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TECHNICAL PAPER UPDATING CBD TECHNICAL SERIES NO. 83 (MARINE DEBRIS: UNDERSTANDING, PREVENTING AND MITIGATING THE SIGNIFICANT ADVERSE IMPACTS ON MARINE AND COASTAL BIODIVERSITY)

Note by the Executive Secretary

1. In decision XIII/10, the Conference of the Parties took note of the Voluntary Practical Guidance on Preventing and Mitigating the Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats (as contained in an annex to the decision), and urged Parties and encouraged other Governments, relevant organizations, industries, other relevant stakeholders, and indigenous peoples and local communities, to take appropriate measures, in accordance with national and international law and within their competencies, to prevent and mitigate the potential adverse impacts of marine debris on marine and coastal biodiversity and habitats, taking into account the voluntary practical guidance, and incorporate issues related to marine debris in the mainstreaming of biodiversity into different sectors.

2. In the same decision, the Conference of the Parties requested the Executive Secretary to facilitate collaboration among Parties, other Governments and relevant organizations on the application of measures within the respective jurisdictions of Parties and other Governments and the mandates of intergovernmental organizations, to prevent and mitigate the impacts of marine debris on marine and coastal biodiversity and habitats, including those in the voluntary practical guidance, by facilitating the sharing of experiences, information, toolkits and best practices.

3. Pursuant to this request, the Executive Secretary issued notification 2018-080, dated 27 December 2018, requesting information on experiences in the implementation of Voluntary Practical Guidance on Preventing and Mitigating the Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats, or activities that are in line with these. Submissions were received from Canada, Colombia, Denmark, Ecuador, Japan, Norway, and the United Kingdom of Great Britain and Northern Ireland.

4. In 2016, the Secretariat published Technical Series No.83: *Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity*, which built on a review of the impacts of marine debris that was previously undertaken by the Scientific and Technical Advisory Panel of the GEF (GEF-STAP) in collaboration with the Secretariat of the Convention on Biological Diversity (SCBD), and published as CBD Technical Series 67 in 2012.

5. This information document, prepared by Mr. Simon Harding, is a technical paper updating Technical Series No. 83 regarding new developments and information that has emerged on this topic since its publication and also incorporates information received in response to the above-noted notification.

* CBD/SBSTTA/24/1.

Contents

EXECUTIVE SUMMARY

Marine debris is recognised as a major environmental issue at the global level and a growing threat to marine and coastal biodiversity. It is aesthetically and economically detrimental, a hazard to commercial shipping and fishing vessels, can facilitate the transport of organic and inorganic contaminants, and is harmful to marine organisms and humans. Although some of the threats posed by marine debris to people and the environment have been recognised for almost sixty years, the issue has gained wide recognition over the last decade. Plastics are the dominant pollutant item within marine debris and can make up 100% of marine litter pollution in specific areas. There are estimated to be 150 million tonnes of plastics currently in the world's oceans with approximately 8 million tonnes of plastics added into the marine environment each year.

This document provides an update to CBD Technical Series No. 83 with regards to new developments and knowledge that have emerged since its publication in 2016, and follows a similar format in terms of structure and subject areas. It also provides information on the implementation of the Voluntary Practical Guidance on Preventing and Mitigating the Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats, submitted by Parties, other Governments and relevant organizations information, in response to CBD notification 2018-080.

Chapter 2 of this document, provides a brief review of new information regarding marine and coastal biodiversity affected by marine debris including further information on the latest understanding of the impacts of microplastics, including toxic effects and the potential effects of nanoplastics. A review of knowledge regarding the potential effects of marine debris (microplastics) on human health is also provided. The effects of marine debris ingestion and/or entanglement for ecologically important of particularly vulnerable taxa are highlighted, namely for polar teleost fish (ingestion), Otariid marine mammals (fur seals and sea lions – ADLFG[1] entanglement) and marine turtles (ingestion and entanglement). The latter faunal group are considered highly susceptible to mortality from plastic ingestion or entanglement (predominantly by ADLFG) in marine debris.

Research is beginning to explain why microplastics are so attractive to some marine fauna during feeding as well as identifying ingestion effects for a variety of taxa. Studies suggest that microplastic particles in the ocean can develop a strong infochemical signature and create an olfactory trap for foraging seabirds and other susceptible marine fauna. Overall, there is strong evidence of demonstrated effects on individual organisms from both marine debris ingestion and entanglement but very little currently available at higher ecological levels in terms of impacts. However, there is thought to be enough evidence for policy makers to recognize the hazards posed by marine debris and take a precautionary and/or anti- catastrophe approach.

Chapter 3 provides an update of recent research studies regarding marine debris monitoring and modelling. Citizen science-based monitoring programs have been successfully implemented in a number of countries for coasts and shorelines. Monitoring of surface macro-debris in rivers can provide valuable information on the debris entering the marine environment from catchments. Extensive guidelines have been developed for the monitoring and analysis of both macro- and microplastics. The monitoring of microplastics ingested by marine organisms is regarded as a key research area to quantify and evaluate effects on individuals, populations and ecosystems, with a number of marine species proposed as bioindicators for microplastics at the global or regional level. Numerical modelling of marine debris movement in the ocean continues to make advances but requires considerable further development to predict the transport and fate of microplastics in complex coastal environments.

Chapter 4 reviews current best practice and both possible new and further developed tools and approaches for the management and mitigation of marine debris, with a focus on plastics. Subject areas covered include:

[1] Abandoned, Derelict or Lost Fishing Gear

- A circular economy approach and producer responsibility, including sustainable circular business models;
- The development of fully biodegradable single use (packaging) items;
- Chemical and/or biotechnological recycling technologies for mixed plastic waste;
- Solid waste management - review and projections;
- Regulatory measures for single-use plastics;
- Addressing sea-based sources of marine debris;
- Engagement with industry through alliances with government and civil society, and;
- New approaches and concepts for raising public awareness

Responses to tackle marine debris at the global and regional level are summarised for international bodies and intergovernmental processes. The chapter also includes the responses of Parties to notification 2018-080 with regards to activities for preventing and mitigating the impacts of marine debris at the national, regional or global level.

Finally, the main needs and recommendations to address marine debris, particularly for plastics, are summarised in Chapter 5. It should be noted that the currently very high level of interest and activity in the field of marine debris and plastic pollution is likely to mean that this report will be partially outdated when released. It is also important to use this report in conjunction with the two previous CBC Technical Series reports (T.S. 67 and 83) to have a more rounded understanding of the marine debris and plastic pollution issue.

Marine plastic pollution has been regarded as an emerging risk in the Anthropocene epoch, in which human activities have a decisive influence on the state, dynamics and future of the earth system, with plastic now considered as a geological marker for this epoch. Whether plastics meet the criteria for being a planetary boundary threat is a matter for ongoing discussion. Studies suggest that two out of the three defined categories for chemical pollution to pose a planetary boundary threat have been met in that there is planetary-scale exposure that is not readily reversible. There is not sufficient evidence at present to confirm that marine plastic pollution meets the third condition of disrupting earth system processes, although evidence is growing for the ecological effects of plastic pollution in the oceans.

Ongoing and further efforts to address marine debris should form part of an integrated multi-sectoral approach containing the four key elements mentioned in the previous CBD marine debris report that have proven successful: regulatory measures; voluntary (non-regulatory) measures; adequate infrastructure; and education and awareness. This report has provided recent examples of initiatives in place and measures taken that enable these elements to address marine debris, particularly with regards to plastics.

1. INTRODUCTION

Marine debris is recognised as a major environmental issue at the global level and a growing threat to marine and coastal biodiversity. The vast majority of marine debris is made up of various types of plastic that enter the oceans from both land- and sea-based sources. Marine debris is aesthetically and economically detrimental, a hazard to commercial shipping and fishing vessels, can facilitate the transport of organic and inorganic contaminants, and is harmful to marine organisms[2] and humans[3]. Although some of the threats posed by marine debris to people and the environment have been recognised for almost sixty years[4], the issue has gained wide recognition over the last decade. In fact, between the years 2000 and 2015, the number of studies published annually on marine debris had doubled [5]. The issue of marine litter, and particularly plastic pollution, has captured the attention of both the media and the general public over the last five years.

Plastics are the dominant pollutant item within marine debris and can make up 100% of marine litter pollution in specific areas[6] [7]. Global plastic production continues to grow each year with an estimated 381 million metric tonnes produced in 2015. A recent analysis developed a comprehensive global material flow for mass produced plastics, which revealed that an estimated 8,300 million tonnes of virgin plastics were produced between 1950 and 2015[8]. Of this, approximately 6,300 million tonnes of plastic waste was generated, around 9% of which was recycled, 12% incinerated and 79% accumulated in landfills or leaked to the environment. It was also estimated that with current waste management trends, 12 billion tonnes of plastic will be in landfills or the natural environment by 2050[9].

According to recent estimates there are currently around 150 million tonnes of plastics in the world's oceans[10] with approximately 8 million tonnes of plastics added into the marine environment each year[11]. Of this, ten rivers, eight in Asia and two in Africa, are estimated to transport between 88 and 95% of the global load of marine plastic debris from land-based sources to the sea[12]. Poor waste management coupled with generally low recycling rates, short product lifetimes and the low economic value of used plastic are the main factors that lead to high leakage rates of plastic into the environment[13]. For example, roughly one third of the global production of plastics is single-use packaging with an average product lifetimes of less than a year[14][15]. The total degradation time for plastics is unknown, with estimates in

[2] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel – GEF. 2012. Impacts of marine debris on biodiversity: current status and potential solutions. Montreal, Technical Series No. 67, 61 pp. https://www.cbd.int/doc/publications/cbd-ts-67-en.pdf.
[3] Campbell, M.L.; Slavin, C., and Grage, A. 2016. Human health impacts from litter on beaches and associated perceptions: A case study of 'clean' Tasmanian beaches. Ocean Coastal and Management, 126: 22–30
[4] Ryan, P.G. 2015. A brief history of marine litter research. In: Bergmann, M.; Gutow, L., and Klages, M. (eds.), Marine Anthropogenic Litter. Berlin: Springer, pp. 1–25.
[5] Rochman, C.M. et al. 2016. The ecological impacts of marine debris: unravelling the demonstrated evidence from what is perceived. Ecology 97: 302-316
[6] Galgani, F.; Hanke, G., and Maes, T. 2015. Global distribution, composition and abundance of marine litter. In: Bergmann, M.; Gutow, L., and Klages, M. (eds.), Marine Anthropogenic Litter. Berlin: Springer, pp. 29–56
[7] Worm, B. 2017. Plastic as a persistent marine pollutant. Annual Review Environmental Resources, 42, 1–26
[8] Geyer, R.; Jambeck, J.R., and Lavender, K., 2017. Production, use, and fate of all plastics ever made. Science Advances, e1700782, 1–5.
[9] Ibid
[10] WEF, EMF and McKinsey & Company. 2016. The new plastics economy - rethinking the future of plastics, Ellen MacArthur Foundation. http://www.ellenmacarthurfoundation.org/publications.
[11] Jambeck, J.R.; Geyer, R.; Wilcox, C.; Siegler, T.R.; Perryman, M., and Andrady, A. 2015. Plastic waste inputs from land into the ocean. Science, 347(6223): 768–771
[12] Schmidt, C., Krauth, T. and Wagner, S. 2017. Export of Plastic Debris by Rivers into the Sea. Environmental Science & Technology, Vol. 51/21: pp. 12246-12253
[13] Watkins, E., et al. 2019. Policy Approaches to Incentivise Sustainable Plastic Design. Environment Working Paper No. 149. Organisation for Economic Co-operation and Development. OECD ENV/WKP(2019)8
[14] Koelmans, A.A. et al. 2014. Plastics in the marine environment. ET & C Perspectives. Environmental Toxicology and Chemistry 33: 5-10
[15] Geyer, R.; Jambeck, J.R., and Lavender, K., 2017. Production, use, and fate of all plastics ever made. Science Advances, e1700782, 1–5.

the hundreds of years for many types of products. Thus, litter in the marine environment is a multi-generational problem that extends far beyond the lifespan of the current human population[16]

A global level analysis of marine plastic pollution effects has suggested that plastic waste has substantial negative impacts on the ecosystem services provided by marine and coastal biodiversity environments. In 2011 there was an estimated 1.5% reduction in ecosystem service delivery caused by marine plastics, with an annual loss of between $500 billion and $2.5 trillion in the value of benefits provided by the marine environment, mainly linked to fisheries, recreation, heritage and charismatic species[17]. The ubiquity of plastic in the environment has enabled it to be considered as a geological marker for the Anthropocene[18]. Whether plastic pollution meets the criteria to be considered a planetary boundary threat[19] is also a subject of discussion[20] [21]. There is a lack of demonstrated scientific evidence for marine debris effects on biodiversity at higher ecological levels[22]. However, as attention continues to focus on the problem of marine debris and plastic pollution it will only be a matter of time before the stressor's effects are more fully understood and provide robust evidence better able to support policy changes.

A review of the impacts of marine debris on marine and coastal biodiversity and habitats was undertaken by the Scientific and Technical Advisory Panel of the GEF (GEF-STAP), in collaboration with the Secretariat of the Convention on Biological Diversity (SCBD), and published as CBD Technical Series 67 in 2012[23]. This report assessed the effects of marine debris as well as the types and potential origins of debris. The second part of the report explored potential solutions to tackle the problem and provided successful examples of land-based waste reduction practices with direct benefits related to addressing marine debris.

At the 11th meeting of the Conference of the Parties (COP 11) to the Convention on Biological Diversity, the COP requested the Executive Secretary, in collaboration with Parties, other Governments, relevant organizations and indigenous and local communities to (decision XI/18):

- Invite Parties, other Governments and relevant organizations, including the Convention on Migratory Species, to submit information on the impacts of marine debris on marine and coastal biodiversity and habitats;
- Compile and synthesize submissions by Parties, other Governments and relevant organizations, along with additional scientific and technical information, as input to an expert workshop;
- Organize an expert workshop to prepare practical guidance on preventing and mitigating the significant adverse impacts of marine debris on marine and coastal biodiversity and habitats that

[16] Hardesty, B.D., Good, T. and Wilcox, C. 2015. Novel methods, new results and science-based solutions to tackle marine debris impacts on wildlife. Ocean and Coastal Management 115: 4-9.
[17] Beaumont, N.J. et al. 2019. Global ecological, social and economic impacts of marine plastic. Marine Pollution Bulletin 142: 189-195
[18] J. Zalasiewicz, C.N. Waters, J.A. Ivar do Sul, et al. 2016. The geological cycle of plastics and their use as a stratigraphic indicator of the Anthropocene. Anthropocene 13: 4–17.
[19] The planetary boundary concept was introduced by Rockström et al. 2009 and aimed to define a set of limits within which humanity could operate without disrupting vital Earth system processes that regulate the planet. See Rockström, J.; Steffen, W.; Noone, K. et al. 2009. A safe operating space for humanity. Nature: 461 (7263), 472−475, and also Persson, L. M.; Breitholtz, M.; Cousins, I. T. et al. 2013. Confronting unknown planetary boundary threats from chemical pollution. Environ. Sci. Technol. 47 (22), 12619−12622, for a chemical pollution perspective
[20]MacLeod, M., et al. 2014. Identifying chemicals that are planetary boundary threats, Environ. Sci. Technol. 48:11057–11063. http://dx.doi.org/10.1021/ es501893m
[21] Jahnke, A. et al. 2017. Reducing uncertainty and confronting ignorance about the possible impacts of weathering plastic in the marine environment, Environ. Sci. Technol. Lett. 4: 85-90
[22] Rochman, C.M. et al. 2016. The ecological impacts of marine debris: unravelling the demonstrated evidence from what is perceived. Ecology 97: 302-316
[23] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel – GEF. 2012. Impacts of marine debris on biodiversity: current status and potential solutions. Montreal, Technical Series No. 67, 61 pp. https://www.cbd.int/doc/publications/cbd-ts-67-en.pdf.

can be applied by Parties and other Governments in their implementation of the programme of work on marine and coastal biodiversity;

A background information document was prepared for the CBD Expert Workshop to Prepare Practical Guidance on Preventing and Mitigating the Significant Adverse Impacts of Marine Debris on Marine and Coastal Biodiversity (held in Baltimore, United States of America, from 2 to 4 December 2014), convened pursuant to COP decision XI/18. It provided information that contributed to the development of practical guidance on preventing and mitigating the significant adverse impacts of marine debris on marine and coastal biodiversity and habitats, including an update on the previous synthesis of the impacts of marine debris on marine and coastal biodiversity contained in CBD Technical Series 67. The background document was then developed into a CBD Technical Series report (No. 83), which was published in 2016[24].

In decision XIII/10, the COP took note of the Voluntary Practical Guidance on Preventing and Mitigating the Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats (as contained in an annex to the decision), and urged Parties and encouraged other Governments, relevant organizations, industries, other relevant stakeholders, and indigenous peoples and local communities, to take appropriate measures, in accordance with national and international law and within their competencies, to prevent and mitigate the potential adverse impacts of marine debris on marine and coastal biodiversity and habitats, taking into account the voluntary practical guidance, and incorporate issues related to marine debris in the mainstreaming of biodiversity into different sectors. In the same decision, the COP requested the Executive Secretary to facilitate collaboration among Parties, other Governments and relevant organizations on the application of measures within the respective jurisdictions of Parties and other Governments and the mandates of intergovernmental organizations, to prevent and mitigate the impacts of marine debris on marine and coastal biodiversity and habitats, including those in the voluntary practical guidance, by facilitating the sharing of experiences, information, toolkits and best practices. Parties, other Governments and relevant organizations were invited to submit information on the implementation of the Voluntary Practical Guidance on Preventing and Mitigating the Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats, or activities that are in line with these, as part of CBD Notification 2018-080 issued in September 2018. Parties were requested to include information on activities at the global, regional, national and/or local levels and consider including relevant scientific and technical information, relevant management plans at sub-national, national or regional levels, descriptions of specific measures taken, tools and guidance applied, as well as case studies and lessons learned. Any relevant activities outlined in National Biodiversity Strategies and Action Plans (NBSAPs) were also to be included.

This document provides an update to the previous CBD report on marine debris (Technical Series 83) with regards to new developments and knowledge since its publication, and follows a similar format in terms of structure and subject areas. In Chapter 2 of this document, a brief review of new information regarding marine and coastal biodiversity affected by marine debris is provided including further information on the latest understanding of the impacts of microplastics, including toxic effects and the potential effects of nanoplastics. A review of knowledge regarding the potential effects of marine debris (microplastics) on human health is also included. Chapter 3 provides an update of recent research studies regarding marine debris monitoring and modelling. Chapter 4 reviews current best practice and possible new or further developed approaches for the management and mitigation of marine debris. It also includes the responses of Parties to notification 2018-080 with regards to activities for preventing and mitigating the impacts of marine debris. Finally, research needs and recommendations to address marine debris, particularly for plastics, are summarised in Chapter 5. It should be noted that the currently very high level of interest and activity in the field of marine debris and plastic pollution is likely to mean that this report will be partially outdated when released. It is also important to use this report in conjunction with the two previous CBC Technical Series reports (T.S. 67 and 83) to have a more rounded understanding of the marine debris and plastic pollution issue.

[24] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel – GEF. 2012. Impacts of marine debris on biodiversity: current status and potential solutions. Montreal, Technical Series No. 67, 61 pp. https://www.cbd.int/doc/publications/cbd-ts-67-en.pdf

2. Updated Review of the Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats

This section provides updates for the research topics covered by the previous CBD report[25] but does not seek to systematically update the records of marine species affected by marine debris. The most recent published reviews (2015) for the number of marine species affected by marine debris indicate that 580 species are known to suffer from the effects of marine litter[26] and that 693 species have encountered debris in the marine environment[27]. The most recent assessment by the CBD of the number of marine species affected revealed that 154 new species were affected since the last review in 2012[28], bringing the total number of impacted species to 817[29], which represents a 23 per cent increase over four years. As these reviews were published more than two years ago it is highly likely that the total number of marine species known to be affected by debris in the oceans has increased given the trend of increasing research efforts on the issue.

2.1 Ingestion and entanglement

Published research documenting the levels of plastic ingestion in marine taxa is accelerating[30] and although motivated by an underlying interest in the conservation of species and ecosystems, there have been calls for a more integrated approach that links research, conservation action and policy to the achievement of positive conservation outcomes for wildlife directly affected by plastic pollution[31]. A recent review of publications on plastic ingestion by marine megafauna (seabirds, marine mammals[32], turtles and fish) between 1949 and 2015 indicates a rapid increase in the number of studies since 1980 mainly driven by research on seabirds[33]. Studies for other megafauna have also increased substantially over the last decade, especially for marine fish. Similarly, increasing attention is turning to the ingestion of debris by marine invertebrates, mainly in the form of microplastics[34] [35] (see section 2.2 for a review of microplastics).

Reports of marine debris ingestion are also emerging for ecologically important species of teleost fish in polar waters. Juvenile polar cod (*Boreogadus saida*) were recently assessed for the presence of microplastic particles and a low frequency of occurrence was recorded (2.4%) in the Central Arctic Ocean[36]. Microplastic items were also recorded in the gastrointestinal tract of an antarctic toothfish

[25] 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, Montreal, 78 pages.

[26] Kühn, S., Bravo Rebodello, E.L., Van Franeker, J.A. 2015. Deleterious effects of litter on marine life. In Bergman, M. et al. (Eds.). Marine Anthropogenic Litter, Springer, Berlin, pp. 75-116

[27] Gall, S.C. and Thompson, R.C. 2015. The impact of debris on marine life. Mar. Poll. Bull. 92: 170-179.

[28] TS 67

[29] 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, Montreal, 78 pages

[30] Provencher, J. et al., 2017. Quantifying ingested debris in marine megafauna: a review and recommendations for standardization. Analytical Methods 9: 1454.

[31] Avery-Gomm, S., Borrelle, S.B., and Provencher, J.F. 2018. Linking plastic ingestion research with marine wildlife conservation. Science of the Total Environment 637-638: 1492-1495.

[32] Cetaceans, pinnipeds, sea cows, otters and polar bears

[33] Provencher, J. et al., 2017. Quantifying ingested debris in marine megafauna: a review and recommendations for standardization. Analytical Methods 9: 1454.

[34] Auta, H.S. et al. 2017. Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects, and potential solutions. Env. Int. 102: 165-176.

[35] Lusher, A.L. et al. 2017. Sampling, isolating and identifying microplastics ingested by fish and invertebrates. Analytical Methods 9: 1346.

[36] Kühn, S. et al. 2018. Plastic ingestion by juvenile polar cod (*Boreogadus saida*) in the Arctic Ocean. Polar Biology doi.org/10.1007/s00300-018-2283-8

(*Dissostichus mawsoni*) in Australian waters although the provenance of the individual could not be determined[37].

For taxa that are under considerable threat globally, such as marine turtles[38], where all seven species are known to ingest plastic debris[39], evaluating the impact of marine debris on their development, survivorship and health is regarded as a global conservation priority[40] [41]. For example, a recent study suggests that plastic ingestion by marine turtles can directly cause mortality. The probability of mortality was estimated to be 0.5 (i.e. half of the animals expected to die) for turtles that had ingested 17 items of plastic. Ingesting a single item of debris led to a 22% chance of mortality[42]. The model used enables the quantification of risk that marine plastic pollution poses to marine turtles and can be adapted for other taxa to understand dose response of plastic ingestion[43].

Marine turtles are also highly susceptible to death once entangled in marine debris. Entanglement is considered to be one of the most common harmful effects of marine (plastic) debris through impairment of mobility, natural behaviour and asphyxia[44] and a major risk for many marine species[45]. A global review of marine turtle entanglement indicates that marine turtle mortality caused by entanglement is in the order of 1000 individuals annually[46]. This was also considered a substantial underestimate of the actual number per year. The vast majority of entanglements were caused by abandoned, derelict or lost fishing gear (ALDFG aka ghost gear). More than three-quarters (84%) of the turtle experts interviewed by the study thought that this issue could be causing population effects in some areas and all rated entanglement a greater threat to marine turtles than oil pollution, climate change and direct exploitation[47]. An assessment by World Animal Protection suggests that ALDFG is at least four times more likely to impact marine life through entanglement than all other forms of marine debris combined[48].

The effect of ghost gear entanglement on marine mammals, reptiles, and elasmobranchs (i.e. sharks, rays, and skates) was reviewed recently. An assessment of publications between 1997 and 2015 revealed that 40 species (27 marine mammal, seven reptile and six elasmobranch species) were recorded

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[37] Cannon, S.M.E., Lavers, J.I. and Figueiredo, B. 2016. Plastic ingestion by fish in the Southern Hemisphere: a baseline study and review of methods. Mar. Poll. Bull. 107: 286-291.

[38] IUCN, 2018. IUCN Red List of Threatened Species. International Union on the Conservation of Nature. http:/www.iucnredlist.org/.

[39] Kühn, S., Bravo Rebodello, E.L., Van Franeker, J.A. 2015. Deleterious effects of litter on marine life. In Bergman, M. et al. (Eds.). Marine Anthropogenic Litter, Springer, Berlin, pp. 75-116.

[40] Klukey, K.E. et al. 2017. Investigation of plastic debris ingestion by four species of sea turtles collected as bycatch in pelagic Pacific longline fisheries. Mar. Poll. Bull. 120: 117-125.

[41] Nelms, S. E., et al. 2016. Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science 73: 165–181.

[42] Wilcox c. et al. 2018. A quantitative analysis linking sea turtle mortality and plastic debris ingestion. Sci Rep. 8: 12536.

[43] Ibid

[44] Franco-Trecu, V. et al., 2017. With the noose around the neck: Marine debris entangling otariid species. Env. Poll. 220: 985-989

[45] Vegter A, Barletta M, Beck C, Borrero J et al. 2014. Global research priorities to mitigate plastic pollution impacts on marine wildlife. Endang Species Res 25: 225−247

[46] Duncan, E.M. et al., 2017. A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endang. Spec. Res. 34: 431-448.

[47] Ibid

[48] Analysis by World Animal Protection based on figures and evidence found in the following papers: (1) Wilcox, C., Mallos, N.J., Leonard, G.H., Rodriguez, A., and Hardesty, B.D. Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife. Marine Policy, No. 65; 107-114; Elsevier Ltd. 2015. Figure 2-110p.; (2) United Nations Environment Programme. Marine Plastic Debris and Microplastics - Global lessons and research to inspire action and guide policy change. UNEP. 2016. Nairobi. Table 7.1. and table 7.2. 82-83p. (3) Werner, S., Budziak, A., van Franeker, J., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J. and Vlachogianni, T. Harm caused by Marine Litter. MSFD GES TG Marine Litter - Thematic Report; JRC Technical report; EUR 28317 EN; doi:10.2788/690366, 2016, 10 – 11p. (4) Moss, E., Eidson, A., and Jambeck, J. Sea of Opportunity – Supply Chain Investment Opportunities to Address Marine Plastic Pollution. Encourage Capital on behalf of Vulcan, Inc., New York. February 2017. 22p

entangled in ALDFG[49]. Most entanglements occurred for marine mammals (70%), followed by reptiles (27%) and lastly, elasmobranchs (2%). The low incidence for elasmobranchs was thought to be more a result of the lack of studies for this taxa rather than a lower vulnerability to entanglement. When reported by studies, the number of sharks or rays entangled was relatively high[50]. A lack of published studies was also noted for dugongs and manatees and for the polar ocean regions. It should be noted that the accuracy of the entanglement records in the aforementioned review was questioned and that some cases were likely attributable to interactions between wildlife and active fishing gear rather than ADLFG[51].

Of the marine mammals, the Otariids (fur seals and sea lions) are one of the most threatened groups by ADLFG entanglement[52] with 13 of the 14 species reported entangled[53] and juveniles more likely to become entangled than adults[54] [55]. Although, population-level effects have not been shown for Otariid species in more recent studies in the southern hemisphere, mortality caused by entanglement in marine debris was previously identified as contributing to the declining trend in the population of Northern fur seals in the North Pacific in the 1980s[56].

2.2. Microplastics

Research efforts concerning microplastics and the marine environment continue to grow with multiple reviews published in the last few years regarding microplastic properties, sources, distribution, sampling and effects on the marine ecosystem[57] [58] [59] [60]. In addition, the second part of a global assessment of the sources, fates and effects of microplastic was recently published by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)[61]. This extensive assessment was compiled by over thirty international experts on marine debris and microplastics and should be referred to for a current detailed overview of microplastics in the marine environment along with the previously mentioned published reviews. In this section we shall highlight a number of new findings and concepts about microplastics and how they affect marine life.

