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# Solutions for global marine litter pollution

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Since the 1950s the amount of plastics in the marine environment has increased dramatically. Worldwide there is a growing concern about the risks and possible adverse effects of (micro)plastics. This paper reflects on the sources and effects of marine litter and the effects of policies and other actions taken worldwide. Current knowledge offers a solid basis for effective action. Yet, so far the effects of policies and other initiatives are still largely insufficient. The search for appropriate responses could be based on possible interventions and profound understanding of the context specific factors for success. Moreover, the scope, timeframe and dynamics of all initiatives are distinctly different and orchestration at all levels, in close cooperation with one another is currently lacking.

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## Introduction

Since the 1950s the amount of plastics in the environment has increased dramatically [1••]. Jambeck *et al.* [2••] estimated that between 4.8 and 12.7 million tons of land-based plastic waste ends up in the ocean every year. Plastics not only negatively affect aquatic ecosystems [3], but also societies and their economies [4]. Economic activities such as shipping, fishing, aquaculture, tourism and recreation are directly affected by plastic pollution and the total negative impact on oceans has been estimated at least $8 bn per year [4]. Moreover, there is an increasing concern about the risks and possible adverse effects of (micro)plastics to organisms [5,6] and human health [1••,7].

Current knowledge on the main causes of marine litter and about possible solutions offers a solid basis for effective actions [8]. Yet, it has become clear that so far the effects of policies and other initiatives are still largely insufficient [1••,2••]. Moreover, global plastic production increases each year, it already exceeded 300 million tons in 2014 [9]. Considering the drivers for plastic use and the vital importance of plastics for modern life, for example due to its properties and the possibility of mass production, it is not expected that plastics production and use will be restricted anytime soon. If the current trend of a 5% production increase per year continues, an additional 33 billion tons of plastic will have piled up around the globe by 2050 [10]. High densities of litter are already found in very remote and uninhabited places like Henderson Island, where the density of litter was the highest reported anywhere in the world [11]. These figures stress the importance of preventing flows of plastics to the (marine) environment.

The solution to marine litter is likely to be found in a transition towards more sustainable ways of production and consumption that are also promoted via the Sustainable Development Goals (SDGs). The UN sustainable development agenda represents a plan of action involving 17 SDGs and includes targets to prevent and significantly reduce marine pollution of all kinds, including marine litter. Such a sustainability transition is a context-dependent, non-linear, evolutionary process that will include successes as well as failures [12,13]. It requires collective actions amongst a large diversity of actors across sectors and scales, and dealing with divergent perspectives and interests [14].

In this paper we set out to explore the particular governance and management challenges of marine litter. We reflect on the extensive literature on the sources and effects of marine litter, current knowledge on the effects of policies and other actions that are taken worldwide to mitigate and prevent pollution and the context-specific requirements for initiatives, policies and strategies. The aim of this paper is to identify the main challenges and to propose ideas that can help to orchestrate and accelerate the implementation of different solutions.

## Marine litter

Marine litter (also called marine debris) is waste created by humans that has been discharged into coastal or marine environments, resulting from activities on land or at sea [15]. The majority of marine litter consists of plastics [1]. Plastics are generally divided into macroplastics and the smaller microplastics; the plastic particles <5 mm in diameter including nanoplastics [1]. Common smaller macroplastic parts (<2.5 cm) can originate from direct and indirect sources such as lost bottle caps or plastic fragments; common macroplastics, smaller than 1 m, originating from rivers or maritime sources such as plastic bags, food and other packaging, fishing floats, buoys, balloons and macroplastics larger than 1 m from fishing activities or catastrophic events such as abandoned fishing nets and traps, rope, boat hulls and plastic films from agriculture [16••]. There are two types of microplastics; primary microplastics that have been made intentionally (such as pellets or microbeads) and secondary microplastics that are fragmented parts of larger objects [16••].

