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MARINE DEBRIS:

UNDERSTANDING, PREVENTING AND MITIGATING SIGNIFICANT ADVERSE IMPACTS ON MARINE AND COASTAL BIODIVERSITY

Note by the Executive Secretary

1. Pursuant to decision XI/18, the Executive Secretary of the Convention on Biological Diversity convened 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 in Baltimore, United States of America, from 2 to 4 December 2014.

2. A background document (UNEP/CBD/MCB/EM/2014/3/INF/2) was made available at the above-mentioned workshop to support the workshop discussions. Following the workshop, the document was further revised and updated, incorporating comments and suggestions received from workshop participants, through a consultancy commissioned by the Secretariat, with the generous financial support of the European Commission.

3. This revised background document was made available for further peer-review by Parties, other Governments and relevant organizations from 12 January 2016 to 16 March 2016, with initial peer-review period of three weeks. Comments were received from Australia and Mexico during this period.

4. Upon further revision to incorporate peer-review comments, the document is being made available for the information of the Subsidiary Body on Scientific, Technical and Technological Advice, at its twentieth meeting, and will be published as a report in the CBD Technical Series in due course.

[*] UNEP/CBD/SBSTTA/20/1/Rev.1.

Marine Debris:

Understanding, Preventing and Mitigating Significant Adverse Impacts on Marine and Coastal Biodiversity

EXECUTIVE SUMMARY

Marine debris is recognized as a globally significant stressor on the marine and coastal environment, with impacts on marine biodiversity having been reported over the last four decades. There are also socioeconomic impacts, as debris can be a health and safety hazard and can also affect commercially-significant resources. The vast majority of marine debris is made up of various forms of plastic that are highly persistent and often contain toxic chemicals or acquire them from the surrounding seawater. The fragmentation of plastics produces large numbers of microplastic particles that are easily taken up by a wide range of marine organisms. Plastic production has grown exponentially since the 1950s and is expected to continue at an increasing rate over the coming decades. According to current estimates, between 4.8 and 12.7 million tonnes of plastic waste entered the marine environment in 2010.

The present document provides an update to the 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. This report follows a similar format and should be referred to in combination with the aforementioned document.

The first section reviews the state of knowledge of the various impacts of marine debris on marine and coastal biodiversity. It provides an update of the total number of species known to be affected by marine debris, which is now almost 800 (including effects of ghost fishing reported in the last two years). The proportion of cetacean and seabird species affected by marine debris ingestion has risen substantially to 40% and 44% respectively. The latest research on the physical and toxicological effects of microplastic is summarized along with evidence of trophic transfer in planktonic food chains in the laboratory, and direct uptake of microplastics by invertebrates in the marine environment. Results of studies of plastic marine debris as a novel habitat for unique microbial communities and a potential vector for disease are also provided. The report also addresses the ability of large macrodebris items to transport invasive species across oceans, based on evidence from recent records of tsunami debris stranding along the west coast of North America. The impacts of lost, abandoned or discarded fishing gear on marine biodiversity, including long-term ghost fishing effects and habitat degradation from mainly plastic-based gear, are also discussed. Recent estimates of the socioeconomic costs of marine debris are also provided to complement the information available in CBD Technical Series 67.

The second section provides a review of policy options and approaches that are in place or have been proposed to address the impacts of marine debris. This includes a summary of the latest research to monitor and model debris distribution and abundance in the marine environment. The responses of management and regulatory bodies at the global or regional level indicate that the issue of marine debris is gaining recognition as a significant ecological and socioeconomic problem that may also have implications for human health. Different types of policy approaches and research needs to tackle predominantly land-based sources of marine debris are provided. These include, among others:

- Packaging and plastics reduction;
- Improved product and packaging design;
- Potential use of waste as a resource;
- Deposit return programmes;
- Economic instruments such as fees for single-use items;
- Regulatory measures to address the prevention of marine debris;
- Bans for certain items (e.g., plastic bags, microbeads);

- Engaging with industry and corporations on sustainability, including plastics disclosure policies;
- Support for innovation in new materials, manufacturing, recycling and product design using fully biodegradable under ambient conditions alternatives to conventional plastics with comparable performance characteristics;
- Improving waste management infrastructure to prevent debris inflow (e.g., storm-water systems);
- Improving awareness of marine debris;
- Providing viable alternatives to synthetic plastic (e.g., bioplastics and natural compounds);
- Eco-labelling / certification schemes; and
- Encouraging reuse and reduction.

A major challenge is to ensure the wide-scale implementation of a range of land-based measures to prevent and reduce marine debris that will be able to match the projected increase in plastic production. A focus on up-stream innovations such as plastic alternatives and environmentally friendly design is important as effective waste management alone may not be able to cope with scale of the problem. Replacing plastic products with commercially viable and environmentally sustainable alternatives is needed in combination with prevention and reduction in the use and availability of plastic products, especially single-use items. Facilitating an increase in plastic recycling through provision of recycling infrastructure and increased public awareness should also be prioritized at the local and national level. Reuse of existing plastic is also an important aspect to reduce the proportion of plastics being disposed of in landfills or through incineration.

There are still significant gaps in our knowledge and understanding of many aspects of marine debris. For example the lack of understanding of microplastic dynamics (e.g., sources, sinks, flows and fragmentation rates) in the marine environment, and their incorporation into marine food webs makes it difficult to assess the potential harmful health effects on marine biota and humans. Existing knowledge gaps and research needs are summarized in the last section of this report along with a series of recent recommendations to address these gaps, many of which involve one or more of the approaches and policies mentioned above.

The evidence for impacts on marine biodiversity and habitats outlined in this review, along with the detailed information provided in CBD Technical Series 67, strongly suggest that marine debris is an important source of anthropogenic stress affecting marine and coastal biodiversity and habitats. This impact is likely to grow considerably in the coming decades unless there is a concerted effort to prevent and substantially reduce the flow of waste materials into the marine environment. A number of measures are available to enable this which could be implemented at the national, regional and global levels according to their unique contexts. Implementation will require effective coordination, close collaboration between industry, producer organizations and government, and substantial involvement of consumers. Failure to adequately address marine debris will lead to continued impacts on marine biodiversity and ecosystems, affecting the services they provide.

1. INTRODUCTION

KEY MESSAGES

1. Marine debris is a key environmental issue at the global level and a major threat to marine and coastal biodiversity
2. Three-quarters of all marine debris is plastic, a persistent and potentially hazardous pollutant, which fragments into microplastics that can be taken up by a wide range of marine organisms
3. The use of plastics continues to grow, with global production expected to rise markedly over the next few decades in order to meet demand.

Marine debris has been identified as a global problem alongside other key environmental issues such as climate change, ocean acidification and the loss of biodiversity[1]. It is regarded as one of the most significant problems for the marine environment[2] and a major perceived threat to biodiversity[3]. Marine debris is aesthetically 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 potentially also humans[4,5]. Three-quarters of all marine debris is plastic, which contaminates habitats from the poles to the equator and from shorelines to the deep-sea[6]. In short, marine debris is damaging to the economy, to wildlife, and the environment; and there is universal agreement that it needs to be urgently addressed[7].

Plastic materials are a particular cause for concern due to their persistence, and inherent or acquired toxicity.[8] Discarded plastics degrade and fragment into millions of microplastic pieces, making them able to be taken up by a wide range of marine biota, from primary producers to higher trophic-level organisms[9], and more likely to infiltrate food webs[10]. Annual plastic production has increased markedly over the last 60 years, from 1.5 million tonnes in the 1950s to 288 million tonnes in 2012, with approximately two-thirds of production occurring in East Asia, Europe and North America[11].

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[1] Sutherland, W. et al. 2010. A horizon scan of global conservation issues for 2010. Trends in Ecology and Evolution 25: 1-7.

[2] Gold, M. et al. 2014. Stemming the tide of plastic marine litter: A global action agenda. 27 Tul. Envtl. L.J. 165 2013-2014.

[3] 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 pages (and references therein).

[4] 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 pages (and references therein).

[5] 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, p. 52.

[6] Barnes, D.K.A. et al. 2009. Accumulation and fragmentation of plastic debris in global environments. Phil. Trans. R. Soc. B 364: 1985-1998.

[7] Koelmans, A.A. et al. 2014. Plastics in the marine environment. ET & C Perspectives. Environmental Toxicology and Chemistry 33: 5-10.

[8] Inherent toxicity: hazardous chemical ingredients of plastics which can be the plastic monomers themselves or chemical additives; Acquired toxicity: adsorption of hazardous (persistent, bioaccumulative and toxic) chemicals and metals from seawater onto the surface of plastic debris.

[9] Ivar do Sul, J.A. and Costa, M.F. 2014. The present and future of microplastic pollution in the marine environment. Env. Poll. 185: 352-364.

[10] Browne, M.A. et al. 2008. Microplastic – an emerging contaminant of potential concern? Int. Env. Assess. and Manag. 3: 559-561.

[11] PlasticsEurope 2013. Plastics – the Facts 2013. An analysis of European latest plastics production, demand and waste data. PlasticsEurope, Brussels. 37 pp.

One third of global production is disposable / single-use packaging that is discarded within a year[12]. Plastics are inherently recyclable, although overall recycling rates are currently low for most countries[13]. By recycling end-of-life plastic, it is possible to reduce the accumulation of marine debris but also reduce our demand for fossil carbon[14,15]. Approximately 8% of global oil production is used to make plastic items[16], with natural gas use also contributing to the production of plastics. Demand for plastic continues to grow. Forecasts indicate that plastic production will reach 33 billion tonnes by 2050, based on current consumption trends[17]. Current global estimates for plastic waste indicate that 192 coastal countries generated 275 million tonnes of waste in 2010, of which between 4.8 and 12.7 million tonnes (1.8 - 4.6% of plastic waste) entered the marine environment[18].

The continual fragmentation of plastic debris items into microplastics means that it is inevitable that microplastic debris will accumulate in the marine environment. Oceanographic models and environmental observations show very high concentrations of floating microplastic in subtropical ocean gyres where converging surface currents trap and retain floating debris[19]. However, it can be difficult to detect long-term trends of floating microplastics in the ocean as there can be large variations in surface concentrations, even in heavily sampled areas[20]. One study for the North Pacific Subtropical Gyre indicated that the abundance and mass of microplastics increased by two orders of magnitude since the 1970s[21]. Other studies in the Pacific and in the North Atlantic were not able to show a robust temporal trend in long-term datasets[22,23]. As well as gyres, other hotspots for microplastic accumulation are industrial and densely populated coastal areas[24]. Conversely, Arctic sea ice has also recently been identified as a major global reservoir of microplastics, with concentrations several orders of magnitude greater than those found in oceanic gyres[25]. As the human population continues to increase, the prevalence of microplastics will also most likely increase[26]. Overall, the relationship between microplastic concentration and its sources is poorly understood because of complex transport mechanisms and unknown fragmentation rates[27].

Plastics can be chemically harmful to wildlife, either because they are themselves potentially toxic[28] or can absorb other toxic pollutants[29,30]. Plastic debris is regarded as a multiple stressor in aquatic

[12] Koelmans, A.A. et al. 2014. Plastics in the marine environment. ET & C Perspectives. Environmental Toxicology and Chemistry 33: 5-10.
[13] Not including incineration
[14] Thompson, R.C. et al. 2009. Plastics, the environment and human health: Current consensus and future trends. Phil. Trans. R. Soc. B 364: 2153-2166.
[15] Ivar do Sul, J.A. and Costa, M.F. 2014. The present and future of microplastic pollution in the marine environment. Env. Poll. 185: 352-364.
[16] Thompson, R.C. et al. 2009. Plastics, the environment and human health: current consensus and future trends. Phil. Trans. R. Soc. B: Biological Sciences 364: 2153-2166.
[17] Rochman, C.M. et al. 2013. Classify plastic waste as hazardous. Comment, Nature 494: 169-171.
[18] Jambeck, J.R., Geyer, R. Wilcox, C. et al. 2015. Plastic waste inputs from land into the ocean. Science 347 (6223): 768-771. DOI: 10.1126/science.1260352.
[19] Law. K.L. and Thompson, R.L. 2014. Microplastics in the seas. Science 345: 144-145
[20] Ibid
[21] Goldstein, M.C.et al. 2012. Increased oceanic microplastic debris enhances oviposition in an endemic pelagic insect. Biol. Lett. 8:817-820.
[22] Lavender Law, K. et al. 2010. Plastic Accumulation in the North Atlantic Subtropical Gyre. Science.328: 1185-1188.
[23] Lavender Law, K. et al. 2014.Distribution of Surface Plastic Debris in the Eastern Pacific Ocean from an 11-Year Data Set. Environ. Sci. Technol. 48: 4732-4738.
[24] Wright, S.L. et al. 2013a. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.
[25] Obbard, R.W. et al. 2014. Global warming releases microplastic legacy frozen in Arctic sea ice. Earth's Future 2: 315-320.
[26] Wright, S.L. et al. 2013a. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.
[27] Law. K.L. and Thompson, R.L. 2014. Microplastics in the seas. Science 345: 144-145.
[28] Lithner, D. et al. 2011. Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. Sci. Total Environ. 409: 3309-3324.
[29] Teuten, E. et al. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Phil. Trans. R. Soc. B 364: 2027-2045.

habitats as a consequence of the large mixture of chemical contaminants associated with it[31]. The chemical ingredients of 56% of plastic polymers are hazardous according to a hazard ranking model based on the United Nations Globally Harmonized System of Classification and Labelling of Chemicals[32]. There is evidence that high concentrations of some additive chemicals used in plastics, such as polyvinylchloride (PVC), can leach out of plastics and into aquatic habitats from landfill sites, especially if there is insufficient treatment and retention of leachate to prevent groundwater contamination[33]. Plastic debris also readily accumulates harmful persistent, bioaccumulative and toxic (PTB) chemicals[34] from seawater, increasing their concentration by orders of magnitude[35]. This process is reversible, with plastics releasing contaminants upon ingestion[36]. Clean plastics may also remove PBTs from contaminated animals[37] and act as a net sink for PBTs, potentially reducing exposure. However, the high uptake of contaminants onto plastics and the longevity of plastics in the environment suggests that plastic debris will not remain 'clean' for any extended period of time[38]. Modelling studies have suggested that the bioaccumulation pathway is unlikely to significantly increase risk at current microplastic concentrations found in marine sediments[39]. Uptake of microplastics has recently been reported in commercially reared bivalve molluscs grown in open systems, indicating that microplastics are being ingested by humans via seafood[40]. The potential health risks to humans of ingesting microplastics from the marine environment are not fully understood.

Although plastics originating from land-based sources make up most of the marine debris in the oceans, there are some sea-based types of plastic debris that can have significant impacts on marine biota and habitats. There are both direct and indirect damaging impacts of abandoned, lost or discarded fishing gear (ALDFG) on marine ecosystems mainly through ghost fishing effects and habitat degradation. Derelict gear is an important threat to endangered species such as the Hawaiian monk seal and causes significant mortality for other marine mammals, seabirds and invertebrates[41]. Ghost fishing is a chronic stressor for fisheries with direct economic losses through target and non-target species mortality[42]. Derelict gear also incurs other socioeconomic costs through gear replacement, vessel damage and reduced fishing time[43].

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30 Rochman, C.M. et al. 2013c. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Sci. Rep. 3: 3263; DOI:10.1038/srep03263.

31 Rochman, C.M. 2013. Plastics and priority pollutants: a multiple stressor in aquatic habitats. Environ. Sci. Technol. 47: 2439-2440.

32 Lithner, D. et al. 2011. Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. Sci. Total Environ. 409: 3309-3324.

33 Teuten, E. et al. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Phil. Trans. R. Soc. B 364: 2027-2045.

34 PBT examples are: polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PDBEs) and dichlorodiphenyltrichloroethane (DDT).

35 Law. K.L. and Thompson, R.L. 2014. Microplastics in the seas. Science 345: 144-145.

36 Teuten, E. et al. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Phil. Trans. R. Soc. B 364: 2027-2045.

37 Gouin, T. et al. 2011. A thermodynamic approach for assessing the environmental exposure of chemicals absorbed to microplastic. Environ. Sci. Technol. 45: 1466-1472.

38 Teuten, E. et al. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Phil. Trans. R. Soc. B 364: 2027-2045.

39 Koelmans, A.A. et al. 2013. Plastic as a Carrier of POPs to Aquatic Organisms: A Model Analysis. Environ. Sci. Technol. 47: 7812-7820.

40 Van Cauwenberghe, L. and Janssen, C.R. 2014. Microplastics in bivalves cultured for human consumption. Env. Poll. 193: 65-70.

41 Gilardi, K. et al. 2010. Marine species mortality in derelict fishing nets in Puget Sound, WA, and the costs/benefits of derelict net removal. Marine Pollution Bulletin 690: 376-382.

42 Arthur, C. et al. 2014. Out of sight but not out of mind: Harmful effects of derelict traps in selected U.S. coastal waters. Marine Pollution Bulletin 86: 19-28.

43 MacFadyen, G. et al. 2009. Abandoned, lost or otherwise discarded fishing gear. Food and Agriculture Organisation of the United Nations (FAO), FAO Fisheries and Aquaculture Technical Paper 523. FAO, Rome, 115 pp.

There are many well-known solutions to address plastic marine debris, especially for land-based sources[44]. These include[45]:

- Reduction in the use of material produced and the reuse of items;
- Disposal of end-of-life items properly, ideally by recycling;
- Recycling to turn end-of-life material back into new items to reduce accumulation of waste and the need for production of new materials;
- Recovery of items that cannot be reused or recycled, including through incineration; and
- Considering how to minimize the overall environmental footprint of plastic products at the design stage.

There is also a need to support research and development of new materials that are non-toxic, truly compostable, fully biodegradable alternatives to conventional plastics, with comparable costs and performance characteristics. This should be accompanied by investment into new manufacturing processes that can handle high volume production for these new materials and new recycling processes that would support mixed recycling streams including compostables, bioplastics, bagasse and other emerging materials. Further research and analysis of the economics of recycling is also required with a focus on facilitating recycling rates in least developed countries. An effective regulatory regime that integrates the principles as set out above would help to address the different approaches in a systematic way while ensuring the compliance and enforcement of agreed environmental standards.

A key approach in addressing marine debris is to prevent items becoming debris in the first place. Source prevention, through a combination of measures and approaches is widely regarded as the most effective means to reduce the impact of debris on marine and coastal biodiversity. Cleaning up marine debris *in situ*[46] is currently regarded as a less-effective solution to the issue[47] given the scale of the problem, and is particularly unfeasible for microplastics[48], in water or in sediments. 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 (http://www.cbd.int/doc/publications/cbd-ts-67-en.pdf)[49]. 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 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;

[44] Koelmans, A.A. et al. 2014. Plastics in the marine environment. ET & C Perspectives. Environmental Toxicology and Chemistry 33: 5-10.
[45] Ibid
[46] Slat, B et al. 2014. How the oceans can clean themselves: A feasibility study. http://www.theoceancleanup.com/the-concept.html.
[47] 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 pages.
[48] Law. K.L. and Thompson, R.L. 2014. Microplastics in the seas. Science 345: 144-145.
[49] To be referred to as "2012 Review Document" hereinafter

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

This document, in an earlier form, served as background information document 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, U.S.A. from 2 to 4 December 2014), convened pursuant to COP decision XI/18. It provided information that to contribute 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. A review of marine debris impacts has also recently been published in the scientific literature[50].

In Chapter 2 of this document, the latest information regarding marine species affected by marine debris is assessed to update the total number of species impacted by this stressor. Further information is provided on the latest understanding of microplastic impacts, including toxic effects and the potential for trophic transfer. Chapter 3 provides a review of recent research studies regarding marine debris monitoring and modelling. Chapter 4 reviews current best practice and possible new approaches for the management and mitigation of marine debris. Finally, knowledge gaps and research needs are highlighted in the last section (Chapter 5), based on recently published information and the findings of the CBD expert workshop, along with recommendations to address marine debris, particularly for plastics.

The compilation of information and background research as well as the report preparation was undertaken with the kind financial support from the European Commission.

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

2. UPDATED REVIEW ON THE IMPACTS OF MARINE DEBRIS ON MARINE AND COASTAL BIODIVERSITY AND HABITATS

Key Messages

1. More than 800 marine and coastal species are affected by marine debris through ingestion, entanglement, ghost fishing and dispersal by rafting as well as habitat effects.
2. More than 500 marine and coastal species are affected by ingestion of, or entanglement in, marine debris, which includes ghost fishing effects.
3. The number of seabird and marine mammal species affected by marine debris ingestion or entanglement is steadily rising.
4. There is increasing recognition of the impact of ghost fishing, with both ecological and socio-economic effects being reported.
5. Microplastics are present in all marine habitats and from the ocean surface to the seabed, and are available to every level of the food web from primary producers to higher trophic levels.
6. Microplastics are also providing a new habitat in the oceans for microbial communities, although the effects on ocean ecosystems and processes are not yet understood.
7. Although laboratory-based studies have indicated that plastics containing hazardous chemicals can have a detrimental effect on marine organism health, this phenomena has not been clearly shown in the marine environment.

CBD Technical Series 67[51] provided a detailed assessment of the status of knowledge of the impacts of marine debris on biodiversity up to April 2012. This section provides an update of this synthesis based on a review of predominantly peer-reviewed publications. New types of impacts are highlighted along with new records of habitats or species that have been affected. Socio-economic impacts are also discussed. The number of marine species affected by marine debris has risen to 817 when effects such as ingestion, entanglement, ghost fishing, dispersal by rafting and provision of new habitat are all considered. There are a total of 154 new species records since the 2012 review representing a 23% increase in the total number of species affected.

The types of marine debris impacts or interactions include: ingestion and entanglement, the effects of microplastics, the effects of persistent, bio-accumulative and toxic substances, marine debris as a new novel habitat, dispersal via rafting and the transport of invasive species, and habitat or ecosystem-level effects. It should be noted that this review is more of a qualitative assessment of marine debris impacts than CBD Technical Series 67, with the exception of reporting on the number of marine and coastal species affected by marine debris in its various forms.

Marine debris is usually defined as any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment[52]. The main types of marine debris at the global scale were summarized in the CBD Technical Series 67 (Section 1.2 – Defining the Problem) and will not be repeated in detail here. Records of the most common items found in surveys and clean-ups clearly show that marine debris is dominated by plastic items both in shallow and deeper waters. The top ten debris items recorded by the 2013 International Coastal Cleanup were, in descending order: cigarette butts, plastic food wrappers, plastic beverage bottles, plastic bottle caps, straws and stirrers, plastic grocery bags, glass beverage bottles, other plastic bags, paper bags and beverage cans. Of these types of items, seven were made of plastic.

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[51] 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.

[52] Ibid

2.1 Ingestion and Entanglement

An assessment of ingestion and entanglement records for marine and coastal species revealed that a further 136 species are known to be affected by marine debris through entanglement or by ingesting debris, since the 2012 review[53], bringing the total number of affected species to 519. The main bulk of the new species records were for the ingestion of plastics, including microplastics, and entanglement in lost or abandoned fishing gear (predominantly line, nets or pots). If ghost fishing entanglements are excluded, then the total number of species known to be affected by marine debris is 453, a 21% increase since 2012.

There is a clear increase in the number of species known to be affected since the CBD Technical Series 67, particularly for marine mammals (Table 1) with 40% of the taxa known to ingest marine debris, mainly attributable to a recent review of marine debris impacts on cetaceans[54]. The number of marine fish and seabirds affected by ingestion or entanglement has also risen. New records for plastic ingestion by fish have been reported in a range of habitats including open ocean, deep-water and temperate pelagic and demersal (Appendix 1a). Studies reporting the entrapment or entanglement of fish species in derelict fishing gear have increased the number of affected species substantially (Appendix 1b) to almost double the number reported in 2012. There has been a steady rise in the number of seabird species affected through ingestion or entanglement with 44% of all species now known to have ingested marine debris (Table 1). The slight increase in affected marine reptile species since the last review is attributable to the first record of a sea snake entanglement[55]. In addition entanglement and drowning of brackish turtles has also been reported for the diamondback terrapin through entrapment in derelict fishing pots[56] (Appendix 1b). Species group totals for a recently published update of debris impacts on marine life[57] are also provided (Table 1).

There a far fewer records of marine debris ingestion by marine invertebrates '*in situ*'. However, plastic ingestion has been documented for four species in the last two years. Stranded Humboldt squid (*Dosidicus gigas*) were found to have ingested plastic pellets and fishing line[58] while sandhoppers (*Talitrus saltator*)[59] and commercially reared bivalves[60] had all ingested microplastics. In addition a range of marine invertebrate species were shown to ingest microplastics in controlled laboratory experiments conducted since 2012 (Appendix 1c). A number of these studies demonstrated the uptake of plastic microspheres by marine zooplankton such as copepods, euphausid and mysid shrimps, and rotifers[61][62]. These findings will be further discussed in the next section on microplastics

Marine invertebrate entanglement records reported since 2012 are also rather scarce. Although there are numerous invertebrate species recorded on or in derelict fishing gear during gear retrieval programmes (e.g., the Northwest Straits Initiative in Puget Sound, Washington State, U.S.A.[63]) it is not clear whether several of these species were biofoulers on the nets or pots or were living on these debris items but not actually entangled or entrapped by them. For fishing pot retrieval studies, only those invertebrate species that were trapped within derelict pots were included (e.g., Bilkovic et. al.

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[53] Ibid

[54] Baulch, S and Perry, C. 2014. Evaluating the impacts of marine debris on cetaceans. Marine Pollution Bulletin 80: 210-221.

[55] Udyawer, V. et al. 2012. First record of sea snake (*Hydrophis elegans*, Hydrophiinae) entrapped in marine debris. Marine Pollution Bulletin 73: 336-338.

[56] Arthur, C. et al. 2014. Out of sight but not out of mind: Harmful effects of derelict traps in selected U.S. coastal waters. Marine Pollution Bulletin 86: 19-28.

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

[58] Braid, H.E. et al. 2012. Preying on commercial fisheries and accumulating paralytic shellfish toxins: a dietary analysis of invasive *Dosidicus gigas* (Cephalopoda Ommastrephidae) stranded in Pacific Canada. Mar. Biol. 159: 25-31.

[59] Ugolini, A. et al. 2013. Microplastic debris in sandhoppers. Est. Coast. Shelf Sci. 129: 19-22.

[60] Van Cauwenberghe, L. and Janssen, C.R. 2014. Microplastics in bivalves cultured for human consumption. Env. Poll. 193: 65-70.

[61] Cole, M. et al. 2013. Microplastic ingestion by zooplankton. Env. Sci. Technol. 47: 6646-6655.

[62] Setälä, O. et al., 2014. Ingestion and transfer of microplastics in the planktonic food web. Environ. Poll. 185: 77-83.

[63] http://www.derelictgear.org/

2014[64]). An assessment of marine debris impacts on marine and coastal species at a number of coastal sites in the Republic of Korea found only one species of shore crab entangled in derelict fishing gear[65]. In that study, recreational fishing gear was an important component of marine debris that affected marine and coastal fauna. An assessment of ghost fishing by derelict fishing pots in Chesapeake Bay, U.S.A., over four years indicates that a number of crab and whelk species were entrapped within derelict pots[66]. In Louisiana, U.S.A., a citizen science pot removal programme reported that both blue crabs and stone crabs were trapped within the derelict gear[67].

Cross-referencing the new records of affected species with the IUCN Red List[68] indicates that approximately 10% of the new species records are near threatened, vulnerable, endangered or critically endangered. These included large baleen whales (blue and sei whales), geographically restricted seabird species (Balearic shearwaters), coastal birds such as the black-faced spoonbill, water deer and diamondback terrapins (Appendix 2). In addition, a further nine species of affected cetacean were identified as either not assessed by the Red List to date or were data deficient, including five species of odontocetes.

[64] Bilkovic, D.M. et al. 2014. Derelict fishing gear in Chesapeake Bay, Virginia: Spatial patterns and implications for marine fauna. Marine Pollution Bulletin 80: 114-123.
[65] Hong, S. et al. 2013. Impacts of marine debris on wild animals in the coastal area of Korea. Marine Pollution Bulletin 66: 117-124.
[66] Bilkovic, D.M. et al. 2014. Derelict fishing gear in Chesapeake Bay, Virginia: Spatial patterns and implications for marine fauna. Marine Pollution Bulletin 80: 114-123.
[67] Anderson, J.A. and Alford, A.B. 2014. Ghost fishing activity in derelict blue crab traps in Louisiana. Marine Pollution Bulletin 79: 261-267.
[68] IUCN 2014. The IUCN Red List of Threatened Species. Version 2014.3. <http://www.iucnredlist.org>.

