 9 May 2018).

News 24 (2005) Eritrea bans plastic bags. Cape Town, South Africa: News 24. Available at: https://www.news24.com/Africa/News/Eritrea-bans-plastic-bags-20050304 (Accessed: 9 May 2018).

Niaounakis, M. (2017) Management of Marine Plastic Debris: Prevention, Recycling and Waste Management William Andrew Applied Science Publishers: Oxford, UK and Cambridge, USA.

NOAA (2015) Detecting Japan Tsunami Marine Debris at Sea: A Synthesis of Efforts and Lessons Learned, National Oceanic and Atmospheric Administration.

NOAA and UNEP (2011) The Honolulu Strategy - A Global Framework for Prevention and Management of Marine Debris, National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program; UN Environment. Available at: http://wedocs.unep.org/bitstream/handle/20.500.11822/12000/Honolulu strategy.pdf?sequence=1&isAllowed=y (Accessed: February 2018).

Ocean Conservancy (2011) Tracking Trash: 25 Years of Action for the Ocean.

Ocean Conservancy (2012) The Ocean Trash Index - Results of the International Coastal Cleanup (ICC).

Ocean Conservancy (2015) Stemming the Tide: Land-based strategies for a plastic-free ocean, Ocean Conservancy and McKinsey Center for Business and Environment.

Ocean Conservancy (2017) International Coastal Cleanup 2017 Report: Together for our oceans., Ocean Conservancy and McKinsey Center for Business and Environment.

Ocean Conservancy (2018) Building a Clean Swell: 2018 Report, International Coastal Cleanup.

OECD (2001) Extended Producer Responsibility: A Guidance Manual for Governments, OECD Publishing: Paris, France. Available at: https://books. google.co.za/books?id= DNM4brpcKO4C&pg=PA44&lpg= PA44&dq=upstream+combination+tax/ subsidy&source=bl&ots=y4ZlDTI6M1&sig= dJKWAGj7PWUw3dBIjUEQTx87fCY&hl= en&sa=X&ved=0ahUKEwip6lOtgurSAhUr K8AKHSazDo4Q6AEIHjAB -

v=onepage&q=upstream%20combination%20tax%2Fsubsidy&f=false (Accessed: March 2017).

OECD (2016) Extended Producer Responsibility: Updated Guidance for Efficient Waste Management, OECD Publishing: Paris, France. Available at: http://www.keepeek.com/ Digital-Asset-Management/ oecd/environment/extended-producer-responsibility_9789264256385-en - page3 (Accessed: March 2017).

Olin, R., Carlsson, B. and Stahre, B. (1995) The West Coast of Sweden - the rubbish tip of the North Sea, in Earll, R. (ed.) *Proceedings of Workshop on Coastal and Riverine Litter: Problems and Effective Solutions*. Marine Environmental Management and Training: Kempley, UK.

Oniang'o, M. (2017) Plastic Bags Ban Applauded in Kenya. Nairobi, Kenya: Africa.com. Available at: https://www.africa.com/plastic-bags-ban-applauded-in-kenya/ (Accessed: 9 May 2018).

Pham, C.K., Ramirez-Llodra, E., Alt, C.H., Amaro, T., Bergmann, M., Canals, M., Davies, J., Duineveld, G., Galgani, F. and Howell, K.L. (2014) Marine litter distribution and density in European seas, from the shelves to deep basins, *PLoS One,* 9(4), pp. e95839.

Plastics Europe (2016) Plastics - the Facts 2016, Plastics Europe: Brussels, Belgium. Available at: http://www.plasticseurope.org/Document/plastics--- the-facts-2016-15787.aspx?FolID=2 (Accessed: January 2017).

Plastics Europe (2017) Plastics - the Facts 2017, Plastics Europe: Brussels, Belgium. Available at: http://www.plasticseurope.org/application/files/2415/ 1689/2630/2017plastics_ the_facts.pdf (Accessed: February 2018).