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[49] Stelfox, M., Hudgins, J. and Sweet. M. 2016. A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. Mar. Poll. Bull. 111: 6-17.
[50] Ibid
[51] Asmutis-Silvia, R. et al., 2017. Rebuttal to published article "A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs" by M. Stelfox, J. Hudgins and M. Sweet. Mar. Poll. Bull. 117:554-555.
[52] Franco-Trecu, V. et al., 2017. With the noose around the neck: Marine debris entangling otariid species. Env. Poll. 220: 985-989
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[54] Lawson, T.J. et al. 2015. Characteristics of marine debris that entangle Australian fur seals (*Arctocephalus pusillus doriferus*) in southern Australia. Mar. Poll. Bull. 98: 354-357
[55] Waluda, C.M. and Staniland, I.J. 2013. Entanglement of Antarctic fur seals at Bird Island, South Georgia. Mar. Poll. Bull. 74: 244-252.
[56] Fowler, C.W. 1987. Marine debris and northern fur seals: A case study. Mar. Poll. Bull. 18: 326-335.
[57] Andrady, A.A. 2017. The plastics in microplastics: A review. Mar. Poll. Bull. 119: 12-22
[58] Auta, H.S. et al. 2017. Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects, and potential solutions. Env. Int. 102: 165-176.
[59] Lusher, A.L. et al. 2017. Sampling, isolating and identifying microplastics ingested by fish and invertebrates. Analytical Methods 9: 1346
[60] Galloway, T.S. et al. 2017. Interactions of microplastic debris throughout the marine ecosystem. Nature Ecology & Evolution 1, 0116. DOI: 10.1038/s41559-017-0116.
[61] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p.

A concept for understanding the behaviour and ecological impacts of micro- and nano-plastics has been proposed recently: the ecocorona[62]. This is the layer of natural organic macromolecules that are absorbed on to the outer surface of a plastic particle in seawater. This may then interact with organic materials and other components in the water column and could potentially represent a record of the environmental progress of the microplastic particle[63]. An absorbed layer of macromolecules also supports the notion that microplastic particles contribute to a 'trojan horse' effect for pollutants, where contaminants are acquired from the surrounding environment and then released within the ingesting organism[64]. The ecocorona could also influence the movement and behaviour of microplastic by absorbed molecules altering the electrical charge or the tendency to aggregate to form clumps that changes the density, sinking rate and bioavailability of the microplastics for suspension or deposit feeders[65].

The chemical nature of the ecocorona may also influence the attractiveness of the microplastic particle as a 'food' item for marine taxa. Chemical cues (infochemicals) can drive complex foraging cascades for microfauna to macrofauna across multiple trophic levels[66] including behavioural attractions for locating foraging zooplankton. Dimethyl sulphide (DMS) is regarded as a 'keystone' infochemical for marine trophic interactions in pelagic ecosystems[67]. Released by phytoplankton, especially when grazed by zooplankton, DMS helps to trigger foraging activity in a range of marine organisms including procellariiform seabirds (e.g. albatrosses, petrels and shearwaters) which are highly olfactory[68]. Studies using polypropylene and polyethylene beads showed that both types of plastic could acquire an active DMS signature after less than a month of exposure in the ocean and at concentrations that procellariform seabirds can detect[69]. Moreover, a positive relationship was found between DMS responsiveness and plastic ingestion using data from over 13,000 seabirds. These results suggest that plastic debris creates an olfactory trap for susceptible marine wildlife[70] and provide compelling evidence to explain the high rates of ingestion of plastic debris by seabirds[71]. Further research in the field is now required to determine whether other marine fauna such as marine turtles, penguins, some marine fish and marine mammals, that all use DMS (or DMSP) in foraging contexts, are susceptible to olfactory driven plastic ingestion[72].

Synthetic fibres generated by domestic washing are a significant component of marine debris and regarded as one of the top ten priorities as a microplastic source[73]. A review of synthetic fibres in the marine environment recently found that there have relatively few studies on domestic washing and a number of knowledge gaps exist for textiles, washing parameters and the ability of waste water

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[68] Nevitt, G.A. 2008. Sensory ecology on the high seas: The odor world of the procellariiform seabirds. J. Exp. Biol. 211: 1706-1713.

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[73] Verschoor, A. et al. 2014. Quick scan and prioritization of microplastics sources and emissions. RIVM Advisory Letter 250012001. National Institute for Public Health and Environment, Bilthoven (NL), p. 41.

treatment plants (WWTPs) to remove textile fibres[74]. The textile industry is recognised as a significant polluter through the use of an extensive range of chemicals[75] including pesticides, monomers, additives, solvents and dyestuffs[76]. One example is the use of nonylphenol ethoxylates (NPEs) as surfactants and detergents, which form nonylphenol in contact with water, a persistant bioaccumulative and toxic substance (PBT). Washing of clothes containing NPEs results in a release of the chemical into the wastewater[77], which may be taken up by fibres or other microplastics. A single wash of 5 kg of polyester fabrics can release more than 6,000,000 fibres depending on the detergent used[78] and a significant proportion of these would not be retained by WWTPs, ending up in the marine environment. Although WWTPs can remove between 83 and 95% of all microplastic particles, estimates for microplastic release from a single WWTP are 9000 per cubic metre in Germany[79] and up to 65 million per day in the UK[80].

Empirical studies in laboratory conditions have demonstrated that trophic transfer occurs for low trophic organisms such as crabs[81]. Indirect evidence of the transfer of microplastics from lower to higher trophic-level organisms was reported in the previous CBD Technical Series report for some fish and pinnepeds[82]. Further evidence of transfer between a fish prey and a marine predator (grey seal: *Halichoerus grypus*) was recently shown for seals in captivity that were fed wild caught fish. Although not an *in natura* study, the use of captive seals did significantly reduce the likelihood of contamination and direct consumption of microplastics which is an issue for field-based research[83]. The study found that almost half the seal scat samples and one-third of the fish samples contained between 1 and 4 microplastics. It was suggested that trophic transfer represents a potentially major pathway of microplastic ingestion for any species whose feeding ecology involves the consumption of whole prey, including humans[84].

Evidence to show that the accumulation of microplastics causes ecological harm is still lacking on the whole, although the case is building for impacts of marine debris more generally[85]. However, ingestion of microplastics by oysters during gametogenesis has been shown to have impacts on their feeding and reproduction, with negative impacts on adult fecundity and offspring quality[86]. These findings are important as they support an emerging paradigm that microplastics can reduce reproductive output and fitness in marine species by altering their food consumption and energy allocation[87]. Microplastic

[74] Cesa, F.L., Turra, A. and Baruque-Ramos, J. 2017. Synthetic fibres as microplastics in the marine environment: A review from textile perspective with a focus on domestic washings. Sci. Tot. Env. 598: 1116-1129.
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[79] Eckert, E.M. et al. 2018. Microplastics increase impact of treated wastewater on freshwater microbial community. Env. Poll. 234: 495-502.
[80] Murphy, F. et al. 2016. Wastewater treatment works (WwTW) as a source of microplastics in the aquatic environment. Environ. Sci. Technol. 50: 5800-5808.
[81] Nelms S.E. et al 2018. Investigating microplastic trophic transfer in marine top predators. Environmental Pollution (in press). (references therein)
[82] 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, Montreal, 78 pages. (page 22).
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[85] Rochman, C.M. et al. 2016. The ecological impacts of marine debris: unravelling the demonstrated evidence from what is perceived. Ecology 97: 302-316.
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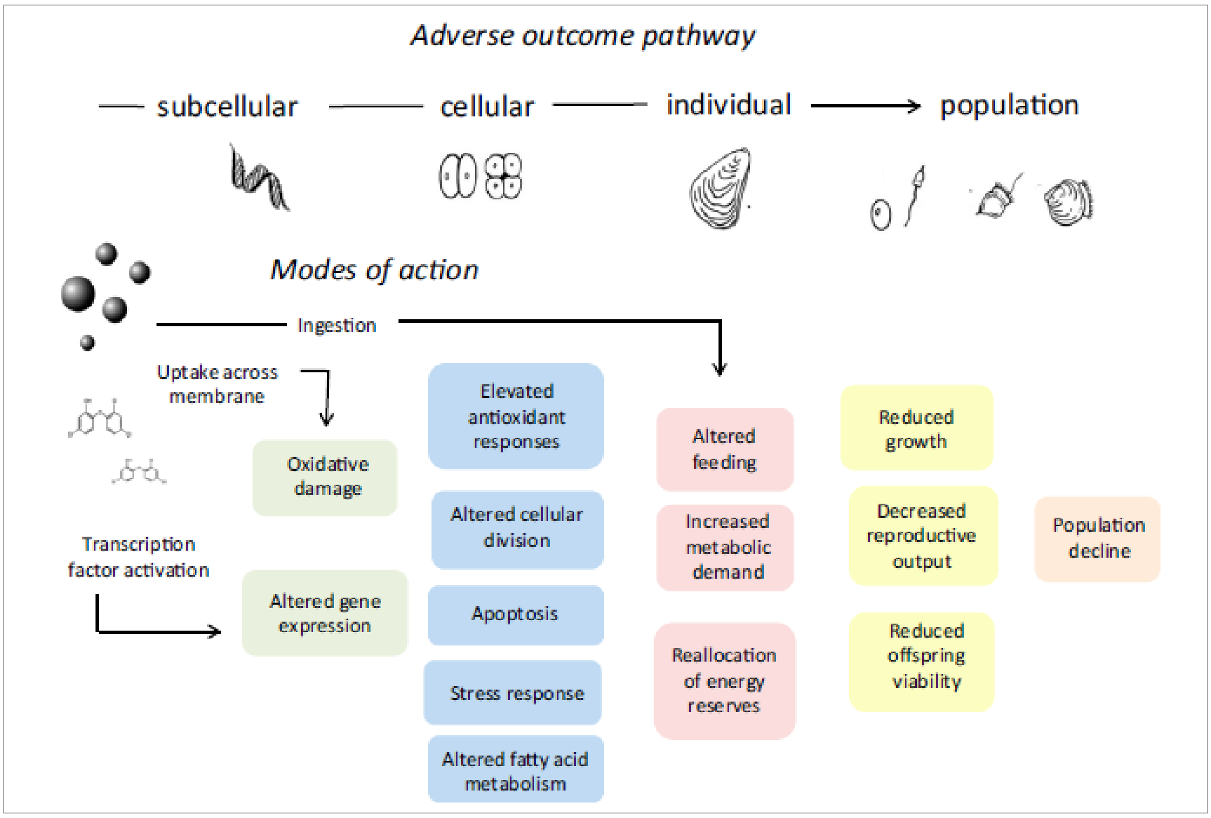
[87] Galloway, T.S. and Lewis, C.N. 2016. Marine microplastics spell big problems for future generations. PNAS 113: 2331-2333.

particles were shown to have both chemical and physical effects on larval fish performance and development. Newly hatched larvae of European perch (*Perca fluviatilis*) from the Baltic Sea preferentially fed on microplastics compared to a more natural food source of free-swimming zooplankton when exposed to environmentally relevant concentrations of microplastic particles[88]. Exposure to the particles decreased growth rates and altered feeding preferences and innate behaviour of the fish larvae. In addition, exposed larvae did not respond to olfactory threat cues, which greatly increases the chance of predator-induced mortality. These findings support the suggestion that the marked population decline of perch in the Baltic was related to feeding by early-stage fish larvae and limited availability of zooplankton[89]. Perch larvae exposure to microplastics in the Baltic is a potential driver for the observed decreased recruitment rate and increased mortality of early-life stages of this species and highlights an ecologically important and underappreciated effect of microplastics on marine and coastal ecosystems[90].

The results reported for oysters and other findings have been used to produce a tentative Adverse Outcome Pathway (AOP) scheme for microplastic uptake in aquatic organisms (Figure 1). AOPs are very useful in deducing the key events linking an end point, such as reduced reproductive output, with a perturbation, such as particle ingestion, because they describe generalized motifs of biological response[91]. The association of chemical contaminants with microplastics may further complicate the situation although the extent to which these contaminants are transferred from an ingested particle into the organism's tissue is not yet known (see section 2.3).



[88] Lönnstedt, O.M. and Eklöv, P 2016. Environmentally relevant concentrations of microplastic particles influence larval fish ecology, ecotoxicology. Science 352, 6290.
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[91] Galloway, T.S. and Lewis, C.N. 2016. Marine microplastics spell big problems for future generations. PNAS 113: 2331-2333

Figure 1. Tentative AOP scheme for microplastics exposure of aquatic species showing potential pathways linking ingestion, uptake across membranes, and chemical release with adverse outcomes of growth inhibition and reproductive decline (Source: Galloway and Lewis, 2016).

2.3. Nanoplastics

Nanoplastics have been defined as plastic particles smaller than 100 nm in at least one of their dimensions[92], smaller than 20 µm[93] (as per nanoplankton) and, most recently, as "particles unintentionally produced and presenting a colloidal behaviour within a size range of 1 to 1000 nm"[94]. Nanoplastics are considered as one of the least known components of marine debris but potentially the most hazardous[95]. Detection methods for nanoplastics are still at an early stage of development[96] and they have only recently been identified in the marine environment[97]. Nanoplastics are formed by the break-down of aged microplastics, during the manufacturing process or during the use of a plastic object[98]. In aquatic environments it is very likely that nanoplastic particles form hetero-aggregates with other natural and/or anthropogenic materials. The colloidal characteristics of particles between 1 and 1000 nm[99] are important as nanoplastic particles within this size range may be in solution in either isolated or aggregated forms depending on their environment (pH, ionic strength, temperature, dissolved organic matter etc.)[100]. Preliminary laboratory-based research has shown that polystyrene nanoplastics can occur in both forms, with the degree of aggregation dependent on ionic strength and the level of electrostatic interaction between particles[101]. Therefore, nanoplastics in aquatic environments may directly associate with dissolved organic and inorganic colloids to form both stable and unstable aggregates under given physical and chemical conditions. In short, it is likely that nanoplastics, like microplastics, will already be ubiquitous in marine environments and readily taken up by organisms at lower trophic levels (suspension and filter feeders). Due to their size and high diffusion properties it is not possible to develop feasible removal strategies for nanoplastics.

Many research questions around nanoplastics are still to be answered including whether they are associated with pollutants such as additives or heavy metals. Analytical methods need to be developed to characterise the physical and chemical properties of nanoplastics, as well as their sources and main pathways in the marine environment. Modelling of the fate of nanoplastics could be developed from adapting elaborate models that exist for nanomaterials in freshwater[102]. Important processes to consider for nanoplastics will be homo- and hetero-aggregation, advective flow, sedimentation, re-suspension, photo- and biodegradation, and sediment burial[103].

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[92] Koelmans, A.A., Besseling, E. and Shim, W.J. 2015. Nanoplastics in the aquatic environment. Critical review. In: M. Bergmann et al. (eds.), Marine Anthropogenic Litter, Chapter 12 p. 325-341.
[93] Wagner, M., et al. 2014. Microplastics in freshwater ecosystems: What we know and what we need to know. Environmental Sciences Europe, 26, 12
[94] Gigault, J. et al. 2018. Current opinion: What is a nanoplastic? Env. Poll. 235: 1030-1034.
[95] Koelmans, A.A., Besseling, E. and Shim, W.J. 2015. Nanoplastics in the aquatic environment. Critical review. In: M. Bergmann et al. (eds.), Marine Anthropogenic Litter, Chapter 12 p. 325-341.
[96] Ibid
[97] Ter Halle, A. et al. 2017. Nanoplastic in the North Atlantic Subtropical Gyre. Env. Sci. & Technol. 2017 51: 13689-13697
[98] Bouwmeester, H. et al. 2015. Potential health impact of environmentally released micro- and nanoplastics in the human production chain: experiences from nanotoxicology. Env. Sci. Technol. 49:8932-8947.
[99] Any particle between 1 and 1000 nm is considered as a colloid as defined by the International Union of Pure and Applied Chemistry (IUPAC): https://doi.org/10.1351/goldbook.C01172
[100] Gigault, J. et al. 2018. Current opinion: What is a nanoplastic? Env. Poll. 235: 1030-1034.
[101] Ibid
[102] Koelmans, A.A., Besseling, E. and Shim, W.J. 2015. Nanoplastics in the aquatic environment. Critical review. In: M. Bergmann et al. (eds.), Marine Anthropogenic Litter, Chapter 12 p. 325-341.
[103] Ibid (and references therein).

The effects of nanoplastics on marine organisms have recently been reviewed in some detail by GESAMP[104][105] and were also reported in Technical Series 83[106]. A few studies have been conducted in the laboratory for fish and invertebrate species exposed to high concentrations and there is also a body of research assessing the effects of nanoplastics on animals and humans from the fields of nanotechnology and medical sciences (summarised in the 2015 GESAMP report). However, many studies involving engineered nanoplastic particles (ENPs) may not be directly applicable to nanoplastics in the marine environment due to their uniformity[107] and the tendency for homo- or hetero-aggregation of particles in aquatic environments. Recent studies have demonstrated the potential of nanoplastics to affect plankton and the early life stages of some marine species, to decrease biological fitness through immunosuppression and to reduce reproductive and predator avoidance behaviours, which could have consequences at the population level or for food webs (summarised in the 2016 GESAMP report).

2.4. Potential impacts of persistent, bio-accumulative and toxic substances (PBTs) associated with marine debris

Potential impacts of PBTs associated with marine debris were covered in some detail by the previous Technical Series report (TS 83)[108] for PBTs adsorbed on to microplastics and the leaching of additives from plastic marine debris. Subsequent reviews have summarised research efforts and findings for interactions between toxic chemicals and microplastics[109] and the effects of plastic additives on marine environments and organisms[110]. An overview of plastic related chemicals for microplastics in the marine environment is also provided by GESAMP[111].

Recent studies have suggested that exposure to hydrophobic organic chemicals (HOCs) adsorbed on to microplastic debris may be negligible compared to natural pathways[112][113][114] given the low abundance

[104] GESAMP 2015. Sources, fate and effects of microplastics in the marine environment: a global assessment. (Kershaw, P. J., ed.).(IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90, 96 p.
[105] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p.
[106] 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, Montreal, 78 pages
[107] Gigault, J. et al. 2018. Current opinion: What is a nanoplastic? Env. Poll. 235: 1030-1034.
[108] 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, Montreal, 78 pages
[109] Wang, F. et al. 2018. Interaction of toxic chemicals with microplastics: A critical review. Water Research 139: 208-219.
[110] Hermabessiere L. et al. 2017. Occurrence and effects of plastic additives on marine environments and organisms: a review. Chemosphere 182: 781-793
[111] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p
[112] Bakir, A. et al. 2016. Relative importance of microplastics as a pathway for the transfer of hydrophobic organic chemicals to marine life. Environ. Pollution 219: 56-65.
[113] Beckingham, B. and Ghosh, U. 2017. Differential bioavailability of polychlorinated biphenyls associated with environmental particles: Microplastic in comparison to wood, coasl and biochar. Environ. Pollution 220, Part A: 150-158.
[114] Paul-Pont, I. et al. 2016. Exposure of marine mussels *Mytilus* spp. To polystyrene microplastics: Toxicity and influence on flouranthene bioaccumulation. Environ. Pollution 216: 724-737.

of plastic particles relative to other suspended particles in the ocean and the baseline contamination levels of seawater and marine organisms[115]. In addition, microplastic ingestion by marine fauna is not thought to increase their exposure to HOCs and could have a cleaning effect. This is based on fugacity gradients, which, according to first principles in environmental chemistry, will drive the direction that the chemical moves, i.e. from plastic to animal or vice versa[116]. Microplastics can introduce these harmful chemicals into organisms only when the fugacity of a chemical in microplastics is greater than that in the organism, which may result in an exposure risk[117].

Compared to adsorbed pollutants and associated HOCs there have been fewer studies on plastic additives, which could represent an increasing ecotoxicological risk for marine organisms[118]. A recent review identified the most commonly found plastic additives found in the marine environment and summarised research that demonstrated the transfer of plastic additives to marine organisms both in laboratory and field-based studies[119]. Exposure experiments based on the leaching processes for additives have confirmed their toxicity for a wide range of polymers and target organisms including coral reef fish, barnacles, copepods and mussels[120]. Studies of plastic additives should be included in future modelling work to better understand their potential for transfer to marine organisms. Particular attention should be paid to hazardous plastic additives known to be major endocrine disruptors such as bisphenol A and phthalates. Other PBTs associated with microplastics include polychlorinated biphenyls, polyaromatic hydrocarbons and polybrominated diphenylethers, all of which possess endocrine disrupting activity[121]. Endocrine disruptors have shown evidence of a nonlinear or nonmonotonic dose response[122], meaning that tiny doses may have larger effects than mid-level doses[123]. Further studies on the potential for hazardous chemicals associated with plastic debris to disrupt the endocrine system of marine organisms are clearly needed.

2.5. Dispersal via rafting and transport of invasive species

Since the publication of the CBD Technical Series 83 report, there have been numerous studies on Japanese Tsunami Marine Debris (JTMD) that originated from the east coast of Japan in 2011, with special issues of journals published on the subject in recent years[124] [125]. Trans-oceanic transport of JTMD across the Pacific to the west coast of the Americas has resulted in extensive research and mitigation programmes to monitor and minimise the effect of the debris and the potentially invasive species carried with it to this coast. For example, researchers from multiple scientific disciplines came together to document and evaluate the potential impacts from JTMD and the associated non-indigenous

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[115] Hermabessiere L. et al. 2017. Occurrence and effects of plastic additives on marine environments and organisms: a review. Chemosphere 182: 781-793
[116] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p
[117] Wang, F. et al. 2018. Interaction of toxic chemicals with microplastics: A critical review. Water Research 139: 208-219.
[118] Hermabessiere L. et al. 2017. Occurrence and effects of plastic additives on marine environments and organisms: a review. Chemosphere 182: 781-793
[119] Ibid
[120] Ibid (and references therein)
[121] Diamanti-Kandarakis E, et al. 2009. Endocrine-disrupting chemicals: An Endocrine Society scientific statement. Endocr. Rev. 30:293–342.
[122] Welshons, W.V. et al. 2003. Large effects from small exposures. I. Mechanisms for endocrine-disrupting chemicals with estrogenic activity. Environ Health Perspect 111:994–1006.
[123] Seltenrich, N. 2015. New link in the food chain? Marine plastic pollution and seafood safety. Environ. Health Perspect. 123: A34-A41.
[124] Clarke Murray, C. et al. 2018. ADRIFT in the North Pacific: The movement, surveillance and impact of Japanese Tsunami Debris. Marine Pollution Bulletin – Special Issue Editorial. Mar. Poll. Bull. 132:1-4.
[125] Carlton, J.T. and Fowler, A.E. 2018. Ocean Rafting and marine debris: A broader vector menu requires a greater appetite for invasion biology research support. Co-editors Preface of the Special Issue: Transoceanic dispersal of marine life from Japan to North America and the Hawaiian Islands as a result of the Japanese Earthquake and Tsunami of 2011. Aquatic Invasions 13: 11-15.

species to coastal ecosystems in North America under the ADRIFT (Assessing Debris Related Impact From Tsunami) project. Research areas included modelling of particle (debris) tracking across the ocean, shoreline debris monitoring programmes, aerial surveys and assessment of the invasion potential of species associated with JTMD[126].

Approximately 370 species of invertebrates, algae and fish were identified from over 630 marine debris items[127] and at least seven new species of marine invertebrates and algae were detected and described from JTMD[128]. Many invertebrate and algal species were able to grow and reproduce despite passing through relatively low-productivity open ocean habitats[129]. A study of the life history and tolerance traits of JTMD species was used to assess the potential invasive impact of the relatively unknown species recorded[130]. More than 30 species associated with JTMD had similar traits to those with known invasion histories and may pose additional risks. In addition, the long lag time between arrival and possible invasion means that sustained monitoring is required for JTMD species along North American coastlines and in the Hawaiian Islands[131].

It is clear from this example that marine debris drifting along coastlines and across oceans with living species aboard adds to the increasing list of human-mediated vectors transporting species across biogeographic barriers[132]. In addition, a combination of a changing climate and increasing vector diversity may set the stage for a new era of invasions in the world's oceans[133], through a combination of increased storm activity and strength washing debris into the sea[134] and the opening up of new regions previously inhospitable to warm-water species[135]. In response to this likely threat there has been a call for a resurgence and reinvestment in 21st century taxonomy given that taxonomic resources are essential ingredients for the detection and management of biological invasions[136]. Without support for fundamental biodiversity assessment resources our ability to document new invasions will continue to decline as will our knowledge of how marine communities respond to invasions and what the consequences will be for the environment and human welfare[137]

[126] Clarke Murray, C. et al. 2018. ADRIFT in the North Pacific: The movement, surveillance and impact of Japanese Tsunami Debris. Marine Pollution Bulletin – Special Issue Editorial. Mar. Poll. Bull. 132:1-4.

[127] Carlton, J.T., Chapman, J.W., Geller, J.B., Miller, J.A., Carlton, D.A., McCuller, M.I., Treneman, N.C., Steves, B.P., Ruiz, G.M., 2017. Tsunami-driven rafting: Transoceanic species dispersal and implications for marine biogeography. Science 357 (6358), 1402–1406.

[128] Carlton, J.T., Chapman, J.W., Geller, J.B., Miller, J.A., Ruiz, G.M., Carlton, D.A., McCuller, M.I., Treneman, N.C., Steves, B.P., Breitenstein, R.A., Lewis, R.., Bilderback, D., Haga, T., Harris, L.H., 2018. Ecological and biological studies of ocean rafting: Japanese tsunami debris arriving in North America and the Hawaiian Islands between 2012 and 2017. Aquat. Invasions 13, 1–9. https://doi.org/10.3391/ai.2018.13.1.01.

[129] Clarke Murray, C. et al. 2018. ADRIFT in the North Pacific: The movement, surveillance and impact of Japanese Tsunami Debris. Marine Pollution Bulletin – Special Issue Editorial. Mar. Poll. Bull. 132:1-4.

[130] Miller, J.A., Gillman, R., Carlton, J.T., Murray, C.C., Nelson, J.C., Otani, M., Ruiz, G.M. 2018. Trait-based characterization of species transported on Japanese tsunami marine debris: Effect of prior invasion history on trait distribution. Mar. Pollut. Bull. 132: 90-101.

[131] Clarke Murray, C. et al. 2018. ADRIFT in the North Pacific: The movement, surveillance and impact of Japanese Tsunami Debris. Marine Pollution Bulletin – Special Issue Editorial. Mar. Poll. Bull. 132:1-4.

[132] Carlton, J.T. and Fowler, A.E. 2018. Ocean Rafting and marine debris: A broader vector menu requires a greater appetite for invasion biology research support. Co-editors Preface of the Special Issue: Transoceanic dispersal of marine life from Japan to North America and the Hawaiian Islands as a result of the Japanese Earthquake and Tsunami of 2011. Aquatic Invasions 13: 11-15.

[133] Ibid

[134] Carlton, J.T., Chapman, J.W., Geller, J.B., Miller, J.A., Carlton, D.A., McCuller, M.I., Treneman, N.C., Steves, B.P., Ruiz, G.M., 2017. Tsunami-driven rafting: Transoceanic species dispersal and implications for marine biogeography. Science 357 (6358), 1402–1406

[135] Canning-Clode J, Carlton JT. 2017. Refining and expanding global climate change scenarios in the sea: poleward creep complexities, range termini, and setbacks and surges. Diversity and Distributions 23: 463–473, https://doi.org/10.1111/ddi.12551

[136] Carlton, J.T. and Fowler, A.E. 2018. Ocean Rafting and marine debris: A broader vector menu requires a greater appetite for invasion biology research support. Co-editors Preface of the Special Issue: Transoceanic dispersal of marine life from Japan to North America and the Hawaiian Islands as a result of the Japanese Earthquake and Tsunami of 2011. Aquatic Invasions 13: 11-15.