Table 1: Number of species with records of entanglement and ingestion documented in 2012 and 2015, the number reported here and the total number of species identified globally (with percentages of the total number of known species in brackets). Sources for total number of known species: First Census of Marine Life (2010)[69], Rasmussen et al. (2011)[70], Ukuwela et al. (2012)[71]

		Number of species with entanglement records			**Number of species with ingestion records**		
Species Group	**Total number of known species**	**SCBD (2012)** (%)	**Gall & Thompson, 2015** (%)	**This report** (%)	**SCBD (2012)** (%)	**Gall & Thompson, 2015** (%)	**This report** (%)
Marine Mammals	115	52 (45%)	52 (45%)	53 (46%)	30 (26%)	30 (26%)	46 (40%)
Fish	16754	66 (0.39%)	66 (0.39%)	129 (0.77%)*	41 (0.24%)	50 (0.30%)	62 (0.37%)
Seabirds	312	67 (21%)	79 (25%)	80 (26%)	119 (38%)	122 (39%)	131 (44%)
Marine Reptiles	70	7 (10%)	7 (10%)	8 (11.4%)	6 (8.6%)	6 (8.6%)	6 (8.6%)
Brackish Turtles	6	n/a	n/a	1 (16.7%)	n/a	n/a	0

*: remains as 66 species (0.39%) if ghost fishing records are excluded

[69] http://www.coml.org/
[70] Rasmussen, A.R. et al. 2011. Marine Reptiles. PLoS ONE 6(11): e27373.
[71] Ukuwela, K.D.B. et al. 2012. *Hydrophis donaldi* (Elapidae, Hydrophiinae), a highly distinctive new species of sea snake from Northern Australia. Zootaxa 3201: 45-47.

It is clear that marine debris continues to have an impact on a large range of marine fauna with many new records of species affected through entanglement or by ingestion of debris items, particularly various forms of plastic. Negative effects on individuals are more obvious to detect for entanglement cases with external injuries or death often observed. Determining the effect of ingesting marine debris on an individual can be more difficult and the consequences of ingestion are still not fully understood[72]. Sub-lethal effects of entanglement and ingestion that alter the biological and ecological performance of individuals are highly likely[73]. These could include compromising the ability of a marine animal to capture or digest food, sense hunger, move, escape from predators, migrate, and reproduce[74]. There is also some concern that the ingestion of microplastics can cause physical effects such as internal abrasion and blockage[75], and may also provide a pathway for the uptake of harmful chemicals by marine organisms (see section below). Species which show a high incidence of debris ingestion may therefore be susceptible to population level effects, which could have negative consequences for endangered species with small populations that are exposed to multiple stressors.

It is also highly likely that there are substantially more marine species affected by marine debris either directly or indirectly given the ubiquitous presence of debris items such as persistent microplastics[76] in the marine environment. Deposit- and filter-feeding marine fauna will be especially susceptible to the uptake or ingestion of microplastics, as well as planktonic invertebrates in oceanic gyre regions where microplastic concentrations are high.

In addition, a thorough and extensive examination of the impacts of ALDFG on marine biodiversity is likely to markedly increase the number of species impacted by marine debris, as detailed reports of species entangled in ALDFG are not readily available for some regions. Analysis of data collected by long-term derelict gear retrieval programmes in Puget Sound in the U.S.A. have estimated that the almost 5000 nets removed from this one location were entangling more than 3.5 million animals per year including 1300 marine mammals, 25000 birds, 100000 fish and over 3 million invertebrates[77]. Net mortality rates were also calculated that included losses through decomposition and consumption, estimating that 76 birds, 153 fish and 1100 invertebrates were killed through entanglement per year for a single gill net[78]. The impacts of ghost fishing on marine communities have not been clearly determined yet but the high mortality rates reported for Puget Sound, particularly for invertebrates, suggest that ghost fishing effects could be significant.

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[72] 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.
[73] Ibid
[74] Ibid : see p. 19 for references
[75] Ivar do Sul, J.A. and Costa, M.F. 2014. The present and future of microplastic pollution in the marine environment. Env. Poll. 185: 352-364.
[76] Ibid
[77] http://www.derelictgear.org/Progress.aspx
[78] http://depts.washington.edu/uwconf/psgb/proceedings/papers/7d_broad.pdf

2.2 Microplastics

Microplastics, defined as plastic pieces or fragments less than 5 millimetres in diameter[79,80], have been accumulating in the marine environment over the last four decades and are likely to increase in abundance given the current dependence of a growing human population on the use of persistent plastics. Microplastics can be primary (purposefully manufactured) or secondary (derived from the fragmentation of macroplastic items) in origin[81]. They are a persistent pollutant that is already present in all marine habitats from pole to pole and from the ocean surface to the seabed[82]. Every level of the food web is exposed to microplastics from primary producers[83] to higher trophic level organisms[84]. They can be ingested by filter, suspension and deposit feeders as well as detritivores and planktivores and have the potential to accumulate within organisms[85]. Potential pathways for microplastic in marine ecosystems and its biological interactions are presented in Figure 1.

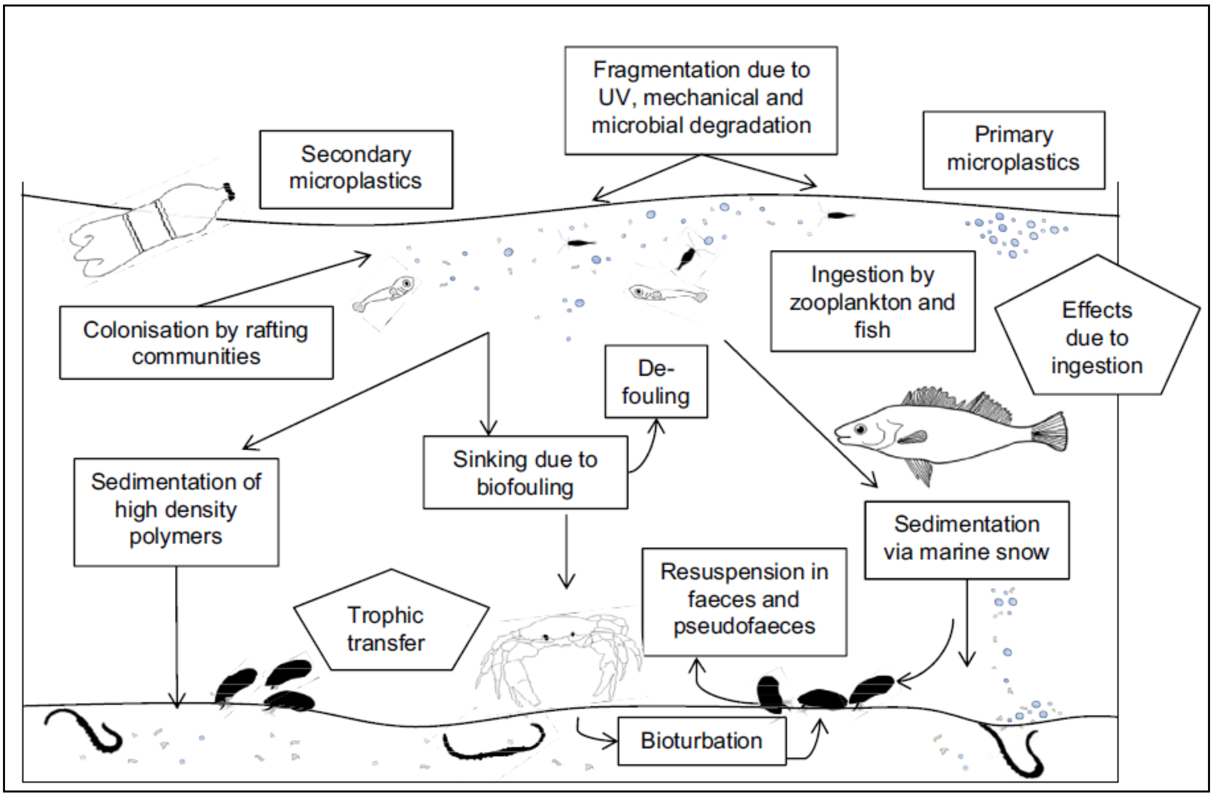

Figure 1. Potential pathways for the transport of microplastics and its biological interactions (after Wright et. al. 2013a).

[79] Arthur, C. et al 2009. Proceedings of the international research workshop on the occurrence, effects and fate of microplastic marine debris. September 9-11, 2008: NOAA Technical Memorandum NOS-OR&R30.
[80] Other authors set the upper limit for microplastics as 1 mm: Claessens, M. et al. 2013. New techniques for the detection of microplastics in sediments and field collected organisms. Mar. Poll. Bull. 70: 277-233.
[81] Wright, S.L. et al. 2013a. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.
[82] Ivar do Sul, J.A. and Costa, M.F. 2014. The present and future of microplastic pollution in the marine environment. Env. Poll. 185: 352-364.
[83] Oliviera, M. et al. 2012. Effects of exposure to microplastics and PAHs on microalgae *Rhodomonas baltica* and *Tetraselmis chuii*. Comp. Bio-chem. Physiol. A Mol. Integr. Physiol. 163: S19-S20.
[84] Wright, S.L. et al. 2013a. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.
[85] Ibid

Extensive reviews on microplastic pollution in the marine environment have been published in recent years by Wright et. al. (2013) and Ivar do Sul and Costa (2014).[86] The former reviews the physical impact of microplastics on marine invertebrates while the latter analyzes over 100 publications to provide a detailed assessment of the effects of microplastics on the marine environment and biota, including ingestion by organisms and interaction with pollutants. Both reviews also provide suggestions for further research and complement previous calls for knowledge of the emissions, transport and fate, physical effects and chemical effects of microplastics[87]. More recently, a thorough global assessment of the sources, fates and effects of microplastic was published by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)[88].

The progressive fragmentation of macroplastic debris in the marine environment is likely to increase the abundance of microplastic fragments and make encountering microplastics more common for a wide range of organisms. Microplastic ingestion has been documented in marine fish and seabirds over the last four decades, but there are only a few published field-based studies for invertebrates, possibly because these studies are time-consuming and require more advanced technology[89]. There are currently only three studies that have documented microplastic ingestion by invertebrates in the field, for intertidal sandhoppers (*Talitrus saltator*)[90], Humboldt squid (*Dosidicus gigas*)[91] and commercially-grown bivalve molluscs (*Mytilus edulis*, *Crassostrea gigas*)[92] with most ingestion studies confined to laboratory conditions (Appendix 1c).

Recent lab-based studies have shown that microplastics are readily ingested by a wide range of zooplankton taxa occurring in the Northeast Atlantic[93] and the Baltic Sea[94]. In addition, high concentrations (4000 ml^{-1}) of 7.3 µm microplastic beads significantly reduced algal consumption by the copepod *Centropages typicus* while smaller microplastic particles (0.4 – 3.8 µm) became trapped between the carapace and external appendages of copepods[95]. A reduction in algal feeding may have severe consequences for some copepod species in terms of reduced fecundity and growth[96]. Functional disruption of a copepod's appendages by microplastics may have an effect on the movement, ingestion, mating and mechanoreception of an individual which could limit the ability to detect prey, feed, reproduce and evade predators[97].

A study of microplastic ingestion by sea urchin larvae (*Tripneustes gratilla*) showed that the larva were able to egest microspheres from their stomach within hours of ingestion[98]. In microsphere concentrations much greater than microplastic levels in the marine environment, there was a small

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[86] See also, Cole, M., Lindeque, P., Halsband, C., Galloway, T.S., 2011. Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin 62, 2588-2597 reviewed the issue of microplastic in the marine environment,

[87] Zarfl C. et al 2011. Microplastics in oceans. Marine Pollution Bulletin 62: 1589-1591.

[88] 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.

[89] Ivar do Sul, J.A. and Costa, M.F. 2014. The present and future of microplastic pollution in the marine environment. Env. Poll. 185: 352-364.

[90] Ugolini, A. et al. 2013. Microplastic debris in sandhoppers. Est. Coast. Shelf Sci. 129: 19-22.

[91] Braid, H.E. et al. 2012. Preying on commercial fisheries and accumulating paralytic shellfish toxins: a dietary analysis of invasive *Dosidicus gigas* (Cephalopoda Ommastrephidae) stranded in Pacific Canada. Mar. Biol. 159: 25-31.

[92] Van Cauwenberghe, L. and Janssen, C.R. 2014. Microplastics in bivalves cultured for human consumption. Env. Poll. 193: 65-70.

[93] Cole, M. et al. 2013. Microplastic ingestion by zooplankton. Env. Sci. Technol. 47: 6646-6655.

[94] Setälä, O. et al., 2014. Ingestion and transfer of microplastics in the planktonic food web. Env. Poll. 185: 77-83.

[95] Cole, M. et al. 2013. Microplastic ingestion by zooplankton. Env. Sci. Technol. 47: 6646-6655.

[96] Ibid

[97] Ibid

[98] Kaposi, K.L. et al., Ingestion of microplastic has limited impact on a marine larva. Environ. Sci. Technol. 48: 1638-1645.

non-dose-dependent effect on larval growth, but no significant effect on survival. Environmentally realistic concentrations of microspheres did not appear to have an effect on sea urchin larvae. The authors suggested that current levels of microplastic pollution pose a limited threat to this species and other marine invertebrate larvae but also recommended further research is needed on a broad range of species, trophic levels and polymer types.

There is currently limited information available regarding the internal accumulation of microplastics in marine invertebrates although laboratory studies have shown that microplastics can accumulate in the digestive cavity and tubules of bivalve molluscs[99,100]. Microplastic accumulation was not observed in deposit-feeders such as lugworms (*Arenicola marina*)[101] or benthic sea cucumbers (Holothuria)[102]. However long-term exposure to microplastic-contaminated sediment was shown to reduce energy reserves in lugworms through reduced feeding activity, increased gut transit times and inflammatory immune responses[103].

External accumulation of microplastics has also been documented for some phytoplankton species where the binding of 20 µm beads to cells of *Chlorella* and *Scenedesmus* inhibited photosynthesis and caused a state of oxidative stress[104]. Although these experiments used very high concentrations of microplastics (1.4 – 40 mg ml^{-1}) that are not present in the marine environment they do indicate the potential for disruption in phytoplankton communities that could compromise the productivity and resilience of marine ecosystems if such high concentrations occur[105].

The translocation of microplastic particles into the cells of marine invertebrates has been demonstrated in mussels (*Mytilus edulis*)[106,107] and crabs (*Carcinus maenas*)[108,109]. In mussels, HDPE particles were taken up by the gills during filter-feeding, transported to the stomach and digestive gland where they accumulated in the lysosomal system and elicited a strong inflammatory response[110]. In the shore crab, microplastic particles were taken up via the gills through ventilation and were retained by body tissues for up to 21 days[111]. Microplastics may also be transported to various tissues and organs via the haemolymph, potentially accumulating and causing harm[112]. Further fragmentation

[99] Brilliant, M.G.S. and MacDonald, B.A. 2000. Postingestive selection in the sea scallop, *Placopecten magellanicus* (Gmelin): the role of particle size and density. J. Exp. Mar. Biol. and Ecol. 253: 211-227.
[100] Browne, M.A. et al. 2008. Microplastic – an emerging contaminant of potential concern? Int. Env. Assess. and Manag. 3: 559-561.
[101] Besseling, E. et al. 2013. Effects of microplastic on fitness and PCB bioaccumulation by the lugworm *Arenicola marina* (L.). Environ. Sci. Technol. 47: 593-600.
[102] Graham, E. and Thompson, J. 2009. Deposit- and suspension-feeding sea cucumbers (Echinodermata) ingest plastic fragments. J. Exp. Mar. Biol. Ecol. 368: 22-29.
[103] Wright, S.L. et al. 2013b. Microplastic ingestion decreases energy reserves in marine worms. Current Biology 23: R1031-R1033.
[104] Battacharya, P. et al. 2010. Physical adsorption of charged plastic nanoparticles affects photosynthesis. The Journal of Physical Chemistry C 114: 16556-16561.
[105] Wright, S.L. et al. 2013. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.
[106] Browne, M.A. et al. 2008. Microplastic – an emerging contaminant of potential concern? Int. Env. Assess. and Manag. 3: 559-561.
[107] von Moos, N. et al. 2012. Uptake and effects of microplastics on cells and tissue of the blue mussel *Mytilus edulis* L. after an experimental exposure. Environ. Sci. Technol. 46: 11327-11335.
[108] Farrell, P. and Nelson, K. 2013. Trophic level transfer of microplastic: *Mytilus edulis* (L.) to *Carcinus maenas* (L.). Env. Poll. 177: 1-3.
[109] Watts, A.J.R. et al. 2014 Uptake and retention of microplastics by the shore crab *Carcinus maenas*. Environ. Sci. Technol. 48: 8823-8830.
[110] von Moos, N. et al. 2012. Uptake and effects of microplastics on cells and tissue of the blue mussel *Mytilus edulis* L. after an experimental exposure. Environ. Sci. Technol. 46: 11327-11335.
[111] Watts, A.J.R. et al. 2014 Uptake and retention of microplastics by the shore crab *Carcinus maenas*. Environ. Sci. Technol. 48: 8823-8830.
[112] Wright, S.L. et al. 2013a. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.

of microplastics into the nanometric range[113] may also have implications. Nanoplastics are known to be absorbed through the chorion of fish eggs resulting in reduced survival and were also subsequently detected in the gallbladders and livers of surviving larvae[114]. Allocating energy to immune responses (for foreign bodies) may compromise normal physiological processes and have a detrimental effect on an organism's health over time[115]. Further research is required to determine the potential for microplastic translocation in other marine organisms and the effects of a range of plastic polymers at the cellular level.

Predation of microplastic-contaminated marine invertebrates may present a pathway for plastic transfer along the food chain[116]. Laboratory studies of marine invertebrates have demonstrated that microplastic particles can be transferred from mussels (*Mytilus edulis*) to crabs (*Carcinus* maenas)[117], and also from meso-zooplankton (copepods and polychaete larvae) to a higher level macro-zooplankton (Mysid shrimps)[118]. Trophic transfer could also occur by planktonic herbivores or omnivores feeding on microplastic-contaminated phytoplankton although there is no evidence for this at the present time. It is likely that microplastic transfer in marine food webs has similar linkages as the transfer of other harmful substances such as hazardous chemicals or phycotoxins[119]. Benthic filter- or deposit-feeders may be more suitable vectors for microplastic trophic transfer than planktonic taxa as they can process large volumes of water or sediment respectively and generally have a longer lifespan than zooplankton. There is also some evidence that higher trophic level organisms (fish and pinnipeds) have ingested microplastics transported by prey items[120]. The presence of microplastics in myctophid fish, and Hooker's sea lion and fur seal scats suggest microplastic transfer through pelagic food chains, indicating that lower trophic organisms can be a vector for the transfer of this pollutant[121]. Potential trophic routes of microplastics are presented in Figure 2.

[113] The nanoscale size range is defined as between 1nm and 100 nm according to the International Organisation for Standardisation (ISO).
[114] Kashiwada, S. 2006. Distribution of nanoparticles in the see-through medaka (*Oryzias latipes*). Environ. Health Perspect. 114: 1697-1702.
[115] Wright, S.L. et al. 2013a. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.
[116] Ibid
[117] Farrell, P. and Nelson, K. 2013. Trophic level transfer of microplastic: *Mytilus edulis* (L.) to *Carcinus maenas* (L.). Env. Poll. 177: 1-3.
[118] Setälä, O. et al., 2014. Ingestion and transfer of microplastics in the planktonic food web. Env. Poll. 185: 77-83.
[119] Ibid
[120] Wright, S.L. et al. 2013. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.
[121] Ibid.

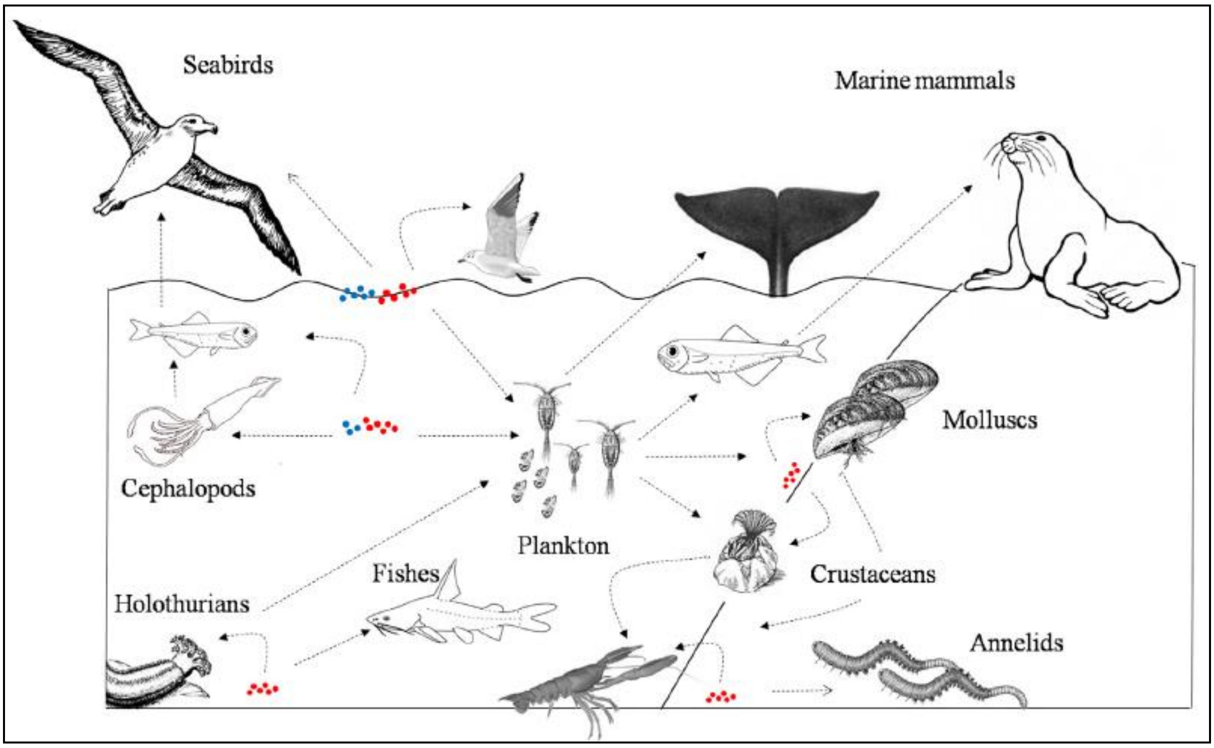

Figure 2. A conceptual model of the potential trophic routes of microplastics across marine vertebrate and invertebrate groups (after Ivar do Sul and Costa, 2014).

Note: Blue dots are polymers less dense than seawater, red dots are polymers more dense than sea water. Dashed arrows represent hypothesized microplastic transfer.

Microplastic ingestion by vertebrates has been documented for a number of teleost fish, seabird and marine mammal species (Appendix 1a). The research highlighted here are mainly for studies published in the last two years. Five species of teleost fish commonly found in the North Sea were found to have ingested microplastic fragments although the incidence of ingestion was low[122]. Ten species of pelagic and demersal fish from the English Channel also ingested microplastic fragments[123] while meso-pelagic lantern fish from a region of the Pacific that is not a microplastic hotspot were also contaminated. Tropical estuarine species of catfish[124], drum[125] and mojarra[126] in Brazil have all been reported to have microplastic filaments (nylon threads) in their digestive systems. In addition, the presence of plastic additives (phthalates) in Mediterranean basking sharks has been proposed as evidence that these large filter-feeders are ingesting microplastics, either from filtering seawater or via the ingested plankton[127].

[122] Foekema, E.M. et al. 2013. Plastic in North Sea fish. Environ. Sci. Technol. 47: 8818-8824.
[123] Lusher, A.L. et al. 2013. Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Marine Pollution Bulletin 67: 94-99.
[124] Possatto, F.E. et al. 2011. Plastic debris ingestion by marine catfish: an unexpected fisheries impact. Marine Pollution Bulletin 62: 1098-1102.
[125] Dantas, D.V. et al. 2012. The seasonal and spatial patterns of ingestion of polyfilament nylon fragments by estuarine drums (Sciaenidae). Environ. Sci. Poll. Res. 19: 600-606.
[126] Ramos, J.A.A. et al. 2012. Ingestion of nylon threads by Gerreidae while using a tropical estuary as foraging grounds. Aquat. Biol. 17: 29-34.
[127] Fossi, M.C. et al. 2014. Large filter feeding marine organisms as indicators of microplastic in the pelagic environment; the case studies of the Mediterranean basking shark (*Cetorhinus maximus*) and fin whale (*Balaenoptera physalus*). Mar. Environ. Res. 100: 17-24.

The ingestion of microplastics by seabirds has been reported for numerous species in various regions over the last two years (Appendix 1a) to add the extensive literature available for this interaction[128]. Fulmars (*Fulmarus glacialis*) in the Northeast Atlantic have been monitored for plastic ingestion for at least three decades and are used as a bioindicator of plastic pollution by the OSPAR Commission and the EU Marine Strategy Framework Directive (MSFD) to monitor spatial and temporal trends. Recent studies of fulmars indicate that microplastics are widespread in this region with pollution levels decreasing towards higher latitudes, and that juvenile birds consumed more plastic than adults[129]. In the Pacific Ocean, fulmars are also highly susceptible to contamination by microplastic fragments with an overall incidence rate of 92.5% for the eastern north Pacific[130]. For some species, microplastics are inadvertently fed to fledglings by their adults[131,132] causing juvenile birds to have high levels of plastic ingestion which can exceed international targets[133]. Threatened endemic shearwater species in the Mediterranean are also highly susceptible to plastic accumulation which is a particular conservation concern[134].

Microplastic ingestion by marine mammals is less well documented than for fish or seabirds. A recent study of the harbour seal (*Phoca vitulina*) indicated that microplastic fragments are ingested by this species at a low incidence (12%), with younger animals most affected[135]. Large filter-feeding cetaceans appear to be susceptible to contamination by microplastics. The presence of phthalates in the blubber of Mediterranean fin whales (*Balaenoptera physalus*) has been linked to the intake of microplastics by water filtering and plankton ingestion[136,137]. The International Whaling Commission (IWC) recently recommended that baleen whales and other large filter-feeders should be considered as critical indicators of the presence and impact of microplastics in the marine environment[138].

The ubiquitous presence and increasing abundance of microplastics in the marine environment strongly suggests that there is a great need to further quantify the amount of micro- and nano-plastic concentrations in marine habitats and determine their effects on marine biodiversity at the individual, population and community level. Moreover, practical and effective ways to reduce microplastic input into marine systems over the long-term should be identified and implemented. This will take a strong commitment by a range of concerned bodies and stakeholders to minimise persistent plastic production at source while also ensuring that existing ways by which plastic enters the marine environment are monitored and substantially reduced.

[128] Ivar do Sul, J.A. and Costa, M.F. 2014. The present and future of microplastic pollution in the marine environment. Env. Poll. 185: 352-364.

[129] Kühn, S. and van Franeker, J.A. 2012. Plastic ingestion by the northern fulmar (*Fulmaris glacialis*) in Iceland. Marine Pollution Bulletin 64: 1252-1254.

[130] Avery-Gomm, S. et al. 2012. Northern fulmars as biological monitors of trends of plastic pollution in the eastern North Pacific. Marine Pollution Bulletin 64: 1776-1781.

[131] Rodriguez, A. et al. 2012. High prevalence of parental delivery of plastic debris in Cory's shearwaters (*Calonectris diomedea*). Marine Pollution Bulletin 64: 2219-2223.

[132] Verlis, K.M. et al. 2013. Ingestion of marine debris plastic by the wedge-tailed shearwater *Ardenna pacifica* in the Great Barrier Reef, Australia. Marine Pollution Bulletin 72: 244-249.

[133] Lavers, J.L. et al. 2013. Plastic ingestion by Flesh-footed Shearwaters (*Puffinus carneipes*): implications for fledgling body condition and the accumulation of plastic-derived chemicals. Environ. Poll. 187: 124-129.