Plastics SA (2015) All About Plastics, Plastics SA: Johannesburg, SA. Available at: http://www.plasticsinfo.co.za/wp-content/uploads/2015/01/All-about-plastics-booklet.pdf (Accessed: January 2017).

Plastics SA (2016a) Growth Though Innovation: An Annual Review 2015/2016, Plastics SA. Available at: http://www.plasticsinfo.co.za/wp-content/uploads/2016/11/ebook 2016.pdf.

Plastics SA (2016b) National Plastics Recycling Survey - 2015, Plastics SA: Johannesburg, SA. Available at: http://www.plasticsinfo.co.za/2014/10/14/recycling/ (Accessed: January 2017).

Pravsky Consulting (2016) Russia: Extended Producer Responsibility for Manufacturers and Importers. Riga, Latvia: Pravsky Consulting. Available at: http://pravsky.com/russia-extended-producer-responsibility-manufacturers-and-importers (Accessed: 22 March 2017).

Prothom Alo (2014) Banned polythene bags make a comeback. Dhaka, Bangladesh: Prothom Alo Bangladesh. Available at: http://en.prothomalo.com/bangladesh /news/53068/Banned-polythene-bags-make-a- comeback-for-lax-law (Accessed: 9 May 2018).

PWMI (2016) An Introduction to Plastic Recycling 2016, Plastic Waste Management Institute (PWMI): Tokyo, Japan. Available at: https://www.pwmi.or.jp/ei/plastic_ recycling_2016.pdf (Accessed: February 2017).

RaboResearch (2018) Plastic Waste Control in India - Is it Really Happening? Utrecht, Netherlands: RaboResearch. Available at: https://research.rabobank.com/far/en/sectors/fa-supply-chains/Plastic-Waste- Control-in-India.html (Accessed: 9 May 2018).

Rech, M. (2013) EU-China Cooperation on Municipal Solid Waste Management, Freie Universitat Berlin: Berlin, German. Available at: http://euchinacrn.org/wp-content/uploads/2013/03/3-4_Max-RECH.pdf (Accessed: February 2018).

Republic of Vanuatu (2010) Ozone Layer Protection Act 2010: No. 27 of 2010: Vanuatu. Available at: http://extwprlegs1.fao.org/docs/texts/van110179.doc.

Reuters (2017) Kenya brings in world's toughest plastic bag ban: four years jail or $40,000 fine. London, UK: The Guardian. Available at: https://www.theguardian.com/environment/2017/aug/28/kenya-brings-in-worlds-toughest-plastic-bag-ban-four-years-jail-or-40000-fine (Accessed: 9 May 2018).

Ryan, P.G., Lamprecht, A., Swanepoel, D. and Moloney, C.L. (2014) The effect of fine-scale sampling frequency on estimates of beach litter accumulation., *Marine Pollution Bulletin,* 88(1-2), pp. 249–254.

Ryan, P.G., Perold, V., Osborne, A. and Moloney, C.L. (2018) Consistent patterns of debris on South African beaches indicate that industrial pellets and other mesoplastic items mostly derive from local sources, *Environmental Pollution,* 238, pp. 1008-1016.

Sanz, V., Rica, E., Palacios, E., Alsina, A. and Mouriz, N. (2015) Redesigning Producer Responsibility: A new EPR is needed for a circular economy, Zero Waste Europe: Brussels, BElgium. Available at: https://www.zerowasteeurope.eu/downloads/redesigning-producer-responsibility-a-new-epr-is-needed-for-a-circular-economy/ (Accessed: March 2017).

SCBD (2016) Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity. Technical Series No.83. , Secretariat of the Convention on Biological Diversity (SCBD): Montreal.

Schmidt, C., Krauth, T. and Wagner, S. (2017) Export of Plastic Debris by Rivers into the Sea, *Environmental science & technology,* 51(21), pp. 12246-12253.

Sharobem, T. (2010) Tertiary Recycling of Waste Plastics: An Assessment of Pyrolysis by Microwave Radiation. MSc in Earth Resource Engineering, Columbia University, Columbia, USA Available at: http://www.seas.columbia.edu/earth/wtert/sofos/Sharobem_thesis.pdf (Accessed: January 2017).