[137] Ibid

2.6. Habitat or ecosystem-level impacts

It is well known that anthropogenic debris contaminates marine habitats globally[138]. Although there is considerable evidence of the harmful effects of marine debris on individual organisms and a number of perceived threats to populations, assemblages and species, there is less knowledge about whether these threats result in demonstrated ecologically relevant impacts at such higher levels of biological organisation[139]. A thorough critical and systematic review of the scientific literature was conducted to identify both perceived and demonstrated impacts across several levels of biological organisation that make up the ecosystem[140]. Of the perceived threats that were tested, 83% were demonstrated and most of the demonstrated impacts were due to plastic. However, only 11% of the demonstrated impacts were at higher levels of organisation (organism, population, assemblage), and of these only two studies (8%) were shown for assemblages with none demonstrated for populations. The remainder (92%) were for effects at the organism level. Overall, demonstrated effects at these higher levels of organisation were scarce, although there were over fifty studies that perceived effects at the population or assemblage level. The authors suggested that both the quantity and quality of research studies regarding ecological impacts requires improvement to collect robust quantitative information before clear general ecological conclusions can be reached[141]. However, it was also recognised that there are logistical difficulties in sampling in the marine environment and a lack of knowledge of how damage or death of individuals affects populations. Despite these issues the systematic review found 245 lines of evidence demonstrating valid concerns regarding adverse effects of marine debris and that this persistent and bio-accumulative material causes impacts across 13 levels of organization, including at ecological levels[142]. Overall it was concluded that there appears to be enough evidence for policy makers to recognise the hazards of marine debris and take a precautionary and/or anti-catastrophic approach to address the problem.

A more recent study has applied a three-step pluralistic approach to synthesise available research into a global assessment of the ecological, ecosystem service and social and economic impacts of marine plastic[143]. Marine ecosystem services comprehensively contribute to human well-being, and their reduction will endanger the continued welfare of human societies, especially in coastal communities[144]. Substantial negative impacts on all ecosystem services by marine plastic were suggested at the global level leading to an estimate of a 1-5% reduction in marine ecosystem service delivery in 2011 and an annual loss of $500 - 2500 billion in the value of benefits derived from the marine environment[145]. Moreover, the suggested reduction in ecosystem service provision was linked to fisheries, heritage and charismatic species, and recreation in particular.

Plastic debris as a new habitat: the plastisphere

Further research has been conducted on the 'plastisphere'[146] since the term was reported in the CBD Technical Series 83 publication. Recent studies have investigated the 'plastisphere' in marine

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138 Thompson, R. C., C. J. Moore, F. S. vomSaal and S. H. Swan. 2009. Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B 364:2153–2166.
139 Rochman, C.M., et al. 2016. The ecological impacts of marine debris: unravelling the demonstrated evidence from what is perceived. Ecology 97: 302-312.
140 Ibid
141 Ibid
142 Ibid
143 Beaumont, N.J. et al. 2019. Global ecological, social and economic impacts of marine plastic. Marine Pollution Bulletin 142: 189-195.
144 Naeem, S., Chazdon, R., Duffy, J.E., Prager, C., Worm, B. 2016. Biodiversity and human well-being: an essential link for sustainable development. Proc. R. Soc. B 283, 20162091.
145 Beaumont, N.J. et al. 2019. Global ecological, social and economic impacts of marine plastic. Marine Pollution Bulletin 142: 189-195.
146 The microbial life growing on plastic debris surfaces

environments such as the North Atlantic Gyre[147] and the Mediterranean Sea[148]. There is also a growing literature that describes the first steps of colonization of new plastic until the formation of a new biofilm[149]. The plastisphere studies mentioned above have emphasised the difference between bacteria living on plastics and free-living bacteria[150], or those living on organic particles in the surrounding seawater[151]. Less is known about the plastisphere present in the water column than on the sea surface[152], although surface plastic debris represents less than 1% of the global load of plastic in the ocean[153]. Very little is currently known of the composition of microbial communities on plastic debris sampled from the seabed[154], but they do appear to share some taxa with those found in the core microbiome of the seafloor[155].

Marine microorganisms that make up the plastisphere microbial community are known to play a key role in the biogeochemical cycles of the oceans[156]. For example, half of oceanic primary production, on average, is channelled via heterotrophic bacterioplankton in the microbial loop, which significantly contributes to food web structure and carbon cycling in the ocean[157]. The role that heterotrophic bacteria living on plastic have within the oceanic carbon cycle in not known, although one short-term study (45 days) found that heterotrophic bacteria on plastic were considerably more active than free-living bacteria in terms of cell-specific activity[158]. Further long-term studies on plastics that have been in the sea for several years are required to evaluate whether and how the plastisphere influences the biogeochemical carbon cycle in the ocean[159]. Microorganisms are also involved in all other biogeochemical cycles including those of nitrogen, iron, and phosphorus[160] and may also be affected by plastics in the ocean.

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[147] Debroas, D., Mone, A., and Ter Halle, A. 2017. Plastics in the North Atlantic garbage patch: a boat-microbe for hitchhikers and plastic degraders. Sci. Total Environ. 599: 1222–1232. doi:10.1016/j.scitotenv.2017.05.059

[148] Dussud, C., Hudec, C., George, M., Fabre, P., Higgs, P., Bruzaud, S., et al. 2018. Colonization of Non-biodegradable and Biodegradable plastics by marine microorganisms. Front. Microbiol. 9: 1571. doi:10.3389/fmicb.2018.01571

[149] Jacquin J, Cheng J, Odobel C, Pandin C, Conan P, Pujo-Pay M, Barbe V, Meistertzheim AL and Ghiglione J-F. 2019. Microbial Ecotoxicology of Marine Plastic Debris: A Review on Colonization and Biodegradation by the “Plastisphere”. Front. Microbiol. 10:865. doi: 10.3389/fmicb.2019.00865

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[151] Dussud, C., Hudec, C., George, M., Fabre, P., Higgs, P., Bruzaud, S., et al. 2018. Colonization of Non-biodegradable and Biodegradable plastics by marine microorganisms. Front. Microbiol. 9: 1571. doi:10.3389/fmicb.2018.01571

[152] Jacquin J, Cheng J, Odobel C, Pandin C, Conan P, Pujo-Pay M, Barbe V, Meistertzheim AL and Ghiglione J-F. 2019. Microbial Ecotoxicology of Marine Plastic Debris: A Review on Colonization and Biodegradation by the “Plastisphere”. Front. Microbiol. 10:865. doi: 10.3389/fmicb.2019.00865

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[156] Pomeroy, L. R., LeB Williams, P. J., Azam, F., and Hobbie, J. E. 2007. The microbial loop. Oceanography 20: 28–33.

[157] Jacquin J, Cheng J, Odobel C, Pandin C, Conan P, Pujo-Pay M, Barbe V, Meistertzheim AL and Ghiglione J-F. 2019. Microbial Ecotoxicology of Marine Plastic Debris: A Review on Colonization and Biodegradation by the “Plastisphere”. Front. Microbiol. 10:865. doi: 10.3389/fmicb.2019.00865

[158] Dussud, C., Hudec, C., George, M., Fabre, P., Higgs, P., Bruzaud, S., et al. 2018. Colonization of Non-biodegradable and Biodegradable plastics by marine microorganisms. Front. Microbiol. 9: 1571. doi:10.3389/fmicb.2018.01571

[159] Jacquin J, Cheng J, Odobel C, Pandin C, Conan P, Pujo-Pay M, Barbe V, Meistertzheim AL and Ghiglione J-F. 2019. Microbial Ecotoxicology of Marine Plastic Debris: A Review on Colonization and Biodegradation by the “Plastisphere”. Front. Microbiol. 10:865. doi: 10.3389/fmicb.2019.00865

[160] Hutchins, D.A., and Fu, F. 2017. Microorganisms and ocean global change. Nat. Microbiol. 2: 17058. doi:10.1038/nmicrobiol.2017.58

There are a number of microorganisms, including bacteria and fungi that have the capability to degrade or deteriorate plastics in laboratory conditions (see Table 2 of Jacquin et al. 2019[161] for an updated list and review references therein). However, rates of degradation by microorganisms are extremely low, even in optimal laboratory conditions, and most conventional plastics are resistant to degradation in marine and terrestrial environments[162]. Data on the rate of plastic mineralisation in the oceans are still lacking. A number of putative xenobiotic degradation genes likely involved in plastic degradation were significantly more abundant in plastic-specific bacterial communities[163] and there are indications that complex microbial communities rather than single species are necessary to degrade recalcitrant plastic[164]. At present there is insufficient knowledge of the plastisphere and the role played by its bacterial communities in plastic biodegradation. Comprehensive multi-disciplinary studies of the biodegradation of polymers at sea that combine several monitoring parameters and include in situ experiments involving physics, chemistry and biology are needed to better understand this process[165] and whether it can address the issue of plastic accumulation in the oceans.

2.7. Socio-economic impacts of marine debris

The CBD Technical Series 83 outlined a number of examples to highlight the costs of preventing or cleaning up marine macro-debris as well as some estimates of losses to fisheries and tourism[166]. The range of known and potential impacts from marine (plastic) debris are summarised by Figure 2. It has been proposed that the calculation of the economic costs per tonne of marine plastic is a fundamental metric for global negotiations to change the way that plastics are designed, produced, used, reused and reprocessed[167]. Furthermore, this could be developed into a calculation of the social cost of marine plastic along the lines of the concept of a 'Social Cost of Carbon (SCC)' with regards to CO_2 and climate change action[168].

[161] Jacquin J, Cheng J, Odobel C, Pandin C, Conan P, Pujo-Pay M, Barbe V, Meistertzheim AL and Ghiglione J-F. 2019. Microbial Ecotoxicology of Marine Plastic Debris: A Review on Colonization and Biodegradation by the "Plastisphere". Front. Microbiol. 10:865. doi: 10.3389/fmicb.2019.00865

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[165] Jacquin J, Cheng J, Odobel C, Pandin C, Conan P, Pujo-Pay M, Barbe V, Meistertzheim AL and Ghiglione J-F. 2019. Microbial Ecotoxicology of Marine Plastic Debris: A Review on Colonization and Biodegradation by the "Plastisphere". Front. Microbiol. 10:865. doi: 10.3389/fmicb.2019.00865

[166] 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, Montreal, 78 pages

[167] Beaumont, N.J. et al. 2019. Global ecological, social and economic impacts of marine plastic. Marine Pollution Bulletin 142: 189-195

[168] Van den Bergh, J., Botzen, W., 2015. Monetary valuation of the social cost of CO_2 emissions: a critical survey. Ecol. Econ. 114, 33–46.

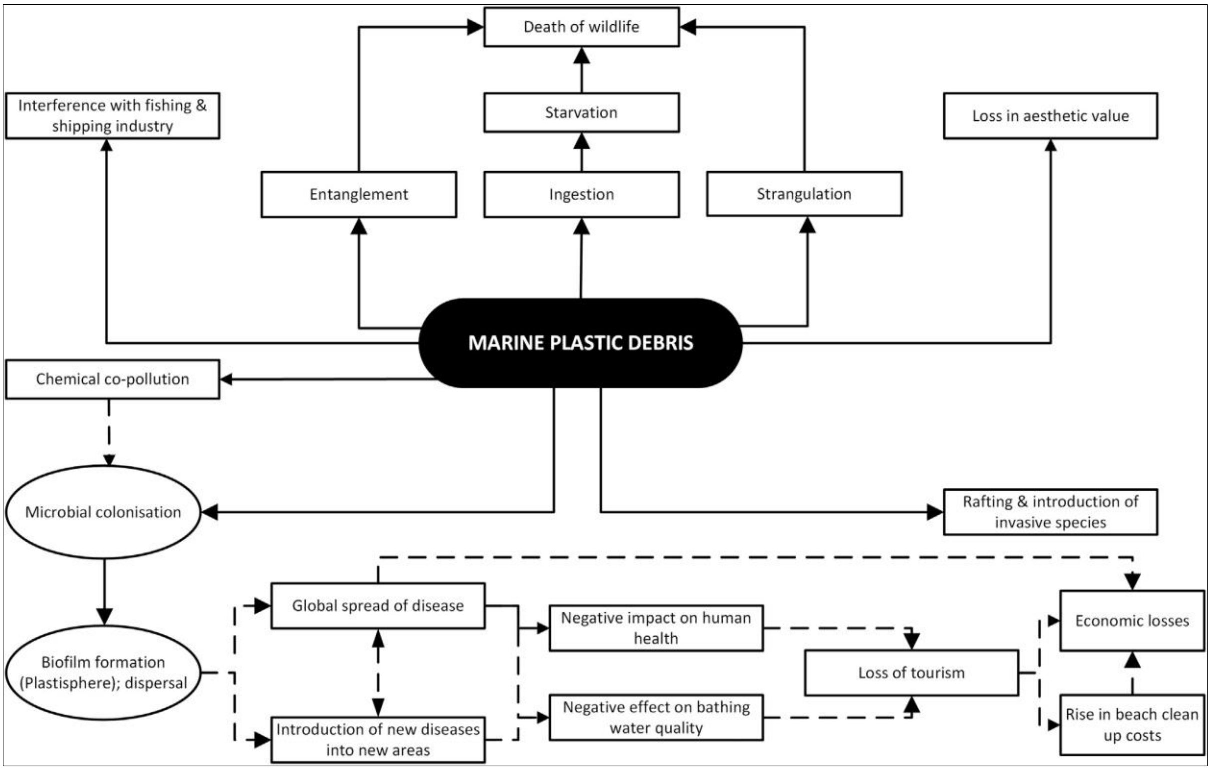

Figure 2. Impacts and interactions of marine plastic debris. Solid black arrows indicate known effects; dotted black arrows indicate the yet unexplored effects/interactions as mediated by marine plastic debris (Source: Keswani et al. 2016)

Microplastic debris and Human Health

The rest of this section focuses on some of the potential issues regarding microplastic debris and human health. The impacts of micro- and nanoplastic particles on human health are not well documented[169] and our knowledge about the fate and toxicity of plastic particles for humans is largely unknown[170][171]. The possible impacts of microplastics on human health will mainly rely on dietary exposure via contaminated marine foodstuffs[172], although exposure to urban dust containing microplastics and airborne microfibres are also potential sources including through ingestion[173][174]. Moreover, a recent study indicates that the potential of microplastic ingestion from shellfish (mussels) was minimal when compared to exposure to microplastics via household dust fallout[175]. There are three possible effects of plastic particles on human health: 1) particle toxicity caused by the very small (nano-size and lower

[169] Eerkes-Medrano, D., et al. 2015. Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Research 75: 63-82.
[170] Bouwmeester, H., Hollman. P.C. and Peters, R.J. 2015. Potential health impact of environmentally released micro and nanoplastics in the human food production chain: Experiences from nanotoxicology. Env. Sci. & Technol. 49: 8932-8947
[171] GESAMP .2015. Sources, fate and effects of microplastics in the marine environment: a global assessment. (Kershaw, P. J., ed.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90, 96 p.
[172] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p
[173] Dehghani, S. et al. 2017. Microplastic pollution in deposited urban dust, Tehran metropolis, Iran. Environ. Sci. Pollut. Res. 1-12.
[174] Dris, R. et al. 2017. A first overview of textile fibers, including microplastics, in indoor and outdoor environments. Environ. Poll. 221: 453-458.
[175] Catarino, A.I. et al. 2018. Low levels of microplastics (MP) in wild mussels indicate that MP ingestion by humans is minimal compared to exposure via household fibres fallout during a meal. Environ. Poll. 237: 675-684.

micro-size range) plastic particles themselves due to interaction with external tissues and cells or after translocation into tissues and cells; 2) chemical toxicity due to the leaching of additives added to the microplastics during manufacturing or the release of pollutants that have accumulated onto the plastics in nature and 3) disease risks due to microbial contamination of microplastics[176]. However, it should also be kept in mind that human exposure to microplastics and plastic additives is more likely to occur from intact goods prior to disposal than from seafood[177].

Micro- and nano-sized particles have been shown to cross cell membranes in controlled laboratory experiments. Experimental evidence with rodents shows that microplastics >1 µm may reach the blood circulation via lymph, but cannot penetrate deeply into organs[178]. They may cause local effects on the gut epithelium, the immune system, inflammation, encapsulation (fibrosis) and cell damage[179][180]. Nanoplastics may reach and penetrate all organs, including the placenta and brain[181].

The second possible human health issue is concerned with the range of chemicals (additives and monomers) inherent in microplastics or chemicals sorbed and transported by microplastics. The toxicity of some of their components to humans, especially plasticizers and additives[182] and the possible leaching of poisonous chemicals, may be considered as a potential human health hazard[183]. Evidence, predominantly based on larger sized microplastics, suggests that, when ingested, the persistent organic pollutants (POPs) adhered to the microplastic and leachable additives in the plastic item will have a minor impact on contaminant exposure to fish[184]. The effect of nanoplastic exposure to humans and their potential chemical risk, especially after translocation into tissues and cells, currently remains unknown. Similarly, nano-sized plastic exposure levels and associated effects in the marine environment are not yet known, while laboratory-based results for marine biota are based on short-term studies with high exposure concentrations[185].

The potential for complex interactions between plastic waste and microorganisms of human health significance are poorly understood but a number of recent studies indicate the ability of potential pathogens to attach to plastic debris and possibly be transported to new environments[186]. For freshwater environments, microbes associated with plastic were identified in the Chicago River and included taxa of potential pathogens, some of which were released from a sewage treatment plant and were known to cause human gastrointestinal infections[187]. More recently, microplastic particles were shown to promote the persistence of typical indicators of microbial anthropogenic pollution, namely the occurrence of

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[176] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p
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[179] Ibid
[180] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p (Sections 4.5.3 and 5.4.3).
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[183] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p
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[185] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p
[186] Keswani, A. et al. 2016. Microbial hitchhikers on marine plastic debris: Human exposure risks at bathing waters and beach environments. Marine Environ. Research 118: 10-19.
[187] McCormick, A. et al. 2014. Microplastic is an abundant and distinct microbial habitat in an urban river. Environ. Sci. Technol. 48: 11863-11871.

integrase 1 (*int* 1), a proxy marker for antibiotic resistance genes (ARGs)[188]. In this study microplastics favoured the survival of bacteria derived from waste water treatment plants including genes associated with ARGs. However, the transport of microplastics from freshwater to marine systems will likely result in the die-off of some microbes associated with freshwater, hence the potential for wider dispersal of possibly harmful microorganisms remains unclear[189].

Plastic marine debris can act as a distinct habitat and source of potential pathogens. The potentially pathogenic bacteria *Vibrio parahaemolyticus* has been identified on microplastic particles of polyethylene, polypropylene and polystyrene from both the North and Baltic Seas[190]. Plastic debris from the Belgian coast was also found to contain *Vibrio* and potential human pathogens, some distinct from surrounding water and sediment[191]. The bacterial fish pathogen *Aeromonas salmonicida* was identified on the surface of microplastics collected from the northern Adriatic Sea[192]. This pathogen is one of the most harmful invasive bacteria on the alien invasive species inventory for Europe (DAISIE) and is responsible for fish infection by furunculosis. Drifting plastic debris can also be colonised by harmful algal bloom (HAB) species such as *Ostreopsis* sp. and *Coolia* sp. as well as cysts and vegetative cells of other potentially toxic dinoflagellates[193].

Studies of coastal sediments have also identified potential pathogens associated with plastic debris. Bacteria within coastal sediments were found to rapidly colonise low density polyethylene (LDPE) microplastics[194]. The colonies were dominated by *Arcobacter* and *Colwellia* spp. with the former genus known to contain some pathogenic species and both genera affiliated with hydrocarbon degradation. Microbial communities also colonised microplastic particles in intertidal environments of the Yangtze estuary and included the potential pathogens *Vibrio*, *Pseudomonas* and *Leptolyngbyas*[195]. These genera were recorded at low levels and were regarded as microbial hitchhikers that colonised marine plastic debris opportunistically.

The confirmed presence of bacterial pathogens on microplastics in the marine and coastal environment further highlights the need for targeted research programmes to better understand the interactions between plastic debris and microorganisms and the potential for pathogens to become incorporated into the food chain as this could have consequences for human health, aquaculture, fisheries and other marine fauna. The recorded concentrations of potential pathogens on marine plastics are very low and may not be relevant in terms of risk, but the behaviour of microbes such as vibrios, which can exhibit very fast growth rates, can change when exposed to the gut of a potential host[196]. However, evidence is

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[188] Eckert, E.M. et al., 2018. Microplastics increase impact of treated wastewater on freshwater microbial community. Environmental Pollution 234: 495-502.

[189] Keswani, A. et al. 2016. Microbial hitchhikers on marine plastic debris: Human exposure risks at bathing waters and beach environments. Marine Environ. Research 118: 10-19

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[191] De Tender, C.A. et al. 2015. Bacterial community profiling of plastic litter in the Belgian part of the North Sea. Environ. Sci. Technol. 49: 9629-9638.

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[196] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p

still lacking to determine whether plastic debris could lead to the spread and prolonged persistence of pathogenic species in the oceans[197].

2.8. Emerging issues

Recent research has found that the most commonly used plastics produce two greenhouse gases, methane and ethylene when exposed to ambient solar radiation[198], with polyethylene, the most produced and discarded plastic globally, being the most prolific emitter of both gases. Environmentally aged plastics incubated in water for at least 152 hours also produced hydrocarbon gases. As plastics degrade and their surfaces become more uneven the surface area available for photo-chemical degradation increases which may contribute to a higher rate of gas production. Breakdown into microplastics may further accelerate this production. As plastic particles degrade and become smaller they will emit more hydrocarbon gases per unit mass. Plastics therefore represent a previously unrecognised source of climate-relevant trace gases which are expected to increase as more plastic is produced and accumulated in the environment[199].

[197] Jacquin J, Cheng J, Odobel C, Pandin C, Conan P, Pujo-Pay M, Barbe V, Meistertzheim AL and Ghiglione J-F. 2019. Microbial Ecotoxicology of Marine Plastic Debris: A Review on Colonization and Biodegradation by the “Plastisphere”. Front. Microbiol. 10:865. doi: 10.3389/fmicb.2019.00865
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[199] Ibid

3. MONITORING AND MODELLING OF MARINE DEBRIS

This section provides a brief update on the monitoring and modelling of marine debris with an emphasis on microplastics and should be considered in combination with the previous CBD Technical Series publications on marine debris[200 201].

3.1. Marine debris monitoring

Monitoring of marine debris is necessary to understand the scale of the problem and inform the development of effective management strategies[202]. Such monitoring programmes should follow trends in marine debris pollution levels as well as identify pathways and sources[203]. Most marine debris monitoring around the world is carried out along the shoreline, although it also occurs to a lesser extent at sea or by sampling marine fauna that have encountered debris. Coastal monitoring of mainly macro-debris through well-designed beach programmes is implemented by governments in a number of countries as part of local, national or regional initiatives. However, these endeavours require considerable time and resources to collect meaningful and robust data and are difficult to sustain over the long-term[204 205]. Existing successful long-term monitoring programmes in Europe[206] and North America[207] or globally[208] are important as they are able to detect long term trends and patterns of coastal debris, but also evaluate the efficacy of legislation, to identify changes in sources, deposition, material types and potential impacts to wildlife[209]. Voluntary or citizen science-based programmes for the coastal monitoring of marine debris can generate large, long-term datasets which may otherwise not be feasible due to logistical or financial constraints[210 211]. In addition, some national governments have incorporated a citizen science-based approach into large-scale marine debris monitoring programmes[212]. Comparison of coastal data collected by this programme in Australia showed that volunteer citizen scientists (school children and teachers in this case) collected data of a comparable quality to researchers with supervision and training[213]. With appropriate protocols, methodology and guidance citizen science volunteers can make a significant contribution to marine debris data collection and enhance national research

[200] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel – GEF. 2012. Impacts of Marine Debris on Biodiversity: Current status and Potential Solutions, Montreal, Technical Series No.67, 61 pp.

[201] 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, Montreal, 78 pages.

[202] Nelms, S.E., et al. 2016. Marine anthropogenic litter on British beaches: A 10-year nationwide assessment using citizen science data, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.11.137

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[205] Hardesty, B. et al. 2017. Using numerical modelling simulations to improve the understanding of micro-plastic distribution and pathways in the marine environment. Front. Mar. Sci. 4:30. doi: 10.3389/fmars.2017.00030.

[206] OSPAR's marine beach litter programme in Europe: http://www.ospar.org

[207] NOAA's marine debris program: http://www.marinedebris.noaa.gov

[208] The International Coastal Cleanup (ICC), organized by the Ocean Conservancy: http://www.oceanconservancy.org

[209] Hardesty, B. et al. 2017. Using numerical modelling simulations to improve the understanding of micro-plastic distribution and pathways in the marine environment. Front. Mar. Sci. 4:30. doi: 10.3389/fmars.2017.00030

[210] Duckett, P.E., Repaci, V. 2015. Marine plastic pollution: using community science to address a global problem. Mar. Freshw. Res. 66: 665–673.

[211] Hidalgo-Ruz, V., Thiel, M. 2015. The Contribution of Citizen Scientists to the Monitoring of Marine Litter. In: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter. SpringerLink, Springer Cham Heidelberg New York Dordrecht London: pp. 429–447.

[212] CSIRO's National Marine Debris program in Australia: http://www.csiro.au/en/Research/OandA/Areas/Marine-resources-and-industries/Marine-debris.

[213] van der Velde, T., et al. 2016. Comparison of marine debris data collected by researchers and citizen scientist: is citizen science data worth the effort? Biol. Conserv. http://dx.doi.org/10.1016/j.biocon.2016.05.025

programmes[214]. Similarly, an assessment of the national ‘beach clean’ in the United Kingdom over a 10 year period showed that citizen science programmes that adopt a defined sampling approach and record effort can be effective for the monitoring of marine anthropogenic litter[215]. As well as generating insightful data, volunteer-based beach cleans and litter surveys facilitate the removal of large quantities of litter from marine and coastal environments, reduce the cost of sampling, and enhance public awareness of environmental issues[216]. Such programmes therefore have important educational value for the general public which may lead to positive changes in behaviours and attitudes[217].

Monitoring of macro-litter in rivers can also contribute to the understanding of marine debris sources given that land-based sources are considered the dominant input of plastics into the oceans. Recent annual estimates for global land-based inputs range from 4.8 to 12.7 million tonnes from coastal areas[218] and 1.15 to 2.41 million tonnes from riverine systems[219]. Developing harmonised riverine monitoring systems for surface macro-debris[220] can therefore provide vital information on the characteristics of debris entering the marine environment from catchments.

Monitoring of microplastics has developed substantially since the publication of the previous CBD report on marine debris in 2016. Microplastic monitoring is reviewed in some detail by the two comprehensive reports produced by working group 40 (WG40) of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) in 2015 and 2016. The first GESAMP report discusses the diversity of methods used to extract, quantify and characterize microplastics from environmental matrices[221]. The second report further discusses the many methods in use to monitor microplastics in the marine environment, including within marine organisms, to facilitate their harmonisation and standardisation[222]. Harmonisation and standardisation of methods for marine debris monitoring is a key theme being investigated across the issue and links into the development and adoption of standard techniques for reporting of national efforts to meet SDG target 14.1[223].

GESAMP has published guidelines covering terminology and methodologies for the sampling and analysis of marine macro-plastics and microplastics, more specifically:

- the size and shape definitions of particles;
- sampling protocols for the whole spectrum of particle/object sizes in surface and sub-surface seawater, seabed sediments, shorelines and biota; and,
- methodologies for physical and chemical identification and analysis of polymers and associated chemicals requirements for monitoring and assessment[224].

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[214] Ibid

[215] Nelms, S.E., et al. 2016. Marine anthropogenic litter on British beaches: A 10-year nationwide assessment using citizen science data, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.11.137

[216] Ibid

[217] Wyles, K.J., Pahl, S., Holland, M., Thompson, R.C., 2017. Can beach cleans do more than clean-up litter? Comparing beach cleans to other coastal activities. Environ. Behav. 49: 509-535.

[218] Jambeck, J. R. et al. 2015. Plastic waste inputs from land into the ocean. Science 347, 768–771.

[219] Lebreton, L. C. M. et al. 2017. River plastic emissions to the world’s oceans. Nat. Commun. 8, 15611 doi: 10.1038/ncomms15611.

[220] González-Fernández, D and Hanke, G. 2017. Toward a Harmonized Approach for Monitoring of Riverine Floating Macro Litter Inputs to the Marine Environment. Front. Mar. Sci. 4:86. doi: 10.3389/fmars.2017.00086.

[221] GESAMP .2015. Sources, fate and effects of microplastics in the marine environment: a global assessment. (Kershaw, P. J., ed.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90, 96 p

[222] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p

[223] ‘By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution’

[224] GESAMP. 2019. Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean (Kershaw P.J., Turra A. & Galgani F. editors), (IMO/FAO/UNESCO-

Weathering of microplastic particles by mechanical, biological, physical or chemical processes should also be considered as this can alter the characteristics of microplastics available to marine organisms and their likely ecotoxicological effects[225].