[134] Codina-Garcia, M. et al. 2013. Plastic debris in Mediterranean seabirds. Marine Pollution Bulletin 77: 220-226.

[135] Bravo-Rebedello, E.L. et al. 2013. Plastic ingestion by harbour seals (*Phoca vitulina*) in The Netherlands. Marine Pollution Bulletin 67: 200-202.

[136] Fossi, M.C. et al. 2012. Are baleen whales exposed to the threat of microplastics? A case study of the Mediterranean fin whale (*Balaenoptera physalus*). Marine Pollution Bulletin 64: 2374-2379.

[137] Fossi, M.C. et al. 2014. Large filter feeding marine organisms as indicators of microplastic in the pelagic environment; the case studies of the Mediterranean basking shark (*Cetorhinus maximus*) and fin whale (*Balaenoptera physalus*). Mar. Environ. Res. 100: 17-24.

[138] IWC 2013. Report of the scientific Committee. Annex K: report of the Standing Working Group on Environmental Concerns. International Whaling Commission, Jeju island, Republic of Korea. IWC/65A/Rep 1 Annex K.

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

At least 78% of the priority pollutants and 61% of priority substances listed as toxic by the United States Environmental Protection Agency and the European Union are associated with plastic debris, either as ingredients of plastic or those absorbed by plastic from the environment [139]. A variety of toxic chemicals are incorporated into plastics during manufacture[140], some of which could be released into the environment[141]. For example HBCD[142], a flame retardant in some polystyrene consumer products can be released during their production, use and once they are disposed of[143]. The natural breakdown of plastics in the environment results in leaching of additives directly into fresh and marine waters[144]. Substantial rapid leaching of HBCD was observed from polystyrene buoys in both fresh and sea water[145]. Research has shown that chemicals used in plastics such as phthalates and flame retardants can have toxicological effects on fish, mammals and molluscs[146].

In addition, toxic, bio-accumulative and persistent substances present in the marine environment from other sources, such as persistent organic pollutants (POPs) and metals, can also be adsorbed to plastic[147,148] and become orders of magnitude more concentrated on the surface of plastic debris within weeks[149].There are, therefore, two mechanisms that may facilitate the transport and uptake of harmful substances to marine biota, mainly via ingestion. There is also a proposed ‘cleaning’ mechanism that could result in POPs being removed from already contaminated organisms through the ingestion of uncontaminated (‘clean’) plastic that then absorbs POPs from the organism’s tissue and is subsequently egested[150]. Modelling studies predict that, in open marine systems, a decrease in POP bioaccumulation can occur due to a cleaning mechanism that counteracts biomagnification [151]. However, the differences were considered too small to be relevant from a risk assessment perspective. The high uptake of contaminants onto plastics and the longevity of plastics in the environment also suggests that plastic debris will not remain ‘clean’ for any extended period of time[152].

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[139] Rochman, C.M. et al. 2013a. Classify plastic waste as hazardous. Nature 494: 169-171.
[140] Lithner, D. et al., 2011 Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. Science of the Total Environment 409: 3309-3324.
[141] 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.
[142] Hexabromocyclododecane
[143] Rani M. et al 2014. Hexabromocyclododecane in polystyrene based consumer products: an evidence of unregulated use. Chemosphere 110: 111-119.
[144] Flint, S. et al. 2012. Bisphenol A exposure, effects and policy: a wildlife perspective. J. Environ. Manag. 104: 19-34.
[145] Rani M. et al 2014. Hexabromocyclododecane in polystyrene based consumer products: an evidence of unregulated use. Chemosphere 110: 111-119.
[146] 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.
[147] Rochman C.M. et al. 2013b. Long-term field measurement of sorption of organic contaminants to five types of plastic pellets: implications for plastic marine debris. Environ. Sci. Technol. 47: 1646-1654.
[148] Holmes, L.A. et al. 2012. Adsorption of trace metals to plastic resin pellets in the marine environment. Environ. Poll. 160: 42-48.
[149] 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.
[150] Gouin, T. et al. 2011. A thermodynamic approach for assessing the environmental exposure of chemicals absorbed to microplastic. Environ. Sci. Technol. 45: 1466-1472.
[151] Koelmans, A.A. et al. 2013. Plastic as a Carrier of POPs to Aquatic Organisms: A Model Analysis. Environ. Sci. Technol. 47: 7812-7820.
[152] Teuten, E. et al. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Phil. Trans. R. Soc. B 364: 2027-2045.

Recent studies that have recorded the presence of toxic chemicals derived from plastics in marine taxa are summarized in Appendix 1c. Inherent chemicals from plastics have been detected in deposit-feeding invertebrates[153], myctophid[154] and predatory fish[155] inhabiting areas of high plastic density, seabirds[156] and large filter-feeding vertebrates[157]. However it has been difficult to determine whether the uptake of these chemicals via plastics in the marine environment is having a negative effect on the health of the species in question. Recent laboratory studies with marine invertebrates have shown that additives (and adsorbed POPs) associated with microplastics are readily taken up into tissues of lugworms (*Arenicola marina*) and can have a negative effect on health[158]. However probabilistic modelling of the leaching of two additives (nonylphenol and bisphenol A) from ingested microplastic for this species suggests that contamination via this mechanism is not a likely relevant exposure pathway when compared to ambient concentrations present in the marine environment[159]. Plastic ingestion was also thought to be a negligible pathway for these contaminants in cod (*Gadus morhua*)[160]. Ingestion of polyethylene was deemed as a small or negligible source of PBTs for marine species according to a thermodynamic modelling assessment [161] although this approach may significantly underestimate the amount of PBT transferred from plastic to the organism in the gut[162].

The presence of toxic substances in marine organisms that had been adsorbed onto microplastic and then taken up after ingestion has been demonstrated in laboratory experiments for lugworms[163] and fish (*Oryzias latipes*)[164]. For the latter, fish that were fed microplastic particles exposed to PBTs in the marine environment for three months showed early warning signs of endocrine disruption[165]. Plastics in the marine environment may serve as a vector for the bioaccumulation of PBTs adsorbed to plastic, suggesting that plastic debris can serve as a vector for the bioaccumulation of PBTs in wildlife[166]. Fish exposed to clean microplastic pellets and pellets with PBTs adsorbed from seawater also developed hepatic stress and lesions with a stronger effect caused by adsorbed microplastic[167]. Adsorption of PBTs also varies between different plastic compounds and is dependent on the physical and chemical properties of the plastic in question[168]. Analysis of various types of plastic fragments exposed to environmental concentrations of PBTs in San Diego Bay (USA) over 12 months revealed

[153] Browne, M.A. et al. 2013. Microplastic moves pollutants and additives to worms, reducing functions linked to health and biodiversity. Current Biology 23: 2388-2392.

[154] Rochman, C.M. et al. 2014b. Polybrominated diphenyl ethers (PDBEs) in fish tissue may be an indicator of plastic contamination in marine habitats. Science of the Total Environment 476-477: 622-633.

[155] Koelmans, A.A. et al., 2014. Leaching of plastic additives to marine organisms. Environ. Poll. 187: 49-54.

[156] Tanaka, K. et al. 2013. Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics. Marine Pollution Bulletin 69: 219-222.

[157] Fossi, M.C. et al. 2014. Large filter feeding marine organisms as indicators of microplastic in the pelagic environment; the case studies of the Mediterranean basking shark (*Cetorhinus maximus*) and fin whale (*Balaenoptera physalus*). Mar. Environ. Res. 100: 17-24.

[158] Browne, M.A. et al. 2013. Microplastic moves pollutants and additives to worms, reducing functions linked to health and biodiversity. Current Biology 23: 2388-2392.

[159] Koelmans, A.A. et al., 2014. Leaching of plastic additives to marine organisms. Environ. Poll. 187: 49-54.

[160] Ibid

[161] Gouin, T. et al. 2011. A thermodynamic approach for assessing the environmental exposure of chemicals absorbed to microplastic. Environ. Sci. Technol. 45: 1466-1472.

[162] Engler, R.E. et al. 2012. The complex interaction between marine debris and toxic chemicals in the ocean. Environ. Sci. Technol. 46: 12302-12315.

[163] Besseling, E. et al. 2013. Effects of microplastic on fitness and PCB bioaccumulation by the lugworm *Arenicola marina* (L.). Environ. Sci. Technol. 47: 593-600.

[164] Rochman, C.M. et al. 2014c. Early warning signs of endocrine disruption in adult fish from the ingestion of polyethylene with and without sorbed chemical pollutants from the marine environment. Science of the Total Environment 493: 656-661.

[165] Ibid

[166] Rochman, C.M. et al. 2013c. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Sci. Rep. 3: 3263; DOI:10.1038/srep03263.

[167] Ibid

[168] Rochman C.M. et al. 2013b. Long-term field measurement of sorption of organic contaminants to five types of plastic pellets: implications for plastic marine debris. Environ. Sci. Technol. 47: 1646-1654.

that polyethylene and polypropylene absorbed more PAHs and PCBs than PET or PVC[169]. Products made from polyethylene and polypropylene may therefore pose a greater risk to marine animals if fragments are ingested.

Overall, it appears that from the laboratory-based studies conducted to date, the ingestion of contaminated plastic debris has the potential to compromise the health of aquatic organisms through the toxic effects of inherent and adsorbed chemicals, and both aspects should be taken into consideration when assessing the ingestion impacts of plastic debris on marine species. However, there is currently insufficient evidence to show that PBTs associated with plastic debris are having an adverse effect on marine organisms in the environment. Considerable further research is required to determine the effects of plastic ingestion on the health of marine biota. It has been suggested that studies should focus on the type, size and shape of the plastic material and the concentration of chemicals that sorb to the material from the environment, while also prioritising research on plastics with the greatest number of priority pollutants or those that sorb the most chemicals[170].

2.4 Dispersal via rafting and transport of invasive species

Rapid, large scale transport of suitable natural substrates (e.g., pumice) is known to fundamentally change the dispersal range and limitations for many marine taxa[171] and is likely to be similarly applicable to floating marine debris. CBD Technical Series 67 reported that 270 species were known to disperse by rafting on debris, including five invasive species, although this was thought to be an under-representation of the actual number due to the limited number of reports and a lack of identification to species level[172]. A recent study of plastic-associated rafting communities in the North Pacific identified a further 25 taxa that had not been previously reported in rafting assemblages, including bryozoans, sponges, molluscs, crustaceans and polychaete worms[173]. One organism of particular interest was the folliculinid ciliate (*Halofolliculina* sp.) recorded on plastic debris in the western Pacific, a pathogen that causes skeletal eroding band (SEB) disease in corals. Plastic debris may be acting as a vector for infectious diseases[174], although this has not been well studied to date[175].

Large anthropogenic debris resulting from natural events such as earthquakes and tsunamis can also provide significant rafting substrates able to transport diverse and substantial benthic communities over vast distances[176]. Fourteen species of hydroids were identified in fouling communities on large tsunami debris items washed ashore along the west coast of the United States that had originated from east coast of Japan[177]. Of these, at least five species had not previously been reported in North America. One of the debris items, a large floating dock washed up in June 2012, supported a community of at least 130 species consisting of molluscs, barnacles, crabs, bryozoans, macroalgae, annelid worms and echinoderms[178]. The dock also harboured a number of invasive species such as the

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[169] Ibid

[170] Rochman C.M. et al. 2013b. Long-term field measurement of sorption of organic contaminants to five types of plastic pellets: implications for plastic marine debris. Environ. Sci. Technol. 47: 1646-1654.

[171] Bryan, S.E. et al. 2012. Rapid long-distance dispersal by pumice rafting. PLoS ONE 7: e40583.

[172] 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.

[173] Goldstein, M.C. et al. 2014. Relationship of diversity and habitat area in North Pacific plastic-associated rafting communities. Mar. Biol. 161: 1441-1453.

[174] Zettler, E.R. et al. 2013. Life in the 'Plastisphere': Microbial communities on plastic marine debris. Environ. Sci. Technol. 47: 7137-7146.

[175] Pham, P.H. et al. 2012. The potential of waste items in aquatic environments to act as fomites for viral haemorrhagic septicaemia virus. J. Fish Dis. 35: 73-77.

[176] Calder, D.R. et al. 2014. Hydroids (Cnidaria: Hydrozoa) from Japanese tsunami marine debris washing ashore in northwestern United States. Aquatic Invasions 9.

[177] Ibid

[178] http://blogs.oregonstate.edu/floatingdock/2013/01/07/january-2013-update-of-agate-beach-tsunami-dock-species-list/

Mediterranean mussel (*Mytilus galloprovincialis*), the brown seaweed (*Undaria pinnatifida*) and the Asian shore crab (*Hemigrapsus sanguinensis*).

2.5 Habitat or ecosystem-level impacts

The impacts of marine debris at the habitat or ecosystem level were previously reported for coral reefs, soft subtidal sediments and sandy intertidal habitats, with the most damaging impacts on shallow reef habitats caused by derelict fishing gear[179]. The long-term impact of ghost fishing on marine communities is also not understood although it is known that derelict gear can be responsible for considerable mortality of fish and invertebrates over years[180]. Some recent attention has been given to the potential implications of microplastic pollution on marine habitats, food webs and ecosystems although the chronic impacts of marine debris at the population or community level are currently not known. However, the increasing abundance of microplastics may be capable of modifying community-wide assemblages and enhancing biogeographic connectivity of rafting species[181]. There is also concern that the negative effects of debris on threatened species with small or geographically restricted populations could be significant at the population level[182]. In addition, negative debris impacts could potentially contribute to deleterious population effects in combination with other anthropogenic stressors in the marine environment.

Recent laboratory-based studies of microplastic effects on lugworms (*Arenicola marina*) have led to the suggestion that microplastic contamination of shallow sediments could lead to ecosystem-level effects[183]. Lugworms provide key ecosystem functions by processing and aerating sediment, helping to maintain it for a wide range of other marine species. Lugworms that ingested sediment spiked with microplastic (UPVC[184]) at environmentally relevant concentrations, had significantly depleted energy reserves of up to 50%[185]. If such an effect were to occur in the marine environment, sediment processing in tidal soft sediment ecosystems could be significantly reduced. For example, in the Wadden Sea, it is predicted that lugworms would process 130 m^3 less sediment annually if exposed to microplastic contamination of 3%, a level already recorded on some polluted beaches[186].

Microplastic pollution in the open ocean may also have effects on pelagic ecosystems, especially in subtropical oceanic gyres. The accumulation of microplastics in gyres provides substantial new hard-substrata habitat for diverse microbial communities and also invertebrates. Furthermore, plastic differs from other types of marine debris in that its hydrophobicity stimulates early colonizers, rapid biofilm formation and microbial succession[187]. Inert surfaces are also known to stimulate microbial respiration and growth by concentrating dilute nutrients[188]. Micronutrient concentration by microplastics in oligotrophic oceanic waters may play a significant role in increasing microbial activity in surface

[179] 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.
[180] Good, T. Et al. 2010. Derelict fishing nets in Puget Sound and Northwest Straits: Patterns and threats to marine fauna. Mar. Poll. Bull. 60: 39-50.
[181] Wright, S.L. et al. 2013a. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.
[182] Codina-Garcia, M. et al. 2013. Plastic debris in Mediterranean seabirds. Mar. Poll. Bull. 77: 220-226. Population level effects were also discussed in the CBD Technical Series No 67 as well as Gall & Thompson (2012).
[183] Wright, S.L. et al. 2013b. Microplastic ingestion decreases energy reserves in marine worms. Current Biology 23 (23): R1031-R1033.
[184] Unplasticised polyvinylchloride
[185] Wright, S.L. et al. 2013b. Microplastic ingestion decreases energy reserves in marine worms. Current Biology 23 (23): R1031-R1033.
[186] Ibid
[187] Zettler, E.R. et al. 2013. Life in the ‘Plastisphere’: Microbial communities on plastic marine debris. Environ. Sci. Technol. 47: 7137-7146.
[188] Zobell, C.E. 1943. The effect of solid surfaces upon bacterial activity. J. Bacteriol. 46: 39-56.

waters of ocean gyres[189] and contribute to changes in primary or secondary productivity in these regions[190].

It has also been suggested that plastic-associated rafting organisms may influence the pelagic ecosystem by reworking the organic particle size spectrum through ingestion and egestion[191]. Filter or suspension feeding invertebrates found on micro or macrodebris can feed on particles that fall within the size range of non-microbial organic particles in oligotrophic oceanic waters. Large-scale alterations in particle size could influence species compositions in subtropical gyres by altering the proportions of energy flowing into the microbial loop and the metazoan food web[192].

The potential impacts mentioned above highlight the need for further research into the impacts of marine debris on marine and coastal biodiversity, particularly at the population and community level where information is currently lacking. However, the evidence gathered to date and the knowledge that many plastics are or become toxic in the marine environment should provide sufficient incentive for concerted action to implement long-term target-driven programmes to reduce the production and disposal of plastic, which will substantially decrease the flow of these persistent waste items into the marine environment.

Potential for debris to provide new habitat

Through the introduction of hard surfaces in the sea, marine debris provides additional habitat, and has the potential to influence the relative abundance of organisms within local assemblages, particularly where debris provides isolated hard habitat in the water column or on soft sediments[193]. This section does not attempt to update the quantitative assessment of studies regarding the use of marine debris as habitat undertaken for the CBD Technical Series 67, but rather provides relevant examples of research completed on the subject since 2012. However, it should be mentioned that fishing gear retrieval programmes for ALDFG continue to provide new records of marine biota, mainly of invertebrates using ghost nets and traps as habitat.

Detailed information is emerging for accumulated buoyant debris, particularly small macroplastic and microplastic fragments, as new habitats in the open ocean. Plastic debris in the sea is rapidly colonized by microbes to form a biofilm on the fragment surface, effectively becoming an artificial 'microbial reef', which has been called the 'plastisphere'[194]. Detailed SEM[195] and molecular analysis of plastic fragments from the North Atlantic Gyre has revealed a rich microbial community living on the fragments' surfaces which is distinct from the microbial community in the surrounding water[196]. The 'plastisphere' community consisted of autotrophs, heterotrophs, symbionts and predators and included several hydrocarbon degrading bacteria and potential opportunistic pathogens (*Vibrio* spp.). Microbial communities were also identified on plastic fragments collected from the North Pacific Gyre, with greater bacterial abundance recorded on foamed polystyrene[197]. In addition the presence of

[189] Zettler, E.R. et al. 2013. Life in the 'Plastisphere': Microbial communities on plastic marine debris. Environ. Sci. Technol. 47: 7137-7146.
[190] Reisser, J. et al. 2014. Millimeter-sized marine plastics: a new pelagic habitat for microorganisms and invertebrates. PLoS ONE 9: e100289. doi: 10.1371/journal.pone.0100289.
[191] Goldstein, M.C. et al. 2014. Relationship of diversity and habitat area in North Pacific plastic-associated rafting communities. Mar. Biol. 161: 1441-1453.
[192] Ibid
[193] 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.
[194] Zettler, E.R. et al. 2013. Life in the 'Plastisphere': Microbial communities on plastic marine debris. Environ. Sci. Technol. 47: 7137-7146.
[195] Scanning Electron Microscope
[196] Zettler, E.R. et al. 2013. Life in the 'Plastisphere': Microbial communities on plastic marine debris. Environ. Sci. Technol. 47: 7137-7146.
[197] Carson, H.S. et al. 2013. The plastic-associated organisms of the North Pacific Gyre. Marine Pollution Bulletin 75: 126-132.

pits on the surface of fragments that conformed to bacterial shapes suggests that active hydrolysis of plastic polymers could be occurring[198].

A more recent study of 'epiplastic' biota on microplastic fragments collected in Australian waters also identified pits and grooves confirming to the shape of microorganisms suggesting that some biota may play an active role in plastic degradation[199]. As well as a diverse microbial community of mainly diatoms and bacteria, a number of invertebrate taxa were identified including bryozoans, barnacles, an isopod, a marine worm and marine insect eggs (*Halobates* sp.). Although invertebrates associated with microplastics are rare and less diverse when compared to those recorded on macroplastic debris there could be significant ecological implications given the abundance and wide distribution of millimetre-sized plastics in the marine environment[200]. The increasing availability of floating plastic debris offers progressively increasing habitat to sessile calcified invertebrates[201] and has the potential to expand populations of open-ocean rafting species such as gooseneck barnacles and oceanic insects[202]. The Australian study also revealed a diverse range of diatom genera and recorded the first coccolithophore genera on floating microplastic fragments[203]. It was suggested that marine plastics create a novel, long-lasting and abundant floating habitat that is stable and beneficial for diatoms.

The formation of biofilms on the surface of plastic is important to the plastic degradation process[204] and there is recognition that microscopic organisms are key to understanding and solving many of the problems with plastic pollution[205]. It is therefore important to identify the dominant organisms in epiplastic microbial communities, their distribution in the ocean and their effects on the plastic debris they inhabit if we want to better understand the future of plastic pollution in the marine environment[206]. Such studies on the 'plastisphere' may also support the development of biotechnological solutions for better waste plastic disposal practices[207,208].

2.6 Socio-economic Impacts of Marine Debris

Marine debris has extensive negative social and economic impacts for society. There have been substantial economic losses for industries such as commercial fishing, shipping, recreation and tourism, caused wholly or partly by various types of marine debris[209,210]. A report by the Asia Pacific Economic Cooperation showed that its member economies lost more than $1 billion per year due to

198 Zettler, E.R. et al. 2013. Life in the 'Plastisphere': Microbial communities on plastic marine debris. Environ. Sci. Technol. 47: 7137-7146.

199 Reisser, J. et al. 2014. Millimeter-sized marine plastics: a new pelagic habitat for microorganisms and invertebrates. PLoS ONE 9: e100289. doi: 10.1371/journal.pone.0100289.

200 Ibid

201 Winston, J.E. 2012. Dispersal in marine organisms without a pelagic larval phase. Integrative and Comparative Biology 52: 447-457.

202 Goldstein, M.C. et al. 2014. Relationship of diversity and habitat area in North Pacific plastic-associated rafting communities. Mar. Biol. 161: 1441-1453.

203 Reisser, J. et al. 2014. Millimeter-sized marine plastics: a new pelagic habitat for microorganisms and invertebrates. PLoS ONE 9: e100289. doi: 10.1371/journal.pone.0100289.

204 Artham, T. et al. 2009. Biofouling and stability of synthetic polymers in sea water. Int. Bioderiot. Biodegrad. 63: 884-890.

205 Harrison, J.P. et al. 2011. Interactions between microorganisms and marine microplastics: a call for research. Mar. Technol. Soc. J. 45: 12-20.

206 Carson, H.S. et al. 2013. The plastic-associated organisms of the North Pacific Gyre. Marine Pollution Bulletin 75: 126-132.

207 Reisser, J. et al. 2014. Millimeter-sized marine plastics: a new pelagic habitat for microorganisms and invertebrates. PLoS ONE 9: e100289. doi: 10.1371/journal.pone.0100289.

208 Sangale, M et al. 2012. A review of biodegradation of polyethylene: the microbial approach. J. Bioremed. Biodeg. 3.

209 Mouat, T. et al. 2010. Economic impacts of marine litter. KIMO (Kommunenes Internasjonale Miljøorganisasjon) 117 pp.

210 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 pages.

marine litter impacts such as clean-up and vessel damage[211]. There are also widespread social impacts of marine debris such as direct, short-term human health issues (e.g., injuries, entanglement and navigational hazards) and indirect, long-term impacts on quality of life (e.g., diminishing recreational opportunities, loss of aesthetic value and loss of non-use value)[212]. The global assessment on the sources, fates and effects of microplastics in the marine environment, which was published by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) concluded that the presence of macro debris has been recorded to have negative social and economic impacts, reducing the ecosystem services and compromising perceived benefits [213.] However, an overall understanding of both social and economic impacts of marine debris is still rather limited with studies generally focussing on the costs to one or two industries in a few regions.[214] In addition to the socioeconomic impact studies provided in CBD Technical Series 67, this section briefly outlines some further examples that highlight the costs of preventing or cleaning up marine debris as well as recent estimates of losses to fisheries and tourism.

The direct economic impacts of ghost fishing by derelict gear includes the loss of targeted commercial species and non-target species, the cost of replacing the lost gear, as well as monitoring, clean-up and disposal costs. Negative impacts of ghost fishing on commercial and recreational fish stocks are not always considered during fisheries management and stock assessment but may have a significant effect for some fisheries. Recent estimates of losses of target species by entrapment in derelict fish traps suggest that between 3[215] and 4.5[216]% of the annual harvest of Dungeness crabs in U.S. west coast fisheries is lost through ghost fishing, with a monetary value of almost $0.75 million estimated to be lost for the Puget Sound fishery. Fish mortality in fish traps in the U.S. Virgin Islands was estimated to cost $190000 annually, which is likely to be an underestimate given that the total number of traps in use is not well known[217]. The impact of ghost fishing on ecological communities and ecosystem services is not fully understood but is likely to contribute to the level of anthropogenic stress on marine and coastal ecosystems, particularly in areas experiencing multiple severe stressors.

Marine debris and coastal litter can impact and deteriorate a range of natural functions that provide ongoing social and economic benefits[218]. The natural capital analysts Trucost on behalf of the Plastic Disclosure Project (PDP) and with the support of the United Nations Environment Programme and the Global Partnership on Marine Litter (GPML) conducted research to articulate the business case for companies to improve their measurement, disclosure and management of plastic used in their designs,

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[211] McIlgorm, A. et al. 2011. The economic cost and control of marine debris damage in the Asia-Pacific region. Ocean and Coastal Management 643: 644.

[212] Sheavly, S.B. and Register, K.M. 2007. Marine debris and plastics: environmental concerns, sources, impacts and solutions. J. Polym. Environ. 15: 301-305. See also, Wyles, K.J., Pahl, S., Thomas, K., Thompson, R.C., 2015. Factors That Can Undermine the Psychological Benefits of Coastal Environments: Exploring the Effect of Tidal State, Presence, and Type of Litter. Environment and Behaviour.

[213] 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, 65 p.

[214] See also the key observations and conclusions on social aspects of microplastic, 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, 65 p.

[215] Maselko, J. et al. 2013. Ghost fishing in the southeast Alaska commercial Dungeness crab fishery. North American Journal of Fisheries Management. 33: 422-431.

[216] Antonelis, K. et al. 2011. Dungeness crab mortality due to lost traps and a cost-benefit analysis of trap removal in Washington State waters of the Salish Sea. North Am. J. Fish. Manage. 31: 890-893.

[217] Renchen, G. et al. 2012. Chapter 4: Ecological impact of derelict traps. pp. 31-47. In Clark, R. et al. (eds.) 2012. Survey and impact assessment of derelict fish traps in St. Thomas and St. John, U.S. Virgin Islands. NOAA Technical Memorandum NOS NCCOS 147. Silver Spring, MD. 51 pp.

[218] Hastings, E. and Potts, T. 2013. Marine litter: Progress in developing an integrated policy approach in Scotland. Marine Policy 42: 49-55.

operations and supply chains[219]. It concluded that the impacts of plastics vary around the world based on background conditions and management practices. The study found that the pollution of marine ecosystems by marine debris has a natural capital cost of at least $13 billion[220].

An assessment of economic losses caused by marine debris for residents of Orange County, California, revealed a considerable impact[221]. A 25% reduction in marine debris for all beaches would save Orange County residents $32 million over three months. Targeting 6 beaches near the outflow of the Los Angeles River to decrease marine debris by 75% would increase visitors by 43% and provide benefits of $53 million. Substantial economic losses for the tourism industry of Goeje Island in the Republic of Korea were caused by a pollution event that washed a large amount of marine debris on to the shoreline[222]. Tourism revenue loss between 2010 and 2011 was estimated to be $29-37 million after there was a 63% reduction in the number of visitors to the island. Marine debris impacts on the health of charismatic marine species and their habitat can also significantly reduce tourism[223].

Preventing land-based sources of debris entering the marine environment is a key management objective but is also complex and expensive. For communities in California, Oregon and Washington states on the west coast of the U.S., the average annual cost per resident is $13 for litter management and marine debris reduction efforts[224] which is equivalent to $520 million per year. The recently launched Marine Litter Strategy for Scotland has estimated that it will cost £17 million per year to tackle the issue[225]. The average cost of removing beach litter for coastal municipalities in the UK increased by 37.4% over a ten year period (2000-2010)[226]. National or regional assessments of the cost of effective litter reduction and management programmes for countries with limited waste management infrastructure in place would help to inform and plan future management approaches.

