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Stemming the Tide of Plastic Marine Litter: A Global Action Agenda

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Introduction

Marine litter is one of the most significant problems facing the world's oceans and seas, and the communities and economies that depend on them. Plastic marine litter presents a particularly significant environmental threat—as well as a considerable regulatory challenge. It has been estimated that 20 million tons of plastic marine litter enter the ocean each year.[1] Plastic marine litter forms a large portion of our waste stream, typically does not biodegrade in marine environments, and has especially deleterious impacts on ocean wildlife, coastal economies, fisheries, and even human health. Manufacturers increasingly are incorporating hardy plastic material into single-use items and other products that are a part of our daily lives. Global mismanagement of ubiquitous plastic materials has fueled the growing international marine litter problem.

For these reasons, drastically reducing the current rate of ocean plastics disposal and loss is a key step in stemming the tide of global marine litter. Over the last decade, researchers and international, governmental, and non-profit organizations have published dozens of reports on the marine litter problem and offered a range of recommendations.[2] There is general agreement about the need for robust, consistent funding for clean-up efforts; better infrastructure to encourage proper waste management; and, most importantly, reductions in the sources of marine litter—especially single-use plastics. Yet, no one has proposed an overarching action plan that would effectively address the plastic marine litter problem.

Like the waste itself, however, awareness of the plastic marine litter problem is on the rise. International volunteer events

What is Plastic Marine Litter?

Marine litter, also called marine debris or solid marine pollution, includes all human-generated solid articles and materials that are discarded, disposed of, or lost into the ocean and remain there.

Plastic marine litter includes all marine litter composed of one of a collection of artificial materials (commonly, petroleum-based compounds) that we broadly refer to as "plastic" (e.g., polystyrene, polyethylene, polyester). Plastic marine litter includes consumer items such as plastic bags, food packaging, cups, bottles, and balloons; industrial components; and items related to fisheries or aquaculture.

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such as International Coastal Clean-Up Day and images of the "Pacific Garbage Patch," a gyre larger than the size of Texas that is polluted with a diffuse soup of plastic objects and fragments, have captured the world's attention. The international community also is engaged in intently tracking the estimated five million metric tons of marine litter (including plastics) swept out to sea by the Japanese tsunami in 2011.[3] Significantly, last year's "Rio+20" United Nations Conference on Sustainable Development recognized marine litter as a major environmental issue that the world must address. The parties to the Rio+20 Conference "note[d] with concern that the health of oceans and marine biodiversity are negatively affected by . . . marine debris, especially plastic . . ." and called for action by 2025 to "achieve significant reductions in marine debris to prevent harm to coastal and marine environments."[4] How to achieve those reductions for the category of plastic marine litter is the subject of this policy brief.

We begin by summarizing the latest information on the sources and impacts of plastic marine litter. Next, we describe why existing international legal mechanisms are inadequate to address the problem. We then offer international, regional, national, and sub-national policy recommendations to address plastic marine litter, including suggestions of ways to improve existing international legal mechanisms. As a first priority, we call upon the global community to develop a new international agreement with a global reach commensurate with the scale of the plastic marine litter problem. Ultimately, we believe the world only may be able to reach the Rio+20 goal through an aggressive, new international regime that incorporates enforceable marine pollution standards as well as strong tracking, monitoring, reporting, and enforcement mechanisms. International law is not likely to solve the plastic marine litter problem independent of domestic efforts, however. Smaller-scale policies and programs should be scaled up rapidly as partial solutions to the problem. We conclude with our "Top Ten" list of recommended actions to implement by 2025 to begin to stem the global tide of plastic marine litter.

I. The Plastic Marine Litter Problem

In recent years, global concern about ocean health has keyed in on the growing problem of plastic marine litter. There is a lot we do not know about plastic marine litter; for instance, there is no hard data on exactly how much plastic is in the marine environment. It has been estimated that

Figure 1. Plastic litter and other trash on the coastline of Green Island, Kure Atoll, Hawaii (2006). *Image courtesy of Claire Fackler, CINMS, NOAA/NOAA Photo Library.*

Figure 2. (Left) Plastic litters the Hong Kong shoreline after Typhoon Vicente knocked six shipping containers packed with bags containing millions of plastic pellets into the ocean. *Image courtesy of Tracey Read and Gary Stokes, Oceanic Love*. (Right) Grounding of the container ship Rena, which carried some containers of plastic beads, off the coast of New Zealand (October 2011). *Image courtesy of New Zealand Defence Force.*

20 million tons of plastic marine litter enter the ocean each year.[5] We do know that, at some locations, the majority of all observed marine litter tends to be plastic items.[6] For instance, one beach litter monitoring pilot project found plastics to comprise an average of 75 percent of all beach litter on reference beaches in nine North-East Atlantic countries.[7] Temporal trends also remain unclear; however, since plastics production increases by almost 5 percent annually,[8] and because most plastics do not biodegrade in marine environments, it is likely that the concentration of plastics in the ocean has been increasing and will continue to increase over time.[9]

Furthermore, it is not clear what proportion of plastic marine litter originates from land-based versus ocean-based sources. Some estimates suggest that 60 to 80 percent of plastic marine litter derives from land-based sources such as waste sites, litter, untreated sewage and stormwater outfalls, poorly managed industrial and manufacturing sites, and tourist activities.[10] Land-based plastic litter commonly found in the marine environment includes everything from single-use packaging to industrial "nurdles" (pre-production pellets). Ocean-based sources such as ships, oil and gas platforms, and aquaculture facilities[11] account for plastic marine litter items such as fishing nets, floats, traps, pots, and lines; bleach bottles; and aquaculture components.[12] Ocean-based litter also includes lost cargo containers. Hundreds or perhaps thousands of shipping containers and their contents, including plastics, are lost at sea each year due to accidents, storms, or poor management practices.[13] Notably, ships are not required to report or clean up lost cargo unless the contents are hazardous.

Once plastic litter enters the marine environment, the natural motion of wind and ocean currents pushes the litter around, sometimes over long distances,[14] resulting in greater concentrations of plastic in certain areas. For instance, plastic litter tends to concentrate in the *gyres*, the five regions of the ocean where currents come together.[15] Alarmingly, plastic marine litter can be found in ocean waters worldwide,[16] as well as in seafloor sediments[17] and coastal sands.[18] Litter may be found throughout the ocean column both because plastics are manufactured at many different densities and because "biofouling," the growth of marine organisms on floating plastics, can cause the plastics to sink.

Left in the marine environment, chemical reactions combined with the motion of wind and currents gradually break larger plastic items down into smaller particles.[19] Most plastics never biodegrade in the ocean, but rather continue to break down into tiny particles (i.e., particles smaller than 1 mm) called *secondary microplastics*. Notably, *primary microplastics*—plastic particles that

Figure 3. Propelled by the natural motion of the water and wind, plastics are concentrated in the regions of the ocean where currents come together to form gyres. *Image courtesy of Claire Hermann.*

Using Fulmars to Track Plastic Marine Litter[35]

Researchers frequently use a seabird called the **fulmar** to study and track plastic marine litter. Up to 95 percent of analyzed fulmars contain plastic in their stomachs. Seabirds like fulmars commonly ingest plastic they confuse with prey, or consume prey that has itself ingested plastic. The plastic found in fulmar stomachs provides some insight into regional and temporal trends in plastics composition. For example, while the typical amount of plastic in fulmar stomachs has remained roughly the same since the 1980s, the composition of plastic types has shifted over time from mostly industrial plastics (e.g., plastic pellets) to mostly consumer plastics (e.g., bottle caps). Fulmars also demonstrate some of the biological processes that transform and redistribute plastics; fulmars break down ingested plastics in their stomachs and then excrete smaller plastics. Amazingly, it is estimated that fulmars annually reshape and redistribute 6 tons of plastic.