Sources and pathways of marine litter are diverse and exact quantities and routes are not fully known. There is, however, a lot of research that aims to determine the exact quantities and types of plastic litter and pathways in the environment [2••,11,17–20]. Most of the plastic in our oceans originates from land-based sources [1••,21]. A study by Jambeck *et al.* [2••] revealed that developing economies are the most polluting. The study also showed that 83% of the 4.8–12.7 million tons of land-based plastic waste that ends up in the ocean from the 192 coastal countries originates from 20 countries (China, Indonesia, the Philippines, Vietnam, Sri Lanka, Thailand, Egypt, Malaysia, Nigeria, Bangladesh, South Africa, India, Algeria, Turkey, Pakistan, Brazil, Burma, Morocco, North Korea and the United States). Total annual waste generation was mainly determined by population size, hence the large populations of the 'leading countries' on the list. The amount of plastic waste eventually ending up in the ocean was mainly determined by the percentage of mismanaged waste. A study by Lebreton *et al.* [17] estimated that between 1.15 and 2.41 million tons of plastic waste flows from rivers into the ocean annually, likewise the main drivers were population density, mismanaged plastic waste and production per country. The top 20 of polluting rivers were mostly located in Asia, and accounted for 67% of the global total (Yangtze, Xi, Huangpu, Dong, Zhuijang, Hanjiang in China; Brantas, Solo, Serayu and Progo in Indonesia; Pasig in the Philippines; Irrawaddy in Myanmar; Imo in Nigeria; Magdalena in Columbia; Tamsai in Taiwan; Kwa Ibio in Nigeria; the Ganges in India/Bangladesh; Cross in Nigeria/Cameroon; Amazon in Brazil/Peru/Columbia and Ecuador and the Mekong in Thailand/Cambodia/Laos/China/Myanmar and Vietnam).

## Global efforts to support marine litter actions

Currently, there are several global efforts aiming at action for reducing and preventing marine litter and for mitigating its impacts. These include worldwide initiatives, for example, by the Global Partnership on Marine Litter (GPML), the Honolulu Strategy [15] and the G7 countries [22]. GPML is a voluntary multi-stakeholder coordination mechanism which brings together policymakers, civil society actors, the scientific community and the private sector to discuss solutions and catalyze actions. The Honolulu Strategy [23] is a planning framework for the prevention and management of marine litter and an effort to reduce the ecological, human health, and economic impacts of marine litter globally. It has a set of three specific goals to reduce marine litter and linked to each goal is a cohesive set of strategies: Goal A: reduced amount and impact of land-based litter and solid waste introduced into the marine environment; Goal B: reduced amount and impact of sea-based sources of marine debris including solid waste, lost cargo, abandoned, lost or discarded fishing gears (ALDFG), and abandoned vessels introduced into the sea; and Goal C: reduced amount and impact of accumulated marine debris on shorelines, in benthic habitats, and in pelagic waters. At the 2015 G7 summit the protection of the Marine Environment was high on the agenda too and it was acknowledged that marine litter, in particular plastic litter, poses a global threat.

More and more countries are taking action against marine litter and during the 2016 United Nations Environment Assembly (UNEA-2) [24] countries unanimously adopted a stand-alone resolution on marine litter. The resolution acknowledged marine plastic and microplastic as a rapidly increasing, serious problem of global concern that urgently needs a global response. The resolution signals countries' continued willingness to put marine plastic pollution high on the environmental policy agenda. In order to keep it also high on national agendas, pollution will be the focus of the 2017 UN Environment Assembly in December.

Four of the SDGs have targets relevant to marine plastic pollution (Table 1). These targets deal with untreated wastewater, waste management in sustainable cities, management of waste throughout their life cycle — with focus on prevention, reduction, recycling and reuse — and sustainable management of oceans.

At the June 2017 United Nations Conference to Support the Implementation of Sustainable Development Goal 14 of the 2030 Agenda affirmed a strong commitment to conserve and use our oceans, seas and marine resources for sustainable development. To increase global action leadership and commitment by government at all levels is needed.

**Table 1**

**Sustainable Development Goals related to marine litter (based on [25,26•,27])**

| Sustainable development goal (SDG) | SDG target related to marine litter |
|---|---|
| *SDG 6 Clean water and sanitation*<br>• Ensure availability and sustainable management of water and sanitation for all. | *Target 6.3: focus on untreated wastewater*<br>By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally. |
| *SDG 11 Sustainable cities and communities*<br>• Make cities and human settlements inclusive, safe, resilient and sustainable. | *Target 11.6: focus on municipal and other waste management*<br>By 2030, reduce the adverse per capita environmental impact of cities, by paying special attention to air quality and municipal and other waste management. |
| *SDG 12 Responsible consumption and production*<br>• Ensure sustainable consumption and production patterns. | *Target 12.4: focus on environmentally sound management of chemicals and all wastes throughout their life cycle*<br>By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.<br>*Target 12.5: focus on waste generation reduction through prevention, reduction, recycling and reuse*<br>By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse. |
| *SDG 14 Life below water*<br>• Conserve and sustainably use the oceans, seas and marine resources for sustainable development. | *Target 14.1: focus on waste generation reduction*<br>By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.<br>*Target 14.2: focus on sustainable management*<br>By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans.<br>*14.c conservation and sustainable use of oceans*<br>Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources as recalled in paragraph 158 of The Future We Want. |

