BACKGROUND BRIEF 3
September 2019

Ocean Plastic Pollution

Ocean plastic pollution has recently become a key focus of public attention and concern. Large ocean plastics such as abandoned fishing nets entangle and kill marine life and can create navigational hazards, while microplastics enter marine food webs and have been identified in seafood for human consumption from both aquaculture and wild capture fisheries. Many key questions about the distribution of ocean plastics and human health impacts remain unanswered. What has become clear, however, is the global scale of the problem, the need for collaboration to address it, and an intense interest from the public, as well as industry and policymakers, in doing so.

Overview of plastic production

The history of plastic production is a short one. The word "plastic" as well as the world's first commercially important synthetic polymer (Bakelite) were invented in 1907 by Leo Bakeland. By the 1930s, Bakelite was already being used in everything from electronic equipment to jewelry. Its broad commercial success has spurred the development of over 2,000 different commercial polymers with varying chemical compositions[1].

Researchers have suggested that plastic production can be roughly categorized into three phases. Phase 1 (1907-1950) was characterized by innovation, and the majority of commercial plastics used today were developed during this period. Production levels remained low, but began to climb during the 1930s and 1940s until mass production began around the 1950s. Rapid growth occurred during Phase 2, a 50-year period (1950-2000) during which production expanded almost exponentially. Since 2000, growth of plastic production has slowed to 3-4% annually (Phase 3), in line with global GDP growth (Figure 1)[2].

As of 2015, annual global plastic production was estimated at 322 million metric tons (Mt), roughly equivalent to the combined weight of the Earth's 7.3 billion people[3]. A total of 6,300 Mt is thought to have been produced since the invention of plastic, of which 9% has been recycled, 12% has been incinerated, and 79% has entered landfills or the natural environment[4]. In some regions, growth has slowed or stagnated: in Europe, for instance, annual production volumes have remained stable at 60 Mt since 2015[5]. Global plastic production is, however, expected to continue to grow, as evidenced for instance by multi-billion-dollar investments in new production facilities[6].

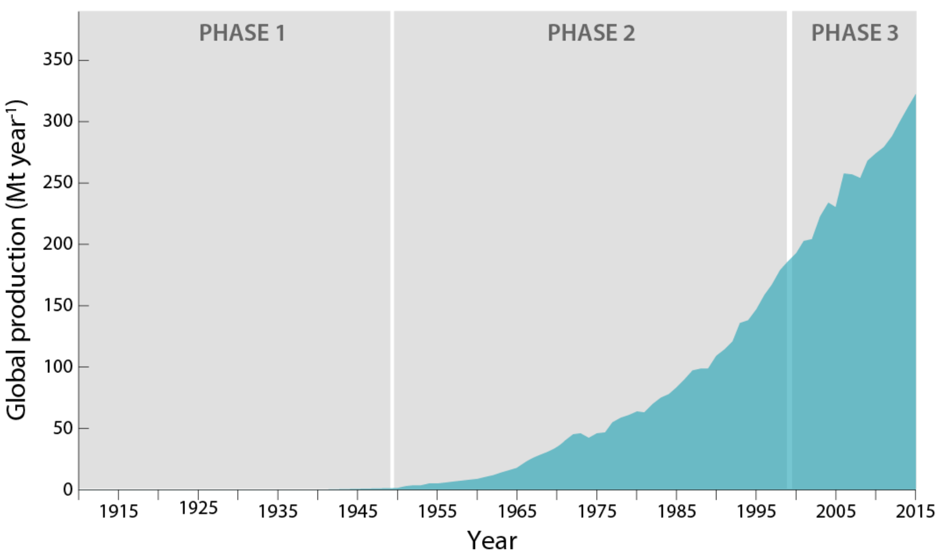

Figure 1: Three historical phases of plastic production: Phase 1 (innovation); Phase 2 (growth); Phase 3 (stabilization). (Reproduced with permission from Annual Review of Environment and Resources, Volume 42, © 2017 by Annual Reviews, http://www.annualreviews.org)