Given these characteristics, seabirds like fulmars show promise as an indicator to track the effectiveness of plastic marine litter policies. For instance, the OSPAR Commission, which implements the OSPAR Convention to Protect the Marine Environment of the North East Atlantic, uses Northern Fulmars to track regional efforts to reduce plastic marine litter. The Commission has set as a policy objective that no more than 10 percent of a certain category of fulmars should have more than 0.1 grams of plastic particles in their stomachs. Unfortunately, no area in the North-East Atlantic currently meets this objective.

Figure 4. Fulmar (2008). *Image courtesy of Lieutenant Elizabeth Crapo, NOAA Corps/ NOAA Photo Library.*

Figure 5. (Left) A Cusk eel hiding inside a plastic container off of Seal Beach, California. *Image courtesy of Jeffery Ernst, Algalita Marine Research Institute.* (Right) A crab entangled in a ghost fishing net in the coral reefs of the northwestern Hawaiian Islands (2005). *Image courtesy of Susie Holst/NOAA/Marine Photobank.*

are already tiny—also can enter the ocean. Common sources of primary microplastics include microplastic spills from industrial processing sites or ships,[20] facial scrubs and cosmetic products containing plastic microbeads,[21] industrial spraying and scrubbing of boat hulls,[22] and plastic-based clothing.[23] Microplastics are ubiquitous in marine and coastal environments, and are a growing cause of environmental concern.[24]

Plastic marine litter has wide-ranging adverse environmental, public health, and economic impacts. Marine litter's most visible environmental impact is harming and killing wildlife through entanglement and ingestion.[25] A 2012 study reported marine litter impacts on 663 species, and more than half of impacted species ingested or were entangled by plastic.[26] Entanglement can cause death by drowning or strangulation, inflict wounds, or result in other harm such a decreased ability to catch food or avoid predators.[27] Lost or abandoned fishing nets and lines adrift in the ocean can cover long distances and continue to entangle marine wildlife indiscriminately for years in a process often referred to as "ghost fishing."[28]

Organisms of all sizes, from small marine invertebrates to whales, have been observed to ingest plastics.[29] Ingestion can cause choking, starvation, and other harm,[30] such as reduced appetite, digestive tract blockages, and internal injuries.[31] Although the full range of consequences of plastic ingestion for wildlife is not yet fully understood, studies have shown that plastic ingestion negatively impacts overall organism health and reproductive rates.[32] Smaller plastics increase the potential threat to the marine environment because a wide range of organisms can ingest them in huge quantities.[33] As an illustration, a recent study estimated that a single population of fish in the North Pacific Subtropical Gyre consumed 12,000 to 24,000 tons of plastic.[34]

Plastic marine litter also could have harmful chemical impacts on wildlife, ecosystems, and human health. We know that plastics in the marine environment can absorb many contaminants already present in seawater, including agricultural, industrial, and pest control chemicals such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), and aqueous metals.[36] These contaminants have been linked to disease, reproductive abnormalities, and other health impacts in wildlife as well as humans.[37] Plastics can contain up to 1 million times the concentration of PCBs as their surrounding waters, which potentially increases the exposure of marine wildlife to these chemicals.[38]

Chemicals added to plastics as part of

Figure 6. The digestive system contents, including plastic material, of a sea turtle in Green Fingal Beach, Australia (2007). *Image courtesy of Lance Morgan, Australian Seabird Rescue/Marine Photobank.*

the production process pose an additional concern.[39] Additives such as bisphenol A (BPA), plasticizers (phthalates), and flame retardant chemicals (polybrominated diphenyl ethers, or PBDEs) are linked to endocrine disruption in wildlife and humans.[40] These additives can dissociate from plastics in the environment and contaminate seawater, or contaminate organisms that ingest plastic litter.[41] Plastic ingestion by smaller organisms leads to a greater potential for bioaccumulation of contaminants, potentially impacting the entire food chain.[42] While further research is needed to determine the proportion of organismal chemical loads that stems from plastics as well as what levels of these chemicals pose a threat to humans, it is clear that an increasing amount of plastic marine litter increases potential risks to humans and wildlife.[43]

Plastic marine litter also degrades marine habitats by introducing foreign substrates and exotic organisms. For example, abandoned nets can strand onto sensitive coral reef habitats,[44] and hard-surfaced shipping containers can land on the soft-bottom seafloor and disrupt soft-bottom populations.[45] Plastic marine litter is even beginning to form its own habitat, the "Plastisphere," which supports communities of organisms that differ from those in the surrounding ocean environment.[46] Plastics also are a potential vector for invasive species or other harmful species such as spores of harmful algal blooms.[47] Furthermore, plastic marine litter is responsible for ocean collisions that have resulted in human injuries and deaths.[48]

For all of these reasons and more, plastic marine litter has significant economic impacts. Marine litter imposes costs on industries, governments, and individuals through cleanup activities,[49] tourism losses, damage to commercial and recreational vessels,[50] and lost fishing revenue.[51] For example, a recent report from the Asia Pacific Economic Cooperation found that its member economies lost more than $1 billion per year to marine litter impacts such as clean-up and damage to vessels.[52] A recent study estimates that communities in Oregon, California, and Washington are spending 13 dollars per resident per year to combat and clean up trash, which translates to an estimated annual combined expenditure of $520 million.[53] Smaller plastics and microplastics can complicate the efficacy and increase the cost of cleanup efforts because they become thoroughly intermingled with beach sands and cannot be removed effectively by traditional beach grooming techniques such as raking or sieving.

Plastic litter also is partially responsible for substantial lost tourism revenue because

tourists pay fewer visits to beaches heavily polluted by marine litter. Studies have estimated that tourism on the Skagerrak coast of Bohuslan in Sweden decreases by 1 to 5 percent as a result of beach litter, resulting in a calculated annual loss of approximately 15 million British Pounds ($23.4 million dollars).[54] Additionally, communities incur costs due to loss of ecosystem services such as healthy fisheries and the aesthetic appeal of clean beaches. Further research into quantifying the economic benefits of healthy coastal and ocean ecosystems would aid in the creation of cost-benefit analyses that accurately reflect the cost of environmental degradation associated with plastic marine litter.

II. The Limits of Existing International Law in Addressing Plastic Marine Litter

The problem of plastic marine litter has obvious international dimensions. Plastic litter often affects the marine environment of the high seas outside the jurisdiction of any one nation or group of nations. Because wind and ocean currents can transport plastic marine litter over long distances, areas most plagued by litter often have very little control over the production or disposal of that litter. Sources of plastic litter are spread across the globe, and, absent a coordinated international response, efforts to restrict plastic production or disposal in one area may be undermined by "leakage" of those sources to an unregulated area.

We surveyed multilateral environmental instruments and institutions and assessed their sufficiency to address the problem of plastic marine litter. Several international agreements designed to address marine pollution are potentially relevant to reducing plastic marine litter, including: the United Nations Convention on the Law of the Sea (UNCLOS), the International Convention for the Prevention of Pollution From Ships (MARPOL), and the Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter, also known as the London Dumping Convention. Some of the most promising regionally-focused agreements and directives include: the European Marine Strategy Framework Directive, Barcelona Convention, Cartagena Convention, Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR), and Helsinki Convention.