## Prevailing global marine litter solutions

We here use the Driver-Pressure-State-Impact-Response framework [28] to structure the insights from the literature on the main global marine litter problems (Table 2). DPSIR is a useful adaptive management tool to analyze environmental problems and to map potential responses [29•]. Moreover, it can be a tool to initiate solutions focusing on sustainable development, hence the SDGs [29•]. Both short-term and long-term solutions are included and links are made to the specific SDGs. A lot of different ways are used in the literature to structure marine litter problems. Table 2 structures the main global marine litter problems based on their source.

Studies have shown that in case waste management does not improve profoundly in the coming years, by 2025 the amount of plastic waste entering the ocean from land is predicted to increase by an order of magnitude [2••]. Many countries, therefore, focus on the improvement of waste management infrastructure at critical locations (Table 2). Jambeck *et al.* [2••] mentioned that waste management must be improved by 85% in the top 35% countries of mismanaged plastic waste to achieve a 75% reduction. However, improving waste management infrastructure would require substantial investments (and time), especially in low and middle income countries. The main focus in these countries is on improving solid waste collection and management. Indonesia, for example, has set ambitious targets at the 2017 World Ocean Summit to reduce plastic waste in 25 coastal cities and reduce marine litter by 70% by 2025 [30].

Land-based microplastics are of global concern too and sources are diverse. Primary microplastics such as microbeads used in personal care and cosmetic products (PCCPs) are a significant direct source to the environment, especially if there is no wastewater treatment in place [31]. Secondary microplastics have diverse sources like fragmented packaging or mechanical abrasion of tyres that wash into sewers or surface waters. Microplastics concentrations vary with proximity to sources and can in general be better managed in freshwater systems than in marine systems [21]. Input of microplastics to oceans via rivers can be decreased by wastewater treatment plants capable of capturing microplastics. These are quite common in developed countries but absent in many developing countries [1••,32].

Sources of sea-based macroplastics are dominated by the fisheries sectors (abandoned, lost or otherwise discarded

**Table 2**

**Main global marine litter problems structured according to the DPSIR framework; including some examples of common measures and main geographical focus areas (explanation of the SDGs is given in Table 1)**

| Drivers | Pressures | State | Impact | Responses | Main geographical areas |
|---|---|---|---|---|---|
| **Macroplastics emitted directly to the ocean from coastal zones** | | | | | |
| Use of plastic, in particular in coastal regions. | 4.8–12.7 million tons of land-based plastic waste ends up in the ocean each year [2••]. | Exact amount of plastics in ocean unknown; Few studies available [1••]; >100 million debris items in 12 Regional Seas [33]; possibly 51 trillion particles floating on the surface of the ocean [19]; South Pacific gyre average abundance and mass approximately 27 thousand particles per $km^2$ and 71 g $km^2$, respectively [38]. | Global environmental impact on aquatic ecosystems such as entanglement or starvation of marine species; spreading of diseases (vector); economic impacts on tourism through littered shores or blocked waterways [1••,4–7]. | **Short-term solutions:** improve waste management; source oriented (for example solid waste collection, good landfill management, recycling opportunities, plastic bag bans); mitigation and awareness raising; Beach clean ups around the world [20]; Large scale ocean clean ups [37,39]. SDG 11.6, SDG12.5, SDG 14. **Long-term solution:** move towards circular economy -reduce, reuse, recycle, redesign, recover — through awareness raising; behavioural change (consumers and producers); reduce single use plastic; phase out non-recoverable plastics; Alternative materials such as biodegradable plastics or textiles. SDG 12.4; SDG 12.5; SDG 14.2. | Global but short-term focus on Asia. Particularly low and middle income countries (top 5: China, Indonesia, Philippines, Vietnam, Sri Lanka); Clean up: beaches around the world; Ocean Clean ups: North and South Pacific gyres; 'hotspots' of plastics. |
| **Macroplastics emitted from rivers** | | | | | |
| Use of plastics, in particular in river basins. | 1.15–2.41 million tons of plastic waste flows from rivers as a result of mismanaged waste/population increase [18]. | Exact amount of plastics in ocean unknown; Few studies available [1••]; >100 million debris items in 12 Regional Seas [33]; possibly 51 trillion particles floating on the surface of the ocean [19]. | Global environmental impact on aquatic ecosystems such as entanglement or starvation of marine species; spreading of diseases (vector); economic impacts on tourism through littered shores or blocked waterways [1••,4–7]. | **Short-term solutions:** as above. **Long-term solutions:** as above; additional wastewater treatment aiming in developing countries [32]. SDG 6.3; SDG 14.2. | Global but short-term focus on Asia; 67% of the top 20 polluting rivers located in Asia [17]. |