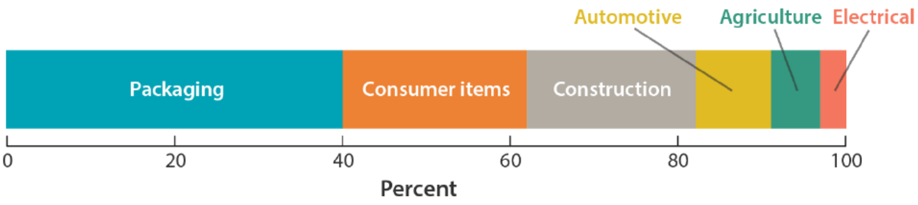

Figure 2: Global usage of plastic by application (adapted from Worm et al. 2017)[1]

Plastic is ubiquitous throughout land-based and ocean-based industries, but the largest single application is for packaging[7]. Specific numbers vary, but somewhere between 33% and 40% of plastic is used for packaging, in the majority of cases, single-use packaging (Figure 2).

How does plastic enter the ocean?

Land-based sources

The majority of ocean plastic arises from land-based sources, particularly from areas characterized by high-population densities and limited waste management facilities or regulatory controls[8]. As a result, different regions have vastly different contributions to ocean plastic pollution (Figure 3). The use and production of plastic has been largely decoupled from plastic disposal, so many countries export plastic waste from recycling schemes (e.g. until 2018, China had been receiving about two-thirds of the world's plastic exports)[9]. Major rivers fed by densely-populated watersheds are also a key source of plastic pollution, as are coastal regions[10, 11].

Ocean-based sources

The disposal of all forms of plastics at sea has been completely banned since 1998 under MARPOL Convention, Annex V. Yet the shipping and seafood industries are considered the primary contributors to ocean-based plastic pollution[12]. Unintentional plastic pollution can result, for instance, from the loss of fishing gear due to severe weather conditions or other unexpected circumstances. In some cases, fishing gear is intentionally abandoned or discarded as a cost-benefit decision, a likely indicator of illegal operations[13].

Types of ocean plastic pollution

The durability of plastic has played a major role in its commercial success and ubiquitous usage. Yet this durability has become an environmental liability. Biodegradation of plastics can take centuries, and is highly dependent on environmental conditions, including exposure to ultraviolet radiation from the sun and the presence of oxygen. In the ocean, this process is prolonged further still, because the majority of ocean plastic pollution sinks, and becomes coated in algae and bacteria[14]. As a result, the majority of ocean plastic is expected to persist for hundreds or even thousands of years. In addition, even some plastics labelled as "biodegradable" are only compostable within industrial facilities operated under conditions that do not occur naturally (Figure 4).

While ocean plastics are slow to degrade, they do break down into smaller pieces due to physical stress from waves and other forces[15]. The result is not, however, less plastic, but rather smaller, more numerous pieces of plastic, and eventually microscopic pieces of plastic (microplastics and nanoplastics) that can easily enter marine food webs. Typologies of ocean plastics often cover four categories (Table 1).