2.7 Emerging Issues

A number of emerging issues were highlighted at the CBD Expert Workshop[227], which have the potential to contribute to one or more of the impacts mentioned in this section. The issues are mainly concerned with sea-based or coastal sources of marine debris and include the storage of employable fishing gear in the marine environment ('wet storage'), the use of sacrificial fishing gear such as fish aggregating devices (FADs), and the potential for debris generation by activities such as offshore development, recreational fishing and marine tourism. In addition, there is concern regarding the increasing contribution of aquaculture materials to marine debris and the potential for aquaculture to increase in marine debris production as the industry grows further. These emerging issues are currently data-deficient with considerable gaps in our knowledge of their contribution to marine debris.

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[219] UNEP (2014) Valuing Plastics: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry.
[220] Ibid, p.7.
[221] Leggett et al. 2014. Assessing the economic benefits of reductions in marine debris: A pilot study of beach recreation in Orange County, California. Final Report for the Marine Debris Division, NOAA. Industrial Economics, Incorporated. 45 pp.
[222] Jang, Y.C. et al. 2014. Estimation of lost tourism revenue in Geoje Island from the 2011 marine debris pollution event in South Korea. Marine Pollution Bulletin 81: 49-54.
[223] Stickel, B.H. et al. 2012. The cost to west coast communities of dealing with trash, reducing marine debris. Prepared by Kier Associates for U.S. Environmental Protection Agency, Region 9, pursuant to Order for Services EPG12900098, 21 p. + appendices.
[224] Ibid
[225] http://www.heraldscotland.com/news/home-news/17m-cost-of-marine-litter-clear-up.1408456188
[226] Mouat, T. et al. 2010. Economic impacts of marine litter. KIMO (Kommunenes Internasjonale Miljøorganisasjon) 117 pp.
[227] Secretariat of the Convention on Biological Diversity. 2015. Report of the Expert Workshop to prepare Practical Guidance on Preventing and Mitigating the Significant Adverse Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats. Baltimore, U.S.A, December 2014. UNEP/CBD/MCB/EM/2014/3/2. 31 pp.

3. MONITORING AND MODELLING OF MARINE DEBRIS

Key Messages

1. Monitoring and modelling of marine debris has grown significantly in the last few decades, but there are still extensive gaps in our knowledge, particularly for microplastics, transport pathways and sources/sinks of microplastic particles.
2. The use of smart technology and citizen science are some of the more innovative tools being employed to improve the monitoring of marine debris.
3. Combining monitoring and modelling information for both marine species and debris types can enable the production of regional or global risk assessments for vulnerable marine taxa.

3.1 Marine Debris Monitoring

On land, regular coastal clean-ups as part of long-term monitoring programmes are important for removing potentially harmful debris items from the marine environment and preventing their reintroduction into inshore waters. There has been a focus on monitoring (and modelling) of marine litter along coastlines and in surface waters in recent years with a particular emphasis on plastic debris, especially microplastics[228]. Monitoring and assessment of microplastics in shallow or coastal sediments has also been well documented[229]. Considerably less information is available for marine debris in deeper waters and on the seabed[230]. However, as 70% of all plastic debris has been estimated to eventually sink to the seafloor[231], there is a need to better understand the abundance and distribution of marine plastic debris in the deep sea. Assessing the occurrence and frequency of such debris in the deep sea is challenging and expensive[232], but can be combined with existing survey programmes to collect information on marine litter during on-going assessments of marine fauna or habitats. A recent study of deep sea litter in European waters provides a large-scale analysis of marine debris on the seafloor across different physiographic settings and depths[233]. The highest densities of marine litter were found in submarine canyons, while ocean ridges and continental shelves had the lowest densities. Marine litter was recorded at all sites and depths (35–4500 m), including remote mid-oceanic ridges and deep basins. Higher densities of plastic litter were found on the seabed than in surface waters for some locations such as the Mediterranean Sea. Submarine canyons were considered to be accumulation zones of land-based marine litter in the deep sea[234], acting as conduits for litter transport from continental shelves into deeper waters[235,236].

The global distribution of floating plastic debris in the surface waters of the open ocean was recently estimated based on sampling on a circum-navigation cruise (Malaspina 2010 expedition), five regional cruises and other data from recent studies[237]. This study confirmed the accumulation of plastic debris in the five subtropical gyres but estimated that the global load of plastic in oceanic

[228] Ivar do Sul, J. and Costa, M.F. 2014. The present and future of microplastic pollution in the marine environment. Env. Poll. 185: 352-364.
[229] Ibid
[230] Van Cauwenberghe L. et al., 2013. Microplastic pollution in deep-sea sediments. Environ. Pollut. 182:495-499.
[231] Engler, R.E. 2012. The complex interaction between marine debris and toxic chemicals in the ocean. Environ. Sci. Technol. 46: 1202-12315.
[232] Pham, C.K. et al. 2014. Marine litter distribution and density in European Seas, from the shelves to deep basins. PLoS ONE 9: e95839.
[233] Ibid
[234] Ibid
[235] Ramirez-Llodra, E. et al. 2013. Effects of natural and anthropogenic processes in the distribution of marine litter in the deep Mediterranean Sea. Prog. Oceanogr. 118: 273-287.
[236] Mordecai, G. et al., 2011. Litter in submarine canyons off the west coast of Portugal. Deep Sea Res. Part II Top. Stud. Oceanogr. 58: 2489-2496.
[237] Cózar, A. et al., 2014. Plastic debris in the open ocean. PNAS 111: 10239-10244.

surface waters to be between 7 and 35000 tonnes, considerably less than expected. The size distribution of floating plastic debris suggests that there are important size-selective sinks that remove millimetre-sized fragments of floating plastic on a large scale. Potential mechanisms for removal of these microplastics include the rapid nano-fragmentation into micron-scale particles and the transfer of microplastics to the ocean interior by ballasting processes or food webs[238]. For the latter it was proposed that ingestion of microplastics by zooplankton and small mesopelagic fish may lead to the transfer of plastic fragments to larger predators or the sinking of microplastics to the seabed either in the bodies of dead animals or in their faeces. These mechanisms are supported by currently available information on the significant abundance of microplastic particles in deep sediments[239]. Identifying and verifying these pathways is regarded as a matter of urgency in order to determine the fate of this missing plastic debris, its effects on marine biodiversity and the significance of any impacts[240].

A document published in 2013 provides comprehensive guidance on the monitoring of marine litter, developed for European waters[241]. This report provides European countries with information and recommendations needed to commence the monitoring of marine litter as part of the EU Marine Strategy Framework Directive (MSFD). Protocols are provided for the monitoring of beach litter, floating litter, seafloor litter, litter in biota and microlitter. The guidance document is designed to support EU member states in implementing harmonized monitoring programmes for marine litter.

Within the OSPAR framework, the Ecological Quality Objective (EcoQO) for plastic litter has provided valuable information on spatio-temporal characteristics of marine litter, and differences between trends in industrial and user plastics and on the sources of marine litter for the North Sea[242]. The EcoQO technique has been taken up by the European MSFD as a marine litter indicator, and can be adapted to apply to most areas of the Northeast Atlantic for northern fulmars (*Fulmaris glacialis*). Other target indicator species and regions are also under consideration such as marine turtles (*Caretta caretta*) in the Mediterranean region and species of fish, zooplankton, shellfish and seals for most European seas or as targets for one or more sub-regions of the MSFD[243,244]. Large filter-feeding vertebrates, such as baleen whales and basking sharks, have recently been selected as wide-scale indicators of microplastic presence and impact for the Mediterranean pelagic environment as part of the MED-SDSN PLASTC-BUSTERS project[245]. Moreover, baleen whales and other large filter-feeders have been recommended for consideration in national and international marine (monitoring) debris strategies as critical indicators of microplastic pollution in the marine environment[246].

The general public can also contribute to national or regional marine debris monitoring programmes on a day-to-day basis through the use of innovative citizen science tools. In the United States, the National Oceanic and Atmospheric Administration's (NOAA) Marine Debris Program have developed a Marine Debris Tracker App in collaboration with the Southeast Atlantic Marine Debris Initiative (SEA-MDI) based at the University of Georgia[247]. As well as being easy to use tools to collect marine debris data for coastlines the technology should also help to spread awareness of the issue. A similar app has also been developed in the European Union by the European Environment

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[238] Ibid

[239] Van Cauwenberghe L. et al., 2013. Microplastic pollution in deep-sea sediments. Environ. Pollut. 182:495-499.

[240] Cózar, A. et al. 2014. Plastic debris in the open ocean. PNAS 111: 10239-10244.

[241] Monitoring Guidance for Marine Litter in European Seas. MSFD GES Technical Subgroup on Marine Litter (TSG-ML). Draft Report, July 2013.

[242] Van Franeker, J.A. et al., 2011. Monitoring plastic ingestion by the northern fulmar *Fulmaris glacialis* in the North Sea. Environ. Poll. 159: 2609-2615.

[243] Galgani, F. et al., 2013. Marine litter within the European Marine Strategy Framework Directive. – ICES J. Mar. Sci. 70: 1055-1064.

[244] Galgani, F. et al. 2014. Monitoring the impact of litter in large vertebrates in the Mediterranean Sea within the European Marine Strategy Framework Directive (MSFD): Constraints, specificities and recommendations. Mar. Env. Research. http://dx.doi.org/10.1016/j.marenvres.2014.02.003.

[245] Ibid

[246] IWC 2013. Report of the 2013 IWC Scientific Committee workshop on Marine Debris. IWC/SC/65a/Rep06.

[247] http://marinedebris.noaa.gov/partnerships/marine-debris-tracker

Agency (EEA) in collaboration with the Marine Conservation Society, the Institute for Water for the Republic of Slovenia, the North Sea Foundation and the PERSEUS FP7 research project. The Marine LitterWatch app[248] aims to fill data gaps for marine litter on beaches and support official monitoring in the European Union as part of the MSFD to achieve the main objective of 'Good Environmental Status'. It is hoped that it will also empower citizen networks in Europe and enable them to take part in a European attempt to address marine litter issues.

Although the issue of plastic debris in the marine environment is receiving considerable attention and recognition as a threat to marine biodiversity, there are still many knowledge gaps and research needs to improve monitoring. In particular, the presence of microplastics in surface waters of the ocean and the need for improved and more widespread monitoring of their abundance and distribution is required. Existing plankton monitoring programmes used as part of fish stock assessments have been suggested as a cost-effective means to assess microplastics in coastal waters[249]. Most microplastic debris is made up of fragments of widely-used polymers such as polyethylene (PE), polypropylene (PP) and polystyrene (PS) that float in seawater and can be collected in plankton nets although the concentration of smaller (micro-nano) particles may be underestimated depending on net mesh size[250]. It is also important to consider the effect of vertical mixing on plastic concentrations to enable better comparison of data collected under different sea states[251][252].

Improvements in extraction techniques for microplastics have been reported for environmental samples (sediment and biota)[253] that increase the efficiency of extraction. The procedure for sediments also enables high density microplastics such as PVC and PET to be extracted which were overlooked by the previous standard method[254]. The technique for detecting microplastics in field-collected organisms involves chemical digestion of the soft tissue of marine invertebrates[255]. This was successful in extracting polystyrene spheres and fishing line fibres but not for nylon rope fibres. Overall both techniques resulted in high extraction efficiencies (93 – 98%) for different types of microplastics and can be used as standardised and validated methods to develop a better understanding of microplastic presence in the marine environment[256].

3.2 Marine Debris Modelling

Recent modelling assessments at the global scale provide a framework for describing the transport and accumulation of floating debris and the formation of oceanic accumulation zones[257,258]. Such studies, along with more regionally or locally focused assessments[259] can be used as part of powerful education and outreach campaigns to inform the public or authorities of the consequences of

[248] http://www.eea.europa.eu/themes/coast_sea/marine-litterwatch/marine-litterwatch
[249] Frias, J.P.G.L., et al. 2014. Evidence of microplastics in samples of zooplankton from Portuguese coastal waters. Mar. Env. Research 95: 89-95.
[250] Hildago-Ruiz, V. et al., 2012. Microplastics in the marine environment: a review of the methods used for identification and quantification. Env. Sci. Technol. 46: 3060-3075.
[251] Reisser, J. et al., 2013. Marine plastic pollution in waters around Australia: Characteristics, concentrations and pathways. PLoS ONE 8 (11): e80466. doi: 10.1371/journal.pone.0080466.
[252] Kukulka, T et al., 2012. The effect of wind mixing on the vertical distribution of buoyant plastic debris. Geophys. Res. Lett. 39: L07601.
[253] Claessens, M. et al., 2013. New techniques for the detection of microplastics in sediments and field collected organisms. Mar. Poll. Bull. 70: 227-233.
[254] Thompson, R.C. et al., 2004. Lost at sea: where is all the plastic? Science 304: 838
[255] Claessens, M. et al., 2013. New techniques for the detection of microplastics in sediments and field collected organisms. Mar. Poll. Bull. 70: 227-233.
[256] Ibid.
[257] Maximenko, N. et al., 2012. Pathways of marine debris derived from trajectories of Lagrangian drifters. Mar. Poll. Bull. 65: 51-62.
[258] Lebreton, L.C.-M., et al. 2012. Numerical modelling of floating debris in the world's oceans. Mar. Poll. Bull. 64: 653-661.
[259] Carson, H.S. et al., 2013. Tracking the sources and sinks of local marine debris in Hawai'i. Mar. Env. Research 84: 76-83.

inadequate solid waste disposal and encourage better management of litter. Modelling efforts can also be useful addressing key information gaps such as assessing important transport pathways and material sources and sinks while also informing monitoring and clean-up strategies that will enable a better understanding of the issue[260,261]. However, these deterministic models that require extended measured or modelled wind or flow fields to forecast floating litter dispersal are not suitable for predicting the beaching of litter as the spatial resolution of the underlying model grids in coastal regions is currently too low[262] and complex coastal dynamics are difficult to predict. Time series modelling of beach litter pollution in the southern North Sea has been conducted using artificial neural networks (ANN) analysis and compared directly to beach survey data collected by the OSPAR beach litter monitoring programme[263]. The time series modelling of general categories marine litter such as litter from fishing, shipping and tourism were in good agreement with the measured beach litter pollution described. The ANN used was deemed suitable to forecast the abundances of general categories of marine litter through the use of selected litter items as input variables which may serve as indicators for these general categories[264]. However, the ANN did underestimate the measured maximum values of general categories when peak values were extremely high. Overall, the ANN used were regarded as useful tools to provide reliable and high-speed predictions of beach litter accumulation and general composition, although the effects of environmental predictors such as flow and wind regimes were not included.

3.3 Integrating Monitoring and Modelling of Marine Debris

Combining both monitoring and modelling data can provide a predictive tool for forecasting marine debris distribution and its effects on marine and coastal biodiversity. Decadal numerical predictions of plastic marine debris in East Asian marginal seas, estimated by combining modelling approaches with beach monitoring data collected via webcams, suggest that the quantity of plastic debris will continue to grow each year even if litter outflows at various sources remain unchanged[265]. In addition, for some beaches, the predicted litter quantities in 10 years will be 250 times the present levels, potentially causing an environmental risk through the leaching of toxic metals from plastic litter into sediments leading to concentrations exceeding known (e.g. EPA) standards. It was also suggested that monitoring of beach litter is essential as it is impossible to predict which beaches will be the next litter hot spots in the coming decade because of variations in ocean currents and wind fields.

Abandoned, lost or otherwise discarded fishing gear (ALDFG) was previously highlighted as a substantial threat for many marine fauna, particularly for rare or threatened taxa. Determining the level of threat or risk for a particular species or faunal group from the various types of marine debris is an important step which can focus mitigation or management measures. For example, by combining information from coastline assessments of ghost nets through beach clean-ups with modelling studies of oceanic drift and ecological data of marine turtle distribution and vulnerability it is possible to predict entanglement risk, identify high-risk areas and recommend locations for targeted surveillance and interception of abandoned fishing gear[266]. Such an approach can be adapted to other threatened

[260] Ibid
[261] Zarfl, C. et al. 2011. Microplastics in oceans. Mar. Poll. Bull. 62: 1589-1591.
[262] Schultz, M. and Matthies, M. 2014. Artificial neural networks for modelling time series of beach litter in the southern North Sea. Mar. Env. Research. 98:14-20.
[263] Schultz, M. and Matthies, M. 2014. Artificial neural networks for modelling time series of beach litter in the southern North Sea. Mar. Env. Research. 98:14-20.
[264] Ibid
[265] Kako, S. et al., 2014. A decadal prediction of the quantity of plastic marine debris littered on beaches of the East Asian marginal seas. Marine Pollution Bulletin 81: 174-184.
[266] Wilcox, C. et al., 2012. Ghostnet analysis of globally threatened turtles, a spatial risk analysis for northern Australia.

taxa and specific types of marine debris such as global risk assessments of debris ingestion for marine turtles[267] or seabirds[268].

[267] Schuyler, Q. et al., 2013. Global analysis of anthropogenic ingestion by sea turtles. Conservation Biology 28: 129-139.
[268] Wilcox, C et al., 2014. A global risk assessment for marine debris impacts on seabirds. Oral presentation, 2014 Ocean Sciences Meeting, Honolulu, Hawai'i, February 2014.

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

Key Messages

1. Recognition and concern regarding marine debris continues to grow at both the regional level, including through regional action plans, and at the global level by numerous UN and international bodies (e.g., UN General Assembly, UN Environment Programme, Food and Agriculture Organization of the UN, International Maritime Organization, Convention on Biological Diversity, Convention on Migratory Species, International Whaling Commission).
2. As the production and use of plastic is likely to continue to grow in the next few decades, responsible disposal of existing types of plastic is an important stage in the waste stream that requires greater attention. Preventing end-of-life materials from leaving the waste stream and entering the marine environment is a critical aspect to address the marine debris problem.
3. Preventing and reducing the production and consumption of environmentally-persistent types of plastic is a key aspect of tackling marine debris, which can be addressed in part through further research and development of new non-toxic, fully compostable and biodegradable alternatives to conventional plastics, with comparable economic properties and performance characteristics materials, new manufacturing and recycling processes and innovation in product design of these alternative biopolymers.
4. The use of campaigns and education to increase awareness and promote behavioural change can be effective and are likely to be particularly important for countries that currently do not have adequate waste management systems in place.
5. Giving consumers incentives to recycle persistent materials that are highly likely to become litter and eventually marine debris can be effective. User fees for particular items such as plastic bags can also be very effective and directly contribute to preventing these items becoming marine debris.
6. There is increasing recognition of the effectiveness and benefits of extended producer responsibility programmes in reducing packaging, especially for plastics. Improving the design of materials and packaging to eliminate or substantially reduce the production of single-use packaging or products will also help to prevent commonly-used items ending up as marine debris.
7. Long-term engagement with industry in addressing waste management issues is important.
8. 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. Such a waste management system may have the potential to increase the amount of waste diverted toward secondary use and recycling.

This chapter 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 Section 2 of CBD Technical Series 67[269]. Progress for management tools and measures to tackle the issue of marine debris, mainly over the 2012-2014 period, are summarized below.

[269] 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.

4.1 Institutional Responses

4.1.1 Global Responses in Intergovernmental Processes

Global recognition and concern of the marine debris problem continues to grow. At the 68th session of the United Nations General Assembly (UNGA) noted with concern in Resolution A/RES/68/70 that the health of the oceans and marine biodiversity are negatively affected by marine debris, especially plastic, from land-based and marine sources and recognised the need for better understanding of the sources, amounts, pathways, distribution trends, nature and impacts of marine debris. Resolution 68/70 focuses on marine debris (and climate change) and encourages States to further develop partnerships with industry and civil society to raise awareness of marine debris impacts on the health and productivity of the marine environment and consequent economic loss.

The first session of the United Nations Environment Assembly held in Nairobi in June 2014 passed a resolution on marine plastic debris and microplastics [270] that encourages governments to take comprehensive action to address the marine plastic debris and microplastic issue through, where appropriate, legislation, enforcement of international agreements, provision of adequate reception facilities for ship-generated wastes, improvement of waste management practices and support for beach clean-up activities, as well as information, education and public awareness programmes. The resolution also requested that a study of marine plastics debris and marine microplastics be undertaken that focuses on:

a. Identification of the key sources of marine plastic debris and microplastics;
b. Identification of possible measures and best available techniques and environmental practices to prevent the accumulation and minimize the level of microplastics in the marine environment;
c. Recommendations for the most urgent actions;
d. Specification of areas especially in need of more research, including key impacts of the environment and human health; and
e. Any other relevant priority areas identified in the assessment of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection.

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 for their 2012-2016 workplan. The GPA launched the Global Partnership on Marine Litter (GPML)[271], in June 2012 at the Rio+20 Conference, which is guided by the Honolulu Strategy, a global framework for prevention and management of marine debris. The GPML is regarded as an important coordinating platform for the management of the issue and provides a forum to assist stakeholders in complementing each other’s efforts, avoid duplication and optimize resource use[272]. The partnership has three overarching goals: to reduce the level and impacts of land-based and sea-based sources of marine debris and of accumulated marine debris on coastlines, in aquatic habitats and on biodiversity. The GPML held its first partnership forum in October 2013[273] which discussed a range of issues concerning marine debris and the development of GPML work plans and priorities. Activities currently underway fall under four main components:

1. Developing an online marine litter network to enable the global marine debris community to monitor progress on implementing the Honolulu Strategy, share information and enhance coordination;

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[270] UNEP/EA.1/L.6

[271] http://www.gpa.unep.org/index.php/global-partnership-on-marine-litter.

[272] Summit Declaration of the Heads of State and Government. G7 Summit 2015 in Schloss Elmau: https://www.g7germany.de/Content/EN/Artikel/2015/06_en/g7-gipfel-dokumente_en.html

[273] http://www.gpa.unep.org/index.php/global-partnership-on-nutrient-management/publications-and-resources/second-global-conference-on-land-ocean-connections-gloc-2/368-annex-13-report-of-the-marine-litter-session-and-partnership-forum/file.

2. Initiating regional activities through regional nodes such as using the Regional Seas Conventions and Action Plans to support implementation of the Honolulu Strategy;
3. Developing and implementing demonstration projects in three main areas: reducing the inflow of solid waste into the marine environment; life cycle approach, and; plastics recycling / redesign; and
4. Building public-private partnerships to promote practical plastics reduction measures and corporate social responsibility.

GPML activities also feed into the work plan of the UNEP-led Global Partnership on Waste Management (GPWM) to ensure that marine litter issues, goals and strategies are tied to global efforts to reduce and manage waste. The current GPWM work plan (2012-2016)[274] for marine litter has set a number of threat reduction results to pursue, including:

- Five new regional policy instruments aligned with the Honolulu Strategy through the RSCAPs within five years;
- Demonstration of at least 20% reduction of solid waste reaching the marine environment and 50% recycling rates of certain wastes in selected demonstration sites;
- Market-based instruments adopted in two countries to reduce the influx of waste into the coastal environment within five years;
- Plastic bag bans in five countries within five years; and
- A 15% reduction in the use of raw material in selected demonstration projects within industry

The Food and Agriculture Organisation (FAO) is proposing a roadmap to tackle the issue of ALDFG through a participatory approach that works closely with fisheries management bodies and the fishing industry. Proposed activities include:

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

A pilot project for the clean-up and removal of ALDFG is in preparation which will involve holding an expert workshop regarding industry-government partnerships to clean up fishing grounds and fishing ports, conducting a baseline study and site selection of a G-77 country fishery for a recovery / clean-up demonstration project that is led by the fishing community. The FAO are also working in partnership with UNEP and the IMO on reducing sea-based marine litter as part of the GPML[275].

The International Maritime Organisation (IMO) has recently revised the pertinent Annex to the convention for the prevention of pollution from ships (MARPOL Annex V for the prevention of

[274] UNEP 2011. Global Partnership on Waste Management. Marine Litter (ML). Work Plan for 2012-2016. United Nations Environment Programme Division of Environmental Policy Implementation. Global Programme of Action for the Protection of the Marine Environment from Land-based Activities. November 2011. http://www.unep.org/gpwm/Portals/24123/images/Work%20Plans/Work%20Plan%20ML%202012-2016.pdf

[275] Global Oceans Action Summit for Food Security and Blue Growth. April 2014. Chair's Summary. COFI/2014/SBD.3.

pollution by garbage from ships) [276]. The revised MARPOL Annex V applies five central elements in preventing pollution from vessel-based garbage: Area-based management, discharge standards, operational requirements (such as on-board garbage management plans), port reception facilities and port state control. The area-based management approach has established the designation of Special Areas in which a higher protection status is applied for particular regions such as the Antarctic, the Mediterranean and the Gulf of Mexico[277]. In case there is an accidental loss or discharge of fishing gear subject to regulation 7 (1) (3 and 4) MARPOL Annex V, it must be reported to the flag ship State and, in case it is located in waters under jurisdiction of a coastal State, also to this State. Where this, of course, does not prevent the loss or discard of fishing gear, it is an important provision that makes a significant step in IMO.

Although the revised MARPOL Annex V is proving to be effective at reducing sea-based sources of marine debris from larger vessels (> 100 Gross tonnage (GT)), there are still many smaller fishing vessels that are not covered by elements of this international treaty. Currently, all vessels at or above 100 GT (or carrying 15 persons or more) are now required to carry and follow a garbage management plan on board. The global fishing fleet is made up of approximately 4.3 million vessels of which 59% are powered by engines[278]. Of the motorized fishing vessels, only 2% (~50 000) are greater than 100 GT[279] (more than 24 m in length) meaning that, globally, there are almost 2.5 million fishing vessels with engines that are exempt from MARPOL Annex V.

Resolution 10.4 of the UNEP Convention on Migratory Species (CMS) instructed the Scientific Council to complete three reviews regarding marine debris:

a. Migratory Species, Marine Debris and its Management[280];
b. Marine Debris and Commercial Marine Vessel Best Practice[281]; and
c. Marine Debris Public Awareness and Education Campaigns[282].

These were provided as information documents to the 18th Meeting of the Scientific Council in July 2014. Subsequently, CMS Resolution 11.30 “Management of Marine Debris” was adopted by the Conference of the Parties to the CMS at its eleventh meeting in November 2014. In Resolution 11.30, the CMS COP addressed knowledge gaps in the management of marine debris, commercial marine vessel best practice and public awareness and education campaigns. It also requested the Scientific Council (SC) to further the Convention’s work on marine debris and investigate the feasibility of close cooperation with other biodiversity-related agreements by means of a multilateral working group[283]. In CMS Resolution 11.30, the CMS COP also encourages Parties that have not yet done so to join other relevant Conventions such as MARPOL Annex V and the London Protocol, and Protocols to Regional Seas Conventions on Pollution from Land Based Sources and to include the prevention and management of marine debris in relevant national legislation;.

MARPOL Annex V for the prevention of pollution by garbage from ships has exemptions based on vessel size (i.e. those vessels equaling or above 100 GT, or those under 400 GT) and currently excludes the vast majority of fishing vessels (see above). Fishing vessels are a significant potential source of marine debris at sea. The cumulative input of marine debris from these exempted fishing vessels may be considerable, especially in areas with heavy fishing activity[284]. However, additional regulation at the national level can address this issue (see ‘National Responses’ section below).

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[276] IMO Resolution MEPC.201(62), effective from January 1st 2013.
[277] See MARPOL Annex V Regulation 1.14 for a full list of Special Areas.
[278] FAO [Food and Agriculture Organization] 2010. World review of fisheries and aquaculture. Rome, FAO.
[279] Chen, C-L. and Lui, T-K. 2013. Fill the gap: Developing management strategies to control garbage pollution from fishing vessels. Mar. Pol. 40: 34-40.
[280] UNEP/CMS/ScC18/Inf.10.4.1
[281] UNEP/CMS/ScC18/Inf.10.4.2
[282] UNEP/CMS/ScC18/Inf.10.4.3
[283] UNEP/CMS/Resolution 11.30 (Management of Marine Debris).
[284] Ibid

The International Whaling Commission's (IWC) Scientific Committee has held two workshops specifically on the subject of marine debris in 2013[285] and 2014[286]. The most recent workshop focused on the mitigation and management of threats to cetaceans from marine debris and discussed a number of issues, particularly ALDFG, but also other macro-debris and micro-debris. A number of recommendations were made concerning the management and mitigation of ALDFG with regard to the marking of fishing gear and the provision of port reception facilities.