Sampling of microplastics in the marine environment requires different approaches for different matrices (sea surface, water column, sediment, organisms) and defining a consistent sampling strategy for these matrices is important to produce robust and comparable datasets[226]. In addition, a high degree of quality assurance is a fundamental requirement to ensure global comparability of results[227]. Well-established quality assurance schemes for microplastic investigations that include all steps of sampling, processing and analysis are not yet in place[228], although efforts to ensure different quality criteria have been proposed but are not fully developed or broadly applied[229]. Monitoring of the water column, sediment and biota have been used to determine spatial and temporal trends of microplastic abundance. However, microplastic abundance in water and sediment can be affected by a variety of environmental factors including biofilms, bioturbation, tides, winds, currents and wave fronts, all of which are stochastic in nature and can complicate the interpretation of impacts on biota[230]. Moreover, sediments are more complicated to analyse than water or most biota, as sampling processing requires multiple steps to degrade organic materials and separate microplastics from natural particles[231].

The monitoring of microplastics ingested by marine organisms is a key research area to quantify and evaluate the effect of this type of marine debris on individuals, populations and ecosystems. The ingestion of microplastics affects a wider range of species than the ingestion of meso- or macroplastics[232] and is considered the most frequent interaction between plastic litter and marine organisms[233]. There is a need for rapid, accurate assessment of the levels of microplastic in marine populations in order to determine baseline levels of contamination and assess the risk of microplastics to organisms and ecosystems[234].

Mussels have been proposed as a global bioindicator species for monitoring microplastics in the marine environment[235]. Mussels have been used extensively as biological indicators in the monitoring of anthropogenic pollution trends in coastal waters[236] and meet almost all of the criteria required for a

IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 99, 130 pp. http://www.gesamp.org/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in-the-ocean

[225] Potthoff, A. et al. 2017. From the sea to the laboratory: Characterization of microplastic as prerequisite for the assessment of ecotoxicological effects. Integrated Environmental Assessment and Management. 13: 500-504.

[226] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p

[227] Wesch, C. et al. 2018. Assuring quality in microplastic monitoring: About the value of clean-air devices as essentials for verified data. Scientific Reports 7: 5424. DOI:10.1038/s41598-017-05838-4.

[228] Ibid

[229] MSFD Technical Subgroup of Marine Litter. 2013. Guidance on Monitoring of Marine Litter in European Seas. JRC - Joint Research Centre. EUR 26113 EN.

[230] Li, J. et al. 2019. Using mussel as a global bioindicator of coastal microplastic pollution. Environ. Poll. 244: 522-533 (and references therein).

[231] Li, J. et al. 2019. Using mussel as a global bioindicator of coastal microplastic pollution. Environ. Poll. 244: 522-533

[232] Wesch, C. et al. 2016. Towards the suitable monitoring of ingestion of microplastics by marine biota: A review. Environmental Pollution 218: 1200-1208.

[233] Lusher, A.L. 2015. Microplastics in the marine environment: distribution, interactions and effects. In: Marine Anthropogenic Litter, pp. 245-307 (Chapter 10).

[234] Lusher, A.L. et al. 2017. Sampling, isolating and identifying microplastics ingested by fish and invertebrates. Analytical Methods 9: 1346.

[235] Li, J. et al. 2019. Using mussel as a global bioindicator of coastal microplastic pollution. Environ. Poll. 244: 522-533.

[236] Beyer, J. et al. 2017. Blue mussels (*Mytilus edulis* spp.) as sentinel organisms in coastal pollution monitoring: a review. Mar. Environ. Res. 130:338-365.

robust bioindicator organism for environmental monitoring[237]. Being sessile, they also enable the collection of quantitative data and the development of robust correlations between well-defined geographical locations, magnitude intensity and exposure time to plastic pollution[238]. The taxa are already used in many regional environmental monitoring programmes including the U.S. Mussel Watch Project and OSPAR's Coordinated Environmental Monitoring Programme (CEMP)[239]. Using mussels as a microplastic pollution bioindicator has also been recommended by ICES for European waters[240] and by WESTPAC[241] for the Western Pacific region[242]. A threefold monitoring approach has recently been proposed to assess the impact of ingested marine litter including microplastics on marine organisms, which combines an accurate measure of marine litter and microplastic loads, the evaluation of plastic additives and POP levels in tissues and the related toxicological effects[243]. According to this concept, mussels have been suggested as ideal biological models as they have been widely used as bioindicators of POPs in coastal environments[244].

Although mussels meet most of the bioindicator criteria, one limitation is that mussels are restricted to coastal waters in the shallow subtidal or intertidal zones. In order to cover a wide range of scales and habitats a suite of sentinel species has been suggested as bioindicators of both macro- and microlitter for particular marine regions[245]. Table 1 provides a list of potential bioindicator species for the Mediterranean Sea that includes sessile and mobile invertebrates, demersal and pelagic fish, mega-faunal filter feeders and seabirds. Species are selected for a range of scales and for both macro- and micro-litter. For further information please refer to Fossi et al. 2018[246].

Table 1. Bioindicator species for marine litter ingestion selected in relation to habitat and home range. In blue: bioindicator for macrolitter, in red: bioindicator for microlitter.

	SEA SURFACE	COASTAL WATERS	OPEN WATERS	SEAFLOOR	COAST LINE AND BEACH SEDIMENT

[237] Goodsell, P.J. et al. 2009. Evidence necessary for taxa to be reliable indicators of environmental conditions or impacts. Mar. Poll. Bull. 58: 323-331.
[238] Bonanno, G. and Orlando-Bonaca, M. 2018. Perspectives on using marine species as bioindicators of plastic pollution. Mar. Pollut. Bull. 137: 209-221.
[239] Beyer, J. et al. 2017. Blue mussels (*Mytilus edulis* spp.) as sentinel organisms in coastal pollution monitoring: a review. Mar. Environ. Res. 130:338-365
[240] ICES, 2015. OSPAR request on development of a common monitoring protocol for plastic particles in fish stomachs and selected shell fish on the basis of existing fish disease surveys. Parma, Italy.
[241] IOC Sub-Commission for the Western Pacific.
[242] WESTPAC, 2017. Training Workshop on Distribution, Source, Fate and Impacts of Marine Microplastics in Asia and the Pacific. Phuket, Thailand.
[243] Fossi, M.C. et al. 2018. Bioindicators for monitoring marine litter ingestion and its impacts on Mediterranean biodiversity. Environ. Poll. 237: 1023-1040.
[244] Li, J. et al. 2019. Using mussel as a global bioindicator of coastal microplastic pollution. Environ. Poll. 244: 522-533 (and references therein).
[245] Fossi, M.C. et al. 2018. Bioindicators for monitoring marine litter ingestion and its impacts on Mediterranean biodiversity. Environ. Poll. 237: 1023-1040.
[246] Ibid

BASIN SCALE (Mediterranean Sea)	*Colonectris diomeda, Puffinus yelkouan*	*Colonectris diomeda, Puffinus yelkouan*	*Balaenoptera physalus; Cetorhinus maximus; Xiphias gladius; Thunnus thynnus Xiphias gladius; Thunnus thynnus; Caretta caretta; Physeter macrocephalus*		
MEDIUM-SCALE (Mediterranean UN Environment / MAP sub-regions			*Thunnus alalunga: Coryphaena hippurus Caretta caretta; Thunnus alalunga*		
SMALL-SCALE (FAO Geographical sub-areas (GSA))		*Boops boops; Trachinotus ovatus*	*Maurolicus muelleri; Engraulis encrasicolus; Sardina pilchardus;* Myctophids	*Mullus barbatus; Neprops norvegicus; Galeus melastomus; Merluccius merluccius: Solea spp. Galeus melastomus; Scyliorhinus canicula*	
LOCAL SCALE				Holothurians	*Mytilus galloprovincialis; Arenicola marina;* Decapods (e.g. *Carcinus sp.*)

Source: Fossi et al. 2018 (Mediterranean)

3.2. Marine debris modelling

Numerical modelling is regarded as one of the key tools with which to gain insight into the distribution of marine litter, especially microplastics[247]. Given the challenges of monitoring micro-plastic both before it arrives and once it is already in the marine environment, combining empirical data, and modelling approaches can be useful to help predict, or forecast, where micro-plastics will occur[248]. There have been numerous studies of the transport mechanisms of floating plastics in oceans and regional seas[249]. Numerical models can now predict the transport trajectory of floating debris in open seas with contributions from geostrophic currents, Ekman drift, Stokes drift and thermohaline

[247] Hardesty, B. et al. 2017. Using numerical modelling simulations to improve the understanding of micro-plastic distribution and pathways in the marine environment. Front. Mar. Sci. 4:30. doi: 10.3389/fmars.2017.00030.
[248] Ibid
[249] Zhang, H. 2017. Transport of microplastics in coastal seas. Estuar. Coast. Shelf. Sci. 199: 74-86. (See section 4 for a list of references).

circulation[250]. Since the publication of the previous CBD report on marine debris[251], modelling studies have partly focussed on increasing the resolution and accuracy of large-scale modelling of surface movement of marine debris[252] or developing fine-scale models to explain the physical transport of marine plastic debris (macro- and/or micro-plastics) in more complex coastal waters[253 254 255]. A conceptual model has also been developed to identify the sources and sinks of plastic debris in estuaries that integrates biological, physical and chemical distribution mechanisms[256].

Transport in coastal environments is one of the major processes controlling the environmental fate of, and risks from, microplastics as it regulates their spatial and temporal distribution among various marine habitats[257]. The trajectory and speed of microplastics are controlled by their physical characteristics (density, size, and shape) and ocean dynamic conditions (wind, waves, tides, thermohaline gradients, and the influence of benthic sediments). Microplastic particles can be subjected to beaching, surface drifting, vertical mixing, and biofouling, as well as bed-load and suspended load transport processes. Field data strongly suggest that a dominant share of the plastic supplied to the marine environment is retained nearshore in estuarine, beach and wetland sediments but the physical mechanisms of this process are not yet known[258]. A study in the Whitsunday islands of the Great Barrier Reef using an advection-diffusion model for plastic debris originating from sea-based sources found that the physical characteristics of the source location had the largest effect on the fate of the debris[259]. Indeed, knowing the source location and the quantity of plastic debris is the prerequisite to use this type of model to quantify where plastics will accumulate. Other important factors include the relationship between debris resuspension/re-floating from beaches and the wind shadow created by high islands. However, the current lack of parameterisation for the fine-scale movement of microplastics in rugged, shallow coastal bathymetry hinders the use of these models for predicting their transport[260 261]. The rate of degradation of microplastics in the water column or on beaches is also an important factor for the prediction of microplastic accumulation.

Modelling efforts have improved greatly in recent years as additional parameters have been incorporated into models to simulate marine debris movement in the oceans in combination with increased computing power[262]. However, it is a large step from modelling ocean circulation to fine grid resolution for local scales and dynamic coastal conditions. Enhancement of numerical models to the fine grid is thought to be decades away when high-resolution computation becomes available and new models are developed to simulate processes that are currently poorly understood[263].

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[250] National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program. 2016. Report on modelling oceanic transport of floating marine debris. Silver Spring, MD. 21 pp.
[251] 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, Montreal, 78 pages
[252] Maximenko, N. et al. 2018. Numerical simulations of debris drift from the Great Japan Tsunami of 2011 and their verification with observational reports. Marine Pollution Bulletin 132: 5-25.
[253] Critchell, K. et al. 2015. Modelling the fate of marine debris along a complex shoreline: lessons from the Great Barrier Reef. Estuar. Coast. Shelf. Sci. 167: 414-426.
[254] Critchell, K. and Lambrechts, J. 2016. Modelling accumulation of marine plastics in the coastal zone; what are the dominant physical processes? Estuar. Coast. Shelf. Sci. 171: 111-122.
[255] Zhang, H. 2017. Transport of microplastics in coastal seas. Estuar. Coast. Shelf. Sci. 199: 74-86.
[256] Vermeiren, P., Muñoz, C. and Ikejima, K. 2016. Sources and sinks of plastic debris in estuaries: A conceptual model integrating biological, physical and chemical distribution mechanisms. Marine Pollution Bulletin 113: 7-16.
[257] Zhang, H. 2017. Transport of microplastics in coastal seas. Estuar. Coast. Shelf. Sci. 199: 74-86.
[258] Ibid
[259] Critchell, K. and Lambrechts, J. 2016. Modelling accumulation of marine plastics in the coastal zone; what are the dominant physical processes? Estuar. Coast. Shelf. Sci. 171: 111-122.
[260] Ibid
[261] Zhang, H. 2017. Transport of microplastics in coastal seas. Estuar. Coast. Shelf. Sci. 199: 74-86.
[262] Hardesty, B. et al. 2017. Using numerical modelling simulations to improve the understanding of micro-plastic distribution and pathways in the marine environment. Front. Mar. Sci. 4:30. doi: 10.3389/fmars.2017.00030.
[263] Ibid

3.3. Integrating monitoring and modelling of marine debris

In addition to models that simulate marine debris movement and accumulation in the marine environment, other types of models can be used to estimate risk or bioaccumulation at the population or ecosystem scale[264]. Coupling models with species distribution maps or other ecological information generates powerful tools to predict or identify risk hotspots for specific marine taxa or geographic regions[265][266]. The modelling of responses from expert elicitation techniques can provide valuable insights for marine debris impacts where field experiments are difficult to undertake[267]. Modelling can also be used to predict the risk of invasion along pathways[268], evaluate the eff ectiveness of local actions and activities[269], or the costs of inaction and efficiency of action[270].

4. EXAMPLES OF MANAGEMENT TOOLS AND MEASURES WITH A FOCUS ON PLASTICS

This section provides an update on progress and proposals made to detect, monitor, manage and mitigate the impacts of marine debris on marine and coastal biodiversity and roughly follows the format adopted in Chapter 4 of CBD Technical Series 83[271]. Progress in the development of management tools and measures to tackle the issue of marine debris, mainly over the 2015-2018 period are summarised below.

4.1. Institutional responses

Global responses in intergovernmental processes

The issue of marine debris and marine plastic pollutions continues to receive substantial recognition at the global level. The United Nations General Assembly (UNGA) adopted resolution 70/1 in 2015, the 2030 Agenda for Sustainable Development[272]consisting of 17 integrated Sustainable Development Goals (SDGs) and 169 targets. Marine debris is directly addressed within Goal 14 by target 14.1[273] and indicator 14.1.1 (Index of coastal eutrophication and floating plastic debris density). In addition, the control and management of marine debris has linkages to a number of other SDGs, namely Goal 6 on clean water and sanitation, Goal 9 on industry, innovation and infrastructure, Goal 11 on sustainable cities and communities, Goal 12 on responsible consumption and production, and Goal 17 on partnerships to achieve the goals. For example, increasing the sustainability of plastics and plastic products, implementing circular economy tools in the plastics sector, and reducing the leakage of plastics to the environment could play a part in achieving several of the SDG targets[274].

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[264] Ibid

[265] Schuyler, Q. A.., et al. 2015. Risk analysis reveals global hotspots for marine debris ingestion by sea turtles. Glob. Change Biol. 22, 567–576. doi: 10.1111/gcb.13078.

[266] Wilcox, C., Van Sebille, E., and Hardesty, B. D. 2015. Threat of plastic pollution to seabirds is global, pervasive and increasing. Proc. Natl. Acad. Sci. U.S.A. 112, 11899–11904. doi: 10.1073/pnas.1502108112

[267] Wilcox, C. et al. 2016. Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife. Mar. Policy, 65, 107–114. doi: 10.1016/j.marpol.2015.10.014

[268] Hardesty, B. et al. 2017. Using numerical modelling simulations to improve the understanding of micro-plastic distribution and pathways in the marine environment. Front. Mar. Sci. 4:30. doi: 10.3389/fmars.2017.00030

[269] Hardesty, B. et al. 2016. Estimating quantities and sources of marine debris at a continental scale. Front. Ecol. Environ. 15: 18–25. doi: 10.1002/fee.1447.

[270] Sherman, P., and Van Sebille, E. 2016. Modeling marine surface microplastic transport to assess optimal removal locations. Environ. Res. Lett. 11:014006. doi: 10.1088/1748-9326/11/1/014006

[271] 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, Montreal, 78 pages.

[272] United Nations. 2015. Transforming our World: The 2030 Agenda for Sustainable Development. Report No. A/RES/70/1.

[273] SDG Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based sources, including marine debris and nutrient pollution.

[274] ten Brink, P. et al. 2018. Circular economy measures to keep plastics and their value in the economy, avoid waste and reduce marine litter. Economics Discussion Papers, No 2018-3, Kiel Institute for the World Economy. http://www.economics-ejournal.org/economics/discussionpapers/2018-3

At the second session of the United Nations Environment Assembly, held in Nairobi in May 2016 (UNEA-2), Member States adopted resolution 2/11 on marine plastic litter and microplastics[275], which called for a comprehensive assessment of the effectiveness of relevant international, regional and sub-regional governance strategies and approaches to combat marine plastic debris and microplastics. The resolution also requested the Executive Director to assist Member States, especially developing countries, with emphasis on small island developing States and least developed countries, in the development and implementation of national or regional measures and action plans. The report produced on governance strategies and approaches[276] was presented at the third assembly (UNEA-3) held in Nairobi in December 2017 and provided three possible legal and policy options to be discussed during the Assembly: Option 1 was to maintain the status quo, Option 2 was to revise and strengthen the existing framework, adding components to address industry, and Option 3 was to establish a new global architecture with a multi-layered governance approach.

In June 2017, a call for action and 1300 voluntary commitments were made by governments and non-government organisations regarding marine debris at the United Nations Conference in New York to support the implementation of SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development (UN Oceans Conference) as part of the adopted "Our ocean, our future: call for action" declaration. The next High-Level UN Conference to Support the Implementation of SDG 14 will convene in Lisbon, Portugal in June 2020. The overarching theme of the Conference is, 'Scaling Up Ocean Action Based on Science and Innovation for the Implementation of Goal 14: Stocktaking, Partnerships and Solutions'. The conference will be co-hosted by the Governments of Portugal and Kenya, and is expected to adopt an intergovernmental declaration on science-based and innovative areas of action, along with a list of voluntary commitments, to further support SDG 14 implementation.

UNEA-3 gathered high-level representatives, leaders from the private sector, and civil society to address the theme "Towards a Pollution-Free Planet". The theme encompassed the broader concept of pollution for the air, land, waterways, and oceans, and the management of chemicals and waste. The outcomes of UNEA-3 included a political declaration on pollution, 13 resolutions and 3 decisions adopted by Member States, voluntary commitments by governments and other stakeholders, and a collection of individual commitments in the form of the #BeatPollution Pledge. The Assembly adopted resolution 3/7 on marine litter and microplastics[277] which noted the urgency of the issue in terms of the rapidly increasing amount of plastic litter in the oceans and the increase in plastic production and consumption. The resolution underlined that the highest priority should be given to waste minimisation and waste management as preventative short-term solutions whilst also stressing the importance of eliminating the discharging of plastic litter over the long-term through the use of extended producer responsibility schemes and the promotion of environmentally friendly material alternatives. The resolution also addressed a wide range of actors demonstrating the need to recognise the complexity of the issue and the numerous measures required to tackle it. Of these actors, the resolution especially highlighted that industry (e.g. plastic producers, retailers, importers, packaging and transport businesses) could contribute to the issue by developing and selecting more environmentally sound business practices.

Resolution 3/7 also made two main requests for the next steps to be undertaken by UN Environment prior to UNEA-4 in 2019. Firstly, that a report is prepared that provides an overview of all the voluntary commitments regarding marine plastic litter and microplastics, and how these commitments support UNEA's work and reaching the SDG 14, Target 14.1. Secondly, that an Ad Hoc Open Ended Expert Group is established with a programme of work to:

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[275] United Nations Environment Assembly. 2016. Marine plastics litter and microplastics. Report No. UNEP/EA.2/Res.11 (United Nations).

[276] UN Environment, 2017. Combating marine plastic litter and microplastics: An assessment of the effectiveness of relevant international, regional and subregional governance strategies and approaches.

[277] United Nations Environment Assembly. 2017.Towards a pollution-free planet. Report No. UNEP/EA.3/L.19 (United Nations).

i. explore all barriers to combating marine litter and microplastics, including challenges related to resources in developing countries;
ii. identify the range of national, regional and international response options, including actions and innovative approaches, and voluntary and legally binding governance strategies and approaches;
iii. identify environmental, social and economic costs and benefits of different response options;
iv. examine the feasibility and effectiveness of different response options, and;
v. identify potential options for continued work for consideration by the UNEA.

The Ad Hoc Open Ended Expert Group on marine litter and microplastics held its first meeting in May 2018 in Nairobi, Kenya and was attended by 270 delegates representing governments, non-governmental organisations, academia and intergovernmental organisations. The main points discussed during the meeting were the:

i. barriers to combatting marine litter and microplastics, and the need to prioritize the most significant barriers;
ii. work of existing mechanisms addressing this issue, including a new global governance structure, and;
iii. feasibility and effectiveness of response options in the short-, medium, and long-term.

The delegates also agreed to hold a second meeting before the end of 2018. A marine litter and microplastics bulletin provides a summary of the meeting[278] with the official report of the discussions available including the co-chairs summary (draft) and suggestions for further work by the group as annexes[279]. A number of discussion and information documents were prepared for, or submitted to the meeting. Two of the reports submitted as information documents provided comprehensive assessments of: i.) global lessons and research to inspire action and guide policy change[280], and ii.) the effectiveness of governance strategies and approaches to tackle marine plastic litter and microplastics[281]. The latter, prepared for UNEA-3, examined 18 international and 36 regional instruments related to marine litter and microplastics, and found that marine litter is not a primary focus of any instrument, and that the governance structures are fragmented.

The assessment also presented the three possible legal and policy options mentioned previously. As well as being discussed at UNEA-3 these three options were deliberated at the first AHEG meeting. Here, there was unanimous agreement that maintaining the status quo[282] was not an option. With regard to global instruments, many delegates said that a new legally binding instrument was necessary to adequately address the threat of marine litter, given the scale and complexity of the challenge[283]. A new, global, dedicated structure to combat marine litter and microplastics in a holistic, integrated manner was suggested by one delegate as this could provide a number of potential benefits, including a dedicated global meeting place at the government level under the United Nations to discuss present and future actions; improved coordination of actions and mobilization of resources; continuity of efforts, enabling long-term planning; effective allocation of available resources in accordance with agreed priorities, in a cost-effective and results-oriented manner; harmonization and standardization of monitoring and reporting; and support for national policymaking and implementation[284].

[278] IISD 2018. Marine Litter and Microplastics Bulletin. International Institute for Sustainable Development. Vol. 186 No. 13. 9 pp. June 2018.
[279] United Nations Environment Assembly. 2018. Report of the first meeting of the ad hoc open-ended expert group on marine litter and microplastics. UNEP/AHEG/2018/1/6. June 2018.
[280] UNEP. 2016. Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change. United Nations Environment Programme, Nairobi.
[281] UN Environment, 2017. Combating marine plastic litter and microplastics: An assessment of the effectiveness of relevant international, regional and subregional governance strategies and approaches.
[282] Option 1
[283] United Nations Environment Assembly. 2018. Report of the first meeting of the ad hoc open-ended expert group on marine litter and microplastics. UNEP/AHEG/2018/1/6. June 2018.
[284] Ibid

At the fourth UNEA in March 2019, after protracted negotiations, delegates adopted a resolution on strengthening global governance on marine plastic litter and microplastics[285] that allows for scientific review, stakeholder engagement and expert meetings on the issue. The mandate of the Ad Hoc Expert Group on Marine Litter was renewed until UNEA 5, although some delegates were pushing for the establishment of a more permanent Open-ended Working Group. Although UNEA resolutions are not legally binding they do represent the joint aspirations of the international community and help to coordinate technical assistance and development aid[286].

Some existing and more binding international agreements were also thought to offer the potential to progress the global agenda on marine litter such as the Basel[287] and Stockholm[288] Conventions and the Strategic Approach to International Chemicals Management, although a coordinated approach should be adopted to avoid duplication of activities. The suggestion of a three-pillar approach drew much interest and support. Pillar 1 would involve strengthened cooperation under the regional seas conventions; pillar 2 would entail the establishment of a platform for knowledge-sharing and cooperation among industry, relevant authorities, non-governmental organizations and other stakeholders, as well as a forum for voluntary and coordinated commitments by member States; and pillar 3 would involve the amendment of the Basel Convention to comprehensively address plastic waste as a waste of concern. It was agreed at the first AHEG meeting that the list of potential options should be kept open and further deliberated at the next meeting to be held in late 2018, where additional information can be considered.

At the eleventh meeting of the open-ended working group of the Basel Convention held in Geneva in September 2018, there was broad support for a number of measures proposed to tackle plastic waste including suggested changes to Annexes II and IX for solid plastic waste, which would categorise marine plastic litter as a waste of special concern[289]. The working group referred the proposals to the contact group on technical matters which further considered the proposals and prepared draft decisions for consideration at the fourteenth meeting of the Conference of Parties (COP) of the Basel Convention held in Geneva in April / May 2019. At the 14th COP the proposal submitted by Norway to amend Annexes II, VIII and IX to include plastic waste were discussed and after some amendments, adopted as a decision[290] on May 10th 2018. In addition, a comprehensive list of actions for further work were adopted[291] and a Partnership on Plastic Waste established. The decisions will mean that global trade in plastic waste is better regulated and more transparent while the new partnership will help to implement the new measures and provide a set of practical support which will include best practices, tools, and technical and financial assistance[292]

The UNEP Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) identified marine litter as one of three top priority pollution source categories in its 2012-2016 work-plan and launched the Global Partnership for Marine Litter (GPML) in 2012. The GPA, working through the GPML, have made substantial progress in building capacity and raising awareness of the issue of marine litter since 2012. A series of workshops, training courses and on the ground initiatives were supported through demonstration projects. One of note is the Massive Open Online Course on Marine Litter (MOOC), developed in collaboration with the Open Universiteit of the Netherlands. This course has been attended by just over 6450 participants from 54 countries and was translated into Spanish in 2017 with the potential to develop the course for other languages. Capacity building activities on the ground included the development of municipal action plans in five Latin

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[285] UNEP/EA.4/L.7
[286] https://sdg.iisd.org/commentary/policy-briefs/what-did-unea-4-do-for-the-environment/
[287] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
[288] Stockholm Convention on Persistent Organic Pollutants
[289] UNEP Basel Convention. 2018. Draft report of the Open-ended Working Group of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal on the work of its eleventh meeting. UNEP/CHW/OEWG. 11/L.1 September 2018.
[290] UNEP/CHW.14/CRP.40
[291] UNEP/CHW.14/CRP.38
[292] http://www.basel.int/Implementation/Plasticwastes/Overview/tabid/6068/Default.aspx

American countries and implementation of local action plans for the management of marine litter involving coastal communities in the Southeast Pacific.

After UNEA Resolution 1/6 in 2014, an advisory group was established within the framework of the GPML to deliver governmental requests within the resolution. This expert group developed a set of policy recommendations to guide decision makers on actions that could be adapted to global, regional, national and local contexts for marine plastic debris and microplastics[293]. Since 2014, the GPML, as part of UN Environment, have produced a series of reports on various aspects of marine debris including:

- Plastics in Cosmetics with the Institute for Environmental Studies VU University Amsterdam[294];
- Biodegradable Plastics and Marine Litter -Misconceptions, concerns and impacts on marine environments[295];
- MARPOL Annex V Training Package (with IMO);
- Abandoned, lost or otherwise discarded gillnets and trammel nets - Methods to estimate ghost fishing mortality, and the status of regional monitoring and management (with FAO)[296],
- Review of the Current State of Knowledge Regarding Marine Litter in Wastes Dumped at Sea Under the London Convention and Protocol (IMO)[297];
- Vital Graphics Marine Litter[298], and;
- Marine Litter Legislation – A Toolkit for Policymakers in collaboration with Environment Law Institute, USA[299].

The Fourth Intergovernmental Review Meeting (IGR) on the implementation of the GPA was held in Bali between October 31st and November 1st 2018. This meeting presented a review of activities between 2012 and 2018 (mainly summarised in the above paragraphs) and discussed the future of the GPA for the period 2018-2022. The proposed 2018-2022 work plan for the marine litter sub-programme has three expected outcomes:

i. A strengthened knowledge base for addressing marine litter, with a focus on marine plastic litter and microplastics, and a normative basis for preventing, managing and monitoring the impacts of marine litter on the marine environment;
ii. A strengthened GPML supported by the expanded online Marine Litter Network and regional nodes;
iii. Increased awareness of marine litter prevention.