Though each of the international instruments

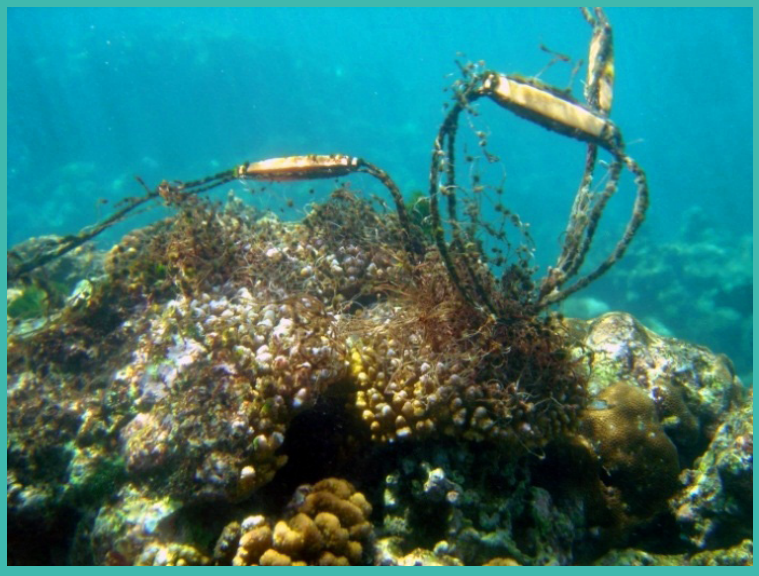

Figure 7. Ghost fishing gear stranded on a coral reef, Mariana Islands, Guam. *Image courtesy of David Burdick/NOAA Photo Library.*

mentioned above is potentially helpful, collectively, their shortcomings make them unlikely to lead to significant reductions of plastic marine litter. Overall, as we discuss in further detail below, their insufficient scope with respect to the main sources of plastic pollution, lack of enforceable standards, and insufficient penalties mean that no existing agreement comprehensively addresses the problem of plastic marine litter.

A. Existing International Agreements Have Limited Jurisdiction over the Main Sources of Plastic Pollution

Most troublingly, existing international agreements largely neglect land-based sources of plastics, which are estimated to be responsible for the majority of plastic litter in oceans.[69] The London Dumping Convention, for example, regulates only land-based waste loaded onto ships for

Table 1 | Selected International Instruments Relevant to Plastic Marine Litter

Agreement	Scope of Regulation	Enforcement & Dispute Resolution
International Convention for the Prevention of Pollution from Ships (MARPOL)[55]	Pollution and dumping from ships due to operational losses or accidents.	Flag state responsible for imposing fees and fines.
MARPOL Annex V[56]	Plastics disposed at sea; port reception facilities.	
UN Convention on the Law of the Sea (UNCLOS)[57]	Prevention of pollution from ships;[58] land-based sources of pollution; dumping and pollution transfer from one nation to another.	Members can settle disputes by any peaceful means chosen by them; if no settlement is reached, compulsory procedures available are (a) the International Tribunal for the Law of the Sea; (b) the International Court of Justice; or (c) arbitral tribunals.[59]
London Dumping Convention[60]	Land-based waste on ships for deliberate at-sea disposal.	Each member regulates discharges of waste on its own ships.
Barcelona Convention[61]	Land- and ocean-based waste from dumping, runoff, and discharges (including plastics) in the Mediterranean Sea region.	Negotiated settlement preferred; if no agreement is reached, an arbitral tribunal of three members elected by the parties or appointed by the UN Secretary-General will be used.
Cartagena Convention[62]	Pollution from ships; dumping at sea; land-based sources of pollution in the Wider Caribbean Region.	United Nations, as secretariat, can initiate limitations and deadlines; monitor waste management infrastructure.
European Marine Strategy Framework Directive[63]	All litter in European Union seas based on where it is found (e.g., washed ashore, in water column, ingested by marine animals) and type (e.g., microplastics).	Members must implement cost-effective programs in compliance with other sea treaties by 2016 to achieve good environmental status by 2020.
Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA)[64]	Land-based pollution from rivers, estuaries, and storm drains.	Non-binding framework provides guidance only.
Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR)[65]	European ship discharges; lost and discarded fisheries materials from vessels; land-based wastes from coastal or riverine disposal; recreational littering.	Negotiated settlement preferred; if no agreement is reached, an arbitral tribunal of three members elected by the parties or appointed by the UN Secretary-General will be used.
Helsinki Convention[66]	Marine pollution from all sources (including point-source or diffuse inputs from all land-based sources; pollution from tunnels or pipelines deliberately discharged into waterways).	Members must establish legislation for prevention and abatement of marine pollution; disputes should be submitted to an arbitration tribunal or the International Court of Justice.

Soft Law versus Hard Law: Understanding International Agreements and Programs[67]

Generally speaking, international instruments addressing marine litter can be divided into two categories: *soft law* and *hard law*. Soft law describes non-binding arrangements between parties (e.g., the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities). Soft law agreements include regional strategic **action plans**, **declarations**, and **resolutions** adopted by conferences, intergovernmental organizations, and international institutions. In contrast, hard law describes legally-binding contracts, often called **conventions**, with compulsory requirements or legal operations (e.g., UNCLOS).

Hard law agreements generally apply to a specific land area and jurisdictional area of the marine environment, as determined by parties. Hard law agreements often refer to a **protocol** that provides detailed information on legal standards the parties must meet. Protocols may address topics such as emergency plans, integrated coastal zone management, and regulation of land-based activities. Because protocols are legally-binding, they may require many years of negotiation to alter. Where marine litter falls under an existing protocol, the existing protocol can serve as a legally-binding foundation for the development of new action plans to address issues such as strategic monitoring and assessment of marine litter. Existing protocols also can support multiple **annexes** that provide additional detail about factors such as permitting, criteria to establish and address priority pollutants, and how to apply the protocol to a specific pollution source.

Unfortunately, many hard law agreements and protocols are neither implemented nor enforced. Additionally, although annexes to protocols can be legally-binding, parties to a convention often are allowed to pick and choose which annexes they want to sign.

purposes of at-sea disposal.[70] Those instruments that do speak to land-based sources are largely non-binding or limited in scope.[71] For instance, UNCLOS acknowledges the existence of land-based sources but simply requests that countries address the problem through domestic means.[72]

Furthermore, the various exemptions and opt-out provisions in existing international treaties perpetuate the problem of careless handling of plastics at sea and further limit the treaties' effectiveness. No agreement covers all of the main sources of plastic marine litter, and many agreements make express exemptions for major sources.[73] For instance, UNCLOS does not penalize ships for the "incidental" loss of otherwise-prohibited waste.[74] The London Dumping Convention does not regulate ship-generated waste and expressly permits disposal "incidental to or derived from the normal operation of vessels."[75] Annex V of MARPOL, which broadly prohibits the "discharge into the sea of all plastics,"[76] nonetheless exempts accidental loss or disposal of plastic resulting from damage to the ship or its equipment.[77] The U.S. Coast Guard's interim rule implementing Annex V also exempts warships, naval auxiliary, and other state-operated ships from Annex V's requirements, leaving navy ships and crew members free to discharge waste without restriction.[78] Moreover, several parties to MARPOL have not yet ratified Annex V.