Sheavly, S.B. (2010) National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary. Lessons learned., pp. 26.

SINIR (2015a) Reverse Logistic. Brasilia, Brazil: Ministry of Environment. Available at: http://www.sinir.gov.br/web/guest/logistica-reversa (Accessed: 17 March 2017).

SINIR (2015b) Sectorial Agreement of Packaging in General. Brasilia, Brazil: Ministry of Environment. Available at: http://www.sinir.gov.br/web/guest/embalagens-em-geral (Accessed: 17 March 2017).

Smith, S.D.A. and Markic, A. (2013) Estimates of Marine Debris Accumulation on Beaches Are Strongly Affected by the Temporal Scale of Sampling, *PLoS ONE,* 8(12), pp. e83694.

Song, Y., Hong, S., Jang, M., Kang, J., Kwon, O., Han, G. and Shim, W. (2014) Large Accumulation of Micro-Sized Synthetic Polymer Particles in the Sea Surface Microlayer, *Environmental Science & Technology,* 48(16), pp. 9014-9021.

ten Brink, P., Schweitzer, J.-P., Watkins, E. and Howe, M. (2016) Plastics Marine Litter and the Circular Economy. A briefing by IEEP for the MAVA Foundation.

Thevenon, F., Carroll, C. and Sousa, J. (2014) Plastic Debris in the Ocean: The Characterization of Marine Plastics and their Environmental Impacts, IUCN: Gland, Switzerland.

Ubwani, Z. (2018) Tanzania weighs likely effect of banning plastic materials. Tanzania: Business Daily. Available at: https://www.businessdailyafrica.com/news/ea/tanzania/Tanzania-weighing-effects-of-banning-plastic-materials/4003154-4301644-5w3jf3/index.html (Accessed: 9 May 2018).

UN (1994) United Nations Convention on the Law of the Sea, United Nations: Washington, USA. Available at: http://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf (Accessed: February 2018).

UN (2015) Resolution adopted by the General Assembly on 25 September 2015, United Nations General Assembly: Washington, USA. Available at: https://undocs.org/A/RES/70/1 (Accessed: 1 February).

UN Environment (2015) Sustainable Consumption and Production - A Handbook for Policymakers. Second edition - Asia - Pacic region, UNEP, SWITCH-Asia Policy Support. Available at: http://www.switch-asia.eu/fileadmin/user_upload/RPSC/Publications/03SCP-Handbook-AP_low-resolution_.pdf (Accessed: August 2018).

UN Environment (2017a) Combating marine plastic litter and microplastics: An assessment of the effectiveness of relevant international, regional and subregional governance strategies and approaches, United Nations Environment Assembly: Nairobi, Kenya.

UN Environment (2017b) Waste Management in ASEAN Countries summary report Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/21134/waste_mgt_asean_summary.pdf?sequence=1&isAllowed=y (Accessed: August 2018).

UN Environment (2018) SINGLE-USE PLASTICS: A Roadmap for Sustainability. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/25496/singleUsePlastic_sustainability.pdf?isAllowed=y&sequence=1 (Accessed: August 2018).

UNEP (2016a) Marine Litter Legislation: A Toolkit for Policymakers, United Nations Environment Programme: Nairobi, Kenya. Available at: http://www.unep.org/stories/Ecosystems/Marine-Litter-Legislation-A-toolkit-for-Policymakers.asp (Accessed: December 2016).

UNEP (2016b) Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change., United Nations Environment Programme,: Nairobi.

UNEP (2018) Global Partnership on Marine Litter. Nairobi, Kenya: United Nations Environment. Available at: http://web.unep.org/gpa/what-we-do/global-partnership-marine-litter (Accessed: 31 january 2018).

UNEP and GRID-Arendal (2016) Marine Litter Vital Graphics., United Nations Environment Programme and GRID-Arendal.: Nairobi and Arendal.