The outcomes of the fourth IGR were used to feed into the preparations for and proceedings of the fourth session of the UNEA. Actions proposed for Member States at the fourth IGR included to:

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[293] UNEP. 2016. Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change. United Nations Environment Programme, Nairobi
[294] UNEP. 2015. Plastics in Cosmetics. United Nations Environment Programme. 33 pp.
[295] UNEP. 2015. Biodegradable Plastics and Marine Litter. Misconceptions, concerns and impacts on marine environments. United Nations Environment Programme, Nairobi.
[296] FAO. 2016. Abandoned, lost or otherwise discarded gillnets and trammel nets: methods to estimate ghost fishing mortality, and the status of regional monitoring and management. FAO Fisheries and Aquaculture Technical Paper No. 600. Rome. Italy.
[297] IMO. 2016. Review of the current state of knowledge regarding marine litter in wastes dumped at sea under the London Convention and Protocol. Final Report. International Maritime Organisation, London. 35 pp.
[298] UNEP and GRID-Arendal, 2016. Marine Litter Vital Graphics. United Nations Environment Programme and GRID-Arendal. Nairobi and Arendal. www.unep.org, www.grida.no.
[299] UNEP. 2016. Marine Litter Legislation: A toolkit for policymakers. United Nations Environment Programme, Nairobi. 98 pp.

- Collaborate with mechanisms established to follow up on the resolutions and commitments to action on pollution from the third UNEA;
- Reaffirm the commitment to engage with all regional seas conventions and action plans on how to align their regional and national targets on pollution with the 2030 Agenda for Sustainable Development, any internationally agreed global action towards a pollution-free planet as well as voluntary targets set by the Member States;
- Consider the three operational options[300] for supporting the future implementation of the GPA between 2018 and 2022 and provide a consensus recommendation to the UNEA at its fourth session in March 2019.

A study commissioned by FAO and the GPA identified best practices to estimate ghost fishing mortality rates and levels, priority research needs, and the status of international monitoring and management of ALDFG and ghost fishing by marine gillnet and trammel net fisheries[301]. Recommendations to improve estimates of regional and global rates and levels of ghost fishing from ALDFG from marine gillnet and trammel net fisheries were provided in the report. Opportunities were also identified to improve the data collection protocols of intergovernmental organizations as well as management measures to prevent and remediate ALDFG and ghost fishing by marine gillnets and trammel nets.

A study produced by the IMO and the GPA reviewed the related scientific literature in order to investigate the need for, and feasibility of, new procedures for assessing litter content of wastes regulated under the London Convention and Protocol (LC/LP)[302]. It identifies the wastes most likely to contain litter and the most commonly occurring materials involved. The study also provides summaries of research into the properties and behaviour of litter in the marine environment and its interactions with marine biota, focusing in particular on sediments. A number of research topics required to fill some of the more important gaps in information were also highlighted.

UN Environment launched the CleanSeas campaign in February 2017, with the aim of engaging governments, the general public, civil society and the private sector in the fight against marine plastic litter[303]. The campaign promotes improved plastics management through a drastic reduction in the use of single-use plastics and a global phasing-out of microplastics in personal care and cosmetics products. As of October 2018, 54 Governments have joined the campaign, making a number of substantial commitments. For example, the Government of Indonesia set an ambitious target of reducing marine litter generated in-country by 70 per cent by 2025, while more than 100,000 people worldwide have pledged to take action to reduce their own plastic footprints. CleanSeas also provides a platform to local organizations who are working on marine litter to highlight their efforts. By connecting individuals, civil society groups, industry and governments through the campaign, UN Environment aims to transform habits, practices, standards and policies around the globe to dramatically reduce marine litter and the harm it causes.

Nearly 200 universities participated in an innovation challenge launched by UNEP and Think Beyond Plastic in June 2017 to engage academia in identifying solutions to marine litter. The winners were announced at the Sixth International Marine Debris Conference, co-organized by the United States National Oceanographic and Atmospheric Administration and UNEP in March 2018 with 750 participants from more than 50 countries. The conference featured more than 74 technical sessions with over 400 oral presentations and 170 poster presentations. It provided a valuable opportunity for knowledge exchange, networking and coordination of activities[304].

[300] Options are to maintain (option A) or expand (option B) the work programme of the GPA, or to disband (option C) the GPA.
[301] FAO. 2016. Abandoned, lost or otherwise discarded gillnets and trammel nets: methods to estimate ghost fishing mortality, and the status of regional monitoring and management. FAO Fisheries and Aquaculture Technical Paper No. 600. Rome. Italy
[302] IMO. 2016. Review of the current state of knowledge regarding marine litter in wastes dumped at sea under the London Convention and Protocol. Final Report. International Maritime Organisation, London. 35 pp.
[303] http://www.cleanseas.org/ #CleanSeas
[304] http://internationalmarinedebrisconference.org/

The Convention on Migratory Species (CMS) adopted resolution 12.2 [305]on the management of marine debris at the twelfth meeting of the conference of parties in Manila, October 2017. This replaced the previous CMS resolutions (10.4 and 11.3) on the subject. The most recent resolution provides guidance and direction for Parties on the following areas: knowledge gaps in the management of marine debris; commercial marine vessel best practice; industry action; public awareness and education campaigns; and collaboration and policy interventions. Within these main subject areas, a number of particular topics were highlighted for action including:

- the use of standardised methodologies for monitoring marine debris, including microplastics, and its impacts on migratory species;
- minimising the amount of abandoned lost or discarded fishing gear (ALDFG) and other types of sea-based solid waste;
- the implementation of regulatory measures or economic instruments to reduce the amount of waste entering the environment and accompany these with behavioural campaigns, drawing on best practice examples already highlighted by the CMS[306];
- increased collaboration between international and regional organisations on tackling marine debris to promote synergies, avoid duplication, share information and maximise efforts including the potential to set up a multilateral working group with other biodiversity-related agreements.

The International Whaling Commission (IWC) has continued to develop it work programme on entanglement since the launch of the Global Whale Entanglement Response Network in 2011[307]. The initial aim of the programme was to build safe and effective entanglement response capability at the global level, with a long-term goal to prevent entanglements from happening in the first place. The programme is led by a technical advisor and supported by an expert panel drawn from countries already operating national entanglement response teams. The network has developed global Best Practice Guidelines and devised a two-day training package. The first training workshop was held in 2012 and has since been delivered on five continents, reaching more than one thousand scientists, conservationists and government representatives from over thirty countries. A ‘train the trainer’ apprenticeship programme has also been developed and led to the creation of six additional trainers, including native Spanish speakers.

The IWC is also starting to conduct research on microplastics with regard to cetaceans. The IWC Pollution 2000+ project began in 1995 with an initial focus on Polychlorinated Biphenyls (PCBs). Using humpback whales and bottlenose dolphins as sample species, the IWC group produced a large body of evidence that PCBs can impact immunity, thyroid health, skeletal integrity and reproductive hormones. A mathematical model was then developed which allowed the group to explore how these physiological effects affect overall population survival. This model is being converted into a web-based tool which can be widely applied to species and locations, and will assist governments and other decision-makers in assessing threats and determining priorities. It will also be used in the next phase of the project, called Pollution 2020, to assess the risks to cetaceans from microplastics and polycyclic aromatic hydrocarbons (PAHs). The origin, fate and distribution of microplastics will be investigated to establish potential high risk areas and therefore species. The group will also examine the direct effects of microplastic inhalation and ingestion and particular emphasis will be placed on the importance of krill and copepods, the prime food for many whale species.

Regional responses

Regional measures can ensure that international conventions and agreements are enacted effectively on a regional scale. Additional forms of governance and interventions can also be developed and implemented that are relevant to the specific circumstances of the region and applied to all relevant

[305] https://www.cms.int/sites/default/files/document/cms_cop12_res.12.20_marine_debris_e.pdf
[306] In document : UNEP/CMS/ScC18/10.4.3
[307] https://iwc.int/private/downloads/-JIGL1_B5rAwUp95eXIMBA/Entanglement_Booklet_v4_for_screen.pdf

member states[308]. A summary of progress by Regional Seas bodies with regard to marine litter indicates that six of them have developed or implemented marine litter action plans with a further eight bodies with plans in development (Table 2). These action plans take into account the specific environmental, social and economic context of each region. Although there is no overall action plan for the Antarctic, CCAMLR has been addressing the issue in the region since 1984 with monitoring by member states on the incidence and impact of marine litter since 1989[309]. Furthermore, a number of mitigation measures to reduce the impact of marine debris on marine life have been introduced by CCAMLR. For other bodies that currently have not implemented a regional plan, marine litter activities primarily occur at the national level.

Table 2. Regional Seas Conventions and Marine Litter Action Plans (updated from Barboza et al., 2019)

Region	Convention, Commission or Coordinating Body	Marine Litter Action Plan	Year Implemented
Arctic Region	Arctic Council	Under development	
Antarctic Region	CCAMLR[310]		
Baltic Sea	HELCOM; Helsinki Convention	Established	2015
Black Sea	Black Sea Commission	Under development	
Caribbean Region	Cartagena Convention and Protocols (UNEP)	Established	Approved 2008, revised 2014
Caspian Sea	Tehran Convention	Under development	
East Asian Seas	COBSEA; Coordinating Body on the Seas of East Asia (UNEP)	Under development	
Eastern African Region	Nairobi Convention (UNEP)	Under development[311]	
Mediterranean Sea	Barcelona Convention	Established[312]	2014
North-East Atlantic	OSPAR Convention	Established	2014
North-East Pacific	Antigua Convention		
North-West Pacific	NOWPAP; North West Pacific Action Plan	Established	2008
Pacific Region	Noumea Convention; SPREP[313]	Established[314]	2015
Red Sea and Gulf of Aden	PERSGA[315]	Under development	
ROPME Sea Area[316]	Kuwait Convention	Under development	
South Asian Seas	SASP; South Asian Seas Programme; South Asia Cooperative Action Plan	Under development	
South-East Pacific Region	Lima Convention		
West and Central Africa Region	Abidjan Convention (UNEP)		

The European Commission (EC) has been developing policy and guidance for a more circular economy. In 2015, the EC adopted a Circular Economy Package, which includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy. In 2016, the EC published a review of the implementation of the Circular Economy Action Plan, and established a Circular Economy

[308] Barboza, L.G., et al. 2019. Macroplastics pollution in the marine environment. Chapter 17: pp. 305-328. In: World Seas: An Environmental Evaluation, Volume 3: Ecological Issues and Environmental Evaluation. Sheppard (Ed.). Elsevier Academic Press.
[309] Ibid
[310] Convention on the Conservation of Antarctic Marine Living Resources
[311] As the Western Indian Ocean Action Plan on Marine Litter and Microplastics
[312] Part of the Mediterranean Action Plan (UNEP-MAP)
[313] Secretariat of the Pacific Regional Environment Programme
[314] Part of the Cleaner Pacific 2025 Strategy
[315] Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden
[316] Regional Organization for the Protection of the Marine Environment – for the marine and coastal areas of Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates

Finance Support Platform together with the European Investment Bank. As part of continuing efforts to implement the Action Plan, in early 2018, the Commission provisionally adopted a new set of measures, including a European Strategy for Plastics in a Circular Economy, which aims to transform the way plastic products are designed, produced, used and recycled in the EU. One of the most challenging goals is that, by 2030, all plastic packaging in the EU should be reusable or recyclable in a cost-effective manner, and that more than half of all plastic waste generated in Europe be recycled[317].

In October 2018, the European Parliament agreed to ban a range of single-use plastic items from the EU market from 2021. The approved draft plans[318] also added items to be banned from 2021 including products made from oxo-degradable plastics such as bags or packaging and expanded polystyrene food containers. Use of other plastics items, although not banned, will be reduced by member states by at least 25% by 2025. These include sandwich boxes and food containers. Cigarette filters containing plastic are to be reduced by 50% by 2025 and 80% by 2030. Member states should also ensure that at least 50% of abandoned or lost fishing gear containing plastic is collected each year and 15% of this should be recycled by 2025. The European Parliament approved these plans as a law in March 2019[319]. The Single-Use Plastics Directive places more responsibility on plastic producers and sets new recycling targets for member States as described above. The plastics covered under the Directive are thought to represent 70% of all marine litter in Europe. The legislation is expected to reduce the environmental damage cost by 22 billion Euros, which is the estimated cost of plastic pollution in Europe until 2030.

At the thirty-fourth summit of the Association of Southeast Asian Nations (ASEAN), the ten member states adopted a declaration to prevent and significantly reduce marine debris, particularly from land-based activities[320]. The Bangkok Declaration is expected to complement actions and policies undertaken at the national level by member states. A framework of action[321] was also published at the summit to address the issue of marine debris which includes research and monitoring, policy planning, engaging the private sector and raising public awareness. It should be noted that the framework makes suggestions for potential action and that no targets or deadlines have been set within the framework or the declaration. It has been said that the declaration mainly focuses on waste management and does not try to tackle plastic production or address the issue further up the production chain[322].

National Responses

Responses at the national level are based on the information provided by Parties to the CBD notification 2018-080. A total of six Parties (Canada, Colombia, Denmark, Ecuador, Norway and the U.K.) submitted information, which is summarised in Annex 2. The following section highlights the main themes and some particular initiatives provided by Parties in their submissions.

All responses by Parties provided information on the range of measures being taken to combat marine debris at the national level. A number of Parties highlighted national policies and commitments. For example, Canada has made a governmental commitment to divert at least 75% of plastic waste generated by federal operations by 2030, through changes to federal practises and the procurement of more sustainable products. There are more than ten federal acts, regulations and agreements in Canada

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317 European Commission 2018. A European strategy for plastics in a circular economy. http://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf

318 European Parliament 2014-2019. Texts Adopted: P8_TA-PROV(2018)0411. http://www.europarl.europa.eu/doceo/document/TA-8-2018-0411_EN.pdf

319 http://www.europarl.europa.eu/news/en/press-room/20190321IPR32111/parliament-seals-ban-on-throwaway-plastics-by-2021

320 Bangkok Declaration on Combating Marine Debris in ASEAN Region, 22nd June 2019: https://www.asean2019.go.th/wp-content/uploads/2019/06/55cd60a076315685ff0520b3d014c9bd.pdf

321 ASEAN Framework of Action on Marine Debris: http://www.mfa.go.th/main/contents/images/text_editor/files/3_%20ASEAN%20Framework%20of%20Action%20on%20Marine%20Debris%20-%20FINAL.pdf

322 https://www.greenpeace.org/southeastasia/press/2677/greenpeace-statement-on-the-bangkok-declaration-on-combating-marine-debris-in-asean-region-and-asean-framework-on-marine-debris/

that contribute to the prevention of marine plastic debris, including the Microbeads in Toiletries Regulations (2017) which is moving towards a complete ban of microbeads in toiletry products by 2019. In Colombia the National Policy for the Integral Management of Solid Waste (CONPES 3874/2016) provides the basis for moving towards a circular economy by maintaining the value of products and materials for as long as possible to minimise waste and resource use. Similarly, the UK’s 25 Year Environmental Plan and Clean Growth Strategy includes a reform of producer responsibility systems to incentivise producers to take greater responsibility for the environmental impacts of their products.

Measures including levies on plastic bags, deposit return schemes and bans on certain types of single-use plastic items are becoming common policies at the national or sub-national level. Of the Parties that responded, levies on plastic bags were mentioned by the UK, Denmark and Canada while Colombia has a regulation for plastic bag use (Resolution 0668/2016) and a national consumption tax on plastic bags implemented through the Tax Reform Law 1819 (2016). In Canada, these types of regulatory measures are also often implemented by governments at the provincial, territorial or municipal level, while all provinces and territories (bar one) have regulated extended producer responsibility schemes in place. Addressing sea-based sources of marine debris, Denmark has a ‘no-special-fee’ system in harbours so that ships can deposit waste whilst in port without having to pay an additional fee as the cost is covered by the port charges.

Research and monitoring of marine debris was highlighted by a number of Parties. Support for research in Canada has been provided through a number of programs including the Natural Sciences and Research Council of Canada and the Northern Contaminants Program that have focused on multiple aspects of microplastics in Canadian waters. In Denmark, a comprehensive national monitoring programme for marine litter and microplastics collects information on macro- or micro-litter on beaches, on the seabed, within seabird (fulmar) and fish stomachs and in sediments. Monitoring of solid waste and microplastics in marine and coastal areas of Colombia has produced a first baseline spatial assessment that shows the level of marine debris pollution as well as the amount of environmental and waste management regulations in place to address the issue. However, it was also stated that there are a number of constraints to implementation including the need for planning instruments at multiple levels (national, sub-national and local) and a lack of information on marine litter and how to manage it in the coastal zone.

Clean-up campaigns for marine debris in coastal habitats have been a key part of data collection, which also involves the general public and contributes to raising awareness around marine debris at the same time. Such campaigns or clean-up events are organised by both government agencies and non-government organisations. For example, in Ecuador the Ministry of Environment implemented clean-up campaigns in 2018 in collaboration with government institutions, NGOs, the private sector and the public. Coastal clean-ups in eight protected areas involving almost 2300 volunteers collected 8,700 kg of marine debris with plastic making up the largest proportion (40.6%). The Great Canadian Shoreline Clean-up is a national program led by WWF and Oceanwise, in partnership with the Canadian government to remove debris from shorelines and collect citizen science data. Beach clean-ups were also noted by Colombia in two provinces as well as the exchange of information and knowledge of good practises for coastal clean-ups in order to mobilise public awareness and participation in keeping aquatic systems clean.

Educational and awareness-raising campaigns or events for the general public or specific target audiences were highlighted by a number of Parties. Environment and Climate Change Canada (ECCC) has provided significant financial support since 2016 for educational and awareness raising projects related to plastics and marine litter. These include the production of an Oceans Plastics Kit in 2018 and a program to help remove abandoned or wrecked small boats which also raises awareness about boat owner responsibility and improving the management of end-of-life boats. An information campaign in Denmark targeted beach visitors, yacht owners and fishermen during 2018 and education curricula have also been developed for the latter target group which includes the marine environment and waste management.

Information campaigns are also established to raise awareness of long-term plans and strategies that governments of Parties are either implementing or developing. For example, Denmark is developing a national plastic action plan that covers the whole value chain including consumers. In Canada, federal, provincial and territorial governments agreed in principle in 2018 to a Zero Plastic Waste Strategy with an action plan to be developed in 2019. Secondly, a Canada-wide waste reduction goal was endorsed to reduce personal waste production by 30% in 2030 and 50% in 2040. A roadmap to characterise and monitor the environmental and socio-economic effects of marine debris has been developed in Colombia that contains five main themes and specific targets for two, five and twenty years' time.

A number of Parties from Europe also reported on their contributions to tackling marine debris at the international level through a range of fora including the G7 and the WEF, UN agencies or agreements (UNEA resolutions, Basel Convention, SDG's, IMO - MARPOL) and programs such as the GPML, funding bodies (GEF, World Bank) and initiatives such as the Global Ghost Gear Initiative.

To sum up this section, although the number of submissions by Parties was low and cannot be considered as a representative sample, it reveals a large range of actions at the national level in terms of both regulatory and non-regulatory measures, as well as research and monitoring programs and long-term plans and strategies to minimise marine debris and its impacts.

4.2. Measures to achieve sustainable production and consumption

This section generally follows the same structure as the previous CBD Technical Series report on marine debris[323] with similar sub-sections. It provides an update on the subject areas previously covered and includes proposed approaches, current examples and new potential developments to better manage and mitigate marine debris. As mentioned in the previous CBD reports, a waste management system based on the principles of circular economy, polluter pays, best management practices, public awareness and participation, and driven by effectiveness and efficiency objectives can, over time, have a positive impact[324] [325]. Such a waste management system would increase the amount of waste diverted toward secondary use and recycling.

Reuse, reduction and cleaner production

Many of the principles mentioned above have been embraced by the New Plastics Economy initiative under Project Mainstream[326] which initially focussed on plastic packaging[327]. The initiative published a comprehensive overview of global plastic packaging material flows, which assessed the value and benefits of shifting the sector to a circular economic model, and identified a practical approach to enable this shift. The study, led by the Ellen MacArthur Foundation, was developed from interviews with over 180 experts and the analysis of over 200 reports over a three year period. In 2016, 95% of plastic packaging material was lost to the economy after a short first use and was valued at $80-120 billion annually[328]. Since this publication there has been substantial progress in further developing the circular economy concept for plastics, not only for packaging but also for plastic materials used in the electronics and textile industries. Particular locations have also been investigated further in terms of a circular economy approach, such as city or urban environments and individual countries (India, China)[329].

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[323] Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity. Technical Series No.83. 2016. Secretariat of the Convention on Biological Diversity, Montreal, 78 pages

[324] Ibid

[325] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel – GEF. 2012. Impacts of marine debris on biodiversity: current status and potential solutions. Montreal, Technical Series No. 67, 61 pp., https://www.cbd.int/doc/ publications/cbd-ts-67-en.pdf.

[326] Project MainStream,is a multi-industry global initiative launched in 2014 by the World Economic Forum and the Ellen MacArthur Foundation, with McKinsey & Company as knowledge partner.

[327] World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company. 2016.The New Plastics Economy — Rethinking the future of plastics (http://www.ellenmacarthurfoundation.org/publications)

[328] Ibid

[329] https://www.ellenmacarthurfoundation.org/publications

Part of the initiative is to reduce fragmentation within the plastics economy so that there can be better coordination of both regulation and innovation across the value chain, with agreed standards and improved linkages between supply and distribution chains and the related after-use systems and infrastructure[330]. Innovative solutions for plastic pollution have continued to be developed through an on-going initiative called 'Think Beyond Plastic', as mentioned in the previous CBD report. Over the last five years the initiative has supported the launch of fifty-two start-up businesses that have developed innovative solutions including bio-benign and sustainably derived materials and consumer or business products such as packaging designs[331].

In October 2018, the Ellen MacArthur Foundation in collaboration with UN Environment launched the New Plastics Economy Global Commitment, which unites businesses, governments and other organisations in a common vision to address plastic waste and pollution at its source[332]. As of June 2019 there have been over 400 signatories including:

- Almost 200 businesses that are part of the plastic packaging value chain and represent over 20% of all plastic packaging used globally, including many of the world's leading consumer packaged goods companies, retailers, and plastic packaging producers;
- 16 governments across five continents and across national, regional, and city levels;
- 26 financial institutions with a combined USD 4.2 trillion worth of assets under management and 6 investors in total committing to invest about USD 275 million;
- Institutions such as WWF, the World Economic Forum, the Consumer Goods Forum, and IUCN;
- More than 50 academics, universities, and other educational or research organisations including MIT Environmental Solutions Initiative, Michigan State University, and University College London.

The commitment means that the signatories have agreed to meet specific targets by 2025 and will work to: eliminate the plastic items we don't need; innovate so all plastics we do need are designed to be safely reused, recycled, or composted; and circulate everything we use to keep it in the economy and out of the environment[333]. The Ellen MacArthur Foundation will help to ensure credibility and transparency by setting a clear minimum level of ambition for signatories, common definitions underpinning all commitments and publishing commitments and progress reports online, with the first progress report to be published in 2019. In addition, the minimum ambition level will be reviewed every 18 to 24 months, and become increasingly ambitious over the coming years to ensure that the Global Commitment continues to represent true leadership.

In terms of innovative products there have been advances in the development of truly biodegradable single use plastic items such as plastic bags and film. Plastic bags made from cassava are completely biodegradable and compostable according to the Indonesian manufacturer[334] and can also dissolve in water. A second type of plastic bag has been developed in Chile called the solubag, which can dissolve in water in a few minutes[335]. Another plant-based single use product is a clear film that feels and looks like plastic but is made from cellulose (wood) derived from agricultural and forestry by-products that has been developed in Finland[336]. An Israeli company produces a range of plant-based packaging products including bags, sachets and films that are all compostable[337]. Lastly, single-use food packaging

[330] World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company. 2016.The New Plastics Economy — Rethinking the future of plastics
[331] https://www.thinkbeyondplastic.com/graduates
[332] https://www.newplasticseconomy.org/projects/global-commitment
[333] Ibid
[334] https://www.avanieco.com/portfolio-item/bio-cassava-bag/
[335] http://sdg.iisd.org/news/chilean-researchers-create-solubag-to-beatplasticpollution/
[336] https://www.newplasticseconomy.org/innovation-prize/winners/vtt-technical-research-centre-of-finland
[337] https://tipa-corp.com/

such as small plastic sachets have been replaced by a seaweed-based material[338] that can dissolve in water, be eaten or used as a natural fertilizer.

Although the development of these new and innovative products to replace single-use plastics is very encouraging it is important that any new product is independently tested to verify its biodegradable or compostable properties. A study of plastic bags labelled as biodegradable, oxo-biodegradable and compostable showed that none of the types of bags tested showed substantial deterioration over a three-year period in three types of natural environment (open air, buried in soil and immersed in seawater)[339]. It was suggested that the deterioration rates of both the biodegradable and oxo-biodegradable types of plastic bag were not noticeably different to those of conventional high density polyethylene bags. Moreover, a review of existing international industry standards and regional test methods for evaluating the biodegradability of plastics within aquatic environments (wastewater, unmanaged freshwater and marine habitats) suggests that current standards and test methods are not sufficient to realistically predict the biodegradability of plastic carrier bags in these environments[340]. The shortcomings in current standards and methods were attributed to several inadequate experimental procedures and a paucity of information in the scientific literature. In addition, existing biodegradability standards and test methods do not involve toxicity testing or account for potentially adverse impacts of carrier bags, plastic additives, polymer degradation products or microplastics that arise from fragmentation[341]. Addressing these knowledge gaps will enable the development of new biodegradability standards for single-use plastic bags.

Reducing the amount of single use plastic and therefore the volume of plastic that requires recycling is a key priority, but plastic items will continue to be produced and will remain in the value chain for some time to come. Collection and then recycling of post-consumer plastics is a challenge as they often contain mixed polymers with both organic and inorganic impurities[342]. The maximum amount of plastic waste that can be sorted and mechanically recycled is estimated to be between 29 and 45%[343], which leaves 55-71% as mixed waste that has limited opportunity for re-use. At the global level 40% of plastic waste is currently disposed of as landfill while 32% is estimated to end up as litter or debris[344].

New processes are required to deal with mixed plastic waste, which can also recover value or use. There is growing interest in chemical and biotechnological recycling technologies to address the issue of plastic waste. Chemical recycling involves transferring a plastic's polymers into its smaller constituents (oligomers or monomers), which can then be converted into chemicals, fuels or virgin plastics[345]. One example currently in development by Recycling Technologies in the U.K., uses low severity thermal cracking in an oxygen-starved atmosphere to process mixed plastic waste. A pilot plant at 1/10 scale is capable of processing 100 kg of mixed waste per hour to produce a waxy hydrocarbon product or heavy fuel oil. A commercial plant is currently in the design stage that scales up to process 1000 kg/hour[346]. The process can also be used to produce a substitute for light fuel oil or natural gas. The company plans to mass produce the technology to make 200 machines a year and ship them around the world. Each

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[338] http://www.evoware.id//product/ebp

[339] Napper, I. E. & Thompson, R. C. 2019. Environmental Deterioration of Biodegradable, Oxo-biodegradable, Compostable, and Conventional Plastic Carrier Bags in the Sea, Soil, and Open-Air Over a 3-Year Period Environmental Science and Technology 53: 4775-4783.

[340] Harrison JP, Boardman C, O'Callaghan K, Delort A-M, Song J. 2018. Biodegradability standards for carrier bags and plastic films in aquatic environments: a critical review. R. Soc. open sci. 5: 171792. http://dx.doi.org/10.1098/rsos.171792

[341] Ibid

[342] Drzyzga, O. and Prieto, A. 2019. Plastic waste management, a matter for the 'community'. Microbial Biotechnology 12: 66–68 doi:10.1111/1751-7915.13328.

[343] Denkstatt, 2014. Criteria for eco-efficient (sustainable) plastic recycling and waste management – fact based findings from 20 years of Denkstatt studies. Vienna, Austria.

[344] World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company. 2016.The New Plastics Economy — Rethinking the future of plastics.

[345] Drzyzga, O. and Prieto, A. 2019. Plastic waste management, a matter for the 'community'. Microbial Biotechnology 12: 66–68 doi:10.1111/1751-7915.13328

[346] Recycling Technologies Ltd. 2017. The RT7000. URL: www.recyclingtechnologies.co.uk/technology/the-rt7000/.

one has the capability to recycle 7000 tonnes of mixed plastic waste per year[347]. A life cycle assessment of the technology suggested that it is a better option environmentally than incineration or landfill[348].