In addition, even where an existing international treaty includes a clear standard, jurisdictional limitations may inhibit enforcement. Generally, when a ship flying a foreign flag violates an existing international treaty, only the foreign-flag state has jurisdiction to investigate the violation and impose penalties.[79] Sometimes, treaties authorize coastal states to penalize foreign-registered or -flagged vessels traveling in the state's territorial waters or exclusive economic zone (EEZ), which encompasses waters within 200 nautical miles of the coast—but even those powers are limited. Under MARPOL, for example, coastal states responding to alleged violations in their territorial waters or EEZ have few

What is the Regional Seas Programme?[68]

The UN Environment Programme (UNEP) established its **Regional Seas Programme** in 1974 to foster the development of environmental management plans for water bodies shared by two or more countries. Today, more than 143 countries participate in one of 18 regional seas and partner programmes covering: the **Antarctic**, **Arctic**, **Baltic Sea**, **Black Sea**, **Caspian Sea**, **Eastern Africa**, **East Asian Seas**, **Mediterranean**, **North-East Atlantic**, **North-East Pacific**, **North-West Pacific**, **Pacific**, **Red Sea & Gulf of Aden**, **ROPME Sea Area**, **South Asian Seas**, **South-East Pacific**, **Western Africa**, and **Wider Caribbean**.

The majority of the regional programmes are implemented by member states through action plans, which set forth the operative legal framework for the programme and a comprehensive environmental management strategy. Fourteen of the regional programmes have adopted legally-binding conventions detailing actions member states must take to implement those action plans (e.g., the Barcelona Convention and Cartagena Convention), and most of these conventions are supplemented by protocols addressing specific marine degradation concerns. Action plans and conventions are tailored to the particular environmental characteristics and restoration needs of the region.

In comparison to broader international agreements, the regional programmes tend to address plastic pollution issues with less ambiguity by taking into account the ecological and economic climate of the region at issue. However, the potential of the Regional Seas Programme to stem the tide of plastic marine litter is limited. Currently, some regions of the world's oceans are not covered by a regional programme (e.g., the South-East Atlantic). Also, as described above, some regional seas programmes have created more meaningful, enforceable standards than others. Even where a legally-binding convention exists, it is not always clear how an action plan relates to the convention or its protocol. Furthermore, the terms of regional conventions must be incorporated into a party's domestic law in order for the party to enforce the agreement against violators. To date, no regional seas programme has been used in any significant way to enforce prohibitions on marine debris. And no regional seas programme currently provides for sanctions against violating parties. (Nonetheless, some countries are starting to publicize violations to gain public support for marine litter programs.)

avenues of recourse other than demanding information from the suspect vessel.[80] If the suspect vessel does not supply the requested information, the coastal state may physically inspect and prosecute a vessel only if it anticipates an imminent threat to the state's coastline, which is a very high burden.[81] Regional treaties contain better enforcement mechanisms, but they typically apply only to the EEZ.[82] And while UNCLOS extends to the high seas and external waters, its enforceability provisions apply only to willful dumping of waste at sea.[83]

B. Existing International Agreements Lack Enforceable Standards

Another common problem with existing agreements is their lack of enforceable standards.[84] UNCLOS, for example, requires only that nations "shall endeavor" to use the "best practical means" to reduce marine pollution "in accordance with their capabilities."[85] Similarly, the Helsinki Convention asks contracting parties to take "all appropriate" measures to prevent and eliminate pollution.[86] OSPAR and the Cartagena Convention go further, instructing parties to take "all possible measures" to prevent and control pollution—a much stronger mandate, but one that obviously

Figure 8. Plastic litter and other trash in Isla Taboga, Panama (2010). *Image courtesy of J.M. van Coutren/Marine Photobank.*

is still difficult to define and enforce.[87] Indeed, it is hard to know what the phrases "best practical means," "all appropriate measures," or even "all possible measures" require of countries with differing legal systems, environmental circumstances, and capacities.

C. Existing International Agreements Have Insufficient Enforcement Mechanisms

Penalties imposed under existing international marine pollution treaties are often insufficient to deter unlawful behavior. MARPOL, for example, does not require the imposition of specific penalties for violations.[88] Instead, the agreement instructs each party to establish its own penalty framework through domestic enabling legislation.[89] Where individual countries have constructed MARPOL penalty schemes, the penalties are insufficient to deter violators. The United States has one of the strongest and most comprehensive domestic implementing laws under MARPOL: The Act to Prevent Pollution from Ships.[90] Yet, according to the U.S. Office of Accounting, as of 1995, less than 10 percent of cases brought under MARPOL Annex V had resulted in penalties against the violating party.[91] Most often, the U.S. Coast Guard chose to settle MARPOL violations with a warning, dismissal, or referral of the case to the ship's flag state.[92] Those parties that were penalized were fined an average of $6,200 per case, an amount that is far too low to serve as an effective deterrent.[93]

The difficulty of identifying ocean-based sources of illegal disposal further complicates enforcement.[94] To enforce obligations under UNCLOS, for example, a state must witness a violator in the overt act of illegally disposing waste or must acquire sufficient evidence to warrant investigation of the suspect vessel.[95] However, without tracking systems, it is extremely difficult to link waste disposal to a particular ship.[96] While some agreements require vessel recordkeeping systems to assist in tracking illegal disposals, most do not.[97] The tracking systems that do exist are not comprehensive. Annex V of MARPOL, for instance, requires vessels that are 400 tons or more, or certified to carry 15 or more passengers, to maintain a "Garbage Record Book,"[98] but it is challenging to verify whether ships are truthful in their assertions that they previously disposed of their waste at other incineration or port facility sites.[99]

III. Recommendations

For the reasons described above and more, existing international legal mechanisms are inadequate to address the plastic marine litter crisis fully. New international legal mechanisms in tandem with regional, national, and sub-national programs are required to realize significant reductions in plastic marine litter. We have examined current and historical efforts to address plastic marine litter, including both domestic and international programs, in order to draw lessons about which policy approaches are most likely to be successful.

As a first priority, given that the scope of existing international law fails to match the scale and severity of the plastic marine litter problem, we urge the global community to develop a new multilateral agreement on the scale and scope of the Montreal Protocol on Substances that Deplete the Ozone Layer ("Montreal Protocol"). This new agreement should incorporate enforceable marine litter standards as well as strong tracking, monitoring, reporting, and enforcement mechanisms, including adequate penalties and the establishment of jurisdiction for party dispute resolution at an international tribunal.

Acknowledging the long and uncertain path to a new agreement, we also recommend policy actions to extend the reach of existing international law and improve enforcement of existing obligations. International law can be strengthened in important respects to better support individual states with the political will to tackle this problem aggressively; however, in our view, international law is not likely to solve the plastic marine litter problem independent of domestic actions. Smaller-scale policies and programs should be scaled up rapidly at the regional, national, and local levels as partial solutions to the plastic marine

litter problem. We list some of the most promising of these policies and programs below.

A. Develop a New International Agreement Targeted to the Plastic Marine Litter Problem

Ultimately, the world may only be able to reach the Rio+20 goal of "achiev[ing] significant reductions in marine debris to prevent harm to coastal and marine environments" through an aggressive, new international regime on the scale of and with the efficacy of the Montreal Protocol. The new agreement should be based in the recognition that ill-managed plastic litter is harmful to people, economies, and the environment. Additionally, the new agreement should address all of the main sources of plastic pollution, and strictly regulate disposal of plastic litter from both ocean- and land-based sources, perhaps drawing from the land-based pollution standards of the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities.