4.1.2. Regional Responses

At the regional level, an action plan on marine litter management for the Mediterranean was adopted by Parties to the Barcelona Convention in December 2013. Objectives of the Mediterranean Action Plan include preventing marine litter generation, reducing marine litter impacts and removing existing marine litter, and enhancing knowledge of marine litter sources, quantities and impacts. Proposed targets are to achieve a decreasing trend in the amount of marine litter that is deposited on the coast or on the water surface and seafloor, and a decreasing trend in the number of entanglements or the amount of litter ingested by selected (sentinel) species.

The development of a regional action plan on marine litter in the Baltic Sea was recently agreed by members of the Baltic Sea Marine Environment Protection Commission (HELCOM) at a workshop[287] following the HELCOM 2013 Ministerial Declaration to address marine litter. The action plan's main objective is to achieve a significant quantitative reduction of marine litter by 2025, compared to 2015. It aims to 'develop common indicators and associated targets related to quantities, composition, sources and pathway of marine litter, including riverine inputs, in order to gain information on long-term trends'. The regional action plan was adopted adopted as HELCOM Recommendation 36/1 at the 36th HELCOM Annual Meeting in March 2015[288]. At its 48th Meeting, the HELCOM Heads of Delegation endorsed the concrete regional actions and voluntary national actions to reduce the input and presence of marine litter in the Baltic Sea[289].

The Northwest Pacific Action Plan's (NOWPAP) Regional Action Plan on Marine Litter (RAP MALI) was implemented in 2008 after approval by the four member states. The three key objectives of the RAP MALI are to prevent the input of marine litter into the marine and coastal environment, monitor the quantities and distribution of marine litter and the removal and disposal of existing litter. Most of the RAP MALI activities are implemented at the national level, in cooperation with local governments and authorities, and non-government organisations such as Our Sea of East Asia Network (OSEAN). Recent activities and successes include:

- Rapid assessment of debris in watersheds in Japan has succeeded in encouraging the active involvement of local residents, providing key information for cost-efficient removal;
- Enabling the use of floating receptacles in Korea to collect derelict fishing gear, which is a less costly and more effective approach than incentive programmes for fishers ('buyback programmes');
- Replacement of fragile EPS[290] floats used in fish aquaculture with highly durable ones (lifespan of at least 10 years) in one particular area of Japan, a successful collaboration with industry;
- An initiative in Korea, led by OSEAN, to address the problem of EPS floats used for bivalve aquaculture, one of the most serious sources of beach debris and microplastics;

[285] Report of the 2013 IWC Scientific Committee workshop on marine debris, Woods Hole, May 2013. IWC/SC/65a/Rep06.
[286] Report of the IWC workshop on mitigation and management of the threats posed by marine debris to cetaceans. Honolulu, August 2014. IWC/65/CCRep04.
[287] http://helcom.fi/news/Pages/Systematic%20action%20for%20Baltic%20marine%20litter%20starts%20next%20year.aspx
[288] Annex 2 of the Outcome of HELCOM 36-2015
[289] Annex 2 of the Outcome of HOD 48-2015
[290] EPS: Expanded Polystyrene

- Promotion of regional monitoring using a harmonized protocol as there are currently different methodologies for national monitoring of marine debris across the region (OSEAN);
- Establishment of a high-level inter-ministry committee in Japan (OSEAN);
- The Japanese NGO Japan Environmental Action Network has organized annual summits since 2003, which provide a platform for information-sharing, communication and collaboration among NGOs and local/national governments;
- Assessment of the impacts of marine debris on wildlife in the coastal areas of Korea, to identify harmful debris items and vulnerable species; and
- Various education and public relation programmes have been implemented in the four member states.

A regional plan for the North-East Atlantic region was adopted by the OSPAR Commission in June 2014. This Regional Action Plan (RAP) on Marine Litter contains both actions to be undertaken collectively at the regional level and actions that can be implemented at the national level by Parties to the OSPAR Convention. Both sets of actions fall under four main themes: combating sea- and land-based sources of marine litter, removal actions and education and outreach. The regional action plan will also form the basis for Parties who are EU Member States to coordinate as they develop their national measures on marine litter for the EU MSFD[291].

The European Union (EU) is discussing whether a quantitative marine litter reduction target should be adopted that stands parallel to regional targets, such as in OSPAR and the Mediterranean, and national targets. The proposed headline regional reduction target is currently defined as 'a 30% reduction of the number of items of the top ten litter categories found as coastal litter in each regional sea, by 2020, compared with 2015…'[292]. This target has the potential to be used for benchmarking progress towards good environmental status (GES) for marine litter as part of the EU Marine Strategy Framework Directive (MSFD). The MSFD is the first EU legislative instrument related to the protection of marine biodiversity and ecosystems through an ecosystem-based approach to manage human activities that have an impact on the marine environment[293]. The Directive focuses specifically on 11 qualitative Descriptors of GES which are required to be achieved by 2020. Descriptor 11 specifically addresses marine debris: 'Marine litter does not cause harm to the coastal and marine environment'. The MSFD has been a political and legal driver of legislative change in the EU to reduce marine litter and other impacts on the marine environment. It does not, however, prescribe specific measures for implementation to achieve GES as this is decided at the national level by Member States.

The MSFD is one of a series of EU Directives that are relevant to marine debris prevention and management. A total of 13 Directives were recently assessed for their current relevance and potential for adaptation in order to develop a more effective and integrated EU marine litter policy[294]. Of these the five most relevant were the Packaging and Packaging Waste Directive, the Water Framework Directive, the Micro-and Nano-Plastics in Cosmetics Directive, the Port Facilities Directive and the Waste Framework Directive. The latter two are also directly linked to the MSFD.

The EC Packaging and Packaging Waste Directive has been successful in increasing the proportion of materials recovered or recycled in Europe over the last 20 years, with 2008 targets met and then exceeded for particular types of packaging such as paper. The Packaging Directive has the potential to

[291] OSPAR14 Summary Record: OSPAR 14/21/1-E.
[292] Van Acoleyen, M. et al. 2014. Marine Litter study to support the establishment of an initial quantitative headline reduction target – SFRA0025. Final Report submitted to the European Commission DG Environment. Project No. BE0113.000668. Arcadis, Brussels, Belgium. http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/final_report.pdf.
[293] http://europa.eu/legislation_summaries/maritime_affairs_and_fisheries/fisheries_resources_and_environment/l28164_en.htm.
[294] Van Acoleyen, M. et al. 2014. Marine Litter study to support the establishment of an initial quantitative headline reduction target – SFRA0025. Final Report submitted to the European Commission DG Environment. Project No. BE0113.000668. Arcadis, Brussels, Belgium.

have a high impact on marine litter, as packaging makes up a large proportion of marine litter in European waters[295]. The directive requires the use of return, collection and recovery systems and also essential requirements for packaging waste. Recovery or recycling of plastic in Europe is increasing between 5 – 6 % per year[296] with most countries recycling 15 – 30% of plastic waste. Recovery of plastic for use in energy generation (incineration) varies considerably within Europe with some countries using 60-70% of recovered plastic to generate energy. Full implementation and enforcement of the Packaging Directive is required by EU Member States to close loopholes in the plastic packaging cycle which will have significant benefits for the quantities of plastic waste and marine litter generated[297]. A broad review of waste management policies is underway in Europe which will include key targets in the Packaging Directive.

The Caribbean Environment Programme (CEP), established under the Regional Seas Programme of UNEP, began to develop a Regional Action Plan on Marine Litter in the Wider Caribbean in 2005 with the Caribbean Regional Coordinating Unit and the Regional Activity Centres for the Land Based Sources of Marine Pollution Protocol and Oil Spills Protocols. The objective of this activity was to assist in the environmental protection and sustainable management and development of the Wider Caribbean Region through the development of a Regional Action Plan on Marine Litter. In 2014, an update was commissioned in which actions regarding resource recovery especially of plastic on the regional, sub-regional or national level were proposed.

The UNEP Regional Office for North America (UNEP RONA) has an active marine litter programme that has co-organised two workshops in 2012[298] and 2013[299] to discuss legal, policy market-based solutions to addressing marine litter at source with a focus on marine plastic pollution in the more recent workshop. The 2012 workshop discussed lessons learned and next steps for preventing the occurrence of marine litter with a focus on upstream reduction approaches, including fostering changes in consumption, improving the design and production of goods and packaging, and improving waste and storm-water management. In 2013, the workshop provided a forum for discussion, information exchange and strategic planning in terms of the legal and policy solutions available to prevent plastic pollution from reaching the marine environment. There was a particular focus on extended producer responsibility programmes for packaging and how these can be applied to single-use plastic packaging.

The first and second African Marine Debris Summit, held in Cape Town in June 2013[300] and in June 2015, respectively, brought together representatives from industry, the research and nongovernmental communities, natural resource managers and policy makers. These summits highlighted recent research, facilitated the sharing of best practice and strategies to assess, reduce and prevent the impacts of marine debris and provided an opportunity to develop specific bilateral or multi-country strategies.

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[295] Newman, S. et al. 2013. How to improve EU legislation to tackle marine litter. Institute for European Environmental Policy, London.

[296] PlasticsEurope 2012. Plastics - The Facts. An analysis of European plastics production, demand and waste data for 2011.

[297] Newman, S. et al. 2013. How to improve EU legislation to tackle marine litter. Institute for European Environmental Policy, London.

[298] Marine Litter Workshop for North America: Legal, policy and market-based approaches to preventing marine litter at the source. UNEP RONA, NRDC. December 2012, Washington D.C. / San Francisco. Analytical Summary. Prepared for UNEP RONA by Duncan Bury Consulting. 26 pp. http://rona.unep.org/about_unep_rona/marine_litter/Analytical%20Summary%20-%20Marine%20Litter%20Workshop%20for%20North%20America%20-%20December%202012%20(3).pdf.

[299] Marine Plastic Pollution Legal and Policy Solution Briefing and Workshop: Extended Producer Responsibility and life-cycle management of plastic products. UNEP RONA, U.S. Senate Oceans Caucus, NRDC, Surfrider Foundation. Washington D.C. / Sacramento, December 2013. http://www.rona.unep.org/about_unep_rona/marine_litter/marine_litter_activities_2013.html.

[300] African Marine Debris Summit 2013. Prospectus. 6-8 June 2013. Cape Town, South Africa.

4.1.3 National Responses including Regulatory Measures (mainly based on submissions for the CBD Expert Workshop)

Submissions from Parties and other Governments in response to the CBD notification 2014-042 (dated 20 March 2014; available at: https://www.cbd.int/doc/notifications/2014/ntf-2014-042-marine-en.pdf) for information for the CBD Expert Workshop to Prepare Practical Guidance on Preventing and Mitigating the Significant Adverse Impacts of Marine Debris Impacts on Marine and Coastal Biodiversity and Habitats are summarized in Appendix 3. Further information is also available in document UNEP/CBD/MCB/EM/2014/3/INF/1[301].

Responses (available at the time of this compilation) were received from 10 Parties and other Governments, which were split relatively evenly between information of debris impacts on marine biodiversity and on mitigation or management approaches. Where applicable, the information provided for impacts on marine biodiversity was incorporated into section 1 of this report.

Information on management and mitigation approaches included details of waste disposal legislation in territorial waters, coastal clean-up and awareness and education initiatives, and government-industry collaboration on preventative actions to reuse plastic packaging (New Zealand), For the latter a new plastic packaging plant opened in 2014 is the first plant in the country to manufacture food grade PET packaging from recycled PET flakes[302]. New Zealand has also amended national regulations on the disposal of rubbish at sea to incorporate the revised MARPOL Annex V. National regulations also go further than MARPOL Annex V to apply operational requirements to a wide range of ships, pleasure craft and offshore installations. Nigeria is also implementing Annex V of MARPOL through the adequate provision of waste reception facilities by Nigeria Ports Authority and their subsequent regulation by a number of relevant government agencies. A proposal to develop a national action plan on marine litter management is also underway through collaboration between UNEP-GPA and the Nigerian Maritime Administration and Safety Agency (NIMASA).

Efforts to mitigate the impacts of ADLFG are reported by Poland through the recent completion of a project by WWF-Poland to remove ghost nets from the Baltic Sea. The initiative has removed over 21000 kg of nets and gear from Polish and Lithuanian waters while also setting up an interactive database of sites with underwater hazards that can entangle fishing gear. The database is available in three languages on the internet[303]. There are plans to continue ghost net removal from the Baltic Sea via a number of programmes and funding sources in Poland and other Baltic States.

The European Commission provided information on activities within the EU to address marine debris, namely through highlighting four recently published documents:

- A Commission Staff Working Document published in 2012 that provides an overview on relevant policies, legislation, strategies and initiatives[304];
- a report on the results of a public consultation undertaken to understand stakeholders' views on a number of potential actions and policies to tackle marine litter[305], which will be used to help formulate an EU-wide headline reduction target;
- A guidance document on the monitoring of marine litter produced by the EC Joint Research Centre in 2013[306], and;

[301] http://www.cbd.int/doc/meetings/mar/mcbem-2014-03/information/mcbem-2014-03-inf-01-en.pdf
[302] http://www.scoop.co.nz/stories/CU1401/S00505/flight-plastics-opens-new-zealands-first-recycled-pet-packa.htm.
[303] http://www.sieciwidma.wwf.pl.
[304] European Commission 2012. Commission Staff Working Document. Overview of EU policies, legislation and initiatives related to marine litter. Brussels, 31.10.2012. SWD (2012) 365 final http://ec.europa.eu/environment/marine/pdf/SWD_2012_365.pdf.
[305] Arcadis 2014. Public Consultation on Marine Litter – An Analysis. European Commission. 31 January 2014. Final. C03041.002950.700. http://ec.europa.eu/environment/consultations/pdf/marine_litter.pdf.
[306] Joint Research Centre 2013. Guidance on Monitoring of Marine Litter in European Seas. MSFD Technical Subgroup on Marine Litter. JRC Scientific and Policy Reports. Luxembourg: Publications Office of the

- The Marine Litter Watch application developed by the European Environment Agency[307]

The use of regulatory measures in the United States, as required by the Clean Water Act, and set by Water Resource Control Boards, has led to the implementation of structural controls to capture plastic and other debris before it reaches rivers and the marine environment. Total Maximum Daily Load plans (TMDLs) are used by local governments in California and Maryland to reduce litter input into urban waterways for particular ‘impaired’ water bodies. For example the Los Angeles county TDML requires that ‘Southern California cities discharging into the river to reduce their trash contribution in these water bodies by 10% each year for a period of 10 years with the goal of zero trash in two waterways by 2015[308]. This has resulted in the installation of nearly 100000 full capture devices which filter litter 5 mm in diameter or greater out of stormwater before it enters the water body[309]. These controls only capture macro-debris greater than 5 mm and are subject to breakage or overflow during heavy storms[310]. A substantial proportion of plastic waste can still routinely enter the watershed. A study of the Los Angeles watershed found that 90% of plastic debris by count and 13% by weight are micro-debris (<5 mm)[311]. Installing such extensive infrastructure is also expensive and currently beyond the budgets of local authorities in many lesser developed countries.

European Union, 2013 doi:10.2788/99475 http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/30681/1/lb-na-26113-en-n.pdf

[307] http://www.eea.europa.eu/themes/coast_sea/marine-litterwatch/marine-litterwatch.

[308] Stickel, B.H. et al. 2012. The cost to west coast communities of dealing with trash, reducing marine debris. Prepared by Kier Associates for U.S. Environmental Protection Agency, Region 9, pursuant to Order for Services EPG12900098, 21 p. + appendices.

[309] Gold, M. et al. 2014. Stemming the tide of plastic marine litter: A global action agenda. 27 Tul. Envtl. L.J. 165 2013-2014.

[310] Moore, C.J. 2008. Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. Env Res. 108: 131-139.

[311] Moore, C.J. et al. 2011. Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of southern California. J. Int. Coast. Zone Manage. 11: 65-73.

4.2 Measures to achieve sustainable production and consumption

The following sub-sections provide a range of current examples, proposed approaches and new potential developments for the management and mitigation of marine debris with a focus on plastics in various forms and also on reducing debris by preventing waste materials from entering the marine environment.

There have been some suggestions to tackle the growth in plastic production and subsequent plastic waste by re-classifying the most harmful types of plastic as hazardous, although the specifics of this approach is not without debate[312]. Concerns regarding the toxicity of plastics have led to suggestions that plastic manufacturers and the food and textile industries should prove that their products and packaging are safe, much like health and safety demands that have to be met by the food and pharmaceutical industries[313]. Plastics that come into contact with food are regulated in the European Union and the U.S.A. and must be proved safe for food contact. Restricting the production of plastic through such regulation in combination with the development and implementation of a closed-loop system in which all plastics are reused and actually recycled (i.e., not incinerated) would drastically reduce the amount of plastic waste that becomes marine debris in the oceans. Plastic products and plastic waste are two sides of the same coin and recycling already starts in the product design phase. Designers need to be involved in the reflection on the entire life cycle of products including the waste phase. In order to allow for effective recycling policies, all actors designing, producing, using and disposing of plastic products and handling plastic waste must be involved.

However, restructuring the plastic waste disposal system to a closed-loop system will take some time and requires further research and development. Classifying potentially harmful plastics as hazardous is currently debated and would also take considerable time to implement with the need for the development and agreement of criteria to determine levels of toxicity for certain types of plastics. For the time being, the production and use of plastic is likely to continue to grow, which means that responsible disposal of existing types of plastic is a key stage in the waste stream that needs greater attention. Therefore, there also needs to be an increased focus on reducing the rate at which waste is produced while also ensuring that there are appropriate management measures in place for the safe disposal of materials that cannot currently be re-used or recycled[314]

Preventing end-of-life materials from leaving the waste stream and entering the marine environment is a key aspect to tackling the marine debris problem. The use of campaigns and education to increase awareness and promote behavioural change needs to be in place to increase the effectiveness of providing hard infrastructure to reduce the amount of solid waste material entering the marine environment. The former approach is likely to be particularly important for countries that do not have effective waste management systems in place which may be partly attributed to inadequate infrastructure and a lack of awareness of the issue in terms of impacts. The increased use and production of plastic in developing and emerging countries is of a particular concern, and existing waste management infrastructure may not be developing at an appropriate rate to deal with the increasing levels of plastic[315].

Providing adequate facilities for the disposal of waste is also key to ensure the consumer or user of materials can responsibly dispose of unwanted items with the minimum of effort or expense. This applies equally to end-of-life fishing gear. Giving consumers incentives to recycle or penalties for the use of persistent materials that are highly likely to become litter and eventually marine debris can be effective. In addition, user fees for particular items of marine debris such as plastic bags can also directly contribute to preventing marine debris.

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[312] Rochman, C.M. et al. 2013. Classify plastic waste as hazardous. Comment, Nature 494: 169-171.
[313] Ibid
[314] 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 pages.
[315] Koushal, V. et al. 2014. Plastics: Issues, challenges and remediation. Int. J. Waste Resources 4: 134. doi: 10.4172/2252-5211.1000134.

There is increasing recognition of the effectiveness and benefits of extended producer responsibility programmes in reducing packaging, especially for plastics. Improving the design of materials and packaging to eliminate or substantially reduce the production of single-use packaging or products, which are often difficult to recycle, will also greatly help to prevent commonly-used items ending up as marine debris[316]. Better coordination at the local, national and regional level is also required to tackle sea-based sources of marine debris, especially ALDFG and other waste materials from fishing vessels.

Overall, 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. Such a waste management system would increase the amount of waste diverted toward secondary use and recycling[317].

4.2.1 Reuse, reduction and cleaner production

This sub-section provides examples of reduction in broader sense of the term (i.e., not only reducing the production of persistent plastics, but also proportion of persistent plastics entering the marine environment and the impact of plastic materials on marine biodiversity once there).

Reducing the production and consumption of non-reusable, persistent types of plastic is a key aspect tackling marine debris.

In 2013, the Plastic Pollution Coalition sponsored a competition called ‘Think Beyond Plastic’[318] to generate innovative proposals for solutions to plastic pollution. The ‘Think Beyond Plastic’ Innovation Forum, launched in 2013, aims to identify and encourage innovation for safe, market-based alternatives to conventional plastics products for businesses and consumers. The forum focuses on ‘hotspots’ of plastic pollution such as disposable plastics, medical waste and packaging, but also on furthering systemic change. Solutions can apply to the supply chain and infrastructure, source materials and packaging and also include the rethinking or redesigning of complete systems. An innovation accelerator, it sources innovation, accelerates businesses and develops the impact investment network for material, manufacturing, recycling and product design innovation. There were over 100 applications for the first competition which culminated in an inaugural conference in June 2013 where the winners were announced, including compostable packaging made from recycled pulp and paper, and recycling plastic bottles to produce fibres for clothing manufacture. The 2014-15 competition brought over 120 innovations, and the winners included innovations in consumer products; and chemicals that degrade plastic waste.

Reducing Persistent Plastics

Reducing the proportion of persistent plastic in the waste stream can be addressed through the further development and use of fully biodegradable alternative biopolymers (bioplastics) such as those derived from starch and some biopolyesters. These differ from other biopolymers which are partly or wholly derived from renewable biomass sources such as vegetable fats and oils or bacteria but do not biodegrade quickly in ambient conditions. Although bioplastics in general have a lower carbon footprint than conventional petroleum-based plastics, some of them can still persist in the environment if discarded and may contribute to marine litter with associated impacts on biodiversity. Their slow degradability in seawater combined with high energy production has led to the suggestion that bioplastics are not a viable solution to the marine debris problem at the present time[319].

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[316] 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 pages.
[317] Ibid
[318] http://plasticpollutioncoalition.org/projects/think-beyond-plastic/
[319] Global Ocean Commission 2014. From decline to recovery – A rescue package for the Global Ocean. Global Ocean Commission Report. 88 pp.

One issue is that there is no standard on what is referred to as bioplastic. Any material that is composed of some organic matter or is derived from biological organisms can be referred to as a bioplastic. In addition, materials that have some plant or organic matter, or are biologically derived, are not always biodegradable. However, in some cases there is a reduction in the amount of fossil fuel needed during manufacture. For this topic, the 'Think Beyond Plastic' innovation forum focuses on the production of truly biodegradable polymers (i.e., those which degrade in aerobic and anaerobic conditions, are non-toxic, completely compostable material, and have the same performance characteristics as petroleum-based plastics).

There is increasing interest in the use of polyhydroxyalkanoates (PHAs) to mass produce fully biodegradable bioplastics[320]. PHAs are polyesters produced as a storage material by bacteria from a wide range of substrates[321]. They are recyclable, are natural materials and can be degraded to carbon dioxide and water in aerobic and anaerobic conditions[322]. The rate of biodegradation of PHA-based bioplastics depends on a combination of environmental conditions (e.g., temperature, moisture, pH, nutrient supply and the presence and type of PHA-degrading organisms) and of the characteristics of the PHA material, such as monomer composition, presence of additives, surface area[323][324]. In seawater PHA polymers can be formulated to biodegrade within one year in different salinity regimes[325]. Although demand for PHA bioplastics is growing there are still a number of obstacles to commercial application as replacements for conventional plastics including undesirable properties (e.g., brittleness, low mechanical strength[326]), high production costs and a lack of proper disposal facilities[327]. Further research and development is required to enable the cost-effective production and disposal of PHA-based and other types of bioplastic. Sugars, plant oils and some agricultural by-products are some of the relatively cheap renewable resources being studied for the production of PHAs[328] in an effort bring down costs. Biodegradable plastics composed of PHA or PHB (polyhydroxybutyrate) polymers can also be made from waste biogas (methane)[329] and are thought to be economically competitive with conventional oil-based plastics. Existing waste management infrastructure also needs to be revised so that bioplastics can be effectively collected and disposed of, through a separation of bioplastic from petroleum-based plastics to prevent contamination issues during recycling.

A new type of bioplastic has recently been developed that is based on chitin, a natural highly abundant polysaccharide found in crustacean shells and insect cuticles[330]. A fabrication method for the chitosan polymer has been developed that has the potential for the large-scale production of components with complex forms that may be able to replace existing non-degradable plastics in commercial manufacturing[331]. Chitosan is also rapidly broken down in compost in less than two

[320] Jain, S. et al., 2013. Poly (3-Hydroxyalkanoates): Biodegradable Plastics. Research and Reviews: Journal of Chemistry 3: 11-14.
[321] Urtuvia, V. et al., 2014. Bacterial production of the biodegradable plastics polyhydroxyalkanoates. Int. J. Biological Macromolecules 70: 208-213.
[322] Philip, S. et al. 2007. Polyhydroxyalkanoates: biodegradable polymers with a range of applications. J. Chem. Technol. Biotechnol. 82: 233-247.
[323] Ibid
[324] Tokiwa, Y. and Calabia, B. 2004. Degradation of microbial polyesters. Biotechnology Letters 26: 1181-1189
[325] Bilkovic, D.M. et al. 2012. Use of fully biodegradable panels to reduce derelict pot threats to marine fauna. Conservation Biology 26: 957-966.
[326] Tokiwa, Y. and Calabia, B. 2004. Degradation of microbial polyesters. Biotechnology Letters 26: 1181-1189
[327] Philip, S. et al. 2007. Polyhydroxyalkanoates: biodegradable polymers with a range of applications. J. Chem. Technol. Biotechnol. 82: 233-247.
[328] Jain, S. et al., 2013. Poly (3-Hydroxyalkanoates): Biodegradable Plastics. Research and Reviews: Journal of Chemistry 3: 11-14.
[329] http://mangomaterials.com/
[330] Fernandez, J.G. and Ingber, D.E. 2014. Manufacturing of large-scale functional objects using biodegradable chitosan bioplastic. Macromolecular Materials and Engineering. Communication. 299: 932-938.
[331] Ibid

weeks[332] and the resulting material can be used to support plant growth. Potential sources of chitosan include the waste products from seafood processing such as chitin-rich shrimp shells and large-scale production by Mucoralean fungi or other microbial cultures[333]. As for other types of bioplastic production costs are currently high (3–4 times more expensive than non-specialized commodity plastics) but are expected to become more cost-effective when the manufacturing approach is applied at the industrial scale[334]. Chitosan-based materials also have an advantage over other types of bioplastic in that they are easy to decompose, can be composted and therefore do not require a restructuring of waste management practices for disposal, where compostable waste is already collected.

Fungal mycelium, a natural composite, is also a potential replacement for plastics used for packaging or insulation, and some types of structural engineering material[335]. Mycelium-based materials are inert, biodegradable, carbon neutral (or carbon negative), can be produced with low feedstock and process costs and have great potential for a scaled manufacturing process in different regions. This ‘mushroom-based’ technology has been taken up by car manufacturers to make a foam for use in bumpers, side doors and dashboards, and as a packaging material for shipping personal computer products.

A biodegradable building material composed of nanocrystaline cellulose and derived from agricultural waste has also been developed that is a viable alternative to styrofoam[336].

Research focusing on the biodegradation of synthetic plastics can also contribute to reducing the impact of plastics in the marine environment. BIOCLEAN[337], an EU funded research consortium involving a range of organization types (universities, research institutes, industry), aims to increase the scientific understanding of plastic biodegradation in natural environments and waste disposal facilities and investigate the feasibility of biotechnological techniques to dispose of plastic waste effectively and sustainably. The project is concentrating on four main types of plastic: PVC, polystyrene, polypropylene, and polyethylene, and is conducting research on the degradation and detoxification of plastic waste in landfills, plastic fragments in waste composting and anaerobic digesters and plastic fragments occurring in marine habitats. Work packages will focus on:

- Identification of microbes and enzymes able to degrade polymers;
- Development of pre-treatments to increase polymers’ degradability;
- Bioaugmentation in marine environments;
- Environmental and economic evaluation of the developed processes and strategies; and
- Development of policy tools to support the MSFD and knowledge transfer once studies are complete.

The International Organization for Standardization (ISO) is conducting work on determining the ultimate aerobic biodegradability of plastic materials under controlled composting conditions[338].