Chemical recycling that involves less energy input is also being developed using biocatalysts (bacterial cells and enzymes). Types of plastic that are traditionally considered non-biodegradable such as polyethylene and polyethylene terephthalate (PET) products are now thought to be susceptible to degradation and transformation by microbes[349]. A number of enzymes have been identified that can hydrolyse polyester plastics[350] while a bacterium has been identified that can use PET as its major energy and carbon source[351]. A number of fungi also have the potential to degrade polyethylene in aquatic and soil environments[352]. New biotech companies are developing conversion technologies to transform waste plastic into valuable products. For example, Biocellection[353] in California uses genetically engineered bacteria to transform polystyrene and polyethylene film into valuable surfactants that are used in the textile industry. The integration of mechanical, chemical, thermochemical and biotechnological recycling techniques with microbial, fungal and even protist biological activity allowed to proceed under controlled and contained conditions, may perhaps be the key to attaining the goal of a circular economy for the mixed plastic waste sector[354]

Solid waste management

Effective solid waste management systems are required to maximise the recycling and re-use of plastic and other types of waste and ensure that remaining solid wastes are disposed of safely. A global assessment of solid waste management systems by the World Bank[355] indicates that there is a large range in management according to how countries are categorised in terms of income level (high, upper-middle, lower-middle and low)[356]. At the global level at least 33% (extremely conservative estimate) of all municipal solid waste is not managed in an environmentally safe manner. A more recent study states that only 16% of the global total is recycled and 46% is disposed of unsustainably[357]. Waste collection in low-income countries increased from 22% to 39% between 2012 and 2018 and there is an overall global trend of increased recycling and composting[358]. However, for low income countries, there are still lower levels of collection outside of urban areas (26%) compared to cities where almost half (48%) of solid waste is collected. The vast majority of the waste that is collected in low income countries (93%) is disposed of through open dumping, but also contains a higher proportion of organic waste

[347] https://www.bbc.com/news/business-43390938

[348] Gear, M. et al. 2018. A life cycle assessment data analysis toolkit for the design of novel processes – A case study for a thermal cracking process for mixed plastic waste. Journal of Cleaner Production 180:735-747.

[349] Alshehrei, F. 2017. Biodegradation of synthetic and natural plastic by microorganisms. J Appl. Environ Microbiol. 5: 8–19.

[350] Wierckx, N., Narancic, T., Eberlein, C., Wei, R., Drzyzga, O., Magnin, A., et al. 2018. Plastic biodegradation: Challenges and opportunities. In Handbook of Hydrocarbon and Lipid Microbiology Series. Consequences of Microbial Interaction with Hydrocarbons, Oils and Lipids: Biodegradation and Bioremediation. Steffan, R. (ed.). Cham: Springer

[351] Yoshida, S., Hiraga, K., Takehana, T., Taniguchi, I., Yamaji, H., Maeda, Y., et al. 2016. A bacterium that degrades and assimilates poly(ethylene terephthalate). Science 351: 1196–1199.

[352] Drzyzga, O. and Prieto, A. 2019. Plastic waste management, a matter for the 'community'. Microbial Biotechnology 12: 66–68 doi:10.1111/1751-7915.13328

[353] https://www.biocellection.com/

[354] Drzyzga, O. and Prieto, A. 2019. Plastic waste management, a matter for the 'community'. Microbial Biotechnology 12: 66–68 doi:10.1111/1751-7915.13328

[355] Kaza, Silpa, Lisa Yao, Perinaz Bhada-Tata, and Frank Van Woerden. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development Series. Washington, DC: World Bank. doi:10.1596/978-1-4648 -1329-0. License: Creative Commons Attribution CC BY 3.0 IGO

[356] https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries

[357] Verisk Maplecroft 2019. Waste generation and recycling indices 2019. Overview and Findings. June 2019, maplecroft.com.

[358] Silpa, K. et al. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development Series. Washington, DC: World Bank. doi:10.1596/978-1-4648 -1329-0.

compared to countries with higher levels of economic development. The proportion of plastic waste is also higher for high income countries (12.5%) than for those with low income (6.6%).

The World Bank report also provides projections for solid waste generation up to 2050. By this time the global production of solid waste is expected to reach 3.4 billion tonnes annually, an increase of 1.3 billion tonnes since 2018. Waste production is projected to triple in low income countries by 2050, although the total predicted for these countries is substantially lower than for any other income category. The largest totals are projected for the lower- and upper-middle income countries, which are expected to surpass the total solid waste generated in the high income category[359]. Waste production per capita is predicted to clearly remain highest in high income countries and still be more than triple the projected levels for low income countries in 2050[360]. Highly developed island or small states can have particularly high levels of waste production per capita (kg/capita/day). Examples are Singapore (3.72), Iceland (4.45) and the U.S. Virgin Islands (4.46)[361]. There is also considerable variation in recycling levels for countries. For example, a new recycling index (REI) suggests that the United States recycles 35% of its municipal solid waste while Germany manages to recycle 68%[362].

Regulatory measures for single use plastics

Building on the progress to implement bans or user fees for single use plastic bags, as reported in the previous CBD technical report (Technical Series 83), a broader suite of regulatory measures to address single use plastic items are being introduced at the national or municipal level. A global overview of the progress of countries in passing laws and regulations that limit the manufacture, import, sale, use and disposal of selected single-use plastics and microplastics was released in late 2018[363]. The study revealed that, as of July 2018, two thirds of the countries assessed (127 out of 192) had adopted legislation to regulate plastic bags including restrictions on the manufacture, distribution, use, and trade of plastics bags, taxation and levies, and post-use disposal. Of these, twenty-seven countries have introduced taxes on the manufacture and production of plastic bags while thirty nations charge consumer fees for plastic bags at the national level[364]. In terms of a north-south split, industrialised countries in the Global North have mainly adopted plastic bag taxes, while developing countries in the Global South have predominantly introduced more stringent legislation such as plastic bag bans[365]. For the latter, more stringent measures are required as there is generally more limited waste collection and lower recycling rates compared to more developed countries.

A review of legislative (and non-legislative) interventions to reduce marine pollution from single-use plastics from 2017 to March 31st 2018 at the national and sub-national level documented legislative measures for plastic bags, microbeads and other single-use items such as plastic straws and cutlery, and polystyrene[366]. The study also assessed the effectiveness of legislative interventions (bans or levies) on plastic bag use. Reduction in plastic bag use ranged between 33 and 96%, and generally resulted in marked reductions across many jurisdictions[367]. Bans are thought to encourage customers to switch to reusable bags but charging has a greater effect on overall reduction as it encourages behavioural change and forces customers to make conscious decisions about purchasing plastic bags[368]. Factors such as

[359] Ibid (Figure 2.6a, p. 27).
[360] Ibid (Figure 2.6b, p. 27).
[361] Ibid
[362] Verisk Maplecroft 2019. Waste generation and recycling indices 2019. Overview and Findings. June 2019, maplecroft.com.
[363] UNEP 2018. Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations. https://wedocs.unep.org/bitstream/handle/20.500.11822/27113/plastics_limits.pdf
[364] Ibid
[365] Knoblauch, D., Mederake, L., and Stein, U. 2018. Developing Countries in the Lead – What drives the diffusion of plastic bag policies? Sustainability 10: doi: 10,3390/su10061994.
[366] Schnurr, R.E.J. et al. 2018. Reducing marine pollution from single-use plastics (SUPs): A review. Marine Pollution Bulletin. https://doi.org/10.1016/j.marpolbul.2018.10.001
[367] Ibid (Table 4)
[368] Romer, J., Tamminen, L., 2014. Plastic bag reduction ordinances: New York City's proposed charge on all carryout bags as a model for U.S. cities. TELJ 27: 237–275.

education level and the cost of living can influence the effectiveness of plastic bag bans as well as geographical location, interest from industry and level of economic development[369]. Knowledge of these factors enables predictions on whether an area will be able to effectively implement a plastic bag ban[370]. Another assessment at the national level for sixty countries on the effectiveness of policies (bans or levies) to reduce single-use plastic bag use indicated that 30% of cases registered dramatic drops in plastic pollution and the consumption of plastic bags within one year of implementation[371]. However, 50% of cases did not have sufficient data to draw a robust conclusion while the remaining 20% reported little or no impact. For the latter, the main reasons for a lack of impact were poor enforcement and a lack of affordable alternatives which led to the development of black markets for plastic bags and a shift to the use of thicker plastic bags, which was not regulated[372]

Regarding regulations for microbeads, as of July 2018, eight countries of the 192 assessed have established bans on microbeads at the national level, while a further four countries proposed new laws or regulations[373]. The European Union also initiated a process to restrict the intentional addition of microplastics to consumer and professional use products. For those with national bans in place, seven countries only include a subset of personal care products in the laws or regulations. Only one country (New Zealand) has a microbead law that includes personal care products as well as abrasive household, car and industrial cleaning products[374].

To assist Governments in tackling single-use plastic waste, UN Environment has developed a ten-step roadmap that covers both regulatory and non-regulatory interventions and can be used to adopt new measures or improve current ones[375]. The steps are based on experiences from sixty countries around the world and are listed in Annex 3. For further detail and a range of case studies please refer to the SUP roadmap sustainability document[376].

Addressing sea-based sources

Sea-based sources of marine debris are predominantly waste from shipping and from the fishing and aquaculture industries. The latter includes abandoned, lost or derelict fishing gear (ALDFG). Although the International Maritime Organisation's (IMO) convention for the prevention of pollution from ships (MARPOL) includes an annex for garbage (MARPOL Annex V), it is unclear how well enforced this regulation is at sea for certain types of vessels. As reported previously[377], the regulation does not apply to vessels under 100 gross tonnage which includes 98% of motorised fishing vessels globally. For some regions, such as the European Union, it is compulsory for ports to provide waste reception facilities for all vessels that use the port. However, use of such facilities can be low especially if it incurs a financial cost for the user. As long as the correct disposal of garbage remains economically costly, it has been suggested that most fishing companies will be unlikely to comply with MARPOL and EU commission laws and legislations[378]. A review of cost recovery systems (CRS) used to charge vessels for waste disposal at European port reception facilities (PRF) indicates that the most common types of CRS in

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[369] Schnurr, R.E.J. et al. 2018. Reducing marine pollution from single-use plastics (SUPs): A review. Marine Pollution Bulletin. https://doi.org/10.1016/j.marpolbul.2018.10.001

[370] Li, Z., Zhao, F., 2017. An analytical hierarchy process-based study on the factors affecting legislation on plastic bags in the US. Waste Manag. Res. 35: 795–809

[371] UNEP 2018. Single-Use Plastics: A Roadmap for Sustainability. https://www.unenvironment.org/resources/report/single-use-plastics-roadmap-sustainability

[372] Ibid

[373] UNEP 2018. Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations. https://wedocs.unep.org/bitstream/handle/20.500.11822/27113/plastics_limits.pdf

[374] Ibid.

[375] UNEP 2018. Single-Use Plastics: A Roadmap for Sustainability. https://www.unenvironment.org/resources/report/single-use-plastics-roadmap-sustainability

[376] Ibid

[377] Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity. Technical Series No.83. 2016. Secretariat of the Convention on Biological Diversity, Montreal, 78 pages

[378] Unger, A., and Harrison, N. 2016. Fisheries as a source of marine debris on beaches in the United Kingdom. Marine Pollution Bulletin 107: 52-58.

the EU do not provide a positive incentive to discharge waste at the PRF[379]. In some cases the CRS can create an incentive to discharge waste at sea rather than at a PRF if the cost of discharging at the PRF is directly related to the quantity of waste discharged. Use of deposits that are only refunded when waste is discharged at a PRF or penalties if a vessel does not use a PRF when in port can provide a positive financial incentive to discharge waste at a PRF. Other disincentives to using a PRF were also discussed in the study plus a number of recommendations to minimise the administration and time spent for the waste disposal process in port[380].

The second main issue in terms of sea-based sources is the generation of marine debris from ALDFG, which is regarded as a significant amount of global marine debris that has a wide range of environmental and economic impacts[381]. An assessment of the Great Pacific Garbage Patch revealed that ALDFG made up almost half (46%) of the plastic observed in the 1.6 million km^2 region surveyed[382]. Other estimates indicate that up to 70% of floating macroplastic in the open ocean is fishing related debris when measured by weight[383]. ALDFG can cause significant damage to marine ecosystems and benthic habitats, act as a navigation hazard, and compromise fisheries yields and incomes[384][385][386]. Removal of derelict gear such as traps and pots used in Chesapeake Bay crustacean fisheries has been shown to increase harvests to a value of US $21.3 million, representing a 27% increase compared to a no-removal scenario[387]. Extrapolation to the global level for major crustacean fisheries indicates that US $831 million could be recovered annually if less than 10% of derelict pots and traps were removed[388].

To tackle ALDFG at the global level major initiatives are underway through the Global Ghost Gear Initiative (GGGI), the FAO and through a new working group (WG 43) at the GESAMP. The GGGI[389] was launched by World Animal Protection in 2015 and is recognised as one of the leading initiatives at the global level to tackle the issue of ALDFG or 'ghost gear'. As of July 2019 the GGGI had 121 participants from private sector, corporations, IGOs and NGOs, academia and governments, with 14 countries signed up including the UK, Sweden and Canada. The GGGI's three main aims are to improve the health of marine ecosystems, safeguard human health and livelihoods and protect marine animals from harm. The initiative supports collaborative projects around the world[390] to build evidence, define best practise and inform policy and catalyse and replicate solutions.

The GGGI's Build Evidence working group organised a technical session at the 6th International Marine Debris Conference (IMDC) in March 2018, to help identify and communicate the current state of knowledge around ALDFG data and research[391]. A range of approaches were presented that covered

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379 Sherrington, C., et al. 2016. Study to support the development of measures to combat a range of marine litter sources. Report for European Commission DG Environment. Eunomia. 411 pp.
380 Ibid
381 Richardson, K., et al. 2019. Building evidence around ghost gear: Global trends and analysis for sustainable solutions at scale. Marine Pollution Bulletin 138: 222-229.
382 Lebreton, L., et al. 2018. Evidence that the Great Pacific garbage patch is rapidly accumulating plastic. Sci. Rep. Vol. 8, 4666.
383 Eriksen, M., L. C. M. Lebreton, H. S. Carson, M. Thiel, C. J. Moore, J. C. Borerro, F. Galgani, P. G. Ryan and J. Reisser. 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.
384 Gilman, E., 2015. Status of international monitoring and management of abandoned, lost and discarded fishing gear and ghost fishing. Mar. Policy 60: 225-239.
385 NOAA Marine Debris Program, 2015. Report on the Impacts of "Ghost Fishing" Via Derelict Fishing Gear. Silver Spring, MD. 25 pp.
386 Macfadyen, G., Huntington, T., Cappell, R., 2009. Abandoned, Lost or Otherwise Discarded Fishing Gear (No. 523). Food and Agriculture Organization of the United Nations (FAO).
387 Scheld, A. M. et al. 2016. The Dilemma of Derelict Gear. Sci. Rep. 6, 19671; doi: 10.1038/ srep1967.
388 Ibid
389 https://www.ghostgear.org/
390 https://www.ghostgear.org/projects
391 Richardson, K., et al. 2019. Building evidence around ghost gear: Global trends and analysis for sustainable solutions at scale. Marine Pollution Bulletin 138: 222-229.

topics such as ocean retrieval, data collection, impacts from active fishing gear and ALDFG and how data collection efforts are informing the development of solutions and helping to raise awareness around the issue. Case studies for data collection and ALDFG removal from Washington State (USA), the Northwestern Hawaiian Islands (USA) and Project Aware (Global) were summarised in a subsequent publication[392].

For the latter, Project Aware developed a global marine debris survey called 'Dive Against Debris'[393] that uses recreational divers to collect data on underwater debris on the seabed and then remove the items from the marine environment. Since the program was launched in 2011 more than 5600 marine debris surveys have been logged representing almost 50,000 divers from 114 countries who have spent 8000 hours underwater. Over one million marine debris items have been removed and recorded including 12,000 fishing nets, 178,000 pieces of fishing line, more than 42,000 hooks, lures and sinkers and almost 3000 traps and pots[394]. Project AWARE has committed to remove and report one million more items by the end of 2020. The project has also developed online and offline tools and materials to educate and train participants, which are available in different languages.

A key aspect that was discussed during the ALDFG session at the Sixth IMDC was the development of a publicly accessible global database for compiling and sharing ALDFG data, best practices and solutions. Information collected by 'Divers Against Debris' has been shared with the GGGI to support the development of this global database. The dataset has helped to inform where ALDFG has and has not been recorded for dive sites and also helps to identify ghost gear hotspots where management effort can be prioritised[395]. The global ALDFG database was relaunched by GGGI in September 2017 in a more flexible form that allows partial records to be submitted, which can still be useful information. Information from multiple sources can be submitted so that data is captured from a diverse range of stakeholders (e.g. beach clean-ups, commercial fishers, fishery observers, NGOs, general public). The GGGI has also developed the Gear Reporter App[396] which enables users to report on ALDFG at a range of detail levels, and can then be uploaded onto the global ALDFG database or sent to GGGI for input.

Understanding the causes of fishing gear loss is an important component of tackling the ALDFG issue. A study in northern Australia[397] interviewed both Australian and Indonesian fishers to conduct a 'fault tree' analysis that identified the chain of events that resulted in gear loss or abandonment (Figure 3). Fishers identified the snagging of nets (78%) and gear conflicts (19%) as the main causes of gear loss while the fault tree analysis highlighted overcrowding, overcapacity and illegal, unreported and unregulated (IUU) fishing as the main drivers of gear loss in this case. A combination of the over-allocation of fishing licenses and IUU fishing initiated a chain of events that resulted in ALDFG and the amount of derelict gear was also directly linked to increased levels of fishing effort (Figure 3). Too many fishers in the area also caused overcrowding and lead to some vessels fishing in riskier areas that can result in damage or loss of gear through snagging. There were also increased levels of gear conflict between fishers using different gear[398]. Recommendations for interventions and improvements in regional fisheries management to reduce fishing gear loss in the Arafura Sea were developed using the fault tree analysis. Regular gear maintenance to prevent loss was also lacking for many of the vessels operating in the study area.

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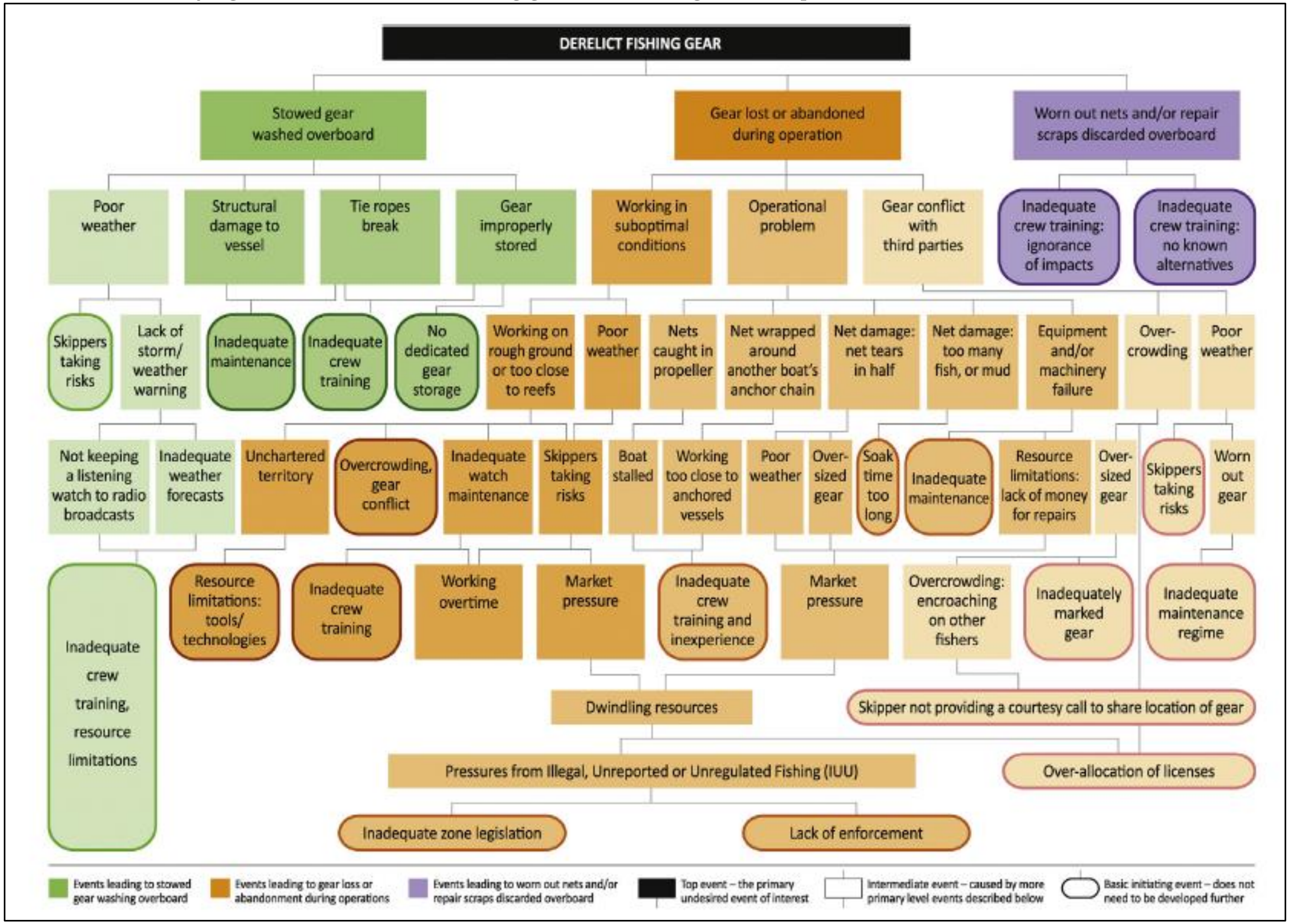
[392] Ibid
[393] https://www.projectaware.org/diveagainstdebris
[394] Richardson, K., et al. 2019. Building evidence around ghost gear: Global trends and analysis for sustainable solutions at scale. Marine Pollution Bulletin 138: 222-229
[395] Ibid
[396] https://www.ghostgear.org/news/2018/7/6/gggi-ghost-gear-reporter-app
[397] Richardson, K. et al. 2018. Understanding causes of gear loss provides a sound basis for fisheries management. Marine Policy 96: 278-284.
[398] Ibid

Figure 3. Fault tree identifying the causes of derelict fishing gear from trawl, gillnet and purse seine vessels in the Arafura Sea



Note: Colours differentiate between different tree 'branches' to better follow the overall causal flow. Source: Richardson et al., 2018.

The FAO has primarily been focusing on the marking of fishing gear as a means to address ALDFG over the last five years. At the 31st session of the FAO Committee on Fisheries (COFI) in 2014, concern was expressed about ghost fishing by ALDFG and the Committee recommended that Members and regional fishery bodies increase efforts in mitigating ALDFG impacts. In response, in 2016, FAO convened an Expert Consultation on the Marking of Fishing Gear, resulting in the development of 'Draft Guidelines for the Application of a System on the Marking of Fishing Gear' ('the Draft Guidelines'). After considering the recommendations of the Expert Consultation, COFI (32nd Session, 2016) encouraged FAO to support the implementation of the Draft Guidelines by conducting pilot projects on fishing gear marking. COFI also supported the further development of the Draft Guidelines via a Technical Consultation on the Marking of Fishing Gear, which was convened in February 2018. To implement COFI's recommendations and support the work of the Technical Consultation on the Marking of Fishing Gear, FAO conducted a pilot project in 2017 in collaboration with World Animal Protection on the marking of gillnets in small scale fisheries in Indonesia to provide further information to support the future implementation of the FAO Draft Guidelines.

The purpose of the pilot project in Indonesia was to test the means and methods of marking gillnets in accordance with FAO's 'Draft Guidelines' and explore the scope for a retrieval and recycling scheme[399]. The study found that the availability of environmentally friendly materials for markers and fisher safety when operating gear with physical markers were both key issues. Secondly, gear marking must be implemented in the context of broader measures for managing fishing gear and wider fisheries management measures as gear marking alone is unlikely to solve the ALDFG and ghost fishing issues that are apparent in Indonesian small-scale fisheries and probably other similar fisheries, particularly in developing countries[400]. Suggested measures included fisher education and awareness raising, capacity building in general, spatial management of fishing effort and a circular economy approach to managing end-of-life gear. These recommendations were provided to the 33rd session of COFI in 2018.

At the 33rd session of the COFI, the Committee welcomed the recommendations of the Technical Consultation and endorsed the Voluntary Guidelines on the Marking of Fishing Gear[401]. It also supported the development of a comprehensive global strategy to tackle issues relating to ALDFG and agreed to support implementation of the Guidelines. The involvement of small-scale and artisanal fisheries and relevant RFMOs, regional fisheries management arrangements and other relevant international bodies were all encouraged by the Committee. The Guidelines are available in the following languages: English, French and Spanish (in one document[402]), and also Arabic, Chinese and Russian.

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) has set up a new working group (WG 43) that is focussing on sea-based sources of marine litter[403]. The lead agencies for the working group are the FAO and the IMO, with UNEP as a co-sponsor. The working group was established in April 2019 with the overall objective to build a broader understanding of sea-based sources of marine litter, particularly from the shipping and fishing sectors. There are two concurrent work-streams for WG 43. Work-stream 1 will primarily conduct an overarching scoping study to support the initial information requirements of the IMO's action plan to address marine litter from ships and also help to identify priorities for ship-based sources of marine debris. Work-stream 2 will focus on specific areas of research to inform interventions on ALDFG. Terms of References (ToRs)

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399 Dixon, C., Satria, F., Wudianto, Nurdin, E., Utama, A.A., Mahiswara, Toole, J., He, P. 2018. Gear Marking Pilot Study in Indonesian Small-Scale Gillnet Fisheries with Reference to FAO's Draft Guidelines on the Marking of Fishing Gear. FAO Fisheries and Aquaculture Technical Paper No.T632. Rome, FAO. May 2018

400 Ibid

401 FAO 2018. Report of the 33rd Session of the Committee on Fisheries (Rome, 9-13 July 2018). Food and Agriculture Organisation of the United Nation. October 2018. C 2019/23 (Paragraph 105).

402 FAO. 2019. Voluntary Guidelines on the Marking of Fishing Gear. Directives volontaires sur le marquage des engins de pêche. Directrices voluntarias sobre el marcado de las artes de pesca. Rome/Roma. 88 pp. Licence/Licencia: CC BY-NC-SA 3.0 IGO. http://www.fao.org/3/ca3546t/ca3546t.pdf

403 http://www.gesamp.org/work/groups/wg-43-on-sea-based-sources-of-marine-litter

for both work-streams are provided on the GESAMP website[404] and also below for the work-stream 2 ToRs:

- Phase 1: Distribution, trends and impacts
  - ToR 5: Identification of ALDFG hotspots – using data from the GGGI portal and other platforms, and building on the work of CSIRO and others for gear loss studies[405];
  - ToR 6: Quantification of the impacts of ALDFG – environmental, social and economic
- Phase 2: Interventions
  - ToR 7: Review and comparison of options for solution delivery through an analysis of all available data from existing sources, including quantification of benefits, mapping of solution 'hubs' against ALDFG hotspots and identifying common themes and gaps that emerge through recommendations.

The working group aims to produce a first report by early 2020 and a second report by the end of that year.

Producer responsibility and the circular economy

This section builds on the information provided for extended producer responsibility (EPR) in previous marine debris reviews by the CBD[406] [407] and links the approach to achieving a circular economy with a focus on plastics, and with examples primarily from Europe for packaging. Waste packaging makes up a substantial proportion of marine litter, with 37% of all items found on coastal clean-ups recorded as packaging[408]. In addition, more than half of the plastic fraction of marine litter can be made up of plastic packaging waste[409].