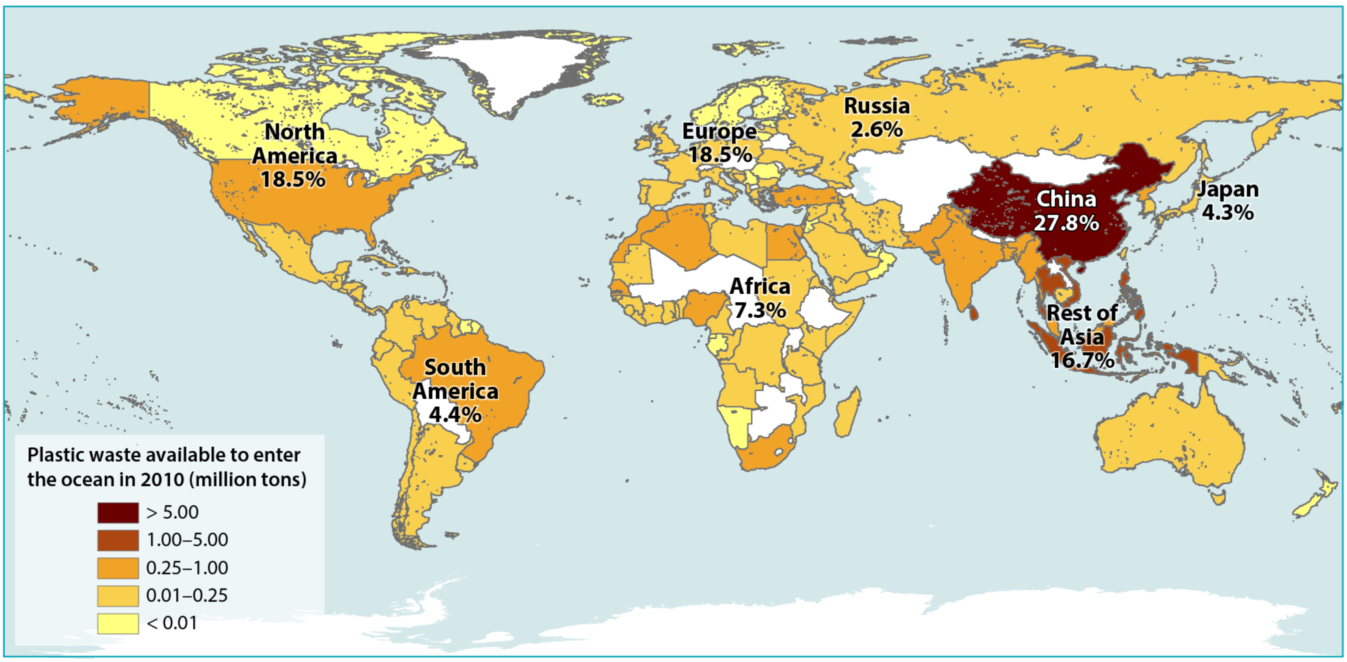

Figure 3: Estimated contribution of different regions to ocean plastic pollution (color-coding indicates contribution by population living within 50 km of coast) (Reproduced with permission from Annual Review of Environment and Resources, Volume 42, © 2017 by Annual Reviews, http://www.annualreviews.org)

Table 1: Types of ocean plastics, and estimated contribution to global ocean plastic pollution			
Types	**Size**	**Example**	**Estimated weight in the ocean (2013)**[16]
Macroplastics	>200 mm	Fishing net, buoy, bottles	202,800 tons
Mesoplastics	5-200 mm	Bottle caps, broken pieces of larger plastics	30,600 tons
Microplastics	1 µm - 5 mm	Microbeads from cosmetics	28,500 tons
Nanoplastics	< 1 µm	Microscopic plastic particles	7,040 tons

Distribution of ocean plastic pollution

The diversity of plastics and the products for which they are used results in a similarly diverse range of ocean plastic pollution. Observational data has been used to estimate that approximately 267,000 tons of plastic have remained floating on the surface of the ocean (Table 1). By weight, the majority (76%) of floating ocean plastics are macroplastics[17].

Ocean currents and winds cause highly variable distribution of ocean plastics, with concentrations along shorelines and within five subtropical "gyres" on the open ocean. Plastic litter has been found everywhere, including some of the most remote deep-sea trenches and polar regions[18]. Some have described the "missing plastic" phenomenon, whereby empirical records of ocean plastic pollution are orders of magnitude lower than estimated flows of plastic into the ocean – further research is needed to clarify this data gap, but it is believed that the majority of plastic flowing into the ocean sinks and is ending up in the deep sea, and buried in seafloor sediment[19].

Main impacts of ocean plastics

Entanglement and ingestion

Ocean plastics have varied impacts on marine biodiversity and ecosystems. Some of the most enduring visuals of the risks from ocean plastic pollution are photos of marine life entangled in macroplastics, and the stomach contents of whales that have beached and died after ingesting plastic waste. Both entanglement and ingestion can have lethal impacts. Some species, like sea turtles, are particular vulnerable and all recorded species of sea turtle have been found to either ingest or become entangled in macroplastics[20]; 90% of surveyed seabirds have been found to be affected by plastic ingestion[21]. Nonlethal impacts from plastic ingestion on marine life vary by species, type of plastic, and a variety of other factors, and are currently an area of extensive research[22].