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332 Ohta, K. et al. 1999. Chitosan treatment affects plant growth and flower quality in *Eustomia grandiflorum*. HortScience 34: 233-234.

333 Fernandez, J.G. and Ingber, D.E. 2014. Manufacturing of large-scale functional objects using biodegradable chitosan bioplastic. Macromolecular Materials and Engineering. Communication. 299: 932-938.

334 Ibid

335 Travaglini, S. et al. 2013. Mycology matrix composites. Proceedings of the American Society for Composites – 28th Technical Conference. 20 pp.

336 http://www.blkldg.com/

337 http://www.biocleanproject.eu/

338 See for example, ISO 14855-2:2007, Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions -- Method by analysis of evolved carbon dioxide -- Part 2: Gravimetric measurement of carbon dioxide evolved in a laboratory-scale test, http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=40617.

Bans and User Fees

Plastic bag bans and user fees continue to be very successful in reducing the use of lightweight plastic bags and their accumulation in the marine environment. At least 30 countries and hundreds of state and local governments have adopted single-use plastic bag restrictions[339]. To date almost 140 local jurisdictions in the United States have adopted plastic bag ordinances[340]. Coastal litter surveys in Ireland recorded a drop in the number of plastic bags collected since the introduction of a 0.15 Euro user fee per bag. The fee had an immediate effect on consumer behaviour with a decrease in plastic bag usage from 328 to 21 bags per capita[341]. Along the coast the number of plastic bags per 0.5 km of coastline fell from 17 in 2002 (before the user fee introduction) to 2 in 2012[342]. User charges for single-use plastic bags have recently been introduced in parts of the United Kingdom (Scotland, Wales and Northern Ireland) with bag use at retailers falling markedly in Wales following the charge introduction[343].

The European Parliament recently agreed to restrict the use of thin plastic bags (<50 microns thickness) in the EU by at least 80% by 2019 with a first reduction of 50% by 2017 compared to 2010 consumption figures[344]. EU Member States can choose their own measures which are likely to be one or more of taxes, levies, marketing restrictions and bans. Very light bags used to wrap food items will also gradually be replaced by biodegradable and compostable bags by 2019.

Advanced Disposal Fees (ADFs) are often used as part of EPR programmes to encourage producer compliance. In South Korea, ADFs are imposed on importers and producers of products that are hazardous or more difficult to recycle[345]. E-waste is subject to an advanced recovery fee system in California which provides market-motivation for high recovery rates[346]. As a state-run programme it ensures that the dismantling and processing of E-waste remains within the state and is not exported. A cigarette litter abatement fee scheme in San Francisco generates revenue of $5 million per year for clean-ups and outreach work.

Bans on the use of styrofoam food containers have also been implemented, mainly in the United States for a number of cities or counties in the states of California, Minnesota, New York and Maine while other cities are currently considering a ban include Honolulu and Miami. Washington D.C. passed legislation in July 2014 to implement a ban which will take effect in 2016. Other cities around the world that have styrofoam bans are Toronto and Paris.

Addressing sea-based sources

The Australian Government funds a range of programmes, including Working on Country (within the Indigenous Advancement Strategy) and the Indigenous Protected Areas Programme to support local residents, community groups and Indigenous rangers to undertake on-ground activities to reduce the

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[339] Gold, M. et al. 2014. Stemming the tide of plastic marine litter: A global action agenda. 27 Tul. Envtl. L.J. 165 2013-2014.

[340] Romer, J.R. and Tamminmen, L.M. 2014. Plastic bag reduction ordinances: New York City's proposed charge on all carryout bags as a model for U.S. cities. Tul. Envtl. L. J. 27: 237-275.

[341] Neumann, S. et al. 2013. How to improve EU legislation to tackle marine litter. Institute for European Environmental Policy, London. 60 pp.

[342] Doyle, T.K. and O'Hagan, A. 2013. The Irish 'Plastic Bag Levy': A mechanism to reduce marine litter? International Conference on Prevention and Management of Marine Litter in European Seas. Berlin

[343] Neumann, S. et al. 2013. How to improve EU legislation to tackle marine litter. Institute for European Environmental Policy, London. 60 pp.

[344] http://www.europarl.europa.eu/news/en/news-room/content/20140423STO44901/html/No-more-plastic-bags-polluting-our-environment.

[345] 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.

[346] UNEP RONA 2013. Marine Plastic Pollution Legal and Policy Solution Briefing and Workshop: Extended Producer Responsibility and life-cycle management of plastic products. December 2013. Hand-outs for Panel III. 9 pp.

volume of debris generated or entering the marine environment. A number of ranger groups perform regular patrols to remove marine debris and ghost nets to minimize its impact on our marine environment. As a result of the dedicated work of the rangers, many marine turtles and other sea creatures are rescued from entanglement in ghost nets and returned to the wild each year. Data collected from annual Great Barrier Reef clean-ups is entered into the Australian Marine Debris database to advise future management and reduction plans with local communities and government.

Reducing the impact of lost fishing gear on marine biodiversity can also be achieved through the use of biodegradable panels on fishing pots or traps[347]. Recent trials with panels made from bioplastic (PHA or PCL[348]) that can sufficiently degrade within a year to allow trapped animals to escape have been successful for a crab pots used in a blue crab fishery in Chesapeake Bay, United States[349]. Fitting biodegradable panels to crab pots did not affect catch rates compared to standard pots. The use of fully degradable panels can be applied to a range of other trap-based fisheries and is thought to be more successful than other techniques to disarm lost gear such as pot lids with a degradable escape cord[350].

Another sea-based source of marine debris is the domestic waste produced by fishing vessels, most of which are currently exempt from international regulation (see previous section). One assessment of fishing vessel-sourced marine litter disposal and management found that a range of materials are disposed of at sea by some fishers such as plastic bags and bottles, batteries, metal cans and derelict fishing gear[351]. Of these items more than half of fishers interviewed stated that they brought all these waste materials back to port with the exception of plastic bags as these were not recyclable. Factors that promote the proper disposal of waste back on land were identified as having or developing a domestic waste recycling practice, having adequate reception facilities at port, encouraging environmental education for fishers and providing incentives to bring rubbish back to port[352]. Reducing the amount of readily disposable material going on board was also suggested as a means to minimize marine litter from fishing vessels, such as using rechargeable batteries or reusing plastic materials such as bags and bottles. Many of the suggestions provided above are also directly applicable to recreational vessels, mainly for inshore waters.

4.2.2 Producer Responsibility

Extended Producer Responsibility (EPR) is increasingly recognized worldwide as an efficient waste management policy to help improve recycling and reduce landfilling of products and materials[353]. EPR programmes, such as those implemented in the European Union, ensure that the producers, manufacturers, brand owners and first importers of products and packaging are given the legal responsibility for collection, recycling and end-of-life management of materials[354].

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[347] Bilkovic, D.M. et al. 2012. Use of fully biodegradable panels to reduce derelict pot threats to marine fauna. Conservation Biology 26: 957-966.

[348] Polycaprolactane.

[349] Bilkovic, D.M. et al. 2012. Use of fully biodegradable panels to reduce derelict pot threats to marine fauna. Conservation Biology 26: 957-966.

[350] MacFadyen, G. et al. 2009. Abandoned, lost or otherwise discarded fishing gear. FAO Fisheries and Aquaculture Technical Paper 523. United Nations Environment Programme Food and Agriculture Organization of the United Nations, Rome 2009. 115 pp.

[351] Chen, C-L. and Lui, T-K. 2013. Fill the gap: Developing management strategies to control garbage pollution from fishing vessels. Marine Policy 40: 34-40.

[352] Ibid

[353] 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.

[354] 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 pages.

Over the last decade there has been a rapid development of EPR policies globally, with over 200 policies implemented out of a total of 384[355]. EPR policies and programmes are well established in Europe, Canada, Japan and South Korea for a wide range of products. In Europe, all EU Member States have implemented EPR schemes for four waste streams that are regulated by EU Directives (packaging, batteries, end-of-life vehicles and electrical and electronic equipment). In 2015, France enacted legislation to combat planned obsolescence (a policy of planning or designing a product with an artificially limited useful life-span), by requiring electronics and appliance manufacturers to inform consumers, before they purchase, how long they can expect their product to last. In the U.S., EPR programmes are not governed under federal law but are developed and implemented by individual States. For example, California has implemented more than a dozen policies that involve producer responsibility for waste reduction and recycling for products such as paint and mercury thermometers[356]. Some producers have also implemented voluntary programmes to organise the collection and recycling of their products. In less developed or emerging countries, EPR schemes are beginning to be implemented in some regions, particularly Latin America and Asia with most programmes partially implemented and not completely functional[357]. EPR and waste management policies in Africa are generally at a less advanced stage (except for South Africa) with a growing concern across the continent for the management of increasing amounts of solid waste and imported waste materials such as electronic waste (E-waste).

EPR programmes, if implemented effectively can provide a number of benefits and opportunities, including increased collection and recycling rates, reduction of public spending on waste management, reduction in overall waste management costs and design for environment (DfE) innovations such as increasing the durability (or compostibility) and reusability of products. However, reducing the weight of items (light-weighting) to meet policy requirements per weight unit of waste may not reduce the number of items being produced and eventually ending up as marine debris. DfE incentives can also allow policy makers to address environmental damages that may occur several years after the point of production or consumption[358].

There are a number of challenges that arise when initiating and developing EPR programmes which are likely to be encountered in emerging and developing countries looking to increase and fully implement EPR. These challenges fall within four main categories: (i) governance and administration, (ii) economic, (iii) those specific to EPR start-up phases and (iv) new or emerging challenges[359]. Learning from experience and sharing best practices between countries with established EPR policies and programmes and those starting up can help to meet some challenges. However, EPR programmes should also be adapted to the specific economic, social and cultural context of different countries.

Of particular concern are the possible lack of enforcement mechanisms to ensure a specific EPR scheme is working well and the integration of the informal waste management sector into the new system that takes into account social issues such as employment or social protection frameworks. In this regard the membership of producers to associations that promote EPR with codes of practice is voluntary and not every producer has joined these associations. Exports of waste products such as E-waste can also damage the efficiency of EPR schemes by creating loopholes in the market. Illegal export of waste to developing countries can generate negative impacts on the environment and human health when there is inadequate capacity to process the waste safely or responsibly[360].

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[355] Kaffine, D. and O'Reilly, P. 2013. What have we learned about Extended Producer responsibility in the past decade? A survey of the recent economic literature, May 2013. OECD.
[356] UNEP RONA 2013. Marine Plastic Pollution Legal and Policy Solution Briefing and Workshop: Extended Producer Responsibility and life-cycle management of plastic products. December 2013. Hand-outs for Panel III. 9 pp.
[357] 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.
[358] Ibid
[359] Ibid
[360] Ibid

EPR programmes have also been designed to make producers responsible for products that are found littering public areas such as plastic and packaging[361]. The provision of sufficient, accessible litter bins and recycling points can help to reduce this land-based litter source entering the freshwater and marine environments.

EPR policies for plastic and plastic packaging, including at the national and regional level, have significant potential to address marine debris. This should go hand in hand with improving the waste management and recycling infrastructure in both developed and developing countries, and the development of environmentally sustainable alternatives to plastics. In addition, EPR policies and programmes could be applied to all internationally traded plastic goods so that there is responsibility for disposal by a designated body in that country (e.g., manufacturers and / or first importers). However, there have been some concerns raised by industry regarding the effects of EPR causing shifts to alternatives to plastics such as for packaging and the associated environmental impacts of this[362].

4.2.3 Incentives for collection, recycling and responsible disposal

Providing incentives for collection and recycling for particular waste items can significantly reduce the number of these waste materials found in marine debris. For example deposit return schemes for beverage containers have a long and proven track record of success[363]. A recent study of beverage containers in marine debris around Australia[364] provides strong indirect evidence that deposit return schemes can result in fewer beverage containers entering the marine environment. Comparison of beverage container records in coastal clean-ups for each State in Australia revealed that the number of containers recorded in South Australia was substantially less than for other States, suggesting that fewer containers are lost into the environment in South Australia. This is the only State in Australia that has implemented container deposit legislation (CDL) that covers a range of beverage containers for both alcoholic and non-alcoholic drinks[365]. Return rates to collection depots are very high (80%), much higher than in other States without CDL. When the ratio of beverage lids to containers collected in clean-ups was calculated for each State there was a much higher ratio of lids to containers in South Australia[366]. This finding further supports the inference that the container deposit scheme is causing beverage containers to be recycled while lids with no deposit refund are more commonly discarded.

An increase in the take–up of deposit return schemes for mixed beverage containers and other plastics items commonly recorded in marine debris either as legislation or voluntary schemes is likely to have a significant impact on the amount of plastic waste material entering the marine environment.

Incentive schemes are also in operation for some sea-based sources of marine debris such as end-of-use fishing nets and ALDFG in a number of countries. A government sponsored fishing gear buyback programme was in operation in the Republic of Korea between 2003 and 2013 where any recovered ALDFG line, rope or net would be bought at the cost of approximately US$10 per 100 litre bag[367].

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[361] 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 pages.

[362] Impacts of Plastics Packaging on Life Cycle Energy Consumption and Greenhouse Gas Emissions in the United States and Canada. 2014. Franklin Associates. Report prepared for the American Chemistry Council (ACC) and the Canadian Plastics Industry Association.

[363] 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 pages

[364] Hardesty, B.D. et al. 2014. Understanding the effects of marine debris on wildlife. A final report to Earthwatch Australia. CSIRO Oceans and Atmospheric Flagship. 353 pp.

[365] http://www.zerowaste.sa.gov.au/upload/facts-sheets/container_deposit_legislation_4.pdf

[366] Hardesty, B.D. et al. 2014. Understanding the effects of marine debris on wildlife. A final report to Earthwatch Australia. CSIRO Oceans and Atmospheric Flagship. 353 pp.

[367] IWC 2014. Report of the IWC workshop on mitigation and management of the threats posed by marine debris to cetaceans. August 2014, Honolulu. IWC/65/CCRep04. 40 pp.

The collected gear was incinerated to produce energy. Between 2007 and 2011 700 tonnes of ALDFG was collected by almost 200 fishing vessels.

In Norway, the Nofir[368] project has created a profitable system for collecting and recycling discarded fishing and fish-farming gear. A nationwide system for discarded gear started in 2008 and has now increased to cover fisheries in six European countries which recycled 4200 tons of gear in 2013. The discarded gear is collected at no cost to the fishing vessel or company which provides sufficient incentive to retain damaged or unwanted fishing materials until they can be collected directly from the vessel or deposited at collection sites or waste facilities along the coast.

The Fishing for Litter scheme[369], also in Europe, provides fishing vessels with large bags to deposit marine debris items encountered in fishing gear. The bags are then collected on the quayside when full. The initiative also raises awareness of the issue within fishing communities. The scheme is operating in four European countries (Netherlands, U.K. Belgium and Sweden) and is expanding its coverage of coasts in England and Northern Ireland. In Scotland the scheme has collected 800 tonnes of marine debris over the last 10 years and has involved 212 fishing vessels.

The Fishing for Energy Partnership[370] in the United States also enables fishing communities to deposit unwanted fishing gear free of charge at port waste disposal facilities where it is collected for sorting and incineration to generate electricity. The public-private partnership is headed by NOAA's Marine Debris Program which also provides major funding. The scheme is currently operating in 37 ports in nine states.

In Europe, the Healthy Seas Initiative[371], an industry-NGO consortium, collects fishing nets to convert them into polymer yarn which can be used to make products such as carpets and clothing. The initiative is working with the aquaculture and fishing industries to collect nets in the North, Mediterranean and Adriatic Seas and have collected 16 000 tons since 2011.

Providing incentives for fishers to switch to more eco-friendly fishing gear such as biodegradable nets or traps have also been suggested[372]. The use of fishing net deposit schemes could also discourage fishers from discarding end-of-life nets at sea. Another possible approach could be to implement EPR programmes for fishing gear products so that manufacturers would be responsible for the collection of end-of-life nets and gear by providing port facilities for disposal. Provision of adequate and easily accessible waste disposal facilities in ports for fishing vessels can also encourage fishers to bring domestic waste back to land instead of irresponsible disposal at sea. Wet storage of fishing gear could also be reduced if incentives are provided to fishers to store their gear on land rather than at sea.

4.2.4 Waste as a Resource

The increasing scarcity of resources and rising commodity prices is encouraging producers to find new ways to recover used products and to turn waste into a resource[373]. Many end-of-life products, including plastics and packaging are increasingly being seen as sources of valuable secondary materials which are lost forever if disposed of[374]. This section provides a range of examples or proposals where predominantly plastic waste is collected and used as a resource to produce new products while also in some cases providing people with income or livelihoods.

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[368] http://nofir.no/
[369] http://www.kimointernational.org/FishingforLitter.aspx
[370] http://marinedebris.noaa.gov/partnerships/fishing-energy
[371] http://healthyseas.org/
[372] Kim, S-G. et al. 2014. The estimation of derelict fishing gear in the coastal waters of South Korea: Trap and gill-net fisheries. Marine Policy 46: 119-122.
[373] 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.
[374] 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 pages.

Converting some types of plastic waste into fuel or other valuable chemical compounds are established industrial processes but generally not applied at a commercial scale. Depolymerisation of waste plastic converts plastics into monomers that can be used to rebuild resins, a process also known as chemical feedstock recovery[375]. The process has been used to recover monomers from PET, nylons and polyurethanes such as styrofoam. Chemical feedstock recovery enables currently non-recyclable plastics to be converted into high quality resins free of impurities. Plastic to fuel (PTF) technology is operated by a number of companies in the United States but the majority of these are still at the pilot or demonstration project stage[376]. Commercial-scale plants have been in operation in Japan for a range of plastic wastes[377] for over a decade. A number of other countries are also now operating large-scale commercial conversion schemes including China, India, Thailand and the U.K.[378]. On the whole, the current generation of plastic to fuel technologies are designed to accept a wide range of plastics, can accommodate many forms of contamination, with little plastic pre-treatment before use[379].

Recent plastic conversion research has been carried out for polyethylene plastic bags[380], styrofoam[381] and for marine debris made up of mixed plastics. Fast pyrolysis of high density polyethylene (HDPE) waste plastic bags followed by distillation produced two liquid hydrocarbons which were tested for applicability as alternative liquid transportation fuels both individually and as blended fuels with standard and biodiesel[382]. After thorough testing, it was concluded that the liquid hydrocarbons were suitable as blend components for conventional petroleum diesel fuel.

Collected marine plastic debris was successfully converted into liquid fuel in a recent trial on the west coast of Canada[383]. The project also demonstrated that the operation of small-scale plastic-to–fuel technology can be logistically and economically viable for small remote communities, providing a means to dispose of domestic plastic waste and a source of heating fuel[384]. The hydrocarbon liquid produced can also be converted into petrol or diesel fuel. A number of recycling companies are currently investigating the feasibility of setting up and using this technology to process mixed plastic waste[385].

Converting a specific type of marine plastic debris (ALDFG) into an energy resource (Fishing for Energy) has already been discussed in the previous section. Discarded or unwanted fishing nets are also being collected for recycling by coastal communities in developing countries such as the Philippines, which provides an invaluable supplemental income. The Net-Works project[386] is an innovative cross-sector initiative designed to tackle the growing environmental problem of discarded fishing nets in some of the world's poorest coastal communities. Fishing nets, one of the most abundant sources of nylon globally, can be readily converted into nylon 6 yarn by a depolymerisation

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[375] 4R Sustainability 2011. Conversion technology: A complement to plastic recycling. 4R Sustainability, Inc. Portland, OR, USA.
[376] Ibid
[377] UNEP 2009. Converting Waste Plastics into a Resource. Compendium of Technologies. United Nations Environment Programme Division of Technology, Industry and Economics(UNEP DTIE), International Environmental Technology Centre (ITEC), Osaka/Shiga, Japan. 48 pp.
[378] 4R Sustainability 2011. Conversion technology: A complement to plastic recycling. 4R Sustainability, Inc. Portland, OR, USA.
[379] Ibid
[380] Sharma, B.K. et al. 2014. Production, characterisation and fuel properties of alternative diesel fuel from pyrolysis of waste grocery bags. Fuel Processing Technology 122: 79-90.
[381] Hamidi, N. et al. 2013. Pyrolysis of household plastic wastes. British Journal of Applied Science and Technology 3: 417-439.
[382] Sharma, B.K. et al. 2014. Production, characterisation and fuel properties of alternative diesel fuel from pyrolysis of waste grocery bags. Fuel Processing Technology 122: 79-90.
[383] UpGyres 2014a. Converting marine based plastic waste in to a usable fuel. http://upgyres.org/dir-dir/uploads/2012/12/UpGyres-Marine-plastic-trials-2014.pdf
[384] UpGyres 2014b. Blest Plastic to Fuel. http://upgyres.org/dir-dir/uploads/2012/12/Blest-landbased-plastic-to-fuel-study-2014.pdf.
[385] Ibid
[386] http://net-works.com/ .

process, and used to manufacture new products such as carpet tiles. The Net-Works project also sets up community banks so that income generated by fishing net sales helps to provide economic security for coastal communities. Over 38 tons of nets have been collected in the central Philippines to date[387]. The concept is being adapted to other locations.

Upcycling[388] of waste plastic into carbon-based nanomaterials, high value products with tremendous application potential, has also recently been proposed[389]. The process is still under development and will need further research and integration into existing plastic waste management systems before it can be fully realized. A number of challenges currently exist regarding the supply of carbon feedstock from waste plastic and the need to further refine the chemical conversion processes. Solutions are theoretically possible through adapting technology advancements from both plastic waste recycling and CNT synthesis processes through a multidisciplinary approach that involves research and industry[390].

Plastic waste has also been proposed as a means to absorb environmental pollutants originating from pharmaceutical and personal care products (PCPPs)[391] which are thought to have physiological and behavioural effects on wildlife at low concentrations[392]. Waste plastics could potentially be incorporated into wastewater management systems to absorb PCPPs and other priority pollutants from wastewater prior to discharge into the environment. Integrated design and development of both plastics and PPCPs could also enable high absorption rates to be achieved.

4.3 Engagement with Industry

Industry can, and already does in many sectors, play an important role to address waste management and marine debris. Many large companies have a global reach with the ability to influence the production, consumption and end-of-life management of their products[393]. Other industries that utilize the marine and coastal environment as a resource (e.g. ecotourism) can also play a significant role, mainly through raising awareness of the marine debris issue, often through practical engagement.

In 2011, plastic associations signed a The Declaration of the Global Plastics Associations for Solutions to Marine Litter (Global Declaration), making a public commitment to tackle the global issue of plastics in the marine environment[394]. As of December 2013, sixty associations representing 34 countries had signed the declaration and over 185 projects had been planned, underway or completed.[395]. The projects fall under six main commitment themes: education, research, public policy, best practices, recycling and recovering plastics, and plastic pellet containment. Notable projects are:

- Operation Clean Sweep that concentrates on the proper containment of plastic pellets and is operating in 12 countries worldwide and also across Europe;
- BIOCLEAN – a EU funded research consortium to find smart and robust technological solutions for the degradation of plastic fragments occurring in marine habitats; and

387 Ibid
388 A process where the quality / value of the final product is upgraded compared to the original material
389 Zhuo, C. and Levendis, Y.A. 2013. Upcycling waste plastics into carbon nanomaterials: A Review. J. Appl. Polym. Sci. doi:10.1002/APP.39931.
390 Ibid
391 Klika, K.D. 2013. Waste plastic and pharmaceuticals, could an integrated solution help? Environ. Sci. Technol.
392 Brodin, T. et al. 2013. Dilute concentrations of a psychiatric drug alter behaviour of fish from natural populations. Science 339: 814-815.
393 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 pages.
394 http://www.marinelittersolutions.com/
395 The Declaration of the Global Plastics Associations for Solutions to Marine Litter – Progress Report 2014. 29 pp.

- Advocating legislation at the state level that would phase out the intentional use of microbeads in personal care products. A coalition of industry groups and NGOs is working on legislation for Illinois and encouraging other states to use the Illinois bill as a model for similar measures.

A new global initiative has also been launched by an alliance of governments, industry, intergovernmental and non-governmental organizations to tackle the problem of ghost fishing gear. The Global Ghost Gear Initiative (GGGI)[396] is a coordinated approach with the following objectives:

- Share data, intelligence and resources to understand ghost gear abundance, causes, impacts and trends;
- Promote a shared commitment to support the expansion and replication of existing effective solutions to reduce ghost gear;
- Share experience and resources from effective solution case studies, in both policy and practice;
- Enable solutions to be focused on ghost gear hotspots and create funding opportunities for projects in these areas;
- Provide a platform to drive and develop new ways to tackle the ghost gear issue; and
- Enable global monitoring and showcase the impacts of projects to catalyse further change.

There are numerous examples of engaging with the fishing industry to tackle the problem of ALDFG as highlighted in the last two sections. The recreational SCUBA diving industry is also engaged with the issue of marine debris, with PADI's Project Aware raising awareness for divers and other users of coastal and inshore waters. There have also been a number of coastal clean-ups organized by ecotourism operators with proposals for collaboration between existing coastal survey and clean-up programmes in Australia and the ecotourism industry to provide sufficient numbers of people to effectively clean stretches of coastline of marine debris[397].

4.4 Environmental Education and Awareness Building

The use of awareness and education campaigns to reduce or prevent waste materials from entering the marine environment can be a very effective tool to target a range of audiences in the public or private sector. Such campaigns often focus on a particular type of litter or activity that make up a significant component of recorded marine debris items such as plastic bags, bottles or cigarette butts. The UNEP Regional Seas programme provides details on a range of campaigns and clean-ups operating at the global, regional and national level[398]. An in-depth review of marine debris public awareness and education campaigns was recently undertaken for the CMS[399] as required under CMS Resolution 10.4 on Marine Debris. The review initially identified the main target audiences in relation to potential sources of marine debris (Table 2).

Table 2: Main target audiences in relation to potential sources of marine litter (adapted from Sherrington et al., 2014)

Target Audience	Examples of sources of marine litter
Members of the general public engaged in marine and coastal activities	Visitors to the coast – debris from overflowing bins, general littering and sporting activities
	Vessel-based litter from recreational activities – motorized boats, yachting, diving, boat-based angling
	Passengers on ferries and cruise ships

[396] http://www.worldanimalprotection.org/build-the-global-ghost-gear-initiative
[397] Tangaroa Blue Foundation, 2014. Marine Debris Management Plan for Cape York Peninsula and the Torres Straight Islands, far North Queensland. An Australian Marine Debris Initiative Report.
[398] http://www.unep.org/regionalseas/marinelitter/other/cleanups/default.asp
[399] Sherrington, C. et al. 2014. Marine Debris Public Awareness and Education Campaigns (Report III). Review for CMS Resolution 10.4. Eunomia Research and Consulting Ltd. March 2014. 34 pp. (UNEP/CMS/ScC18/Inf.10.4.3).

	Subsistence fishers and gleaners
Members of the general public engaged in land-based activities	General littering
	Domestic disposal of solid waste into the wastewater system
	Smoking
	Hunting
Private firms and employees	Commercial marine activities, including shipping and commercial fishing
	Port and harbour authorities
	Agriculture and aquaculture
	Formal waste management: including ship breakers, municipal solid waste management, commercial and industrial waste, landfill sites, scrapyards, wastewater management
	Informal / unregulated waste management
	Plastics manufacturing and other manufacturing
	Construction industry
	Healthcare
	Retail including fast food, coastal and retail outlets
	Hospitality industry
Public bodies and employees	Central and local government
	Military
	Storm water drainage planners and management firms

A range of case studies were selected to demonstrate campaigns that either focused on a particular audience or type of marine debris. A total of 58 campaigns implemented by larger, better networked or prevalent organizations were assessed[400] which used a wide range of campaigning techniques including industry pledges, petitions, clean-up events, educational materials, competitions, smartphone apps., social media and direct engagement. Four key gaps were identified for the campaigns assessed which were audience, geographic, species and debris type gaps. In terms of target audiences the main gaps identified were for the military, waste management firms and storm water drainage. However, both waste management and storm water drainage planning can vary considerably both between and within countries suggesting that further assessment of these sectors is required to target localities where management is less effective with regard to marine litter. A number of recommendations were made for CMS to consider:

- Support, promote and replicate current campaigns to different regions and countries. A few of the examples provided were Operation Clean Sweep, Beat the Microbead and campaigns to tackle fishing line and tackle recycling for the recreational fishing sector;
- Address identified gaps, especially for target audiences (waste management, storm water drainage and the military) and data on the relative importance of these sources of marine debris; and
- Promote best practice within campaigns including data collection and reporting to evaluate campaign success.