The new agreement should incorporate strong tracking, monitoring, reporting, and enforcement mechanisms, including adequate penalties and establishment of party dispute resolution before an international tribunal. Taking cues from the success of the Montreal Protocol, and while recognizing the differences between this challenge and the one presented by ozone depletion, the new agreement should ban altogether the most common or damaging types of plastic marine litter (e.g., microbeads and fish-egg-sized nurdles), and support the development of and transition to product substitutes. For example, the new agreement could call for a phase-out of all plastics that are not recycled at a rate of 75 percent or higher by a certain date.

The process of developing a new agreement and cultivating the political will to adopt it likely would take years or decades. But because a new agreement will become increasingly necessary as the problem of plastic marine litter worsens, we believe that the world community must begin now to lay a framework for agreement. For countries with the capacity and political will to initiate the process toward a new agreement, immediate steps could include:

- Convening an international body of scientific experts to publish periodic assessments of current knowledge about the problem.
- Ramping up international public education efforts.
- Convening international leadership through the G8, G20, or the United Nations to begin developing a legal framework for a new agreement.
- Funding a data collection network to gather better information about the sources and effects of plastic marine litter, including economic, human health, and wildlife impacts and the efficacy of abatement programs. (Given that the global scientific community already knows enough about the plastic marine

Figure 9. Abandoned ghost fishing nets are loaded onto the deck of the vessel CASITAS in the northwest Hawaiian Islands. *Image courtesy of Dr. Dwayne Meadows, NOAA/NMFS/OPR/NOAA Photo Library.*

Could a Transboundary Adjudication Help Address the Plastic Marine Litter Crisis?

A state looking to take progressive action on the international stage to bring attention to the plastic marine litter crisis could seek redress for litter-related damages in **the International Court of Justice**, which increasingly is open to resolving transboundary environmental disputes.[100] In general, the International Court of Justice would be more likely to hear a dispute where a regional seas programme addresses sources of plastic marine litter and grants the Court jurisdiction over resolution of regional disputes.[101]

To use a real-world example, Japan potentially could seek redress for the ecological and economic damage to areas on its west coast caused by plastic litter originating in the Republic of Korea. Korean plastic litter is known to impact Japanese shores based on the direction of the winds and currents between the two countries. Every winter, 20-liter plastic containers drift onto the Japanese coast, many with Korean lettering.[102] Although this example potentially constitutes a case that Japan could take to the International Court of Justice, the two countries thus far have relied on bilateral compacts and diplomacy to address the issue. Japan and Korea are member states of the Northwest Pacific Action Plan (NOWPAP), a regional seas programme. One of the NOWPAP priorities is to prepare and implement a marine litter action plan.[103]

litter problem to take immediate action, however, additional data collection should not be seen as a prerequisite for a proactive policy response).

Ultimately, we hope that the community of nations, with support from non-governmental advocates, businesses, regional organizations, and local governments, and with better information about the plastic marine litter problem, will lead the way in negotiating a new agreement.

B. Amend Existing International Law to Narrow Exceptions and Improve Enforcement

Acknowledging the long and uncertain path to a new agreement, we recommend in the near term that treaty parties amend existing international legal obligations in useful, if incremental, ways. Small modifications could help eliminate some of the gaps in existing laws that have become apparent through the last decade of monitoring. Potential actions include the following:

- The parties to MARPOL should amend the current vessel size and tonnage limitations in Annex V for requirements respecting placards, garbage management plans, and garbage record-keeping, so that fewer vessels are exempted.
- The parties to MARPOL should develop stronger qualitative and quantitative standards for port reception facilities, so that ships are more reliably and easily able to discharge their waste at ports worldwide.
- The parties to MARPOL should clarify the circumstances in which loss of fishing gear is prohibited by defining in Annex V when an “accidental loss” will be deemed to have occurred despite “all reasonable precautions.”
- Regional fisheries management organizations (RFMOs) should adopt management standards to minimize the impacts of gear loss. Standards should address reducing gear; minimizing gear loss; minimizing the impacts of lost gear; and improving gear marking, tracking, and recovery. Certification and tracking programs for fishing and aquaculture operations should require logs to track lost fishing gear; require traceable tags on nets; and encourage the use of more sustainable materials in aquaculture gear.
- RFMOs should move toward the replacement of plastic and synthetic gear with biodegradable nets and traps to minimize ghost fishing and entanglement.

Figure 10. A sample of litter from the garbage patch in the South Pacific subtropical gyre (2011). *Image courtesy of Algalita Marine Research Institute.*

- RFMOs should develop and incentivize gear-recovery programs that encourage fishing-for-gear programs.

In addition, we have identified several instances where current enforcement mechanisms and penalty structures could be improved. In general, all international agreements with enforceable standards relevant to plastic marine litter should require more thorough data collection through mechanisms such as vessel-tracking databases, port incineration logs, and waste disposal logs. Collected data should be made widely available online to the general public as well as treaty parties. Improved data collection and publication not only could improve enforcement of treaty obligations but also could enhance the ability of states and advocates to pressure routine violators through public campaigns, political dialogue, consumer boycotts, transboundary lawsuits, and other means. Furthermore, we recommend imposing stiffer penalty schedules under MARPOL and all other agreements with enforceable standards.

C. Strengthen New and Existing Regional Seas Programmes with Substantive Requirements and New Research Programs

With the recognition that the UN Environment Programme (UNEP) is currently focusing on strengthening regional efforts rather than creating a new global agreement, we recommend that existing and new regional seas programmes could be strengthened in the following ways:

- Agreements should cover inland activities throughout the entire watershed of the protected waterbody, not just specific areas such as coastlines or territorial seas.
- Marine litter should be included explicitly.
- The scope of application should include activities that generate plastic marine litter (e.g., river discharge, outfalls, and watercourses) as well as its sources.
- Agreements should, to the extent possible, contain narrowly drafted language with timelines, enforcement, third-party assessment, and a funding mechanism.
- Parties should outline clear procedures to assist countries with domesticating

the international legal framework, thereby increasing countries' abilities to enforce the agreement. Alternatively, a regional third-party organization should be established and funded to ensure compliance.

We also note that improved information about plastic marine litter could help galvanize support for stronger policies and help policymakers worldwide focus their efforts. For example, improved information might empower developing countries to begin requiring importers of goods packaged in plastic to fund a program for properly handling that waste at the end of its life. Requiring importers to contribute to end-of-life reuse or recycling programs as a condition of import would both provide a sorely needed funding source for clean-up programs and incentivize importers to minimize plastic imports. We recommend that a research institution or non-governmental organization assess each of the regional seas programmes to determine where strengthened language could improve enforcement of substantive marine-litter standards. Additionally, such entities should secure funding through UNEP or another international body to develop and disseminate better information on plastic marine litter's impacts to human health, the economy, and the marine environment; better information on the origin and point-of-sale of plastic marine litter around the world; and better guidance for states and other jurisdictions seeking to strengthen domestic approaches to the problem.