Figure 4: A "biodegradable" bag is still able to carry a full load of groceries after three years in the ocean. (Reprinted with permission from Napper and Thompson, Environmental Science & Technology. © 2019 American Chemical Society.)

Entanglement of marine life often involves abandoned, lost or discarded fishing gear (also referred to as "Ghost Gear"). One study found that an abandoned fishing net in the northeastern Pacific could be expected to catch, over the course of one year, at least 700 invertebrates, 120 fish, and 70 seabirds[23]. Another study found that Ghost Gear was catching 5,000-15,000 turtles in the Arafura Sea[24].

Bioaccumulation

There is evidence that microplastics and nanoplastics bioaccumulate within marine foodwebs, similar to other pollutants like mercury and PCBs. Some plastics act almost like sponges, soaking up pollutants and concentrating these to levels of up to 1 million times the surrounding environmental levels[25]. Upon ingestion, it is possible for these pollutants to pass from the plastic to the organism, although the effects vary across organisms and remain poorly understood[26]. Filter feeders like mussels have been found to accumulate microplastics. In one study in the Northwestern Atlantic, wild and farmed mussels destined for human consumption were compared, and both were found to have over 100 microplastic filaments each in their gills[27].

Human health impacts

A comprehensive understanding of the human health risks associated with ingestion of plastics is lacking, but many studies identify concerning impacts. For instance, Bisphenol A (BPA), a widely used additive to plastic water bottles, accumulates in humans displaying estrogen-like properties and causing hormonal imbalances[28]. Other additives used in plastic production (e.g. styrene and vinyl chloride) are known cancer-causing agents[29]. Bioaccumulation, as described above, is of particular concern, as humans occupy the top position in many marine food webs, and consumption of seafood may be increasingly associated

Table 2: Estimated costs of marine litter for trawlers in the European Union fleet (Acoleyen et al. 2013)[33]

	Annual cost	Vessels in EU fleet (#)	Total annual cost
Cost of reduced catch (trawlers)	EUR 2,340	12,238	EUR 28,640,000
Cost of removing litter from fishing gear (trawlers)	EUR 959	12,238	EUR 11,740,000
Cost of broken gear and fouled propellers	EUR 191	87,667	EUR 16,790,000
Cost of rescue services	EUR 52	87,667	EUR 4,540,000
Total			**EUR 61,710,000**

with ingestion of plastics and high levels of toxic substances. A 2017 FAO review of knowledge regarding microplastics in fisheries and aquaculture found that human consumption of microplastics has negligible health impacts. In the most extreme case identified in the study, consumption of 225 g of mussels would contribute 7 micrograms of microplastic (0.1% of total dietary exposure to associated contaminants)[30].

Economic impacts
Macroplastics are a navigational hazard and have been implicated in accidents that have resulted in loss of human life[31]. Trawl fisheries also suffer directly from plastic pollution, as this waste must be removed from nets; one study in the European Union estimated over EUR 61 million in related annual losses (Table 2)[32].

Emerging threats
An intense focus within the research community to better understand the role of plastics in the marine environment has suggested a range of concerning novel threats. For instance, microplastics act as stable substrates within marine environments, and have been linked to the spread of invasive species, sparking harmful algal blooms, jellyfish blooms, and the spread of antimicrobial resistant (AMR) bacteria[34,35,36]. Plastics are primarily synthesized from fossil fuels, and the breakdown of plastics has been linked to the release of the potent greenhouse gas methane[37].

Figure 5: Ghost net retrieved by Scottish trawler in 2004 (Directorate of Fisheries Norway)[1].