**Table 2** (*Continued*)

| Drivers | Pressures | State | Impact | Responses | Main geographical areas |
|---|---|---|---|---|---|
| **Macroplastics from abandoned lost or otherwise discarded fishing gear** | | | | | |
| Fishing. | Current emission not well known; rough estimate 640 000 tons per year [1••]. | A very rough estimation of 10% of global marine litter by volume [34]. | Impacts on non-target species like entanglement through ghost fishing and habitat damage (for example coral reefs) [3,5,40,41] economic impacts through depletion of commercial fish and shellfish stocks. | **Short-term solutions:** legislation ALDFG (MARPOL V) now only aiming at large scale vessels (>400 GT) should also aim at smaller vessels. Work on implementation of port reception facilities. Fishing for litter/stimulate fishermen to bring ALDFG to shore and recycle/re-use. SDG 11.6, SDG 12.5; SDG 14c. **Long-term solutions:** target at smaller vessels; work on ALDFG circular economy principles like better design and use of materials [42,43] SDG 12.4 and SDG 12.5. | Worldwide. |
| **Primary microplastics** | | | | | |
| Use of primary microplastics; production pellets or microbeads used in PCCPs, or industrial abrasives both on land and at sea [16••]. | Current emission levels unknown. | Estimated 32 000–236 000 metric tons microplastics in oceans [16••,19]. | Possible direct ecotoxicological impacts, accumulation in food chains, economic damage because of food safety concerns. | **Short-term solutions:** prevention of microplastics entering the ocean; industrial spills, spills/accidental losses of cargo from ships; improve wastewater treatment facilities; bans like microbeads SDG 6.3; SDG 11.6, SDG 14. **Long-term solutions:** as above and new technologies and alternative materials SDG 12.5. | Worldwide. |
| **Secondary microplastics** | | | | | |
| Weathering and fragmentation of macroplastics; tear and wear of tyres; fragmented (single-use) packaging [16••]. | Current emission levels unknown. | Estimated 32 000–236 000 metric tons microplastics in oceans [16••,19]. | Possible direct ecotoxicological impacts, accumulation in food chains, economic damage because of food safety concerns. | **Short-term solutions:** prevention of macroplastics (see first 3 rows) and microplastics entering the ocean; improve wastewater treatment facilitiesSDG 6.3; SDG 11.6, SDG 14. **Long-term solutions:** as above and new technologies such as filters washing machines SDG 12.5. | Worldwide. |

fishing gear (ALDFG)) followed by aquaculture, shipping and offshore industry and ship-based tourism [33]. ALDFG are very context and region specific. A very rough estimation indicates that ALDFG comprises up to 10% of global marine litter by volume [34]. Microplastics at sea also originate from the shipping industry, mainly by routine cleaning of ship hulls using plastic abrasives that flow directly into the ocean [35].

Risk analysis for macroplastics was used to determine global hotspots, like for example in areas where risks for marine debris ingestion by sea turtles was highest [36]. Schuyler *et al.* [36] used models to predict the highest risk of debris ingestion to global sea turtle populations and found these to be off the east coast of the USA, Australia and South Africa; the east Indian Ocean and Southeast Asia. Sherman and van Sebille [37] determined optimal microplastics removal locations primarily located off the coast of China and in the Indonesian Archipelago.

## Context specific requirements for initiatives, policies and strategies

Global commitment and goals, such as the SDGs, provide a good basis for measures around the world if global agreements are translated to regional and national levels. There are large global differences in the causes of plastic pollution, both on land and at sea, and solutions will only be effective if they are context specific and if local conditions are taken into account [2••,44]. The design and implementation of effective, efficient and legitimate actions thus needs to be based on a thorough understanding of the local governance context [13].