[400] See Sherrington et al., 2014. Marine Debris Public Awareness and Education Campaigns (Report III). Review for CMS Resolution 10.4. Eunomia Research and Consulting Ltd. March 2014. 34 pp. (UNEP/CMS/ScC18/Inf.10.4.3), Appendix A.1.0 for details.

One aspect that the review identified with regards to best practice was that campaigns should be implemented before the introduction of legal or economic measures that sought to change behaviour so that the general public have a good understanding of the reasoning behind the measure and are more likely to support it. Public support is regarded as crucial if the measures are to be effective[401]. A good example of this was the successful introduction of a plastic bag ban in Rwanda which was preceded by a comprehensive and multi-faceted awareness and education public campaign[402]. A similar ban imposed in Somaliland was not successful[403] and was thought to be partly caused by a poorly managed campaign that did not generate enough public support for the proposed change.

The 'Beat the Micro Bead' campaign[404] was started in 2012 by the Plastic Soup Foundation and the North Sea Foundation to target a specific type of microplastic marine debris. The campaign uses tools such as petitions, social media and a 'smartphone app' that enable consumers to make more informed choices about their choice of personal care product[405]. The app is a bar code scanner that identifies whether a product contains plastic microbeads or not but also whether the producer has indicated that it will stop using microbeads. The consumer can scan products before purchase and then boycott brands and products containing microbeads. The potential purchasing power pressure combined with the bad publicity of having products listed in the campaign has been a strong motivation for some large international companies with many making the commitment to remove microbeads from their products[406]. The campaign originated in The Netherlands but is now global with the phone app available in Europe, North America and the Caribbean[407]. However, it has been suggested that industry-led voluntary commitments alone are not sufficient to enable a complete phase-out of microbeads[408].

Awareness and education campaigns targeting schools, communities and industry can be very successful in encouraging behaviour change in both children and adults. In Australia the TeachWild[409] programme has engaged with more than 5000 students, teachers and industry employees in one day research and training projects concerned with marine debris[410] that have helped to build knowledge, skills and change attitudes. Teachers also participated in multi-day field-based research expeditions led by Government scientists and were instrumental in teaching marine debris as part of the school science curriculum that met national curriculum guidelines. The TeachWild project has reached more than 1 million people in Australia to date through extensive communication, outreach, interviews, webinars, video calls and face-to-face activities[411]. Although a national programme, the project also worked well at the community level and encouraged marine debris related activities carried out by local primary schools[412].

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[401] Sherrington, C. et al. 2014. Marine Debris Public Awareness and Education Campaigns (Report III). Review for CMS Resolution 10.4. Eunomia Research and Consulting Ltd. March 2014. 34 pp. (UNEP/CMS/ScC18/Inf.10.4.3).

[402] Rwanda's Plastic Bag Ban – The story of banning the plastic bag in Rwanda: http://thedeliciousday.com/environment/rwanda-plastic-bag-ban/

[403] Somalis ignore plastic bag ban. http://www.panapress.com/Somalis-ignore-plastic-bag-ban-12-564930-40-lang2-index.html .

[404] http://www.beatthemicrobead.org/en/.

[405] Neumann, S. et al. 2013. How to improve EU legislation to tackle marine litter. Institute for European Environmental Policy, London. 60 pp.

[406] Sherrington, C. et al. 2014. Marine Debris Public Awareness and Education Campaigns (Report III). Review for CMS Resolution 10.4. Eunomia Research and Consulting Ltd. March 2014. 34 pp. (UNEP/CMS/ScC18/Inf.10.4.3).

[407] http://www.beatthemicrobead.org/en/results

[408] Neumann, S. et al. 2013. How to improve EU legislation to tackle marine litter. Institute for European Environmental Policy, London. 60 pp.

[409] http://teachwild.org.au/.

[410] Hardesty, B.D. et al. 2014. Understanding the effects of marine debris on wildlife. A final report to Earthwatch Australia. CSIRO Oceans and Atmospheric Flagship. 353 pp.

[411] Ibid

[412] http://teachwild.org.au/what-is-your-school-doing.

Building awareness and enabling behaviour change is particularly important in developing countries with remote coastal communities that have minimal infrastructure and capacity to manage waste at the local level. Campaigns and outreach programmes implemented by local councils in Australia were found to be effective in reducing marine debris found in coastal areas[413] and may be more cost-effective than building waste management infrastructure. Local authorities with insufficient capacity to deliver outreach and education programmes could work in partnership with NGOs with expertise in social marketing to focus activities on the issue of community-based solid waste management practices that reduce land-based sources of marine litter.

5. SUMMARY AND CONCLUSIONS

It is universally agreed that marine debris poses a significant global stressor to marine and coastal biodiversity and habitats and that inputs of debris into the ocean need to be reduced. The increasing number of marine species being affected by debris and the greater incidence of ingestion, entanglement and dispersal shown by CBD Technical Series 67[414] provided a solid base of evidence to strongly support such concerns. This study has added to the total number of species affected by marine debris and provided further information on the types of impacts occurring, particularly with respect to microplastics and their physical and chemical effects. The transfer of adsorbed and inherent toxins from microplastics to marine organisms has been demonstrated with negative effects on health reported in some cases. Experimental work has also confirmed the potential for trophic transfer of microplastics in marine food webs. However, there is currently a lack of evidence of these effects in the marine environment. Similarly population effects of marine debris have not been demonstrated. However, it is very difficult to isolate the effects of one stressor in a multi-stressor scenario to show population-level changes, and there are only a few clear examples of population-level effects from any form of man-made contamination[415]. It is thought likely that marine debris in combination with other anthropogenic stressors could contribute to the extinction of threatened species and may have indirect effects on trophic interactions and on assemblages[416].

Although the evidence for the impacts of marine debris on marine and coastal biodiversity has grown considerably in the last few decades, there are still significant gaps in our knowledge and understanding of debris in the marine environment and how it affects coastal and marine organisms, communities and ecosystems. Recently published suggestions regarding knowledge gaps and research and monitoring needs are summarized in Appendix 4a and 4b respectively. A review of marine debris knowledge gaps was undertaken for the Convention on Migratory Species in 2014 that clearly highlights the overall lack of information for this stressor in terms of debris distribution, its impacts on marine biota and the effectiveness of current management approaches in both reducing debris input into the marine environment and impacts on marine organisms[417]. The selected research and monitoring needs (Appendix 4b) also indicate that extensive further work is required to fully understand the issue. Particular research areas that are in need of attention are the standardized monitoring and reporting of debris for the marine environment to allow comparison between habitats

[413] Hardesty, B.D. et al. 2014. Understanding the effects of marine debris on wildlife. A final report to Earthwatch Australia. CSIRO Oceans and Atmospheric Flagship. 353 pp.
[414] 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 pages.
[415] Koelmans, A.A. et al. 2014. Plastics in the marine environment. ET & C Perspectives. Environmental Toxicology and Chemistry 33: 5-10.
[416] 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 pages.
[417] Sherrington, C. et al. 2014. Migratory Species, Marine Debris and its Management (Report I). Review for CMS Resolution 10.4. Eunomia Research and Consulting Ltd. March 2014. 169 pp. (UNEP/CMS/ScC18/Inf.10.4.3).

or regions and understanding the dynamics of microplastic in marine systems, their interactions with biota and the various impacts of plastics on species, populations and food webs. Using the appendices (4a and 4b) as a baseline, marine debris knowledge gaps and research and monitoring needs in addition to suggestions on how to address them, were further developed by participants of the CBD Expert Workshop on marine debris mitigation and prevention[418]. Further details on the aspects of the workshop discussions are available in Annex 4 of the CBD Expert Workshop report[419].

There is considerable focus on the management and mitigation of plastic marine debris given that they make up the bulk of debris items in the marine environment. A recent review of research needs for marine plastic pollution generated a list of research questions to facilitate the control and mitigation of marine plastic impacts on marine wildlife and habitats (Appendix 4b). These highlight, in particular, the need for marine debris data at scales relevant to management and the urgent need to develop interdisciplinary research and management partnerships to limit the release of plastics into the environment and minimize the future impacts of plastic pollution[420]. Mitigating the impacts of plastic pollution will require the delivery of a multidisciplinary approach across various spatial and temporal scales. One of the research needs listed is concerned with the influence of climate change on marine plastic pollution impacts. This is an important research area that has not been investigated to date. Climate change alterations to precipitation patterns, sea level, storm frequency, and ocean currents may all influence the impacts of plastic pollution on the marine and coastal environment in different ways[421]. Also, addressing the impacts of marine debris on the marine ecosystem must also take into consideration the transboundary dimension of the problem. In some regions, this has been implemented by regional cooperation through an ocean basin approach. Measures to address impacts and the prevention of marine debris should also take into consideration potential impacts and implications in marine areas beyond national jurisdiction.

Main Solutions and Key Approaches to address Marine Debris

As mentioned previously in Section 1, the main solutions to address land-based sources of plastic marine debris are well known[422], as follows:

- Reduction in the use of material produced and the reuse of items
- Disposal of end-of-life items properly, ideally by recycling
- Recycling to turn end-of-life material back into new items to reduce accumulation of waste and the need for production of new materials
- Recovery of items that cannot be reused or recycled, including through incineration
- Considering how to minimize the overall environmental footprint of plastic products at the design stage

An additional and solution is the need to support research and development of new materials that are non-toxic, truly compostable, fully biodegradable alternatives to conventional plastics, with comparable economic properties and performance characteristics. These efforts should be accompanied by investment into new manufacturing processes that can handle high volume production for these new materials and new recycling processes that would support mixed recycling

[418] Secretariat of the Convention on Biological Diversity. 2015. Report of the Expert Workshop to prepare Practical Guidance on Preventing and Mitigating the Significant Adverse Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats. Baltimore, U.S.A, December 2014. UNEP/CBD/MCB/EM/2014/3/2. 31pp.

[419] Ibid

[420] Vegter, A.C. et al. 2014. Global research priorities to mitigate plastic pollution impacts on marine wildlife. Endang. Species Res. 25: 225-247.

[421] Ibid

streams including compostable, bioplastics, bagasse and other emerging materials. The currently implemented examples provided in section 3 mainly fall in to one of the above solutions. The key lessons learned from the examples provided are summarized in Table 3. Four main approaches are highlighted that have proven to be successful in addressing waste and marine debris issues: Regulatory Measures; Voluntary (non-regulatory) Measures, Adequate Infrastructure and Education and Awareness. Ideally, these approaches should be part of an overall integrated strategy so that any measures implemented are supported by specific awareness raising and communication campaigns and the provision of adequate waste collection and processing infrastructure.

A major theme is the use of regulatory measures to enable change in the production, use and disposal of items that commonly end up as marine debris. Putting legal or economic measures in place at the municipal or national level can be very effective as part of an integrated approach. Of these, bans have been successfully implemented for certain types of plastic waste such as single-use bags or styrofoam. User fees for plastic bags can also dramatically change consumer behaviour and the number of single-use bags in circulation. Providing economic incentives for recycling such as deposit schemes for beverage containers or the free disposal of end-of-life fishing gear in port reception facilities can also be very effective. These measures can be part of EPR legislation for particular products or items, or individual regulations enacted by local or national governments. The effective implementation of EPR policies to tackle plastics is a critical requirement. EPR policies that focus on plastic product design aspects such as degradability or re-use will have a significant impact on the amount of waste plastic entering the marine environment. Learning from experience and sharing best practice between countries with established EPR policies and programmes and those starting up will help to ensure newly implemented EPR measures are effective. For complete elimination of the major sources of marine debris stronger, regulatory measures are required to tackle the problem at source. Regulatory measures should provide a governance structure within which mechanisms are established that ensure compliance and enforcement of agreed environmental standards.

Voluntary (non-regulatory) schemes implemented by industry often in partnership with government or non-government organizations can also play an important part in tackling specific types of marine debris such as end-of-life fishing gear or microbeads (Table 3). However, these initiatives are often quite localized or are partially effective.

In addition to source reduction and producer responsibility measures, increased education and awareness is also generally regarded as a key approach to minimizing further increases in marine debris and its associated impacts[423]. Implementing targeted well-conceived awareness programmes can be a key factor for the success of regulatory measures as was shown in Rwanda for a plastic bag ban (Table 3). There have been calls for the better understanding of economic and socio-economic barriers and opportunities to change behaviour and markets through undertaking research in a number of social domains involving behaviour-change models, social marketing and cost-benefit analysis[424].

Having an effective waste management infrastructure that creates enabling conditions to support recycling programmes but also to prevent litter items entering the marine environment through watershed and storm-water management is also an important aspect of an integrated approach. Where infrastructure for waste management is lacking, focusing on education and awareness for coastal communities may have a greater impact on reducing the flow of waste materials into the marine environment. Non-regulatory initiatives can also help to build up waste management infrastructure where it is lacking and where capacity is low. There is a general need to better integrate plastic waste recycling and re-use into waste management plans and strategies, which will also be dependent on existing infrastructure and capacity.

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[423] 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 pages.

[424] Vegter, A.C. et al. 2014. Global research priorities to mitigate plastic pollution impacts on marine wildlife. Endang. Species Res. 25: 225-247.

Table 3: Approaches to Marine Debris Reduction

Main Approach	Measure	Examples
Regulatory Measures	EPR Programmes	Multiple EPR programmes in California and Europe
	Bans or User Fees	Plastic bag bans (Rwanda) or levies (Ireland)
	Economic Incentives	Deposit Return Schemes for beverage containers (South Australia)
		Fishing gear buy-back scheme (South Korea)
Non-regulatory / voluntary measures	Economic Incentives	Fishing gear purchase: Net-Works (Philippines)
		Free disposal of fishing gear (Europe, U.S.A.)
Adequate infrastructure for waste collection and management	Waste collection facilities	Port reception facilities for fishing vessel waste and end-of-life fishing gear
		Waste receptacles in public places (California, Australia)
	Storm-water management systems	TDML systems (U.S.A.: California, Maryland)
Education and Awareness	Targeted campaigns in support of regulatory measures	Comprehensive national campaign in Rwanda prior to plastic bag ban
	Campaigns targeting specific types of marine debris	Ban the Microbead, Operation Cleansweep

There have also been calls for some types of plastic waste to be classified as hazardous waste [425] and regulations for the phasing out of microbeads. For the latter, in Europe, this could be partly achieved by amending the Cosmetics Product Regulation to prohibit the use of plastic micro particles in cosmetic products and has been regarded as the most obvious and cost-effective way to prevent this type of marine litter pollution[426]. Manufacturing and retail bans on the use of microbeads by industry in personal care products have been suggested[427].

Key policy-related recommendations have also been proposed by GESAMP that consist of action-orientated recommendations addressing microplastics and recommendations to improve future assessments:

1. Identify the main sources and categories of plastics and microplastics entering the ocean;
2. Utilize end-of-life plastic as a valuable resource rather than a waste product;
3. Promote greater awareness of the impacts of plastics and microplastics in the marine environment;

[425] Rochman, C.M. et al. 2013. Classify plastic waste as hazardous. Comment, Nature 494: 169-171.
[426] Neumann, S. et al. 2013. How to improve EU legislation to tackle marine litter. Institute for European Environmental Policy, London. 60 pp.
[427] Doughty, R. and Erikson, M. 2014. The case for a ban on microplastics in personal care products. 27 Tul. Envtl. L. J. 277-298.

4. Include particles in the nano-size range in future assessments of the impact of plastics in the ocean;
5. Evaluate the potential significance of plastics and microplastics as a vector for organisms in future assessments; and
6. Future assessments should address the chemical risk posed by ingested microplastics in greater depth.

Suggested solutions and responses to address these recommendations are provided in a 2015 GESAMP report[428]

A series of recommendations for practical guidance to prevent and mitigate marine debris impacts were identified at the CBD Expert Workshop, which are set out in Annex 5 of the workshop report[429]. These elements are grouped into a number of approaches. For land-based sources these aim to:

- Empower communities and relevant stakeholders/civil society groups at the local level;
- Engage the private sector;
- Mainstream marine debris issues into national regulatory and policy frameworks;
- Enhance international and regional cooperation; and
- Influence consumer choice and behaviour.

To address sea-based issues, the workshop identified four main areas:

- Abandoned, lost or otherwise discarded fishing gear (ALDFG);
- Area-based management as a potential tool to minimize loss of fishing gear from gear conflicts and boating interactions;
- Vessel-associated inputs; and
- Aquaculture

In addition, a number of emerging issues were identified during the workshop that should also be considered when addressing marine debris impacts, such as the storage of employable fishing gear in the marine environment (‘wet storage’), the use of sacrificial fishing gear such as fish aggregating devices (FADs) that can become marine debris, and the potential impacts of offshore development, recreational fishing and marine tourism activities.

A conceptual framework to reduce the quantity of plastic debris entering the ocean has been proposed[430]. This mainly consists of a series of key steps (Figure 3) to achieve a reduction in the quantity of waste material being produced. Further details for the framework are available in the STAP report, provided as an additional background information document for the CBD Expert Workshop[431].

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[428] 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.

[429] Secretariat of the Convention on Biological Diversity. 2015. Report of the Expert Workshop to Prepare Practical Guidance on Preventing and Mitigating the Significant Adverse Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats. Baltimore, U.S.A, December 2014. UNEP/CBD/MCB/EM/2014/3/2. 31pp.

[430] STAP 2011. Marine debris as a global environmental problem: Introducing a solutions based framework focused on plastic. A STAP Information Document. Global Environmental Facility, Washington, DC.

[431] http://www.cbd.int/doc/meetings/mar/mcbem-2014-03/other/mcbem-2014-03-sbstta-16-inf-15-en.pdf

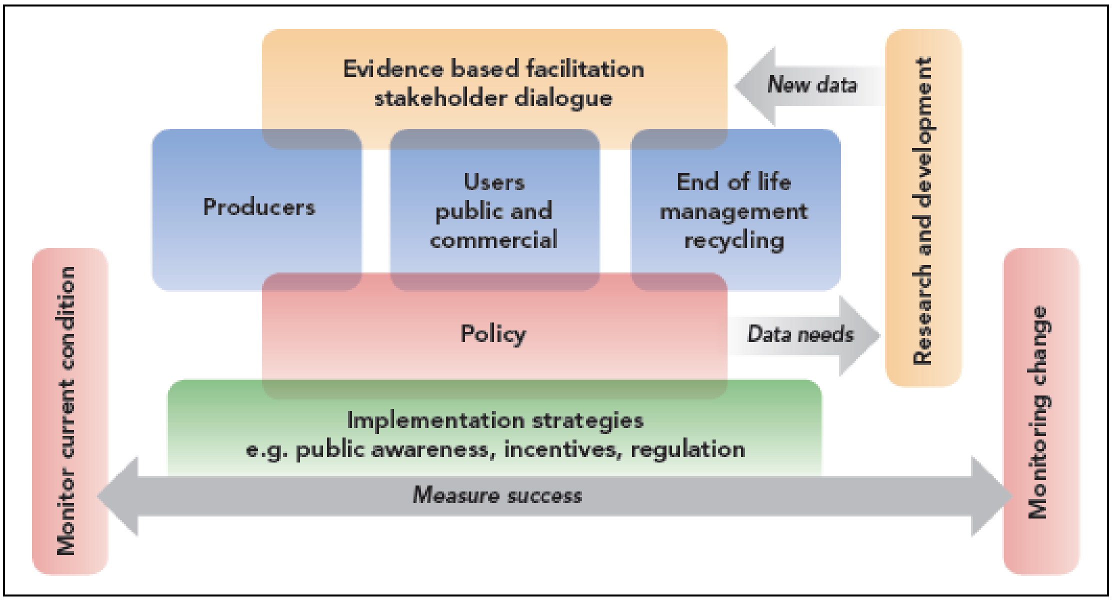

Figure 3. A framework illustrating approaches to address marine debris (based on STAP, 2011)

Potential funding sources for marine debris mitigation and management are taxation or user charges with a proposal to establish a Global Marine Responsibility Fund that can directly finance activities such as building waste management infrastructure capacity[432]. Establishing marine debris task forces at the national level may facilitate the coordination of debris monitoring and mitigation, while the regional level could be coordinated through existing networks such as the UNEP Regional Seas Programme.

Cleaning up marine debris *in situ*[433] is not generally regarded as an effective solution to the issue[434] given the scale of problem, and is particularly unfeasible for microplastics[435], in water or in sediments[436]. Coastal clean ups can be useful exercises for the monitoring and removal of particular types of macrodebris such as derelict fishing gear and for maintaining high amenity coastlines to minimize socioeconomic costs. They are also regarded as an effective tool for increasing public awareness of the problem and encouraging behaviour change. Derelict fishing gear removal programmes are also worthwhile to prevent ongoing ghost fishing effects and remove potential costs and hazards to maritime industries.

Redesigning plastic products and producer responsibility are key approaches that should be prioritized, potentially through municipal and national legislation with clear time-bound targets to reduce plastic waste. Further research and development of more efficient technology for plastic sorting and separation during recycling and recovery, including for bioplastics, should go hand in hand with producer responsibility to ensure waste management infrastructure can support the implementation or expansion of EPR programmes. In addition the commercial-scale development of

[432] Global Ocean Commission 2014. From decline to recovery – A rescue package for the Global Ocean. Global Ocean Commission Report. 88 pp.
[433] Slat, B et al. 2014. How the oceans can clean themselves: A feasibility study. http://www.theoceancleanup.com/the-concept.html.
[434] 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 pages.
[435] Law. K.L. and Thompson, R.L. 2014. Microplastics in the seas. Science 345: 144-145.
[436] Ivar do Sul, J.A. and Costa, M.F. 2014. The present and future of microplastic pollution in the marine environment. Env. Poll. 185: 352-364.

alternative materials to plastic that are derived from natural biodegradable compounds should be prioritized.

The use of technologies to convert waste plastics into fuels or recover their chemical constituents for re-use deserves greater attention, particularly their development to commercial-scale operations.

Research and development and further commercialization and manufacturing of new and alternative materials to conventional plastics should be prioritized. The focus of these developments should be in key problem areas, or "hot spots", of the highest plastics consumption: disposable plastic products and packaging, plastic medical waste and microbeads, food and other types of packaging, retail, personal care products, construction, transportation, and agricultural plastic. The innovations that could provide high-value investment opportunities are in (i) new materials that are non-toxic, truly compostable, fully biodegradable alternatives to conventional plastics, with comparable economic properties and performance characteristics, (ii) new manufacturing processes that can handle high volume production for these new materials, (iii) new recycling processes that can handle mixed recycling streams including compostable, bioplastics, bagasse and other emerging materials, and (iv) new consumer product design that conforms to the principles of "circular economy" and reduces dependence on conventional plastics.

Sharing of best practices between regions, countries or municipalities will also help to design and implement waste management and source reduction strategies that fit into the local or national context.

6. Appendices

Appendix 1. Summary Tables of Published Impacts of Marine Debris on Marine and Coastal Biodiversity and Habitats (as of 2014)

1a Peer-reviewed papers on the ingestion of debris (mainly microplastics) by vertebrates (fish, seabirds, marine mammals and marine turtles), published since 2012. All were field surveys of contaminated animals (adapted from Ivar do Sul and Costa, 2014).

Biota	Main focus/findings	Reference
Fish		
Gerreidae	~13% ingested blue nylon fragments (1-5mm) probably during feeding.	Ramos et al., 2012
Stellifer brasiliensis, Stellifer stellifer	~8% ingested blue nylon fragments	Dantas et al., 2012
Myctophidae	~40% (mostly *M. lychnobium* and *C. andreae*) ingested plastics.	van Noord, 2013
5 species of pelagic *(Merlangius merlangus, Micromesistius poutassou, Trachurus trachurus, Trisopterus minutus, Zeus faber*) and 5 spp. of demersal fish *(Aspitrigla cuculus, Callionymus lyra, Cepola macrophthalma, Buglossisium luteum, Microchirus variegatus)*	English Channel. ~36% ingested fibres and fragments (~1-2mm). All 10 species had ingested plastic debris.	Lusher et al., 2013
5 deep water fish species: *Pteroplatytrygon violacea, Galeus melastomus, Squalus blainville, Etmopterus spinax, Pagellus bogaraveo*	Depth range: 300–850 m, Eastern Ionian Sea, Mediterranean. Debris items were plastics (87%), metals (8%) and wood (3%). Plastics comprised of hard fragments (56%), bag fragments (22%), fishing lines and nylon rope filaments (19%) and textile fibres (3%). Plastic fragments size range: 5-60 mm	Anastasopolou et al., 2013

Alepisaurus ferox, Coryphaena hippurus, Gempylus serpens, Thunnus obesus, Lampris sp. (big-eye), *Lampris sp.* (small-eye), *Xiphias gladius*	Central Pacific. Debris recorded in 19% of all fishes examined. Frequency of ingestion for the ten species ranged from 0 to 58%. Seven of ten species had ingested debris. Ingested debris was mainly plastic fragments, fishing lines and rope pieces	Choy and Drazen, 2013
Alepisaurus ferox	Northern Pacific. 25% of individuals had ingested plastic marine debris, mainly fragments (52%).	Jantz et al., 2013
5 species of temperate fish: *Gadus morhua, Merlangius merlangus, Clupea harengus, Melanogrammus aeglefinus, Trachurus trachurus*	North Sea. Five of seven species analysed had ingested plastic. Frequency of fish with plastic was higher in the southern North Sea compared to the northern N. Sea. Highest frequency recorded for Cod in the English Channel	Foekema et al., 2013
Cetorhinus maximus	Phthalates in muscle tissue related to the ingestion of microplastics	Fossi et al., 2014
Seabirds		
Fulmarus glacialis	> 90% ingested fragments; the incidence is higher when compared to other regions.	Avery-Gomm et al., 2012*
Fulmarus glacialis	78% ingested fragments and pellets; pollution levels in the North Atlantic decrease towards higher latitudes.	Kühn & van Franeker, 2012
Calonectris diomedea	83.5% ingested nylon threads; plastics were regurgitated by parents during feeding.	Rodriguéz et al., 2012
Larus glaucescens	Fragments (<1cm) were found in 12% of boluses (N=589) collected by volunteers.	Lindborg et al., 2012
Phoebastria immutabilis, P. nigripes	>60% of albatrosses ingested fragments and nylon lines; lines related with fishing.	Gray et al., 2012
20 marine and aquatic bird species	2.7% of the Common Murre (*Uria aalge*) ingested plastic fragments and pellets. Two other species ingested plastic: Sooty shearwater (*Puffinus griseus*) and Glaucous-winged gull (*Larus glaucescens*). No debris found to be ingested by remaining 17	Avery-Gomm et al., 2013*

	species examined (some small sample sizes)	
Puffinus tenuirostris	Transference of PBDEs from ingested plastics to the tissues.	Tanaka et al., 2013
Puffinus tenuirostris	>67% of birds had ingested marine debris, mainly plastics, with juveniles ingesting significantly more than adults. Active selection of some debris items by birds.	Acampora et al., 2014
Puffinus carneipes	Australian waters. >60% fledglings exceeded international targets for plastic ingestion by seabirds. Amount of plastic ingested was the highest reported for any marine vertebrate.	Lavers et al., 2013
Ardenna pacifica	Southern Great Barrier Reef, Australia. 21% of surveyed chicks were fed plastic fragments by their parents. All plastic fragments floated.	Verlis et al. 2013
9 species of seabirds: 3 shearwaters, 3 gulls, kittiwake, gannet and great skua	All species accidentally caught by longline fishing in the Mediterranean. All species ingested plastic with highest frequency in the endemic and threatened three shearwater species.	Codina-Garcia et al., 2013
13 species of marine birds	North Atlantic. *Puffinus gravis* and *Fulmarus glacialis* had highest plastic ingestion prevalence (71% and 51% respectively). Great shearwaters had the most pieces of plastic. Seven species had no plastic debris.	Provencher et al., 2014
Fulmarus glacialis rodgersii	Study of relationships between prey and plastic ingestion of northern fulmars and their muscle index.	Donnelly-Greenan et al., 2014
Fulmarus glacialis, Puffinus gravis, Puffinus griseus, Calonectris diomedea	Sable Island, Nova Scotia, Canada. All species except *Calonectris diomedea showed high prevalence of plastic ingestion (>72%).*	Bond et al., 2014
Marine Mammals		
Balaenoptera physalus	Phthalates in blubber related to the ingestion of microplastics.	Fossi et al., 2012; 2014
Phoca vitulina	12% ingested microplastics.	Bravo Rebolledo et al., 2013

Physeter macrocephalis	Mortality of a sperm whale in the Mediterranean related to the ingestion of large amounts of marine plastic debris	De Stephanis et al., 2013
Pontipora blainvillei	16% frequency of plastic debris in stomachs	Di Beneditto and Ramos, 2014
Sotalia guianensis	1.3% frequency	Di Beneditto and Ramos, 2014
Trichechus manatus latirostris	Florida. Incidental ingestion of derelict fishing gear by manatees during foraging.	Adimey et al., 2014
Marine Reptiles		
Marine turtles (multiple species)	Australian waters. 33% of turtles had ingested plastic	Schluyer et al., 2012
Marine turtles (multiple species)	Review and analysis of 37 published studies for data collected between 1896 and 2012. Probability of plastic ingestion has increased for green and leatherback turtles.	Schluyer et al., 2014
Caretta caretta	Tuscany Coasts, Mediterranean. 71% of assessed (dead) turtles had ingested marine debris, mainly sheet plastic. Confirms high impact of marine debris in the region.	Campani et al., 2013
Caretta caretta	Sardinia, Mediterranean. 14% of assessed loggerhead turtles had ingested marine litter, mainly plastics as sheet or fragments. Both living and dead turtles were assessed.	Camedda et al. 2014 (in press)
Caretta caretta	South Indian Ocean. Debris found in 51% of gut or faecal samples of loggerheads, with plastics accounting for 96% of it. Highlights gravity of plastic pollution and its threat to sea turtles.	Hoarau et al., 2014

1b. Peer-reviewed papers on the ingestion of microplastics by invertebrates, published since 2012. Most were controlled laboratory experiments testing the potential ingestion of microplastics (adapted from Ivar do Sul and Costa, 2014).