Box 1: Recent developments

China stops importing the world's plastic
For years, China has been the leading importer of plastic waste, handling approximately two-thirds of the world's plastic waste. But in January 2018, China's new National Sword law banned imports, and flows of plastic were diverted to Southeast Asian countries like Malaysia[53]. In October 2018, Malaysia also banned import of plastic waste[54]; Thailand soon followed[55]; India has also announced it will not accept plastic imports[56]. Recycling programs in plastic-exporting countries had been based on high market prices for plastics (e.g. plastic was once valued at USD 300 per ton), but the shifting market has thrown uncertainty over the future of plastic recycling programs[57]. It is too early to determine what impact this will have on levels of ocean plastic pollution.

Spread of bans on single-use plastics
In March 2019, the European Union joined a growing number of governments and companies by voting to ban some of the most common single-use plastic items like straws (by 2021), and to aim for 90% collection of plastic bottles and greater reliance on the "polluter pays" principle[58]. 34 countries across Africa have enacted bans or taxes on single-use plastic bags, as have the states of California, New York and Hawaii, and a growing list of groups and governments[59]. The broad appeal of eliminating single-use plastics can even be seen in the announcement by the al-Qaeda-linked terrorist group al-Shabab that plastic bags would be banned in areas of Somalia under their control[60]. Notably, the first bag ban was passed in Bangladesh in 2002, highlighting that concerns around this issue transcend North-South divides[61].

Concern that ocean plastic pollution is getting too much attention
Recently, researchers have raised questions about the long-term impacts of the recent explosion of public interest in ocean plastic pollution[62,63]. Although the world faces a range of severe environmental risks, research has shown that people tend to have a "single-issue focus", and that climate change largely replaced biodiversity loss as the single issue a decade ago[64]. Today, some researchers emphasize that although ocean plastic pollution is a critical issue, it is one among several. They argue that a single-issue focus on ocean plastic pollution may be crowding out potentially more pressing risks to ocean health, including over-fishing, ocean acidification, climate change and biodiversity loss[65,66].

Table 3: Elements in a comprehensive strategy to reduce the flow of plastic waste into the ocean (adapted from Worm et al. 2017)[39]

Value chain step	Potential actions
1. Plastic production	Reduce volume of production by reducing demand (e.g. for single-use packaging)
2. Plastic material and product design	Eliminate use of excessive packaging; support development of new biodegradable alternatives to plastics
3. Waste generation	Educate public about environmental and health risks
4. Waste management	Create training programs for experts to support countries with low levels of expertise in waste system management
5. Litter capture	Support cleanup programs (citizen-led / industry-led)

Strategies for addressing ocean plastics

Value-chain approaches

While ocean plastic pollution is a complex issue, there are multiple entry points for addressing it. Some approaches are aimed primarily at reducing input of plastic into the ocean while others focus on trying to remove plastic already in the ocean. Yet many researchers and practitioners argue that preventative steps are a more impactful investment. One research group identified five elements in a comprehensive strategy to reduce the flow of plastic into the ocean[38] (Table 3). Such a strategy would entail reductions in plastic production, and reduced usage of plastic additives of particular environmental concern, incentives to reduce single-use plastics, and improved waste management efforts. Education and awareness-raising campaigns are seen as important complementary instruments to any market-based or regulatory approaches.

Key global efforts in line with the above strategy include the **Global Partnership on Marine Litter (GPML)**[40] (launched in 2012), the **Global Partnership on Waste Management (GPWM)**[41] (launched in 2010) and the **UN Community of Ocean Action on Ocean Pollution**. The aim of these international partnerships is to bring together multi-sectoral actors from government, civil society, industry and academia to enhance international cooperation, innovation and collaboration on waste-related issues in order to mitigate negative human health and environmental impacts in line with the Sustainable Development Goals and relevant international commitments.

Key national initiatives include the **Japan Clean Ocean Material Alliance (CLOMA)**[42], which was established in late 2018 and now includes many of Japan's largest companies. CLOMA takes a holistic approach to ocean plastic pollution with efforts that encompass the reduction of plastic use, proper waste management and recycling, and ocean cleanup efforts. The European Union also adopted its first-ever **Strategy for Plastics in a Circular Economy** in January 2018, and has proposed additional EU-wide rules on addressing plastics.