D. Create an "Ocean Friendly" Certification Program

The primary focus of efforts to reduce plastic marine litter should be decreasing the fraction of the estimated 265 million tons of plastic generated annually that ends up in the marine environment.[104] One way to reduce both the generation of plastic and its improper disposal is to create strong, consumer-driven incentives for corporations to align with plastic reduction goals. Companies already are beginning to react to an increased consumer interest in sustainability through participation in programs such as the Forest Sustainability

"Ocean Friendly" Certification Requirements Could Include the Following Common-Sense Standards:

- Plastic products should be designed to minimize waste by ensuring that no loose plastic pieces can escape into the environment (e.g., beverage bottles should include a "lid leash" attaching lids to bottles, and juice boxes should eliminate separate straws).
- New products should incorporate some minimum high percentage of recycled plastics.
- The materials used to make disposable plastic products, particularly single-use products, should be standardized to encourage the use of materials that are easily recycled and have large markets (e.g., polyethylene terephthalate and high-density polyethylene, which have recycling codes 1 and 2, respectively).
- Products and packaging should be labeled to allow for tracking, showing where products were both manufactured and sold. This critical information would allow policymakers and advocates to target education, publicity, or regulatory enforcement funds toward the highest volume contributors to plastic marine litter.
- Because many varieties of biodegradable and oxy-degradable plastics do not degrade as easily in marine waters as they do in industrial composting or landfill conditions,[105] plastics should only be labeled as biodegradable or compostable if they degrade completely and without adverse environmental impacts under normal environmental conditions in a short timeframe.

Figure 11. Ghost fishing nets washed up on a beach in Hawaii. *Image courtesy of Chris Pincetich/Marine Photobank.*

Council, which promotes sustainable wood harvesting, and the Marine Stewardship Council, which promotes sustainable fishing practices. Companies also are increasingly incorporating recycled materials into their products, then touting those products as environmentally friendly through labeling. Additionally, some companies and restaurants are beginning to offer biodegradable or compostable packaging and take-out containers. Incentivizing and standardizing the production of more sustainable products and packaging would aid and grow these nascent corporate efforts, and would help an increasingly educated consumer population to make ocean-friendly choices.

We propose the creation of a corporate certification program aimed at reducing the amount of land-based plastic litter in our oceans. The program should be open to all plastic products commonly found in the marine environment but should impose tough standards for labeling conforming products as "Ocean Friendly." To achieve certification, companies should satisfy requirements related to product design, manufacture, composition, labeling, and life-cycle handling.

Inevitably, there will be some hurdles to overcome in developing the "Ocean Friendly" certification program. For example, there is, as of yet, no complete standard for the degradation of plastic in a marine environment.[106] Further, a standard definition for bio-based plastic does not yet exist, nor are any of the currently available bio-based plastic alternatives fully sustainable.[107] For these reasons, consumers must be correctly informed about the environmental impact of these alternative plastics as we try to find suitable replacements for the varied uses of plastics in our daily lives. Despite the current lack of a perfect replacement material, and even though no existing standards or management tools are sufficient to address the plastic marine litter problem effectively, many existing programs incorporate valuable elements that should be included and strengthened in an "Ocean Friendly" certification program. For instance, the International Organization for Standardization (ISO) recently released a suite of international standards related to product packaging, including standards and measurement information for source reduction, reuse, recycling,

energy recovery, chemical recovery, and composting. However, the ISO standards do not define success or failure. The certification program we propose should incorporate and expand upon these ISO guidelines and other relevant standards to include assessment mechanisms to gauge compliance and programmatic success, as well as indicators, metrics, third-party monitoring programs, and enforcement mechanisms.

Another promising model for the certification program is the Sustainable Packaging Coalition's Comparative Packaging Assessment (COMPASS), an internet-based design software program that combines life-cycle analysis and regional solid waste modeling to address the most likely end-of-life scenarios in a given region.[108] Incorporation of life-cycle analysis into product design allows product developers to evaluate environmental costs as well as economic factors. Our proposed certification program could draw upon such models to help companies identify the least expensive supply chain changes required to reduce marine litter substantially and quickly.

The "Ocean Friendly" certification program also could draw upon some of the voluntary corporate sustainability frameworks developed by non-profit and corporate organizations. For instance, the Global Reporting Initiative, a non-profit organization, has developed a sustainability-reporting framework with a robust list of performance indicators that could be modified to certify an ocean-safe product.[109] The Consumer Goods Forum, an industry network, has published a "global language for packaging and sustainability" that includes packaging- and industry-specific metrics and goals.[110] Another useful tool is the Plastics Scorecard, which rates a plastic's environmental impact using a life-cycle analysis approach.[111] Combining metrics from these voluntary frameworks and others could contribute to the creation of a robust, easily measurable program to certify products as ocean-friendly.

E. Improve Plastics Management Through Extended Producer Responsibility Programs and Requiring Redemption Fees upon the Return of Plastic Beverage Containers

Extended Producer Responsibility (EPR) programs can play an important role in preventing land-based plastic pollution from entering the marine environment. EPR programs hold manufacturers responsible for the handling of their products and product packaging through the end of a product's life. EPR programs also incorporate fee schemes to ensure that manufacturers pay for waste management

Figure 12. Deep-sea litter, including plastic beverage bottles, 20 km off the Mediterranean coast at a depth of 992 m. *Image courtesy of Francois Galgani/Ifremer.*

Principles for Effectively Harnessing EPR to Address Land-Based Sources of Plastic Marine Litter[118]

1) Extend producer responsibility to cover all primary sources of disposal, including street trash pickup, direct disposal by consumers, and disposal at stores.
2) Include measurable targets for "successful capture of material"—not just target recycling rates.
3) Impose a variable materials fee on top of poundage recycling fees to ensure that disposing of more environmentally harmful materials costs more. This materials fee should be steeply tiered to incentivize use of sustainable materials.
4) Separate recycling rates into subcategories (e.g., plastic, cardboard, etc.) so that high recovery rates for materials like cardboard do not mask low recovery rates for products that are highly impactful to the marine environment.
5) Develop product design and packaging criteria to discourage the use of virgin materials.
6) Include requirements for local reuse and recycling of collected products. Fund any relevant infrastructure through the EPR program.

at the end of their supply chain, and to capture additional waste for recycling and reuse. In general, a manufacturer's fee rate rises with the amount of waste generated; thus, EPR programs incentivize companies to reduce the amount of packaging on their products. Although fees typically only amount to a price per unit that is similar to California's bottle redemption value of 5 to 10 cents or less, EPR programs can result in high overall recycling or reuse rates.[112] Additional economic analysis is needed to determine effective fee rates to incentivize companies to reduce plastic packaging, minimize illegal dumping to avoid fee payments, and provide sufficient funding for effective enforcement.

Currently, EPR programs exist mainly in Europe and Canada.[113] In the United States, a non-profit organization called Recycling Reinvented is working to increase recycling rates of waste packaging through an EPR model.[114] More jurisdictions should adopt EPR programs to improve management of land-based plastic pollution.

Another good way to boost recycling rates is to provide a redemption fee upon the return of plastic beverage bottles and cans to designated facilities for recycling. Many such programs exist in the United States, but they could be improved and more widely adopted globally. Current redemption fees should be altered to better protect the environment by requiring the return of both bottle and cap, as bottle caps are among the most frequent types of waste found during beach cleanups and are often discovered in the stomachs of large sea birds such as albatrosses. [115] Bottle redemption fee models also could be extended to fishing nets, fishing lines, and aquaculture components to encourage the return of these items to shore facilities for proper disposal.

We recognize that EPR and recycling redemption fee programs have their limits. Even programs that achieve very high recycling rates still fail to capture a significant portion of potential marine pollution. For instance, even if 70 percent of plastic waste was recycled worldwide—an optimistic rate that has never been achieved on a wide scale—that still would fail to account for about 80 million tons of plastic waste per year that could end up in the marine environment.[116] The good news is that the options for reuse or transformation of traditionally non-recyclable plastics are expanding. New technologies have the power to incentivize the collection of non-recyclable plastics by increasing their

monetary value. For example, Korea now recycles its aquaculture floats into combustible fuel rods, and Method soap brand is using collected marine litter to manufacture some of its soap bottles. The British company Cynar plans to open ten new fuel plants, each capable of transforming 20 tons of non-recyclable plastic trash into fuel per day.[117] One advantage of EPR and recycling redemption programs is that they provide a source of well-sorted plastics for innovative efforts like these.