The measures to deal with the marine litter problem can be supported by scientific research [19], including understanding of the sources, fate and effects [45,46] and customized to the local situation. Identifying risk hotspots for both macroplastics or microplastics is important [16••,37,47,48]. It is proposed that measures preferably aim at these hotspots [16••,37], and at most cost-effective locations. There is, however, a need for well-defined protection goals [49] that are currently absent at many levels. These might, for example, relate to biodiversity goals since plastics was found in 17% of IUCN Red list of threatened species out of 693 marine species [5]. Furthermore, various authors argue that removal of plastics in the ocean needs to be carried out in places where such efforts are ecologically most effective, which is in most cases closer to the shores [37], and not in the middle of the Pacific gyres where impacts on marine animals may be limited [50]. Risk assessment models can help to predict possible effects to marine life and guide the design of effective and resource-efficient management measures [36,37]. However, the actual negative effects or risks of microplastics and nanoplastics, and associated chemicals, are hard to predict and depend on local conditions [51–53].

There are also ample examples showing that market-based instruments and legislation, such as waste management policies, bans on certain products, or a plastic bag tax, can be very effective [44,54–57]. Strategies aiming at plastic bags, like taxes and charges, have proven to be successful in both developed and developing countries. Market-based instruments, such as bottle deposit refund schemes [58] and container deposit schemes were shown to be effective too [47]. Yet, there are also concerns about the effectiveness of certain policies because of a lack of monitoring and enforcement [59–61]. Furthermore it is often difficult to get legal frameworks in place due to political resistance and a lack of cooperation from market parties, while voluntary approaches that are easier to adopt might fail to offer an effective solution [59].

Long-term sustainable solutions are moving from a linear economy towards a more circular economy [62,63]. The circular economy approach involves waste reduction, more sustainable production and consumption patterns. Veiga *et al.* [64] suggested that the marine litter problem may stimulate sustainable economies and lifestyles. Plastic solid waste management strategies can, for example, involve recycling [65], reuse or upcycling (recycling to improve a materials value) [66], extended producer responsibility and redesigning products (for example to make them less hazardous) [65]. These strategies can also include the use of novel equipment and technologies to reduce emission such as filters for washing machines. Depending on the quality of the waste, there are different recycling options [67] and waste streams can be optimized by using a performance indicator (e.g. if the quality is insufficient energy recovery via incineration is still an option).

A move towards sustainable and resilient societies may need increased awareness within society of all stakeholders, for example producers, consumers and governments. Awareness raising can be change-oriented like the 'Beat the Microbead' campaign [68]. The campaign resulted in the announcement by manufacturers to stop using microbeads in their cosmetic products and the US passed a federal law to ban microbeads in rinse-off personal care products in 2018 [16••,69]. This can serve as a source of inspiration for other change-oriented actions, for example in the single-use plastics, both for consumers and for manufacturers having an extended producer responsibility. Legislation and measures to reduce the use of plastics, could also be a way of restricting the use of single-use plastics in all sectors. The Clean Seas global campaign on marine litter by United Nations Environment (UN Environment) also aims at worldwide elimination of microplastics in cosmetics and the excessive, wasteful usage of single-use plastic by the year

2022. However, bottom up initiatives, like the 'Beat the Microbead' campaign, are important to keep it high on local agendas.

In line with the notion that the involvement of many actors is required, most studies emphasize the importance of public awareness [1••,64,70]. It is here that a pivotal role is given to beach clean-ups, education programs, and outreach experiences [71–76]. Behaviour change and awareness raising can be increased through citizen science, in which volunteers collect data [47]. A review study on personal and social factors influencing pro-environmental concern and behaviour concluded that persons with accurate knowledge of the environment, its problems and potential solutions, are more likely to be concerned about the environment and act in a pro-environmental way [77•].

However, apart from environmental knowledge, skills to turn plans into action and in the right context are required too [78]. Education has been demonstrated to be important for school children, as it increased their understanding and stimulated them to come into action [79]. Higher education for sustainable development also reflects on the complexity of behaviour and decisions in a future-oriented and global perspective of responsibility [80]. Open education in the form of Massive Open Online Courses (MOOCs) has attracted many institutions and learners worldwide with its goal to make education available to a global and massive audience [81–84] (see the Box for the Massive Open Online Course on Marine Litter). Global problems are targeted on a local or regional level in a concrete problem context. A remaining challenge in this context is how these open courses can produce 'actionable knowledge', that is knowledge that can be translated into actions [85,86].

Initiatives exist to promote collaboration among marine litter actors and to establish solid networks dealing with marine litter problems. The Global Partnership on Marine Litter, the Marine litter network, and the Regional Seas Conventions and Action Plans (RSCAPs) are examples of networks addressing marine pollution. Social media are thereby effectively used as a tool to create and stimulate communication networks.