Box 2: Recent headlines and additional detail

"90% of ocean plastic comes from 10 rivers"

This figure comes from a 2017 study[67] of plastic waste transported by river systems. It looked at 57 river systems, and found that 10 of these systems were responsible for 90% of plastic waste. An important distinction missed by the headlines is that the study does not claim that 90% of ocean plastics come from 10 rivers – it states that 90% of the plastic waste carried by rivers comes from 10 of these rivers. Plastic pollution coming from coastal areas, waste mismanagement, ocean-based sources, etc. are not considered in this study. Moreover, the researchers are cautious about their findings, which are heavily dependent on population density estimates and limited empirical data ("Due to the limited amount of data high uncertainties were expected and ultimately confirmed").

"70% of ocean plastic is from the fishing industry"

This figure comes from a 2014 study[68] which relied on visual transect surveys across the five subtropical ocean gyres to estimate the number and weight of floating plastic debris. Aggregating for all ocean gyres, the study estimated that 20% of floating ocean plastics were from the fishing industry, and that they accounted for 70.4% of the floating plastic weight. While the study provides useful estimates, some caution is needed. First, no plastic was collected during the transects, and weight estimates were calculated based on the weight of comparable plastic debris found on coastlines. Second, limited data is used to extrapolate for global estimates: only a single transect was conducted in the South Pacific and South Atlantic, respectively; two transects in the Indian Ocean, and five in the North Pacific. Third, the majority of plastic sinks from the surface over time, meaning that surveys of surface plastic provide a limited understanding of the larger issue. Fourth, mesoplastics, microplastics and nanoplastics are not considered in the analysis. As comparison, a 2009 report[69] commissioned by the FAO found that plastic pollution from ocean-based industries demonstrates wide regional variation, and likely accounts for less than 10% of total ocean plastic pollution globally.

Ocean cleanup efforts

Many opportunities exist for removing macroplastics from marine and coastal ecosystems, including through beach clean-ups. The **International Coastal Cleanup**, organized by the Ocean Conservancy for the past 30 years, for instance, mobilized over 21 million people to collect nearly 24 million kilograms of waste from 78,000 miles of coastline in 2018[43]. Among the most frequently collected items in the cleanup were cigarette butts (11.8 million), food wrappers (6.5 million) and plastic bottles (5.2 million)[44].

The **Global Ghost Gear Initiative (GGGI)** was launched in 2015 to bring together actors from industry, academia, governments and civil society to motivate policy, science and action to eliminate and remove ghost gear[45]. As described above, many economic incentives exist to eliminate ghost gear, and multiple local and regional programs have emerged with these aims, including the **Korean Waste Fishing Gear Buy-back Project**, the **California Lost Fishing Gear Recovery Project**, and the **Abandoned, Lost and Discarded Fishing Gear Survey and Removal Program of Washington State**[46]. The latter estimated a positive cost-benefit ratio for cleanup of 1:1.28 for pots and traps, and 1:1.27 for abandoned, lost and discarded nets[47].

The high-profile **Ocean Cleanup Project** was launched in 2013 by entrepreneur Boyan Slat. It aims to deploy dozens of floating cleanup systems throughout the ocean gyres to collect floating plastic waste, with the aim of eliminating 50% of plastic waste in the Great Pacific Garbage Patch by 202[48]. A test deployment in October 2018 encountered functional difficulties and part of the system became detached. Ultimately, 2,000 kg of plastic were collected over a two-month deployment. Critics note that the system only collects macroplastics, and suggest the project's resources would generate greater impact if targeted at root causes of plastic pollution such as waste mismanagement and overreliance on single-use plastics[49].

All of these cleanup efforts are aimed at macroplastics, and strategies for eliminating microplastics and nanoplastics from marine and coastal systems are yet to be developed.

Port State Measures Agreement

A report commissioned by the Food and Agriculture Organization (FAO) found a linkage between intentional abandonment and discarding of fishing gear and IUU fishing operations[50]. Illegal operators are less likely to follow national and international regulations, including the International Convention for the Prevention of Pollution from Ships (MARPOL)[51] under the International Maritime Association, and are therefore leading contributors to the problem of ghost gear. Stronger port state measures aimed at eliminating IUU fishing activities and implementing regular monitoring of fishing gear records would help to reduce a primary ocean-based source of plastic pollution[52].