F. Target Policies to Ocean-Based Sources of Plastic Marine Litter

Ocean-based sources of plastic marine litter require specially targeted policies. In addition to the amendments to existing international laws that we mentioned above, we support the creation of a certification and tracking program for fishing ships and aquaculture. This certification program should require the tracking of fishing gear in vessel logs to determine how much gear is "lost" overboard, with effective third-party monitoring, assessment and penalties for any excessive losses. Fishing nets should be tagged so that they can be easily located in and removed from the ocean before they damage delicate habitats or contribute to ghost fishing. The certification program also should mandate the use of sustainable aquaculture facility materials such as the use of bamboo instead of polyvinyl chloride (PVC) pipes, and the use of glass floats rather than expanded polystyrene foam. Much like the "Ocean Friendly" certification program that we propose above, this certification program could expand upon existing standards, and establish measurable indicators and targets to determine compliance.

Additionally, we urge coastal jurisdictions to be mindful of well-intentioned recycling policies such as bans on plastic in landfills that create a disposal problem for derelict fishing nets. Jurisdictions with such policies should amend them to ensure that vessels can easily dispose of fishing nets on shore.[119]

G. Expand the Use of the Most Successful Domestic Management Models

National, state, and local governments

Figure 13. (Left) Oyster aquaculture practices utilizing polystyrene foam. (Right) Polystyrene foam buoys used in oyster aquaculture off of the southern coast of the Korean Peninsula near the City of Busan. *Images courtesy of Chulhoon Song, Korean Broadcasting System.*

What are Total Maximum Daily Loads (TMDLs)?

Under the **Clean Water Act**, states are required to establish water quality standards for each waterbody in the state. Water quality standards designate uses for the waterbody (e.g., recreation, public water supply, aquatic life) and set criteria necessary to protect those uses. Any waterbody that receives a pollution load that prevents the attainment of its water quality standards is listed as "impaired." To address the impairment, regulators are required to develop ***Total Maximum Daily Loads (TMDLs)***, which specify the maximum amount of a pollutant that the impaired waterbody can receive without violating its water quality standards.

around the world should ban the most common and damaging types of plastic marine litter, such as microbeads, fish-egg-sized nurdles, single-use plastic bags, and polystyrene foam food packaging. At least 37 countries, including Ireland, China, Bangladesh, and Ethiopia, and hundreds of state and local governments, including Mexico City, Washington, D.C., and Delhi, have adopted single-use plastic bag or polystyrene foam restrictions with extraordinary success.[120] Examples of effective bag bans from jurisdictions around the world demonstrate that such policies can alter consumer behavior and meaningfully prevent plastic marine litter. For instance, in the first year of implementation of China's policy banning ultra-thin plastic bags and requiring retailers to charge consumers for thicker plastic bags, overall plastic bag use decreased by two-thirds, or 40 billion bags.[121] Similarly, a single-use plastic bag ban in Los Angeles County, California has resulted in litter reduction and healthier beaches and waterways.[122]

In addition to banning common types of plastic marine litter, United States coastal jurisdictions should harness tools in the federal Clean Water Act to address plastic marine litter. Several U.S. local governments have begun to use the Clean Water Act tool of Total Maximum Daily Loads (TMDLs) to limit plastic and trash pollution. TMDLs for trash set a numeric goal for the amount of trash (including plastic trash) in a trash-impaired waterbody by a certain date (e.g., zero trash by 2023). To achieve the TMDL, the local government must implement trash reduction measures in the watershed.

Cities in California and Maryland have led the way in developing TMDLs for California's Los Angeles River, Ballona Creek, and Santa Monica Bay, and Maryland's Anacostia River. The Los Angeles-area TMDLs have resulted in the installation of nearly 100,000

Figure 14. Litter, including plastic litter, covers the beach at the mouth of Ballona Creek in Southern California. *Image courtesy of Heal the Bay.*

full capture devices, which filter litter 5 mm in diameter or greater out of stormwater runoff before it enters the waterbody. The California State Water Resources Control Board is currently in the process of creating a statewide trash policy that builds upon the innovative trash control measures of local governments like Los Angeles. The goal of the statewide policy is to target land uses that produce high volumes of trash with control requirements ranging from full capture systems to street-sweeping and educational campaigns. California will implement these requirements through the National Pollutant Discharge Elimination System (NPDES) permits it issues under the Clean Water Act.[123]

Regulators in coastal watersheds across the United States should develop similar TMDLs for plastic marine litter, using the programs in California and Maryland as models. Coastal areas outside of the United States should use the TMDL system as a model for similar regulatory programs in their jurisdiction. Regulators adopting similar programs should collect local data in order to identify and target the greatest contributors to the pollution problem. Prioritizing high-use generators, such as high-density urban developments or industrial facilities with existing stormwater permits, allows for a rapid initial decrease in marine litter, after which a program can then pursue smaller generators.[124] In most cases, TMDL programs should address floating litter, trash, and litter discharges, as well as the issue of legacy litter on river bottoms or the ocean floor.

Figure 15. Plastic bag floating in the water column in the Red Sea. *Image Courtesy of Ben Mierement, NOAA NOS/NOAA Photo Library.*

H. Expand Plastic Marine Litter Clean-Up Programs

While there is certainly a need to continue researching the issue of plastic marine litter to further understand the scale and scope of its impacts, we have enough information to know that we need to begin cleaning up existing plastic marine litter now. Clean-up efforts should focus on all regions of the marine environment that are affected by plastic marine litter, including coastlines, coral reefs, the seafloor, and the deep ocean. Capturing plastic litter from the marine environment is a complex proposal, given the costs of marine litter retrieval and the need for sufficient on-shore disposal sites. Despite these complexities, many excellent existing programs could be expanded and adapted.

For instance, "Fishing for Litter" programs provide trash bags and easy on-shore disposal options to incentivize fishermen to properly dispose of litter captured in fishing nets. Such programs also can incentivize the return of plastic litter through per-item or per-weight payments.[125] Some existing programs even have established partnerships with local residents to repurpose collected plastic marine litter into art, which serves to educate the public about the plastic marine litter problem.[126] Additionally, derelict fishing gear removal projects, which encourage ocean users to recycle and report lost gear, have been successful in several regions of the United States. Since 2006, California's Lost Fishing Gear Recovery Project has retrieved over 60 tons of gear from California's coastal ocean and over 1,400 pounds of gear from public fishing piers.[127] And since 2002, the Northwest Straits Derelict Fishing Gear Removal Program has removed 4,500 nets, 3,081 crab pots, and 47 shrimp pots from Puget Sound.[128]

Marine litter clean-up program managers should consider investing limited program funds into emerging technologies to increase the efficiency of clean-up activities. For example, overlaying maps

Figure 16. Plastic litter in Rome, Italy's Tiber River heads out to see (2007). *Image courtesy of Oceansart.us/Marine Photobank, http://www.OceansArt.us.*

of marine debris concentrations and maps of marine animals could help identify ocean areas that should be prioritized for clean-up efforts. Additionally, plastics surveys could be added onto planned marine organism studies; archived samples could be checked for plastic concentrations; old video and photographic footage of the deep sea floor could be analyzed; and remote sensing could be employed to identify existing plastic marine litter hotspots.[129] Web-based forums where interested parties can post and obtain information about plastic marine debris, such as the NOAA Marine Debris Clearing House,[130] also can help researchers identify hotspots.