Biota	Type of items	Main focus/findings	Reference
Mytilus edulis	Nanopolystyrene	Ingestion triggered the formation of pseudofaeces and reduced filtration.	Wegner et al., 2012
Mytilus edulis	Polyetylene	Microplastics ingested	von Moos et al., 2012
Dosidicus gigas	Pellets, fishing line	8 out of 30 animals ingested plastics.	Braid et al., 2012*
Arenicola marina	Polystyrene microplastic	Lugworms ingested but did not accumulate plastics; contamination by PCB sorbed onto plastics.	Besseling et al., 2013
Mytilus edulis, Carcinus maenas	Polystyrene microplastic	Small amounts were transferred from mussels to crabs.	Farrell and Nelson, 2013
Marine zooplankton	Polystyrene pellets	Copepoda, Tunicata, Euphausiacea, Cnidaria, Mollusca and Decapoda ingested microplastics in the laboratory. Potential impacts are highlighted.	Cole et al., 2013
Tigriopus japonicus	Micro polystyrene particles	Copepod adults and nauplii ingested microsized beads (6 µm) and nanosized particles (0.05-0.5 µm) which may negative effects including a decrease in survivorship and retardation of development	Lee et al., 2013
Talitrus saltator	Polyetylene pellets	Sandhoppers ingested and expelled microplastics in the laboratory. Effects not observed during the 7 days of experimentation.	Ugolini et al., 2013*
Arenicola marina	Microscopic UPVC	Deposit-feeding worms had significantly depleted energy reserves by up to 50% which were linked to a combination of reduced feeding activity, longer gut residence times of ingested material and inflammation	Wright et al., 2013
Tripneustes gratilla (larvae)	Polyethylene microspheres	Ingestion rates related to microsphere concentration. Able to egest microspheres from their stomachs within hours. Microsphere concentrations had no significant effect on larval survival and a small effect on growth.	Kaposi et al., 2014
Marine zooplankton: Mysid shrimps, copepods, cladocerans, rotifers, polychaete	Polystyrene microspheres	Baltic Sea Zooplankton. Ingestion of microspheres by all taxa studied with highest percentage of individuals with ingested spheres for pelagic polychaete larvae (*Marenzelleria* spp.). Trophic transfer of microspheres demonstrated in experiments where mysid shrimps (macrozooplankton) fed on copepods (mesozooplankton) that had	Setälä et al., 2014

larvae, ciliates		ingested microspheres. Copepods and mysid shrimps egested microspheres within 12 hours.	
Oryzias latipes	Polyethylene pellets	Altered gene expression observed in the choriogenin (Chg H) gene in males and the vitellogenin (Vtg I), choriogenin (Chg H), and estrogen receptor (ERα) gene in females.	Rochman et al., 2014
Allorchestes compressa	Polybrominated diphenyl ethers	Presence of microplastic particles reduced polybrominated diphenyl ethers (PBDEs) uptake compared to controls with unabsorbed free chemicals, but caused greater proportional uptake of higher-brominated congeners than lower-brominated ones.	Chua et al., 2014
Carcinus maenas	Polystyrene microspheres	Microplastic uptake possible through inspiration through gills for a common non filter feeding shore crab.	Watts et al., 2014
Mytilus edulis, Crassostrea gigas	Microplastic	Microplastics present in commercially grown bivalves and may be a source of human microplastic intake.	Van Cauwenberghe and Janssen, 2014*

*: Includes field-based studies

1c. Peer-reviewed studies that recorded the presence of toxic chemicals derived from plastics in marine biota or habitats (includes both adsorbed and inherent chemicals)

Biota	Type of Chemical	Main focus/findings	Reference
Vertebrates			
Fish			
Gadus morhua	Nonylphenol, Bisphenol A	Leaching of plastic additives modelled with predictions suggesting that ingestion of plastic is a negligible exposure pathway for cod	Koelmans et al., 2014
Oryzias latipes	Cocktail of PAHs, PCBs and PDBEs	Plastics serve as a vector for the bioaccumulation of PBTs adsorbed to plastic. Fish exposed to plastic suffered hepatic stress and liver damage	Rochman et al., 2013
Seriola lalandi	PCBs, DDTs, PDBEs and Nonylphenol	Concluded that nonylphenol detected in juvenile yellowtail in the North Pacific Central Gyre was derived from ingested plastic debris.	Gassel et al., 2013
Lanternfish (Myctophidae)	PDBEs	Fish sampled in areas with high plastic density had significantly greater levels of higher brominated congeners	Rochman et al., 2014
Cetorhinus maximus	Phthalates	Detected in muscle tissue related to the ingestion of microplastics	Fossi et al., 2014
Seabirds			
Puffinus tenuirostris	PDBEs	Presence of higher-brominated congeners in some analysed birds suggests the transfer of plastic-derived chemicals from ingested plastics to the tissues of these marine-based organisms	Tanaka et al., 2013
Marine mammals			
Balaenoptera physalus	Phthalates	Detected in blubber related to the ingestion of microplastics.	Fossi et al., 2012; 2014
Invertebrates			
Arenicola marina	PCB	Contamination by PCB adsorbed onto plastics.	Besseling et al.,

			2013
Arenicola marina	PCB	Modelling of PCB scenarios for polystyrene and polyethylene microplastics in closed and open systems.	Koelmans et al., 2013
Arenicola marina	Nonylphenol, Triclosan	Uptake of nonylphenol and Triclosan from PVC microplastic. Recorded the transfer of pollutants from plastic to the gut tissues of lugworms which had negative effects on ecophysiological functions.	Browne et al., 2013
Arenicola marina	Nonylphenol, Bisphenol A	Leaching of plastic additives modelled with predictions suggesting that leaching of these two chemicals is not a relevant exposure pathway for lugworms	Koelmans et al., 2014
Paracentrotus lividus	Bisphenol A	Effects of BPA on embryonic development of rocky sea urchins. Efflux transporter involvement, endocrine disruption, and delayed mitosis studied.	Bosnjak et al., 2014
Algae			
Chlorella pyrenoidosa, Scenedesmus obliquus	Bisphenol A	Acute toxic tests inhibited growth rates of both algae whereas chronic exposure affected it slightly. Chlorophyll a synthesis displayed inhibitory trend following acute exposure, and in chronic exposure, caused no adverse effect on *C. pyrenoidosa* but dose-dependent inhibitory effect on *S. obliquus.*	Zhang et al., 2014
Bacteria			
Bacterial communities	Polybrominated diphenyl ethers (BDE47)	BDE47 altered bacterial community and reduced alpha-diversity and species richness. Selected for certain species.	Chan et al., 2014
Habitats			
Beaches	Toxic metals	Plastic debris is a potential ‘transport vector’ for contamination of the beach environment by toxic metals	Nakashima et al., 2014

Appendix 2: Cross-referencing of new records of species known to be affected by marine debris with the IUCN Red List.

Species	Common Name	IUCN Red List Status	Marine Debris Impact
Balaenoptera borealis	Sei Whale	Endangered	Ingestion
Balaenoptera musculus	Blue Whale	Endangered	Ingestion
Neophocoena phocaenoides	Finless porpoise	Vulnerable	Ingestion / Entanglement
Orcaella brevirostris	Irrawaddy dolphin	Vulnerable	Ingestion
Puffinus mauretanicus	Balearic shearwater	Critically Endangered	Ingestion (plastic)
Puffinus yelkouan	Yelkouan shearwater	Vulnerable	Ingestion (plastic)
Ichthyaetus audouinii	Audouin's gull	Near Threatened	Ingestion (plastic)
Phoebastria immutabilis	Laysan albatross	Near Threatened	Ingestion (plastic, fishing line)
Phoebastria nigripes	Black-footed albatross	Near Threatened	Ingestion (plastic, fishing line)
Platalea minor	Black-faced spoonbill	Endangered	Entanglement (plastic, fishing line)
Galeocerdo cuvier	Tiger shark	Near Threatened	Entanglement (fishing net)
Hydropotes inermis	Water deer	Vulnerable	Entanglement (fishing net)
Limulus polyphemus	Atlantic horseshoe crab	Near Threatened	Entanglement (fishing pots)
Malaclemis terrapin	Diamondback terrapin	Near Threatened	Entanglement (fishing pots)

Appendix 3: Summary Table of Submissions[437] from Parties and Other Governments on the Impacts of Marine Debris on Marine and Coastal Biodiversity, and Management Approaches in response to CBD Notification 2014-042.

Respondent	Information Provided
Austria	University of Vienna published research on the effect of beach debris on hatchlings of the endangered loggerhead turtle *Caretta caretta*. Certain types of marine debris on beaches can be a lethal trap for hatchlings. Coastal clean-ups should be conducted just before the hatching season and focus on critical items such as canisters, drinking cups and fishing nets. Information available in: Triessnig, P., et al., 2012. Beach condition and marine debris: new hurdles for sea turtle hatchling survival. Chelonian Biology and Conservation 11(1): 68-77.
Colombia	Summary of national or regional workshops and meetings held or attended regarding marine debris and invasive species. Information Document on solid waste contamination of Atlantic coasts
Denmark	Currently no national monitoring of marine litter but this will improve when the monitoring programme as part of the MSFD is implemented. National Institute of Aquatic Resources, Technical University of Denmark published a brief report on marine litter in herring and whiting. Study focussed on marine litter between 0.5 and 5 mm in size. Approx. 30% of fish examined from the Great Belt area had ingested micro-litter, mainly fibres between 0.5-4 mm in size. Report available (in Danish only) at: http://orbit.dtu.dk/en/publications/analyse-af-marint-affald-i-sild-og-hvilling-fra-det-nordlige-storebaelt(97f2fc4b-c38e-4f85-92e4-ebc76d5d8e25).html
European Commission	• Commission Staff Working Document on marine litter – contains an overview of relevant EU legislation, policies and strategies that touch on the problem, as well as an indication of relevant on-going and future initiatives. • Report on the results of a public consultation – conducted to understand stakeholders' views on a range of actions and policies which could be undertaken in order to tackle the problem of marine litter. The results of the consultation will be used as one of the bases for formulating an EU-wide quantitative headline reduction target for marine litter.

[437] CBD Notification 2014-042 available at: https://www.cbd.int/doc/notifications/2014/ntf-2014-042-marine-en.pdf. Only those available at the time of this compilation. Further updated compilations are available at http://www.cbd.int/doc/meetings/mar/mcbem-2014-03/information/mcbem-2014-03-inf-01-en.pdf

	• Guidance document on the monitoring of marine litter in Europe, prepared by the Commission's Joint Research Centre (JRC). • Marine LitterWatch application developed by the European Environment Agency (EEA). This app. aims to help fill data gaps for marine litter on beaches, while involving citizens in its collection and monitoring. It also allows the collection of other types of data from initiatives such as clean-ups.
Germany	Four studies provided as scientific input: • Butterworth, A., et al. (2012): Untangled – Marine debris: a global picture of the impact on animal welfare and of animal-focused solutions. London: World Society for the Protection of Animals. • Fossi, M.C., et al. (2012): Are baleen whales exposed to the threat of microplastics? A case study of the Mediterranean fin whale (*Balaenoptera physalus*), Marine Pollution Bulletin 64, 2374–2379. • Rochman, C. M., et al. (2013): Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress, Scientific Reports 3, 3263. • STAP (2011): Marine Debris as a Global Environmental Problem: Introducing a solutions based framework focused on plastic, A STAP Information Document, Global Environment Facility, Washington DC. The references given in Section 2.1 “Impacts of Marine Litter” in the Issue Paper to the "International Conference on Prevention and Management of Marine Litter in European Seas" were also recommended.
Italy	Impacts for two specific topics provided: marine litter and sea turtles; and the impact of lost or abandoned fishing gear. Text includes 17 citations. Recent research of impacts on marine turtles in the Mediterranean Sea (Italian coastal waters) is summarised. Higher incidence of the ingestion of sheet-like plastic debris which may be more similar to turtle prey (jellyfish) in terms of their suspension in the water column and not on the water surface.
New Zealand	No specific studies or systematically collected/analysed scientific information provided, but more general information highlighted under the following points: Legislation: • Disposal of waste in New Zealand’s waters is managed under both domestic and international legislation. Waste disposal within 12 nautical miles is regulated under the Resource Management Act 1991 and the Marine Pollution Regulations 1998. Waste disposal beyond the 12 nautical mile limit in New Zealand's exclusive economic zone is administered by Maritime New Zealand under the Maritime Transport Act 1994. • New rules restricting the disposal of garbage (or marine debris) from ships, pleasure craft and offshore installations come into force on 1 January 2013. The Marine Protection Rule Parts 170 and 200 were amended to give effect to Annex V (Regulations for the Prevention of Pollution by Garbage from Ships) of MARPOL. The changes tightened limits on disposal of garbage at sea and apply operational requirements (such as the use of placards, garbage management plans and record books) to a wider range of ships and offshore installations. Plastic, ropes, fishing gear and plastic garbage bags, plastic-derived incinerator ashes, cooking oil, dunnage, lining and

	packing material that floats, papers, glass, metal, bottles, crockery and similar refuse are banned for disposal at sea. Dumping water containing cleaning agents or additives that are harmful to the marine environment is also prohibited. Lost fishing gear must be reported if it poses a significant threat to the marine environment or a navigation hazard. http://www.maritimenz.govt.nz/Environmental/Garbage-disposal.asp Other activities and sources of information: • Sustainable Coastlines (http://sustainablecoastlines.org/about/impact/) is a New Zealand charity that coordinates and supports large-scale coastal clean-up events, educational programs, public awareness campaigns and riparian planting projects. They have presented to 96,000 people (mainly school students) on marine pollution issues. 33,000 people have attended beach clean-ups around NZ and collected over 135 tonnes of rubbish. The 5 most commonly collected items were microplastic pieces 200,000; food wrappers 158,000; bottle caps 90,000; plastic bags 89,000; polystyrene 82,000. • Preventative actions are also taken, such as through the New Zealand Government's Waste Minimisation Fund and work with private businesses. E.g. Flight Plastics's new plastic packaging plant which opened in early 2014 and is the country's first plastic packaging plant to manufacture food grade PET packaging from recycled PET (RPET) flakes. http://www.scoop.co.nz/stories/CU1401/S00505/flight-plastics-opens-new-zealands-first-recycled-pet-packa.htm • Surveys of fishermen have highlighted that lost fishing gear is frequently encountered, but there is very little data about the scale of this problem, despite the threat it poses to marine life and ship safety.
Nigeria	Currently managing litter from ships by implementing Annex V of MARPOL Convention. This is by ensuring adequate pollution of waste reception facilities by Nigeria Ports Authority (NPA) and regulated by Nigeria Maritime Administration and Safety Agency (NIMASA) and other relevant agencies of government. For upland litter management, NIMASA has been conducting awareness campaigns in coastal communities and recently developed a package on marine litter clean up i.e. demonstration projects to change people's attitudes in regarding the ocean as a bottomless pit for waste disposal. Obvious marine litter issues for Nigeria are from plastic products, abandoned ship wrecks and fishing gear. However, there is no direct official study on the impacts of marine litter in Nigerian waters. Currently, there is a collaborative proposal with UNEP-GPA and NIMASA to increase awareness on marine litter and develop a National action plan on marine litter management.
Poland	Recent completion of the WWF Poland project "Removal of the Ghost Nets from the Baltic Sea". Removal of 21,275 ghost nets in total, 1,400 kg in the Lithuanian waters and 19,875 in the Polish waters. One of the project's outputs is an interactive database of sites where there are underwater hazards (shipwrecks, rocks, other obstacles) which may entangle fishing gear. There are currently 333 objects recorded in the database, 233 of these objects were provided by the Hydrographic Office of the Polish Navy at the end of 2013 as a part of an information exchange. The removal of the ghost nets from the Baltic Sea will be continued within the frameworks of the Operational Programme "Fisheries and Sea" in Poland as well as in other Baltic states via other programmes and funding sources.

	The database is available in three languages (Polish, English and Lithuanian) on the website http://www.sieciwidma.wwf.pl.
USA	Provided resources for two main topics: impacts of marine debris on 1) biodiversity and 2) habitat: Biodiversity Impacts Although there is a growing appreciation for the total number of species impacted by marine debris, minimal work has directly quantified this impact, especially on how it affects overall biodiversity. There is a good understanding on which species can be impacted by marine debris (i.e., occurrence of impact), but we don't fully understand the magnitude of this impact on populations and communities of organisms (i.e., relative magnitude of impact). Several species of animals have attracted more attention in research studies (e.g., Hawaiian monk seal, northern fur seals, sea turtles, etc.), and provide more detailed information to estimate the population-level effects of marine debris. However, this level of work has not been replicated broadly given the immense amount of work and technical capabilities required to provide these estimates. Without this information, it will be difficult to identify the direct impacts of marine debris on biodiversity across various spatial scales and amid other stressors (e.g., other sources of water pollution, climate change, ocean acidification, etc.) impacting those organisms. Without fully understanding the added risk marine debris imposes on the existence of these organisms over time, it will be difficult to draw definitive, quantifiable conclusions on the overall impact of marine debris on global biodiversity. Despite these challenges, it is still useful to continue to assess the current state of knowledge on how and where marine debris could be affecting sensitive or vulnerable species and habitats. Habitat Impacts Degraded marine habitats reduce the resilience of marine life and their ability to survive in open waters and on the ocean floor. Changes in marine habitats can change the complexity of species in marine ecosystems and ultimately affect biodiversity. Few studies have addressed specific impacts of marine debris on habitat, and much needs to be done to document and study these potential impacts. More specifically, better metrics and sampling methods need to be employed in the field to assess the net impact of marine debris on various habitats. Certain habitats, however, may represent areas for focused assessment; especially areas where the organisms impacted physically provide the substrate that facilitates the development of highly diverse ecosystems (e.g., coral reefs).

Appendix 4. A Summary of Recently Published Knowledge Gaps, Research Needs and Recommendations for Marine Debris

4a. Knowledge Gaps for marine debris sources, pathways, impacts and management approaches (adapted from Sherrington et al 2014[438])

Subject Area	Knowledge Gap
Marine debris origins and pathways	• Very limited information available for debris prevalence by source and pathway; • Information for prevalence by material type is not collected systematically in most regions, even where there is monitoring effort • Monitoring of debris prevalence in different marine compartments (sea bed, water column and sea surface) is poor compared to the monitoring of beach debris; • There are no robust data for the amount of debris in the ocean or how much enters the ocean each year; • There are no robust data (yet) for the geographical distribution of debris or its distribution between marine compartments; • The fate of debris in terms of fragmentation, decomposition, distribution and accumulation is not well characterised; • Knowledge of marine debris characteristics is constrained by methodological limitations and the uneven geographical distribution of monitoring and research effort; • Current studies in different geographical regions and marine compartments tend to produce incomparable data because standardised methods either do not exist or are not applied.
Debris impacts (on migratory species)	• Insufficient quantitative information on the prevalence of impacts within populations to understand which species are most affected by marine debris; • Mechanisms and extent of harm associated with sub-lethal impacts of marine debris are poorly characterised; • Interaction between sub-lethal impacts of marine debris and other stressors are unknown; • Reporting of impacts does not take into consideration measures of animal welfare;

[438] Sherrington, C. et al. 2014. Migratory Species, Marine Debris and its Management (Report I). Review for CMS Resolution 10.4. Eunomia Research and Consulting Ltd. March 2014. 169 pp. (UNEP/CMS/ScC18/Inf.10.4.3)

	• There are almost no data on population level effects of marine debris; • Specific effects of marine debris on migratory species are poorly understood; • Further research is needed to establish if associations between vulnerability to marine debris and life history stage or habits warrant targeted approaches; • Absence of evidence for debris impacts generally reflects uneven allocation of monitoring resources rather than regional distinctions; • Impact studies generally produce incomparable data because standardised methods do not exist • Scoring of impacts according to marine debris type does not currently allow risk of harm comparisons across different species groups • Effect of microplastic ingestion is not yet fully characterised • Effects of colour, shape or plastic type on the likelihood of causing harm are generally not fully understood to warrant focussing on management strategies at present.
Management approaches for debris in marine ecosystems	• Efficacy of debris removal initiatives in terms of: – impact on stock and flow of marine debris; – mitigating impacts on marine species; – public awareness and behaviour change for the public, fishermen, industry, and other stakeholders; – Cost-effectiveness • Effectiveness of waste prevention approaches in terms of: – flow of marine debris; – impacts on marine species; – Cost-effectiveness

4b. Potential Research and Monitoring Needs for Marine Debris

Subject Area	Research and monitoring recommendations	Source
Macrodebris impacts on marine fauna	• Standardised reporting methods for debris effects on wildlife to assist in the creation of a globally consistent and comparable data set • Increase efforts to understand debris effects in under-researched areas where turtles (or other taxa of interest) occur at high numbers • Create and maintain a global survey and comprehensive database of marine debris ingestion and entanglement.	Schulyer et al 2013[439]
Marine Debris (Europe)	• Harmonised monitoring methods at the regional level that take into account regional differences • Compatible reporting categories for different survey types (beach, sea surface, seabed) to allow comparison • Long-term monitoring programmes required to understand trends for persistent litter such as plastic • Prioritise monitoring of marine areas that are most affected by litter • Monitor seabed litter alongside routine biological trawling surveys • Extend the use of ecological quality objectives using region-specific indicator species such as turtles in the Mediterranean Sea • Evaluation of new monitoring tools as they are developed • Estimating the costs of implementing monitoring tools so that regulatory bodies can make informed choices regarding appropriate monitoring programmes and tools • Evaluation of waste flows to better understand the mechanisms of transport, fluxes and potential impacts on species and habitats • Understanding transport mechanisms to provide a better description of the spatial distribution of marine litter [accumulation of litter on the seabed, degradation rates at sea, kinetics of chemical sorption/ desorption and litter	Galgani et al. 2013[440]

[439] Schuyler, Q. et al. 2013. Global analysis of anthropogenic debris ingestion by sea turtles. Conservation Biology
[440] Galgani, F. et al., 2013. Marine litter within the European Marine Strategy Framework Directive. – ICES J. Mar. Sci. 70: 1055-1064

	ingestion rates by different marine organisms are all poorly understood mechanisms]	
Marine debris ingestion by large marine organisms (Europe)	• Evaluate the potential of nested litter as a monitoring tool (MSFD indicator) for seabirds • Evaluate the potential of fishes for monitoring the ingestion of litter by (large) marine organisms • Identify bird species suitable for the development of a Fulmar type EcoQo • Better understand impacts of debris on nesting seabirds • Increase understanding of turtle migration (Mediterranean) • Increase understanding of how debris is affecting marine organisms (digestion, physiology, reproduction, population dynamics, etc.) • Understand interactions between long-term marine environmental changes and debris effects on marine mammals for the assessment of the quality of pelagic marine ecosystems • Investigate how microplastics cause harm to large filter-feeders (mammals, sharks) • Evaluate types and size of debris ingested in relation to the stage of development	Galgani et al. 2014[441]
Ingestion impacts on large marine organisms (Europe)	• Develop or use existing comprehensive models to define source and destination regions of litter, especially accumulation areas • Evaluate the environmental consequences of litter-related chemicals (Phthalates, bisphenol A, etc.) in marine organisms using specific diagnostic biomarkers • Establish the environmental consequences of micro-litter to establish potential physical and chemical impacts on wildlife • Evaluate the effects of litter on metabolism, physiology, survival rate, reproductive performance, and, ultimately, on populations and communities • Study dose/response relationships in relation to types and quantities of marine litter to enable science-based definitions of threshold levels.	Galgani et al. 2014[442] (MSFD research priorities stated by the Marine Strategy Coordination Group (MSCG) Technical Group)

[441] Galgani, F. et al. 2014. Monitoring the impact of litter in large vertebrates in the Mediterranean Sea within the European Marine Strategy Framework Directive (MSFD): Constraints, specificities and recommendations. Mar. Env. Research. http://dx.doi.org/10.1016/j.marenvres.2014.02.003.

[442] Galgani, F. et al. 2014. Monitoring the impact of litter in large vertebrates in the Mediterranean Sea within the European Marine Strategy Framework Directive (MSFD): Constraints, specificities and recommendations. Mar. Env. Research. http://dx.doi.org/10.1016/j.marenvres.2014.02.003.

Marine plastic pollution impacts (Global research priorities)	• Impacts of plastic pollution on the physical condition of key marine habitats? • Impacts of plastic pollution on trophic linkages? • How does plastic pollution contribute to the transfer of non-native species? • Species-level impacts of plastic pollution and can they be quantified? • Population-level impacts of plastic pollution and can they be quantified? • Impacts of wildlife entanglement? • How will climate change influence the impacts of plastic pollution? • What, and where, are the main sources of plastic pollution entering the marine environment? • What factors drive the transport and deposition of plastic pollution in the marine environment, and where have these factors created high concentrations of accumulated plastic? • What are the chemical and physical properties of plastics that enable their persistence in the marine environment? • What are some standard approaches for the quantification of plastic pollution in marine and coastal habitats? • What are the barriers to, and opportunities for, delivering effective education and awareness strategies regarding plastic pollution? • What are the economic and social effects of plastic pollution in marine and coastal habitats? • What are the costs and benefits of mitigating plastic pollution, and how do we determine viable mitigations options? • How can we improve data integration to evaluate and refine management of plastic pollution? • What are the alternatives to plastic?	Vegter et al 2014[443]
Microplastics (invertebrates)	• Studies focussing on the physical impacts of ingested microplastics • Research on the effects of microplastic shape and type on marine organisms • Further studies on the effects of ageing on the concentration of additives in microplastics, their bioavailability and	Wright et al 2013[444]

[443] Vegter, A.C. et al. 2014. Global research priorities to mitigate plastic pollution impacts on marine wildlife. Endang. Species Res. 25: 225-247.
[444] Wright, S.L. et al. 2013a. The physical impacts of microplastic on marine organisms. Env. Poll. 178: 483-492.

	associated toxicological impacts • Further studies on the role of microplastics as a vector for environmental POPs / PBTs, their bioavailability and associated toxicological impacts • Studies of the transfer of microplastics and their associated contaminants to higher trophic levels to understand the capacity for transfer along marine food webs and estimate population and ecosystem level impacts.	