United Nations Environment Programme (2017) Towards a Pollution-Free Planet Background Report, United Nations Environment Programme,: Nairobi, Kenya. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/21800/UNEA_towardspollution_long version_Web.pdf?sequence=1&isAllowed=y (Accessed: May 2018).

USEPA (2016) Advancing Sustainable Materials Management: 2014 Tables and Figures, United States Environmental Protection Agency: Washington, USA. Available at: https://www.epa.gov/sites/production/files/2016-11/documents/2014_smm_tablesfigures_508.pdf (Accessed: January 2017).

Van Acoleyen, M., Laureysens, I., Lambert, S., Raport, L., van Sluis, C., Kater, B., van Onselen, E., Veiga, J. and Ferreira, M. (2013) Marine litter study to support the establishment of an initial quantitative headline reduction target, *Final report—SFRA0025 (315 pp., Available from: http://ec. europa. eu/environment/marine/good-environmentalstatus/descriptor-10/pdf/final_report. pdf)*.

Van Sebille, E., Wilcox, C., Lebreton, L., Maximenko, N., Hardesty, B.D., Van Franeker, J.A., Eriksen, M., Siegel, D., Galgani, F. and Law, K.L. (2015) A global inventory of small floating plastic debris, *Environmental Research Letters*, 10(12), pp. 124006.

Vianello, A., Boldrin, A., Guerriero, P., Moschino, V., Rella, R., Sturaro, A. and Da Ros, L. (2013) Microplastic particles in sediment of Lagoon of Venice, Italy: First observations on occurance, spatial patterns and identification, *Esturine, Coastal and Shelf Science*, 130, pp. 54-61.

VINM (2018) Vanuatu govt says plastic bag ban achievable. Vanuatu: The Vanuatu Independent News Magazine. Available at: https://vanuatuindependent.com/2018/01/04/vanuatu-govt-says-plastic-bag-ban-achievable/ (Accessed: 9 May 2018).

World Bank (2012) What a Waste: A Global Review of Solid Waste Management, World Bank: Washington, USA. Available at: https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf (Accessed: May 2017).

World Economic Forum and Ellen MacArthur Foundation (2017) The New Plastic Economy: Catalysing action. Available at: http://www.ellenmacarthurfoundation.org/publications.

World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company (2016) The New Plastics Economy - Rethinking the future of plastics, World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company: Cowes, UK. Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/EllenMacArthurFoundation_TheNewPlasticsEconomy_15-3-16.pdf (Accessed: January 2017).

Wright, S., Thompson, R. and Galloway, T. (2013) The physical impacts of microplastics on marine organisms: A Review, *Environmental Pollution,* 178, pp. 483-492.

Xanthos, D. and Walker, T. (2017) International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review.

Xinhua (2017a) China unveils extended producer responsibilty plan. Beijing, China: China Daily. Available at: http://www.chinadaily.com.cn/china/2017-01/03/content_27851701.htm (Accessed: 20 March 2017).

Xinhua (2017b) Ethiopia puts squeeze on plastic bags. Addis Ababa, Ethiopia: XinhuaNet. Available at: http://www.xinhuanet.com/english/2017-05/22/c_136302987.htm (Accessed: 9 May 2018).

Xinhua Net (2017) Tanzania's plan to ban use of plastic bags sparks debate. Dar es Salaam, Tanzania: Xinhua Net. Available at: http://www.xinhuanet.com/english/2017-07/23/c_136464723.htm (Accessed: 9 May 2018).

Yamashita, R., Takada, H., Fukuwaka, M. and Watanuki, Y. (2011) Physical and chemical effects of ingested plastic debris on short-tailed shearwaters, Puffinus tenuirostris, in the North Pacific Ocean, *Marine Pollution Bulletin,* 62(12), pp. 2845-2849.

Zero Waste Euorpe (2017) Extended producer responsibility - Creating the frame for circular products. Available at: https://www.zerowasteeurope.eu/wp-content/uploads/2017/01/EPRpolicypaper.pdf (Accessed: May 2018).

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