The MOOC on Marine Litter, as part of the Clean Seas Campaign [UN Environment 2017], calls on actors to work on change-oriented solutions; on governments that are urged to pass plastic reduction policies; on private sector enterprises to commit to improving plastic waste management and work on circular economy principles (re-design, re-use, recycle, recover plastics and phase out non-recoverable plastics) and on the general public to reduce their plastic footprint. Zhan *et al.* [87•] stressed the importance of providing sustainability related MOOCs or MOOC material in other languages than English, also important in the local context of dealing with marine litter.

**Box Massive open online course on marine litter**

The Open University of the Netherlands and United Nations Environment developed a Massive Open Online Course on Marine Litter, which was run for the first time in 2015-2016. The MOOC targeted a variety of sectors and stakeholders including governments and policymakers, private industry and businesses, nongovernmental and intergovernmental organizations, civil society and academia. The MOOC was developed in order to stimulate leadership and offer opportunities for actionable and change-oriented learning, related to marine litter, within the framework of the Global Partnership on Marine Litter. The MOOC, therefore, not only aimed at enhancing knowledge, but also at skills for tackling the complex issues surrounding marine litter. These are, for example, identification and reduction of land-based and sea-based sources of marine litter; the environmental, economic and social impacts of marine litter, modelling the transportation and risk assessments of marine litter and identification of efficient, practical and innovative solutions available to the diverse range of stakeholders involved with and impacted by this global problem. The initial version of the MOOC attracted participants with a high awareness and prior knowledge for the topic of marine litter. The knowledge of the course enabled participants to take concrete action against marine litter in their local and regional environment. Future activities are targeting participants with a lower awareness and knowledge level.

Through its educational design, the MOOC prepares participants for an active role in addressing marine litter by providing in-depth knowledge, useful tools and instruments and connects participants to marine litter networks around the globe. Results of the first MOOC on marine litter show that MOOCs can actually stimulate pro-environmental behaviour and reach a global audience. In the future, the MOOC will be adapted to better take into account regional and cultural differences and to enable participants to sustain their knowledge and transfer it into action.

## Conclusions: mobilizing environmental action

Marine litter pollution is a complex environmental problem, with numerous land-based and sea-based sources and few easy solutions [1••,15]. The scientific understanding of the problems and the range of effective solutions has significantly increased, although there are still many gaps to fill. Sources, pathways and effects of macroplastics and microplastics are still not fully known, there is a lot of discussion about which actions and solutions are most effective under which conditions, and many of those solutions get dashed in political realities. It has become clear that despite all policies and other initiatives, the problem will only increase if no further actions to prevent waste are taken. It is therefore, that various authors argue for a shift in focus from effect-oriented to source-oriented solutions. Many measures, initiatives, policies and strategies are aiming at action for reduction and prevention of marine litter. Short-term solutions, focussing on improved waste management in developing countries, can be important. Long-term solutions are aiming at large system changes like moving towards a circular economy and behavioural changes.

The literature shows that designing and implementing sustainable solutions is anything but easy.

Successful solutions to the marine litter problem require coordinated action amongst a wide range of public and private actors, across sectors, and from the local to the global level [16••]. The search for appropriate responses could be based on both an overview of possible interventions as well as a more profound understanding of the factors that help to explain why certain policies and legal institutions to prevent pollution are more successful in one context than in another [56]. Moreover, the scope, timeframe and dynamics of all these initiatives are distinctly different and orchestration at all levels in close cooperation with one another is currently lacking.

Successful actions aim at a diversity of goals, ranging from changing consumer behaviour, the introduction of new technologies, the design, implementation and enforcement of a multitude of plans, policies and laws, to full-scale revision of current practices of production, use and management of waste. This implies active involvement of consumers, producers, policy makers, managers, inhabitants, tourists, (fisheries) industries, companies, and many other actors. A move towards sustainable and resilient societies may need to raise awareness and involvement of all stakeholders in society. Knowledge, leadership and skills to deal with the problem can be stimulated at all levels to raise global awareness and increase action and interaction between all stakeholders. Searching for ways in which initiatives strengthening each other's impact can lead to crucial innovative solutions. The Global Partnership on Marine Litter, the Clean Seas Campaign, the Regional Seas Conventions and Action Plans (RSCAPs) or global education, like the Massive Open online Course on Marine litter, are ways to accelerate the already ongoing worldwide positive actions.

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Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest


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