EPR can be defined as an environmental policy principle in which a producer's responsibility is extended to the post-consumer stage of a product's life including take-back, recycling and final disposal[410]. This concept has been widely implemented in the European Union over the past 20 years, with the introduction of a variety of EPR schemes and the creation of producer-responsibility organisations (PROs), collective entities set up by producers or through legislation to meet the recovery and recycling obligations of individual producers[411]. PRO-based EPR schemes for packaging typically apply variable fees based on the type of packaging material placed on the market (e.g. glass, paper/card, metals, plastic)[412]. Fees for plastic and for composite packaging materials tend to be significantly higher than fees for other packaging materials[413]. Successful EPR schemes and the associated recycling infrastructures play a significant role in achieving high recycling and recovery rates and diverting

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[404] Ibid
[405] Richardson, K. et al. 2018. Understanding causes of gear loss provides a sound basis for fisheries management. Marine Policy 96: 278-284
[406] CBD 2012
[407] CBD 2016
[408] Ocean Conservancy. 2014. Turning the tide on trash: 2014 Report. http://www.oceanconservancy.org/our-work/marine-debris/icc-data-2014.pdf
[409] European Commission. 2013. Integration of results from three marine litter studies. http://ec.europa.eu/environment/marine/pdf/Integration%20of%20results%20from%20three%20Marine%20Litter%20Studies.pdf
[410] OECD 2014. The state of play on extended producer responsibility (EPR): Opportunities and Challenges. Global Forum on Environment: promoting sustainable materials management through extended producer responsibility (EPR). June 2014, Tokyo, Japan. Issues Paper. 17 pp.
[411] Newman, S. et al. 2015. The Economics of Marine Litter. In: M. Bergmann et al. (eds.), Marine Anthropogenic Litter, Chapter 14 p. 367-394.
[412] Watkins, E., et al. 2019. Policy Approaches to Incentivise Sustainable Plastic Design. Environment Working Paper No. 149. Organisation for Economic Co-operation and Development. OECD ENV/WKP(2019)8.
[413] Pro-Europe. 2017. Participation Costs Overview 2017. http://www.pro-e.org/files/Participation-Costs_2017.pdf

packaging waste away from final disposal[414]. In 2015, recycling of plastic packaging reached 40% on average in the EU, well above the requested 22.5% by the EU Packaging and Packaging Waste Directive[415]. In addition to packaging, a number of EU countries have implemented EPR schemes for other waste items that can contribute to marine litter including textiles, agricultural plastic, medical and pharmaceutical packaging and bulky plastics[416].

Some of the European EPR schemes for packaging charge different fees according to the type of plastic. Schemes in the Netherlands, Latvia, Germany and Austria have lower fees for bio-plastic or biodegradable plastic than other types[417]. Plastic packaging containing additives that make recycling or production of high quality secondary material difficult or impossible could also have higher EPR fees[418]. In France the CITEO EPR scheme operates as a bonus-malus system with increased fees (malus) for undesirable packaging and reduced fees (bonus) for packaging with a lower environmental impact[419]. For example, it applies a 100% increase ('malus') in the fee charged to producers for rigid PET packaging that contains more than 4% mineral opacifier or for plastic bottles that cannot be recycled[420].

Although quite successful, EPR implementation in the EU for waste streams that contain plastics has had a number of problems and weaknesses[421]. A summary of the main actions to re-design EPR schemes in Europe highlights the following points: harmonisation of EPR across the EU, extending schemes to other plastic products, improving the separate collection and treatment of wastes, extending deposit refund schemes, incorporating EPR in a sustainable and circular business models and the use of circular design[422]. The latter, design for reuse and recyclability, is regarded as one of the key issues to improve reuse and recycling levels of end-of-life products. The design stage of a product determines 80% of its environmental impact[423]. Re-design of products could enable the reuse or recycling of a further 30% of plastic packaging[424]. Moreover, improved design can significantly reduce the cost of recycling plastic waste[425]. The introduction of eco-design products standardisations would mean that decisions made at the design stage for a product could be regulated and that the management of a product can be pre-determined at the end of use[426].

More attention should also be paid to the type of business model used when products are developed and included in EPR schemes. Although EPR is targeted to enable the transition to a circular economy, it is also important to clarify the role of the business model that the producers are to adopt for this context

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[414] Newman, S. et al. 2015. The Economics of Marine Litter. In: M. Bergmann et al. (eds.), Marine Anthropogenic Litter, Chapter 14 p. 367-394.
[415] Fihlo, W.L. et al. 2019. An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. Journal of Cleaner Production. 214: 550-558.
[416] Ibid
[417] Watkins, E., et al. 2019. Policy Approaches to Incentivise Sustainable Plastic Design. Environment Working Paper No. 149. Organisation for Economic Co-operation and Development. OECD ENV/WKP(2019)8.
[418] Watkins, E., Gionfra, S., Schweitzer, J.-P. et al. 2017. EPR in the EU Plastics Strategy and the Circular Economy: A focus on plastic packaging. Institute for European Environmental Policy. Brussels, Belgium. 52 pp.
[419] Ibid
[420] CITEO .2017. Le Tarif 2018 pour le recyclage des emballages ménagers. Eco-Emballages. https://www.citeo.com/sites/default/files/2017-10/Tarif2018_Citeo_Emballages_sept2017_0.PDF
[421] Watkins, E., Gionfra, S., Schweitzer, J.-P. et al. 2017. EPR in the EU Plastics Strategy and the Circular Economy: A focus on plastic packaging. Institute for European Environmental Policy. Brussels, Belgium. 52 pp
[422] Fihlo, W.L. et al. 2019. An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. Journal of Cleaner Production. 214: 550-558.
[423] Watkins, E., et al. 2019. Policy Approaches to Incentivise Sustainable Plastic Design. Environment Working Paper No. 149. Organisation for Economic Co-operation and Development. OECD ENV/WKP(2019)8.
[424] Fihlo, W.L. et al. 2019. An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. Journal of Cleaner Production. 214: 550-558.
[425] Ellen MacArthur Foundation, 2017. The New Plastics Economy: Catalysing Action. January 2017. World Economic Forum, 2017. http://www3.weforum.org/docs/WEF_NEWPLASTICSECONOMY_2017.pdf
[426] Watkins, E., et al. 2019. Policy Approaches to Incentivise Sustainable Plastic Design. Environment Working Paper. No. 149. Organisation for Economic Co-operation and Development. OECD ENV/WKP(2019)8.

and take into account the producers' business and economic profitability[427]. A combination of a sustainable and a circular business model that considers EPR has been suggested for businesses that produce or rely on plastic. The 'sustainable circular business model' (SCBM) combines the triple bottom line approach in terms of sustainability with the (circular) systems perspective[428]. A SCBM views the entire business system holistically, analyses sustainability costs and benefits, and evaluates iterative cycles of sustainability and circularity in a business context[429]. As minimising the environmental impact of end-of-life products is implemented on a systems level, the products and production systems of firms need to be designed on circular design principles. SCBMs have been classified into eight archetypes that provide different models to facilitate the transition to a circular economy: 1) Maximise material and energy efficiency; 2) Create value from 'waste'; 3) Substitute with renewables and natural processes; 4) Deliver functionality rather than ownership; 5) Adopt a stewardship role; 6) Encourage sufficiency; 7) Re-purpose the business for society/environment; and 8) Develop scale-up solutions[430].

EPR can provide clear economic incentives for producers/firms and consumers that favour circular products and opportunities for new/innovative circular business models and initiatives[431]. Regarding plastic products, EPR could also stimulate a circular bio-based economy as bio-based plastics are beginning to offer potential for all three pillars of sustainability[432]. Development of sustainable and biodegradable materials such as lignocellulose offers a way to replace oil-based plastics in production and packing materials. Financial resources collected through EPR schemes can be used to develop or improve high quality separate collection and sorting processes for plastic waste, which will be needed to meet more ambitious recycling targets. Overall, EPR should be seen as a part of a wider policy mix so that there is coherence between the objectives and implementation of EPR and other regulatory or economic instruments such as recycling targets, bans, product/material and waste taxes, pay-as-you-throw schemes, labelling, voluntary agreements, procurement policies, and information and awareness campaigns[433].

4.3. Engagement with industry

Industry continues to play an important role in addressing waste management and marine debris. A number of new alliances have been set up both at the global and regional level involving industry, government and civil society. This section highlights a selection of these alliances or consortia.

A cross-industry consortium of companies called NextWave Plastics[434] was launched in 2017 as part of a commitment to Sustainable Development Goal 14. NextWave companies focus on plastics destined for or retrieved from the ocean (ocean-bound plastics), create products and supply chains for these plastics, helping to establish recycling infrastructure in regions where it is lacking. The aim is to develop the first global network of ocean-bound plastics supply chains while also reducing the use of virgin plastic by the companies involved. NextWave are working in countries such as Chile, Cameroon, Denmark, Haiti, Indonesia and the Philippines, with plans to include India, Taiwan and Thailand in the

[427] Fihlo, W.L. et al. 2019. An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. Journal of Cleaner Production. 214: 550-558.
[428] Antikainen, M., and Valkokari, K. 2016. A framework for sustainable circular business model innovation. Technol. Innov. Manage. Rev. 6, 7.
[429] Fihlo, W.L. et al. 2019. An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. Journal of Cleaner Production. 214: 550-558
[430] Bocken, N.M., Short, S.W., Rana, P., Evans, S., 2014. A literature and practice review to develop sustainable business model archetypes. J. Clean. Prod. 65, 42e56.
[431] Fihlo, W.L. et al. 2019. An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. Journal of Cleaner Production. 214: 550-558
[432] Spierling, S., Knüpffer, E., Behnsen, H. et al., 2018. Bio-based plastics-A review of environmental, social and economic impact assessments. J. Clean. Prod. 185, 476e491.
[433] Fihlo, W.L. et al. 2019. An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. Journal of Cleaner Production. 214: 550-558
[434] https://www.nextwaveplastics.org/

next five years. NextWave is committed to diverting a minimum of 25,000 tonnes of plastics from entering or remaining in the ocean by 2025, which is equivalent to 1.2 billion single-use plastic water bottles. The consortium also includes the 5Gyres Institute, the New Materials Institute (University of Georgia), UN Environment and the Zoological Society of London.

By the end of 2017 The Declaration of the Global Plastics Associations for Solutions on Marine Litter had been signed by seventy-five plastics organisations and allied industry associations from forty countries[435]. Since 2011 more than 355 projects have been implemented or completed to tackle marine debris. A snapshot of projects initiated since 2016[436] includes:

- A litter prevention campaign for both land and marine environments called 'Keep it Beachy Clean' in Virginia, USA, targeting beach visitors;
- Public opinion research for residents of the Arabian Gulf Cooperation Countries (GCC) to measure awareness and attitudes towards plastics and environmental responsibility;
- The Alliance for Marine Plastics Solutions (AMPS) launched in Indonesia to develop public-private partnerships and accelerate marine litter projects across the country;
- The African Marine Waste Network (AMWN), for the 38 coastal and island states of Africa, provides a platform to share resources and knowledge between countries;

The Alliance to End Plastic Waste (AEPW)[437] was launched in January 2019 by a group of global companies from the plastics and consumer goods value chain. It brings together the finance community, government and civil society to tackle the issue across the whole plastics value chain including chemical and plastic manufacturers, consumer goods companies, retailers and waste management companies. The alliance includes more than 35 global companies and has committed USD $1.5 billion to address plastic waste over the next five years. The World Business Council for Sustainable Development is a key strategic partner for the alliance. The aim is to drive progress in four key areas:

1. Infrastructure development to collect and manage waste and increase recycling;
2. Innovation to advance and scale new technologies that make recycling and recovering plastics easier and create value from all post-use plastics;
3. Education and engagement of governments, businesses, and communities to mobilize action; and,
4. Clean up of concentrated areas of plastic waste already in the environment, particularly the major conduits of waste, such as rivers, that carry land-based plastic waste to the sea.

In Africa a group of global consumer goods companies operating across the continent launched the African Plastics Recycling Alliance[438] at the Africa CEO Forum in March 2019, with the aim to transform plastics recycling infrastructure in sub-Saharan Africa. Companies in the alliance have agreed to support their local subsidiaries to engage in market-level public-private partnerships and industry collaborations. The alliance promotes innovation and collaborates on technical solutions and local pilot initiatives to improve plastics collection and recycling, which is expected to create jobs and commercial activity. The companies involved[439] also engage with the investment community and policymakers to accelerate the development and financing of waste management systems including infrastructure.

In May 2019, the World Wildlife Fund (WWF), as part of their global 'No Plastic in Nature' campaign, launched an 'activation hub' called ReSource[440] to help companies and organisations translate commitments to reduce or eliminate plastic into measurable action. The hub promotes a systems-based

[435] https://www.marinelittersolutions.com/about-us/joint-declaration/
[436] https://www.marinelittersolutions.com/wp-content/uploads/2018/04/Marine-Litter-Report-2018.pdf
[437] https://endplasticwaste.org/
[438] https://sdg.iisd.org/news/companies-launch-african-plastics-recycling-alliance/
[439] The Coca Cola Company, Diageo, Nestlé and Unilever
[440] https://resource-plastic.com/

approach to tackling plastic production, consumption, waste management and recycling. Through ReSource, WWF helps member companies to 'maximise, measure, and multiply their impact' with regard to their plastic footprint and then provide the expertise and tools to implement those interventions. The hub also connects businesses with other stakeholders to share best practices, help improve the speed and scale of efforts, and stimulate additional investments to multiply these efforts and their impact on plastic pollution.

4.4. Environmental education and awareness building

Since the release of the previous CBD report on marine debris[441] there has been a substantial increase in public awareness of the issue which has predominantly focussed on plastic. This has partly come about through various types of media including 'social media'. The documentary series Blue Planet II highlighted plastic pollution in the marine environment and was watched by an estimated 750 million people worldwide[442] in 2017. This programme, amongst others, has inspired people to take action in reducing or eliminating single use plastic from their daily lives. Plastic pollution has certainly caught the public's attention as it is visually impactful, with images of plastic filled shorelines or charismatic megafauna entangled or ingesting plastic have become common[443].

Awareness and education campaigns to reduce or prevent waste materials from entering the marine environment can be very effective tools to target a range of audiences in the public or private sector[444]. An assessment of waste abatement strategies in Australia compared outreach programmes run by local councils to state-enacted policies aimed at targeting human behaviour to reduce waste[445]. The study revealed that investments in campaigns led to larger reductions of waste in the environment than did investment in policies. Councils that provided litter education programmes had significantly less waste on their coastlines. Implementing a combination of recycling, litter prevention and illegal dumping outreach programmes was regarded as the best approach for reducing waste on a coastline[446]. Raising public awareness through education programmes is effective as it creates a sense of environmental responsibility in participants[447]. Such programmes have successfully reduced waste in Europe[448 449], the USA[450] and Malaysia[451]. Clean-up campaigns have immediate aesthetic results but do not address the source of the waste materials or result in a net reduction in waste reaching the marine system[452]. Such end-of-pipe solutions have been likened to fixing an overflowing bath by mopping up the water spilling onto the floor rather than turning off the tap[453]. However, coastal clean-ups can create a sense of beach

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441 CBD Technical Series No.83
442 https://canvas-story.bbcrewind.co.uk/blue-planet-two-six-months-on/
443 Stafford R., Jones P.J.S. 2019. Viewpoint – Ocean plastic pollution: a convenient but distracting truth? Marine Policy 103, 187-191. https://doi.org/10.1016/j.marpol.2019.02.003
444 TS 83
445 Willis, K., et al. 2018. How successful are waste abatement campaigns and government policies at reducing plastic waste into the marine environment.? Marine Policy 96: 243-249.
446 Ibid
447 Uneputty, P., Evans, S.M. and E. Suyoso. 1998. The effectiveness of a community education programme in reducing litter pollution on shores of Ambon Bay (eastern Indonesia). J. Biol. Educ. 32: 143–147.
448 Veiga, J.M., Vlachogianni, T., Pahl, S. et al. 2016. Enhancing public awareness and promoting co-responsibility for marine litter in Europe: the challenge of MARLISCO. Mar. Pollut. Bull. 102: 309–315.
449 B.L. Hartley, B.L., Thompson, R.C. and Pahl, S. Marine litter education boosts children's understanding and self-reported actions, Mar. Pollut. Bull. 90: 209–217.
450 Hasan, S. Public awareness is key to successful waste management, J. Environ. Sci. Health, Part A 39:483–492
451 Pudin, S. 2015. Development of an Environmental Education Programme for Waste Management with Local Communities in Sabah, Malaysia, University of Waikato, Hamilton, New Zealand.
452 Willis, K., et al. 2018. How successful are waste abatement campaigns and government policies at reducing plastic waste into the marine environment.? Marine Policy 96: 243-249
453 Pahl, S., Wyles, K.J., and Thompson, R.C. 2017. "Channelling Passion for the Ocean Toward Plastic Pollution". Nature Human Behavior 1: 697-699. doi:10.1038/s41562-017-0204-4

custodianship and encourage the participants to question their littering behaviour by educating them on the issue of marine debris[454].

Human behaviour is a major factor contributing to marine debris and behavioural change by individuals can help to tackle the issue[455]. Working with educators and school students has considerable potential to facilitate greater public understanding of the solutions for tackling marine litter, and to enable action[456]. A study as part of the European MARLISCO project[457] examined two educational activities designed to empower educators and students to engage with the topic of marine litter[458]. Firstly, participation in an online training course for an educator resource pack significantly bolstered educators' perceived understanding and knowledge on the topic, and their sense of confidence, competence and skills in marine litter education[459]. Secondly, after participating in an environmental education project (a video competition about marine litter) school students were more concerned about the issue and perceived greater negative impacts and causes. They also reported more waste reduction behaviours and encouraged their family and friends to take more action regarding marine litter indicating the potential of a wider social multiplication effort[460].

The resource pack developed for educators is designed for use with students aged between 10 and 15 years in both formal and non-formal educational settings[461]. It contains seventeen learning activities that examine the characteristics, sources, effects and possible ways to tackle marine litter, addressing it from an environmental, societal, cultural and economic point of view[462]. The educational pack is available online and has been translated into fifteen languages[463]

Education of the general public on marine litter issues is available at the global level through a massive open online course (MOOC) launched in 2015-2016. The third version of the Marine Litter MOOC was launched in April 2019 by UN Environment and The Open University in the Netherlands as part of the Clean Seas campaign[464]. This version builds on the previous two courses to provide the latest knowledge and insights on marine litter while also responding to feedback from former students. The course provides examples and case studies to inspire leadership through action orientated learning to increase awareness of marine litter problems. The MOOC is available as a two-week or eight-week course in six languages.

There have been calls to use psychological principles and behavioural science to motivate and implement change by connecting symptoms and sources of plastic pollution[465]. It is suggested that solutions to the problem require individuals and communities to make connections between the issues in the marine environment and day-to-day behaviours and systems. Using powerful tools for engaging and motivating people can ultimately change behaviour. One example is visualisation with the

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[454] Storrier, K.L. and McGlashan, D.J. 2006. Development and management of a coastal litter campaign: the voluntary coastal partnership approach, Mar. Policy 30: 189–196.
[455] Pahl, S., Wyles, K.J., and Thompson, R.C. 2017. "Channelling Passion for the Ocean Toward Plastic Pollution". Nature Human Behavior 1: 697-699. doi:10.1038/s41562-017-0204-4.
[456] Hartley, B.L., Pahl, S., Holland, M. et al. 2018. Turning the tide on trash: Empowering European educators and school students to tackle marine litter. Marine Policy 96: 227-234
[457] MARine LItter in European Seas: Social AwarenesS and CO-Responsibility. http://www.marlisco.eu
[458] Hartley, B.L., Pahl, S., Holland, M. et al. 2018. Turning the tide on trash: Empowering European educators and school students to tackle marine litter. Marine Policy 96: 227-234
[459] Ibid
[460] Ibid
[461] Iro Alampei, I. et al. 2014. Know, Feel, Act! To Stop Marine Litter: Lesson Plans and Activities for Middle School Learners, MIO-ECSDE, Greece. ⟨http://www.marlisco.eu/education.en.html⟩.
[462] Hartley, B.L., Pahl, S., Holland, M. et al. 2018. Turning the tide on trash: Empowering European educators and school students to tackle marine litter. Marine Policy 96: 227-234
[463] http://www.marlisco.eu/education.en.html
[464] https://www.ou.nl/-/unenvironment-mooc-marine-litter
[465] Pahl, S., Wyles, K.J., and Thompson, R.C. 2017. "Channelling Passion for the Ocean Toward Plastic Pollution". Nature Human Behavior 1: 697-699. doi:10.1038/s41562-017-0204-4

suggestion that using powerful images on everyday plastic products could be one way of linking people's passion for the ocean to the use of plastics in daily life, which may result in more careful consumption and disposal behaviours[466]. Stories and narratives are also powerful tools for raising awareness and motivating change[467]. There is a need to work together across disciplines and sectors to implement solutions to marine plastic pollution and build on the strengths of humans to facilitate change, which must be socially acceptable as well as economically and technically viable[468].

5. SUMMARY AND CONCLUSIONS

Marine debris is regarded as a significant global stressor to marine and coastal biodiversity and habitats[469]. An increasing number of marine species are being affected by debris, mainly through ingestion or entanglement. However, some of the impacts on marine and coastal biodiversity have been perceived but not adequately demonstrated scientifically. There is strong evidence of demonstrated effects on individual organisms from both ingestion and entanglement but very little currently available at higher ecological levels in terms of impacts[470]. The quantity and quality of research on marine debris effects at the ecological level needs to be improved in order to draw any clear conclusions for higher levels of organisation (e.g. populations)[471]. However, particular marine taxa have been highlighted as particularly vulnerable to marine debris, with strong concern that population effects could occur. For example, marine turtles are highly susceptible to mortality from either macro-debris ingestion or entanglement and have been regarded as a global conservation priority[472]. Otariid marine mammals (seals and sea lions) are also considered to be highly threatened through entanglement by derelict fishing gear[473]. Despite the problems and uncertainties in the research conducted to date, there appears to be enough evidence for policy makers to recognize the hazards and take a precautionary and/or anti-catastrophe approach[474].

Microplastic marine debris has gained considerable attention over recent years both in terms of measuring and monitoring microplastics in the marine environment and the perceived and demonstrated effects on marine life. Research is beginning to explain why microplastics are so attractive to some marine fauna during feeding as well as identify ingestion effects for a variety of taxa. Microplastic particles in the ocean can develop a strong infochemical signature and create an olfactory trap for foraging seabirds and other susceptible marine fauna. Ingestion of microplastics can also have significant effects on marine invertebrates such as oysters in terms of feeding and reproduction. Physical and chemical effects on larval fish development have also been reported which may influence recruitment and early mortality for populations. More attention is turning to nanoplastics and their interactions with marine life, for which little is known in coastal and oceanic waters, but are regarded

[466] Ibid (Figure 1).
[467] Dalhstrom, M.F. 2014. Using narratives and storytelling to communicate science with nonexpert audiences. Proc. Natl Acad. Sci. USA 111: 13614–13620
[468] Pahl, S., Wyles, K.J., and Thompson, R.C. 2017. "Channelling Passion for the Ocean Toward Plastic Pollution". Nature Human Behavior 1: 697-699. doi:10.1038/s41562-017-0204-4
[469] Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity. Technical Series No.83. 2016. Secretariat of the Convention on Biological Diversity, Montreal, 78 pages.
[470] Rochman, C.M. et al. 2016. The ecological impacts of marine debris: unravelling the demonstrated evidence from what is perceived. Ecology 97: 302-316.
[471] Ibid
[472] Nelms, S. E., et al. 2016. Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science 73: 165–181
[473] Franco-Trecu, V. et al., 2017. With the noose around the neck: Marine debris entangling otariid species. Env. Poll. 220: 985-989
[474] Rochman, C.M. et al. 2016. The ecological impacts of marine debris: unravelling the demonstrated evidence from what is perceived. Ecology 97: 302-316.

as potentially the most hazardous[475]. Techniques to detect and characterise nanoplastics in the marine environment are still being developed. Research has identified some effects on marine fauna in laboratory conditions for plankton and some organisms at early life stages, but these have not been shown in the wild and are carried out in un-natural conditions or with engineered particles. Nanoplastic research in the marine context is a key area in need of development.

Marine plastic pollution has been regarded as an emerging Anthropocene risk[476] with plastic considered as a geological marker for this epoch in which human activities have a decisive influence on the state, dynamics and future of the earth system[477]. There has been some discussion in recent years on whether plastics meet the criteria for being a planetary boundary threat[478] [479]. Studies suggest that plastics do meet two out of three defined categories for chemical pollution to pose a planetary boundary threat in that there is planetary-scale exposure that is not readily reversible[480] [481]. However, there is not sufficient evidence at present to confirm that marine plastic pollution meets the third condition of disrupting earth system processes[482], although evidence is growing for the ecological effects of plastic pollution in the oceans. With this in mind, other global stressors, biodiversity loss and climate change, that have long-exceeded core planetary boundaries (safe operating limits for humanity), have been regarded as more pressing issues to tackle[483].

Large-scale systemic changes are needed globally to tackle all environmental concerns, including plastic[484], that include extensive initiatives to reduce consumption, decarbonise economies and move beyond materialism as the basis of human well-being[485]. Addressing plastic through a circular economy approach that embraces EPR will be an important part of this process for transformative change. This should form part of an integrated multi-sectoral approach containing the four key elements mentioned in the previous CBD marine debris report that have proven successful: regulatory measures; voluntary (non-regulatory) measures; adequate infrastructure; and education and awareness[486]. This report has provided recent examples of initiatives in place and measures taken to enable these elements and address marine debris, particularly with regards to plastic.

To improve governance of marine debris there is a need for stronger regulation at national, regional and international levels. There have been calls for the creation of new laws specifically for marine plastic pollution or the strengthening of existing national laws, especially for waste management and

[475] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p.
[476] Villarubia-Gómez, P., Cornell, S.E., and Fabres, J. Marine plastic pollution as a planetary boundary threat – The drifting piece in the sustainability puzzle. Marine Policy 96: 213-220.
[477] J. Zalasiewicz, C.N. Waters, J.A. Ivar do Sul, et al. 2016. The geological cycle of plastics and their use as a stratigraphic indicator of the Anthropocene. Anthropocene 13: 4–17.
[478] Rockström, J. and Noone, K. 2009. Planetary boundaries: exploring the safe operating space for humanity, Ecol. Soc. 14.
[479] MacLeod, M., et al. 2014. Identifying chemicals that are planetary boundary threats, Environ. Sci. Technol. 48:11057–11063. http://dx.doi.org/10.1021/ es501893m.
[480] Jahnke, A. et al. 2017. Reducing uncertainty and confronting ignorance about the possible impacts of weathering plastic in the marine environment, Environ. Sci. Technol. Lett. 4: 85-90.
[481] Villarubia-Gómez, P., Cornell, S.E., and Fabres, J. Marine plastic pollution as a planetary boundary threat – The drifting piece in the sustainability puzzle. Marine Policy 96: 213-220
[482] Ibid
[483] Stafford, R. and Jones, P.J.S. 2019. Viewpoint - Ocean plastic pollution: A convenient but distracting truth? Marine Policy 103: 187-191. https://doi.org/10.1016/j.marpol.2019.02.003
[484] Ibid
[485] Raworth, K. 2017. Why it's time for Doughnut Economics. IPPR Progressive Review, 24: 216222. https://doi.org/10.1111/newe.12058
[486] Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity. Technical Series No.83. 2016. Secretariat of the Convention on Biological Diversity, Montreal, 78 pages

recycling[487]. Regulatory measures have been introduced across the world at the national level for plastic bags with generally high success. A new raft of measures for single-use plastics have been implemented in some regions such as Europe and should be realised in others keeping in mind both national and regional context using recently developed guidance (Appendix 3)[488]. The development and implementation of regional marine litter action plans has also progressed well over the last five years with most Regional Seas bodies having these in place or underway. A new international agreement for marine plastic pollution has been suggested so that there is global collaboration to reduce the demand for single-use plastics, shift to a sustainable plastics economy and improve waste management infrastructure that promotes zero waste[489]. New decisions within existing agreements are starting to address the issue of plastic waste. For example, the Basel Convention has recognised plastic waste as a waste type of special concern which, along with the complementary work of the Partnership on Plastic Waste, will mean that the trade in plastic waste is better regulated and more transparent.

Solid waste management in many countries remains a challenge and should be a key priority given the projections for the increase in solid waste quantities over the next few decades[490]. The development of adequate infrastructure for solid waste collection and processing including recycling is required and should be supported both logistically and financially. This should go hand in hand with the development and implementation of EPR policies and schemes with expansion to a wider range of mainly plastic products once, or if already, established. As waste management infrastructure is developed, national or municipal education and awareness campaigns should also be implemented to inform the public of the management system, which should help improve human behaviour with regards to litter and recycling.

Increased education and awareness are regarded as key to minimizing further increases in marine debris and its associated impacts[491]. Implementing targeted, well-conceived awareness programmes can be a crucial factor for the success of regulatory measures[492]. Raising awareness is also an important part of citizen science initiatives; for example, coastal clean-ups allow participants to tackle marine debris as well as collect useful information in terms of monitoring. However, such downstream activities do not address the root causes of marine / plastic debris generation, which is where the development of the circular economy is crucial. Recommendations to enable this include the use of circular design for products and the development of sustainable circular business models.