In addition to marine clean-up efforts, capturing litter at river mouths and on land in ocean-connected watersheds can prevent plastics from reaching the ocean.[131] Through one of the largest annual beach clean-up events, International Coastal Clean-up Day, nearly 9 million volunteers from 152 countries have removed 145 million pounds of trash from shorelines over the past 25 years.[132] Expansion of voluntary programs like this to incorporate more regular clean-up events in urban watersheds would decrease the amount of litter entering the marine environment and, more importantly, educate the populace to change harmful waste disposal behaviors. It is also critical that cleaning up coastlines be incorporated into municipal responsibilities in the same manner as park and street maintenance so that beach users can share clean-up costs.

A problem on the scale of plastic marine litter cannot be tackled without viable, consistent sources of funding for clean-up efforts. On a subnational or local scale, governments can raise funds for marine litter clean-up efforts through fees or taxes imposed on plastic products. Such fees should be designed to reflect the product's disposal and environmental costs accurately. One local model that could be scaled up internationally is the City of Oakland's litter tax on fast food establishments, the revenues of which fund clean-up programs.[133] As another example, in 2010, Washington, D.C. instituted a 5-cent fee on disposable plastic bags, 1 cent of which is returned to the store while the other 4 cents fund environmental programs such as Anacostia River clean-up efforts and education and outreach programs. This program generates around 2 million dollars per year and has resulted in a 60 percent reduction in bags in the Anacostia River.[134] Yet another option is to impose a small fee or tax on non-biodegradable plastics only, the revenues of which could be used to fund marine litter clean-up efforts. This approach would encourage the use of ocean biodegradable plastics by making ocean biodegradable plastics cost-competitive with petroleum-based plastics.[135]

On a larger scale, imposing a nominal fee on shipping containers exported through port facilities would create a large fund for marine pollution clean-up programs. A 1-dollar fee per shipping container would be very small relative to the average value of the goods within the container, but could generate substantial revenue for clean-up efforts. For instance, a one dollar per loaded container fee would have produced $4.1 million of funding at the Port of Los Angeles in 2012 alone.[136] Expanded internationally, a one-dollar per loaded shipping container fee would generate $114 million annually for the top 20 importers of shipping containers, based on 2010 numbers.[137]

I. Develop and Expand Education and Awareness Programs

Educational programs targeted to the global public, youth, boaters, civil society organizations, religious groups, and the plastic, fishing, and aquaculture industries are important parts of the plastic marine litter solution. The extension of existing citywide anti-litter campaigns and local beach cleanups would contribute to raising public awareness of the plastic marine litter problem. Incorporating litter and marine litter curricula into primary education also would help. Example curricula include the "Save Our Seas" and "Waves, Wetlands, and Watersheds" programs developed by the California Coastal Commission.[138] Local events are another important vehicle to promote awareness of recycling and reducing; when events themselves are zero-waste, they both increase awareness and limit litter.

Industrial education efforts also have contributed to the growing global awareness of the problem. One such example is the Society of Plastics Industry and the American Plastics Council's "Operation Clean Sweep," which informs employees at a plastic pellet manufacturing facility of the importance of preventing pellet loss.[139] In 2011, plastics organizations signed a declaration to address the problem of marine litter through a suite of actions including education programs.[140] Global educational programs and programs targeting the fishing and aquaculture industries, however, must be greatly expanded and improved. Few examples of targeted educational campaigns about the effect of derelict fishing gear exist, although programs that encourage fishermen to capture and return marine litter they encounter have provided some benefits. Similarly, targeted educational programs centered on high-use areas such as ports, boat rental facilities, and boat launch ramps would help increase awareness of plastic marine litter among recreational and professional boaters.

Conclusion

Plastic marine litter is far more than an aesthetic problem. Increasing harm to marine wildlife and rising economic costs provide an enormous incentive to tackle the global plastic marine litter problem more aggressively. Although plastic marine litter has grown into a high-profile international environmental issue over the last two decades, efforts to address it so far have not adequately protected water quality or the health of the marine environment. Significantly, the many existing international treaties relevant to plastic marine litter lack the scope, standards, and penalties necessary to address the problem comprehensively. We suggest that attaining the Rio+20 goal of "achiev[ing] significant reductions in marine debris" by 2025 will require not one "silver bullet" action but rather a panoply of international, regional, national, and local policies and programs.

Below, we have included a list of our Top 10 Plastic Pollution Prevention Actions. Implementation of all 10 measures by 2025 would drastically reduce the current rate of ocean plastics disposal. Stemming the tide of plastic pollution is a first and important step, but additional efforts will be required to address the millions of tons of plastic litter already present in the ocean. It is our hope that collaborative work toward reducing plastic marine litter disposal will lay a foundation for increased and continued global cooperation on marine health issues.

Top 10 Plastic Marine Litter Prevention Actions

1) **Develop a new international plastic marine litter treaty of the scale and scope of the Montreal Protocol.** The agreement should incorporate enforceable marine litter standards as well as strong tracking, monitoring, reporting, and enforcement mechanisms, including adequate penalties and the establishment of jurisdiction for party dispute resolution before an international tribunal.
2) **Through a new international treaty and regional and domestic action, ban the most common and damaging types of plastic marine litter** (e.g., microbeads, fish-egg-sized nurdles, single-use plastic bags, and polystyrene foam food packaging), and phase out all plastics that are not recycled at a rate of 75 percent or more by a certain date. Support the development of and transition to substitutes.
3) **Create and implement a voluntary "Ocean Friendly" certification program for all plastic products that commonly result in marine litter.** The program should include common-sense certification standards for: minimum recycled plastic content; incorporation of easily-recyclable plastic; sustainable single-use packaging design; ocean plastic degradability; and phase-out particularly harmful manufacturing materials such as nurdles.
4) **Expand Extended Producer Responsibility programs**, with the stipulation that such programs must be designed to result in high recovery rates of plastics and the phase-out of environmentally harmful materials.
5) **Expand and strengthen existing regional agreements and other international agreements** relevant to plastic marine litter by incorporating enforceable marine litter standards, closing loopholes, strengthening penalties, and supporting improved enforcement.
6) **Create and implement certification and tracking programs for fishing and aquaculture operations** through regional fisheries management organizations and other relevant institutions. Programs should require logs to track lost fishing gear; require traceable tags on nets; and encourage the use of more sustainable materials in aquaculture gear.
7) **Establish funding sources for marine litter remediation** through product redemption fees and shipping container fees, such as a port fee of 1 dollar per shipping container. Impose fees or taxes on the most common types of plastic marine litter (e.g., single-use plastic bags, cigarettes, and expanded polystyrene foam).
8) **Expand the use of "zero-trash" Total Maximum Daily Loads or similar requirements within urban coastal watersheds in the United States and internationally.** Sources of marine litter should be identified and assigned a waste load allocation of zero trash to be achieved within a decade.
9) **Accelerate efforts to clean up beaches and existing marine litter.** Clean-up efforts should focus on plastic marine litter hotspots and all regions of the marine environment that are affected by plastic marine litter, including coastlines, coral reefs, the seafloor, and the deep ocean.
10) **Improve our understanding of the plastic marine litter problem** by funding research and data collection regarding the main sources of plastic marine litter; its effects on human health, the environment, and the economy; and the most effective means of control. Expand public education programs to raise awareness of the plastic marine litter crisis.

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