Engagement with industry is an important part of tackling marine debris and plastic pollution. A number of alliances have been set up, both at the global and regional level, involving industry, government and civil society. A notable example is the New Plastics Economy initiative[493] that has established a global commitment to tackle plastic packaging with over 400 signatories from a range of stakeholders including countries, inter-governmental and civil society organisations, educational and financial institutions and over 200 businesses involved in the plastic packaging value chain. The commitment includes specific reduction targets up to 2025 with the option to revise the minimum level of ambition going forward. Key aspects are better coordination and innovation across the value chain.

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[487] Garcia, B., Fang, M.M., and Lin, J. 2019. All Hands on Deck: Addressing the Global Marine Plastics Pollution Crisis in Asia. APCEL Working Paper Series 19/02, May 2019.

[488] UNEP 2018. Single-Use Plastics: A Roadmap for Sustainability. https://www.unenvironment.org/resources/report/single-use-plastics-roadmap-sustainability

[489] Borelle, S.B. et al. 2017. Opinion: Why we need an international agreement on marine plastic pollution. PNAS 114: 9994-9997.

[490] Silpa, K. et al. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development Series. Washington, DC: World Bank. doi:10.1596/978-1-4648 -1329-0.

[491] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel – GEF. 2012. Impacts of marine debris on biodiversity: current status and potential solutions. Montreal, Technical Series No. 67, 61 pp. https://www.cbd.int/doc/publications/cbd-ts-67-en.pdf

[492] Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity. Technical Series No.83. 2016. Secretariat of the Convention on Biological Diversity, Montreal, 78 pages.

[493]

Ensuring that the maximum amount of plastic waste can be re-used is an important aspect, especially for mixed plastic waste that is difficult to recycle. Chemical and biotechnological processes are in development that are able to recover use or value from mixed plastic waste. It has been suggested that the integration of these and other recycling techniques with controlled biological activity (e.g. microbial or fungal) could make a significant contribution to achieving the goal of a circular economy for the mixed plastic waste sector. Further work is needed for this sector along with support for research and development up to a commercial scale.

The development of fully biodegradable and compostable single use items that can replace plastic ones continues to make progress with multiple items now in small-scale production made from organic materials such as cellulose, seaweed or cassava. However, verification of biodegradability is important. There is a need to improve standards for testing the biodegradability of plastics within aquatic environments and also test for potential adverse impacts from the plastic item in question such as toxicity, degradation and fragmentation.

Sea-based sources of marine debris are responsible for a high proportion of debris items on the surface of the oceans, with ALDFG a major cause of injury or death to marine fauna through ghost fishing. Understanding the causes of gear loss are important for tackling the issue. Studies have shown that fishing gear loss can be closely linked to how well a fishery is managed. The marking of fishing gear is one approach to reduce loss and guidelines have recently been developed for this by the FAO. Another global initiative to address ALDFG that is making substantial progress is the GGGI while a new working group has been set up by GESAMP to further focus on the issue.

The GESAMP Working Group 40 highlighted a range of recommendations for management, as part of phase two of their assessment of microplastics[494], many of which are applicable to marine debris in general (Table 3). Those listed in bold have been highlighted in the various sections of this report through examples of policies, measures or activities to mitigate the production or build-up of marine debris. Many of the others have been covered in the previous marine debris technical series reports.

Table 3. Recommendations for management of marine debris by the GESAMP WG 40 (2016).

Subject Area	Recommendation
Sources	• Identify the intervention point to stop debris at source • Target mitigation in local waste streams • Phase out plastics that are designed to be littered • Design and produce plastics that have a more recoverable end-of-life strategy • Reduce single-use items • Build more infrastructure for waste management in a rapidly developing world • Raise awareness by teaching others where marine debris comes from and ultimately goes
Distribution, fate and hot-spots	• Focus source reduction and clean-up efforts in locations with larger sources of marine litter • Target hotspots that overlap with MPAs for mitigation • Raise awareness in hot-spot regions • Use government intervention to fund large-scale clean-up in regions with high concentrations of marine litter
Ecological Impacts	• Develop educational and awareness programmes: i. to describe the impacts of marine debris on ecosystems to industry, government and non-government organisations, and ii. for the public and students at all levels to increase motivation for action to help mitigate the problem
Commercial fish and shellfish	• Mark fishing gear and aquaculture nets to keep track of lost gear • Redesign fishing and aquaculture equipment to be more environmentally sustainable

[494] GESAMP 2016. Sources, fate and effects of microplastics in the marine environment: part two 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). Rep. Stud. GESAMP No. 93, 220 p

	• Include microplastic contamination as a criterion for aquaculture site selection • Reduce practices that can increase microplastic generation • Integrate microplastic into seafood guidelines for sustainability and food safety • Provide incentives for recovering lost fishing gear • Increase port facility infrastructure for waste removal and recovery
Socio-economic aspects	• Create a cost for plastic polluters e.g. through EPR • Increase the cost of plastic by internalising external costs of end-of-life waste management and/or costs for addressing littering and marine litter • Make plastic more valuable to encourage reuse, repair, remanufacture and recycling • Increase support for separate waste collection by households • Put tax or deposit-refund fees on single-use plastics (e.g. bottles and bags) • Pay fishermen to collect litter • Invest in new / improved waste management infrastructure especially along rivers, in ports and on beaches • Engage more stakeholders through awareness campaigns • Encourage positive changes in behaviour

Not mentioned in the above table are some of the emerging issues regarding marine debris that are linked to climate change. Degrading plastic waste is known to release greenhouse gases into the atmosphere. The amounts released are predicted to increase as plastic waste increases in the environment although it is not yet known if this is a significant source, as yet unrecognised in global estimates. Secondly, it has been suggested that the projected increase in adverse weather conditions and changes in climate for ocean regions such as at the poles is likely to enhance the spread of invasive species that are transported on floating marine debris. Both known and potential interactions between marine debris and climate change related factors, and their effects on marine and coastal biodiversity, require further investigation.

This report has provided an update to the previous work undertaken on marine debris by the SCBD. However, it should be noted that there are likely to be new initiatives and findings for this topic, particularly for plastics, that have not been reported here as the subject is receiving considerable and increasing attention from the research community, governmental bodies, industry and the general public. The key solutions and successful approaches have been provided or reiterated with examples, and can be taken up by parties as needed at the local, national or regional level.

6. APPENDICES

Appendix 1. Summary Table of Relevant International and Regional Resolutions, Decisions and Agreements relating to Marine Debris (2015 – 2018)

No.	Year	Title of Document	Link
1	2016	Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity-XIII/10. Addressing impacts of marine debris and anthropogenic underwater noise on marine and coastal biodiversity	https://papersmart.unon.org/resolution/uploads/2016-impacts_of_marine_debris_and_underwater_noise.pdf
2	2016	Creating Innovative Solutions Through the Basel Convention for the Environmentally Sound Management of Household Waste	https://papersmart.unon.org/resolution/uploads/2016creating_innovative_solutions_through_basel_conv.pdf
3	2017	Basel Convention Regional and Coordinating Centres	https://papersmart.unon.org/resolution/uploads/2017basel_convention_regional_and_coordinating_centres.pdf
4	2017	BC-13/17: Work programme and operations of the Open-ended Working Group for the biennium 2018–2019	https://papersmart.unon.org/resolution/uploads/2017work_programme_and_operations_of_the.pdf
5	2017	2017 World Trade Organization-Regular Notification	https://papersmart.unon.org/resolution/uploads/2017world_trade_organization-chn1211_1.pdf
	2016	Resolution adopted by the General Assembly on 23 December 201671/257. Oceans and the Law of the Sea	https://papersmart.unon.org/resolution/uploads/2016-ungaoceans_and_the_law_of_the_sea-n1646662.pdf
6	2017	Resolution Adopted by the General Assembly on 6 July 2017-71/312. Our Ocean, Our Future: Call for Action	https://papersmart.unon.org/resolution/uploads/2017our_ocean_our_future-n1720756.pdf
7	2017	Resolution adopted by the General Assembly on 7 December 2016-71/123. Sustainable fisheries, including through the 1995 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, and related instruments	https://papersmart.unon.org/resolution/uploads/2017-ungasustainable_fisheries-n1643033.pdf
8	2015	Resolution adopted by the General Assembly on 25 September 2015-70/1. Transforming Our World: The 2030 Agenda for Sustainable Development	https://papersmart.unon.org/resolution/uploads/2015-ungatransforming_the_world.pdf
9	2015	Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions Closing the loop - An EU action plan for the Circular Economy	https://papersmart.unon.org/resolution/uploads/2015eu_action_plan_for_the_circular_economy.pdf

Appendix 2: Compilation of submissions received in response to notification 2018-080

Submitter	Main Actions described in submission	Specific measures/actions described in submission
PARTIES AND OTHER GOVERNMENTS		
Canada	**International Actions**	Contributes to the advancement of policies and scientific knowledge in international fora including the G7, G20, the Artic Council and various U.N. bodies Active implementation of legally binding international agreements that contribute to waste / litter prevention including the: • Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal • International Convention for the Prevention of Pollution from Ships (MARPOL) • London Convention and Protocol to prevent marine pollution by dumping at sea • As G7 President, championed the development of an Ocean Plastics Charter (2018) • Commitment by fifteen governments and twenty companies / organisations to improve the sustainability of production and management, reducing waste and marine litter • As part of G7 agenda, committed $100 million CAD to support the development of plastic waste solutions in developing countries which includes: o $65 million for improved waste management and clean-ups (via World Bank) o $20 million to support the G7 Innovation Challenge to Address Marine Litter o $6 million for innovative public-private partnerships through the World Economic Forum's Global Plastics Action Partnership • Pledged to take action via the UN Clean Seas Campaign (2017) • Member of the UN Global Partnership on Marine Litter (GPML) • Contributed to the updated FAO guidance on fishing gear • Member of the Global Ghost Gear Initiative

		• Contributing to the study of marine litter and microplastic in the Arctic as part of the Arctic Council's Protection of the Arctic Marine Environment Working Group
		• Contributing to work under the London Convention to improve analysis of plastic particles in dredged materials and sewage sludge by developing methods to detect plastics in dredged materials from ocean disposal sites
		• Collaboration with the U.S.A. and Mexico since 2017 via the Commission for Environmental Cooperation, working in two transboundary watersheds to:
		   o engage local decision makers and communities in identifying marine litter challenges
		   o implement small-scale solutions, build local capacity and awareness through citizen science and outreach

	Domestic / National Actions	Increased action by government (all levels), industry, non-profit organizations and academia to prevent and reduce marine litter in Canada
	Federal Level	Government has over ten federal acts, regulations and agreements that contribute to the prevention of marine plastic debris. These include the: • Canada Shipping Act and Canadian Environmental Protection Act (CEPA) - prohibit the discharge or disposal of litter in Canadian waters • Fisheries Act – prohibits the deposit of deleterious substances into domestic waters • Species at Risk Act – has a provision for the protection of critical habitat for listed species including aquatic species at risk in the marine environment • Microbeads in Toiletries Regulations (2017) – prohibit plastic microbead containing toiletries with complete ban in place by July 2019 Government commitment to divert at least 75% of its plastic waste in federal operations by 2030. To be accomplished through change to federal practices and procurement of more sustainable plastic products (reusable, recyclable, repairable or made with recycled plastic)
	Sub-Federal Levels	Range of policies, programs and regulatory initiatives at other government levels, especially for improvements in the production, use and disposal of materials: • Provincial, territorial and municipal governments have implemented regulatory (e.g. bans, levies, extended producer responsibility programs, litter by-laws) and non-

		regulatory measures (e.g. educational campaigns, recycling and deposit programs) for some plastic products and other waste materials • All provinces and territories (except Nunavut) have regulated extended producer responsibility (EPR) programs in place • Over 160 regulated and voluntary stewardship programs are in place covering more than twenty product categories including packaging and beverage containers • Municipalities have local waste programming and anti-litter byelaws
	All Government Levels	Federal, Provincial and Territorial Governments agreed (in principle) in November 2018, through the Canadian Council of Ministers of the Environment (CCME), to: • A **Strategy on Zero Plastic Waste -** committed to work with all stakeholders to develop an action plan in 2019 focusing on identifying specific solutions. The circular economy approach taken will address plastics throughout the value chain and provide a platform for collaboration • The endorsement of a Canada-wide waste reduction goal to reduce personal waste production by 30% in 2030 and 50% by 2040

	Advancement of Scientific Knowledge	Canadian Government is improving its understanding of the plastics economy in Canada and the sources, distribution, fate and impacts of marine litter in the environment and biota:
		• Federal research on the interactions of plastic pollution on marine fauna, mainly fish and seabirds
		• Environment and Climate Change Canada (ECCC) hosted a science symposium to help inform Canada's plastic science agenda
		• Support for researchers through a number of programs including the Natural Sciences and Engineering Research Council of Canada and the Northern Contaminants Program e.g.:
		    o ECCC supported Ocean Wise with $68,000 CAD to develop methodologies for microfiber sampling, identification and quantification
		    o Support of more than $130,000 CAD to academia and NGOs to improve understanding of microplastics in specific locations including the Great Lakes, Atlantic region and the St John river watershed

	Industry and Innovation
	
	Education and Awareness Raising
		• Fisheries and Oceans Canada committed over $2 million CAD since 2016 for research on microplastics in aquatic ecosystems such as the Ocean Wise pollution tracker program along the coast of British Columbia
		
		In 2018, the Canadian Government committed over $12 million CAD to innovators and businesses to tackle plastic challenges is seven key areas: separation of mixed plastics, food packaging, plastic wastes from construction activities, removal and management of ghost fishing gear and marine debris, improved compostability of bioplastics, recycling of glass fiber-reinforced plastic, and, sustainable fishing and aquaculture gear.
		
		Both industry and public engagement and support for communities and organisations for educational and on-the-ground projects:
		• ECCC provided over $2.2 million since 2016 for educational and awareness raising projects related to plastics and marine litter:
		  o Launch of Oceans Plastics Education Kit in 2018 (Federal Gvt and five NGOs)
		  o Canadian- German Government partnership to bring the Oceans Plastic Lab exhibit to Canada
		  o Great Canadian Shoreline Clean-up – national program led by WWF and Ocean Wise, in partnership with the Canadian Government to remove debris from coastlines and collect citizen science data
		• Transport Canada's Abandoned Boats Program provides financial support to help remove abandoned or wrecked small boats and raises awareness about boat owner responsibility and improving the management of end-of-life boats

Colombia	**Domestic / National Actions**	National Policies: • National Policy for the Integral Management of Solid Waste (CONPES 3874/2016) o Initial basis for moving towards a circular economy by maintaining the value of products and materials for as long as possible to minimise waste and resource use • Resolution 646 of the Ministry of Environment and Sustainable Development (2017) enabled INVEMAR to assess the state of pollution through estimates of marine litter, plastics and microplastics in coastal and mangrove ecosystems[495]:

[495] Instituto de investigaciones Marinas y Costeras "José Benito Vives de Andréis" (INVEMAR). , INVEMAR. 2017. Diagnóstico y evaluación de la calidad de las aguas marinas y costeras en el Caribe y Pacífico colombianos. Bayona-Arenas, M. y Garcés-Ordóñez, O. (Ed). Red de vigilancia para la conservación y protección de las aguas

		○ 2250 types of plastic articles recorded from 23 Caribbean beaches in 5 provinces, and from 15 Pacific beaches in three provinces ○ Mainly disposable, domestic and industrial types of plastics ○ Information also collected from National Authority of Aquaculture and Fisheries (AUNAP) for fishing-related contribution to marine debris indicated that this makes up 10% of marine debris, comprised mainly of abandoned fishing gear. Assessment of the environmental management of solid waste in the coastal zone: • Process led by INVEMAR in collaboration with the Ministry of Environment and Sustainable Development; Coastal CARs, Vice Ministry of Housing and Sanitation and the Colombian Ocean Commission • Based on the information collected INVEMAR developed a roadmap to characterize and monitor marine debris in terms of environmental and socio-economic effects • Roadmap contained five themes with specific targets for 2, 5 and 20 years • Five themes are (i) research and monitoring (ii) strengthening operational and technical capacity (iii) communication (iv) awareness and participation, and (v) articulation with technical and normative instrumentation. Beach clean-ups carried out on seven beaches of the Antioquia province[496] and six beaches of Magdalena province[497]. The number, type and total weight of marine debris articles was recorded.

marinas y costeras de Colombia – REDCAM: INVEMAR, MinAmbiente, CORALINA, CORPOGUAJIRA, CORPAMAG, CRA, CARDIQUE, CARSUCRE, CVS, CORPOURABÁ, CODECHOCÓ, CVC, CRC y CORPONARIÑO. Informe técnico 2017. Serie de Publicaciones Periódicas No. 4 del INVEMAR, Santa Marta. 336 p.+ anexos

[496] Instituto de investigaciones Marinas y Costeras "José Benito Vives de Andréis" (INVEMAR). 2018a. Diagnóstico del estado de contaminación por basura marina y microplásticos en las principales playas turísticas del Departamento de Antioquia. En: INVEMAR y Corporación para el Desarrollo Sostenible del Urabá (CORPOURABÁ). 2018. Actividades de investigación para la gestión de las aguas marino-costeras del departamento de Antioquia. Convenio interadministrativo No. 037 de 2018 CORPOURABA-INVEMAR

[497] Instituto de investigaciones Marinas y Costeras "José Benito Vives de Andréis" (INVEMAR). 2018b. Evaluación de la calidad del recurso hídrico marino costero del departamento del Magdalena en el marco del programa nacional de monitoreo de la REDCAM en: INVEMAR y Corporación Autónoma Regional del Magdalena (CORPAMAG). 2018. Evaluación de las condiciones ambientales de la zona marino costera del departamento del Magdalena como herramienta para la gestión ambiental de CORPAMAG. Convenio de asociación No. 211 de 2017 CORPAMAG-INVEMAR

	Priority Measures:	Pilot study of the amount and effects of marine litter on mangrove ecosystems conducted in the Ciénaga Grande de Santa Marta (CGSM) in 2018[498]:
		• Twenty-one potential environmental impacts were identified
		• Fieldwork confirmed ten of these impacts including:
		  ○ Physical change to sediment structure from marine debris burial / accumulation
		  ○ Reduction in propagule establishment and seedling growth
		  ○ Physical damage to roots and branches
		  ○ Change in the quality of the habitat – landscape deterioration
		• Other impacts identified from secondary information included:
		  ○ Decrease in the natural regeneration of mangroves
		  ○ Obstruction of gaseous exchange between mangroves and atmosphere
		  ○ Presence of hazardous wastes – sediment pollution
		  ○ Entanglement and physical damage to mangrove associated fauna
		  ○ Changes to the composition of mangrove associated fauna
		  ○ Possible socio-economic impacts from a reduction in fisheries resources and potential for eco-tourism
		
		INVEMAR has conducted pilot studies on the presence of microplastics in the digestive tracts of important marine fish species on the Caribbean and Pacific coasts. Microplastics were recorded in 16 species on the Caribbean coast and 15 species on the Pacific coast.
		
		Actions have been carried out at the national, sub-national and local levels to control marine debris but implementation is challenged within the existing biodiversity and sustainable development policy frameworks and in terms of:
		• the development of planning instruments for the different levels
		• insufficient inter-institutional coordination to ensure compliance to existing regulations
		• a lack of information for marine litter and its management in coastal areas
		• the formulation of tools to address solid waste problems in the coastal zone

[498] Instituto de investigaciones Marinas y Costeras “José Benito Vives de Andréis” (INVEMAR). 2018c. Evaluación de impactos de la basura marina y microplásticos sobre el ecosistema de manglar en la Ciénaga Grande de Santa Marta. En: INVEMAR y Ministerio de Ambiente y Desarrollo Sostenible (Minambiente). 2018. Convenio Interadministrativo No. 659 de 2017. 202 p. + anexos

	Determine baseline data for the main terrestrial sources, quantities and effects of marine debris	• National monitoring program of the network for the conservation and protection of marine and coastal waters (REDCAM) provides support to the government in the implementation of strategies for pollution and environmental monitoring and has produced an updated inventory of pollution sources for land and sea. Information was collected for different coastal departments between 2009 and 2017 • First national diagnosis of solid waste and microplastics in marine and coastal areas – provides a spatial assessment of the issue in terms of the level of current environmental and waste management regulations and the degree of pollution from marine debris. • Assessment of marine litter pollution and environmental impacts in mangrove ecosystems, and the development of management tools
	Promote structural economic changes that reduce the production and consumption of plastics	Ministry of Environment and Sustainable Development has developed a number of regulatory instruments: • Regulation of plastic bag use – Resolution 0668 (2016) • Environmental management of waste packaging and paper, cardboard, plastic, glass, metal and multi-material packaging – Draft Resolution • National Communication and Citizen Culture Strategy developed - for greater public participation in waste management Multiple regulations developed or updated by the Ministry of Housing, Cities and Territory regarding public cleaning, recycling and waste management plans (2014-2017)
	Information and knowledge exchange, awareness and capacity building and the development of economic incentives	**Information and knowledge exchange** on good practices for coastal (beach) clean-ups – collaboration between the Directorate of Coastal Marine Affairs and Aquatic Resources (DAMCRA) and the Communications Office to mobilise public participation and **awareness** around keeping aquatic systems (rivers and coastal waters) clean. National strategy falls under framework of activities promoted by UN Environment such as the Clean Seas campaign. **Economic dis-incentive** to use plastic bags – national consumption tax on plastic bags implemented through the Tax Reform Law 1819 (2016)

Denmark	**International Actions** **Regional Actions** **Domestic Actions**	• Acting individually and through support from the Nordic Council of Ministers, contributing to efforts under UN Environment to implement UNEA-resolutions on marine litter and microplastics • Participates in the UN ad hoc expert group on marine litter and microplastics and in the development of the new IMO action plan on marine plastic litter from ships. • Active member of the Clean Seas campaign • Bilaterally and multilaterally Denmark supports: o Contribution to the Global Environment Facility (GEF) of 450 million DKK some of which will go to projects related to the marine environment including ones that will address plastic in accordance with a life cycle/circular economy approach. o P4G public-private partnerships; Strategic sector cooperation in Kenya on green growth and recycling of plastic. In Indonesia the programme is on circular economy and waste in addition to support for a national plan of action on marine debris in collaboration with the World Bank. o DKK 20 million in support of marine litter and pollution in the PROBLUE multi-donor trust fund in the World Bank. • Implements EU legislation on waste, wastewater, port reception facilities, marine strategy framework directive • Implements the EU Plastics strategy • Supports the implementation of OSPAR and HELCOM regional action plans on marine litter • Through the Nordic Council of Ministers supported several projects on marine plastic pollution. New projects for 2019 focus on plastic from blasting, plastic in commercial fish species and regional monitoring of plastic in fish in the Northeast Atlantic. • ”No-Special-Fee” system in harbours ships that call at ports can deliver their waste without having to pay a special fee, as this fee is covered by the port charges. • No open waste dump sites. Less than 3% of generated waste is landfilled and at very controlled sites. • Taxes on plastic bags. • Deposits on plastic bottles.

		• Organising litter collection events. • Information campaign targeted beach visitors, yacht owners and fishermen (2018) • Lead country for an action on regionally coordinated knowledge gathering on polystyrene in the Baltic Sea (HELCOM Marine Litter Action Plan). • National monitoring programme for marine litter and microplastics (beach litter, litter on the seabed, litter in fulmar and fish stomachs, microlitter in the sediment) • Active contributor to the development of standardized monitoring methodologies for microlitter in sediments • National environmental targets for marine litter established under the EU MSFD • Education curricula for fishermen that includes the marine environment and waste management • Report produced on lost fishing gear (pilot project) • Several reports on microplastics (occurrence, sources, effects, wastewater, drinking water) • Developing a national plastic action plan that covers the whole value chain including consumers, with information campaigns
Ecuador	**National / Domestic Actions**	In 2018, the Ministry of Environment, working through the Marine and Coastal Management Unit has implemented clean-up campaigns in coordination with government institutions, NGOs, the private sector and public citizens to raise awareness about material use and waste management. Coastal clean-ups in eight protected areas involving almost 2300 volunteers collected 8,700 kg of marine debris with plastic making up the largest proportion (40.6%).
Norway	**International Actions (and rationale)**	• Combatting marine litter and microplastics is a key priority for the Norwegian government. • Active contributor to efforts under UN Environment to implement UNEA-resolutions on marine litter and microplastics. • Proposed measures under the IMO and the Basel Convention that will contribute to the combatting of marine litter and microplastics. • Active engagement in the development of The Global Partnership on Marine Litter (GPML) as an important platform for voluntary cooperation on information sharing and concrete projects to reduce marine litter and microplastics • Committed to supporting capacity building and technology transfer in key countries. A Development Programme dedicated to combat marine litter and microplastics has

		been established. This program will focus on reducing waste, improving waste management systems, and other cost-effective measures to combat marine litter • Taken the initiative to make improved waste management and prevention of marine litter focus areas of the World Bank's fund PROBLUE.
	Rationale	• There is a need for more action and an effective governance structure that can coordinate all (global, regional, national) efforts to combat marine litter and ensure that there is prioritization of resources to where it is most needed. The aim of such a structure would be to eliminate all leakage of plastic litter into the marine environment • Also a need to strengthen the implementation of existing instruments, including the regional seas conventions as there are gaps in the global frameworks, and the need of a mechanism to monitor and guide measures
UK	**International Actions**	• Committed to a number of international or regional conventions including the Oslo-Paris Convention, European Marine Strategy Framework Directive, MARPOL and the London and Basel Conventions • Dedicated to international unions with marine litter focused action plans such as the G7 and G20 • Committed to the UN SDG's and the 2030 Agenda • Support increased action within the Basel Convention • Welcome the IMO's efforts to create a marine litter action plan • Will work within new platforms including the New Plastics Economy Global Commitment by the Ellen MacArthur Foundation, the Plastic Charter of the G7 and the Plastic Partnership of the Basel Convention • Committed significant levels of funding to support programmes such as the Commonwealth Clean Oceans Alliance, the Global Plastic Action Partnership, and the Global Environment Facility • Running programmes in some UK Overseas Territories
	Domestic Actions	• Legislative action to ban microbeads and put a levy on plastic bags • Commitments to consult on banning a number of single-use plastic items • Increased penalties for littering as part of the Litter Strategy • Public donations to charities tackling plastic waste will be doubled by the UK Governments Aid Match funding programme

		• Committed to a review of waste management systems through the 25 Year Environmental Plan and Clean Growth Strategy – new Resource and Waste Strategy will have clear social, environmental and economic considerations • Includes a reform of producer responsibility systems to incentivize producers to take greater responsibility for the environmental impacts of their products

Appendix 3: UN Environment 10-step roadmap for Single-Use Plastic Sustainability

1. **Target the most problematic single-use plastics** by conducting a baseline assessment to identify the most problematic single-use plastics, as well as the current causes, extent and impacts of their mismanagement.

2. **Consider the best actions to tackle the problem** (e.g. through regulatory, economic, awareness, voluntary actions), given the country's socio-economic standing and considering their appropriateness in addressing the specific problems identified.

3. **Assess the** potential social, economic and environmental **impacts** (positive and negative) of the preferred short-listed instruments/actions. How will the poor be affected? What impact will the preferred course of action have on different sectors and industries?

4. **Identify and engage** key **stakeholder groups –** retailers, consumers, industry representatives, local government, manufacturers, civil society, environmental groups, tourism associations – to ensure broad buy-in. Evidence-based studies are also necessary to defeat opposition from the plastics industry.

5. **Raise public awareness** about the harm caused by single-used plastics. Clearly explain the decision and any punitive measures that will follow.

6. **Promote alternatives.** Before the ban or levy comes into force, assess the availability of alternatives. Ensure that the pre-conditions for their uptake in the market are in place. Provide economic incentives to encourage the uptake of eco-friendly and fit-for-purpose alternatives that do not cause more harm. Support can include tax rebates, research and development funds, technology incubation, public-private partnerships, and support to projects that recycle single-use items and turn waste into a resource that can be used again. Reduce or abolish taxes on the import of materials used to make alternatives.

7. **Provide incentives to industry** by introducing tax rebates or other conditions to support its transition**.** Governments will face resistance from the plastics industry, including importers and distributors of plastic packaging. Give them time to adapt.

8. **Use revenues** collected from taxes or levies on single-use plastics **to maximize the public good**. Support environmental projects or boost local recycling with the funds. Create jobs in the plastic recycling sector with seed funding.

9. Enforce the measure chosen effectively, by making sure that there is clear allocation of roles and responsibilities.

10. **Monitor** and **adjust** the chosen measure if necessary and update the public on progress**.**

For further information please refer to the UN Environment report: Single-Use Plastics – a Roadmap for Sustainability (https://www.unenvironment.org/resources/report/single-use-plastics-roadmap-sustainability).

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