Summary

Ocean plastic pollution is a complex and global challenge, aspects of which remain poorly understood. At the same time, many of the steps towards addressing this challenge are comparatively straightforward. These include conducting an inventory of current plastic usage, and then using this as a basis to reduce plastic use, explore alternatives to plastic, and promote proper waste management along value chains. Important complements to these corporate activities include educational efforts aimed at the general public about recycling, and cleanup campaigns.

References

1. Worm, B., Lotze, H.K., Jubinville, I., Wilcox, C. and Jambeck, J., 2017. Plastic as a persistent marine pollutant. Annual Review of Environment and Resources, 42, pp.1-26.
2. Worm, B., Lotze, H.K., Jubinville, I., Wilcox, C. and Jambeck, J., 2017. Plastic as a persistent marine pollutant. Annual Review of Environment and Resources, 42, pp.1-26.
3. Europe, P., 2016. Plastics—The Facts 2012. An Analysis of European Latest Plastics Production, Demand and Waste Data. Available online: https://www.plasticseurope.org/application/files/4315/1310/4805/plastic-the-fact-2016.pdf.
4. Geyer, R., Jambeck, J.R. and Law, K.L., 2017. Production, use, and fate of all plastics ever made. Science advances, 3(7), p.e1700782.
5. Europe, P., 2016. Plastics—The Facts 2012. An Analysis of European Latest Plastics Production, Demand and Waste Data. Available online: https://www.plasticseurope.org/application/files/4315/1310/4805/plastic-the-fact-2016.pdf.
6. Taylor, M. 2017. $180bn investment in plastic factories feeds global packaging binge. The Guardian. Available online at: https://www.theguardian.com/environment/2017/dec/26/180bn-investment-in-plastic-factories-feeds-global-packaging-binge
7. UNEP, 2016. Marine Plastic Debris and Microplastics: Global Lessons and Research to Inspire Action and Guide Policy Change. UN.
8. UNEP, 2016. Marine Plastic Debris and Microplastics: Global Lessons and Research to Inspire Action and Guide Policy Change. UN.
9. Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R. and Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science, 347(6223), pp.768-771.
10. Schmidt, C., Krauth, T. and Wagner, S., 2017. Export of plastic debris by rivers into the sea. Environmental science & technology, 51(21), pp.12246-12253.
11. Moss, E., Eidson, A. and Jambeck, J., 2017. Sea of Opportunity: Supply Chain Investment Opportunities to Address Marine Plastic Pollution.
12. Cheshire, A. and Adler, E., 2009. UNEP/IOC guidelines on survey and monitoring of marine litter.

13. Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear (No. 523). Food and Agriculture Organization of the United Nations (FAO).

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

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

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

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

18. Chiba, S., Saito, H., Fletcher, R., Yogi, T., Kayo, M., Miyagi, S., Ogido, M. and Fujikura, K., 2018. Human footprint in the abyss: 30 year records of deep-sea plastic debris. Marine Policy, 96, pp.204-212.

19. Cózar, A., Echevarría, F., González-Gordillo, J.I., Irigoien, X., Úbeda, B., Hernández-León, S., Palma, Á.T., Navarro, S., García-de-Lomas, J., Ruiz, A. and Fernández-de-Puelles, M.L., 2014. Plastic debris in the open ocean. Proceedings of the National Academy of Sciences, 111(28), pp.10239-10244.

20. Dias, B.D.S., 2016. Marine debris: understanding, preventing and mitigating the significant adverse impacts on marine and coastal biodiversity. CBD Technical Series, (83).

21. Worm, B., 2015. Silent spring in the ocean. Proceedings of the National Academy of Sciences, 112(38), pp.11752-11753.

22. Gall, S.C. and Thompson, R.C., 2015. The impact of debris on marine life. Marine pollution bulletin, 92(1-2), pp.170-179.

23. Good, T.P., June, J.A., Etnier, M.A. and Broadhurst, G., 2010. Derelict fishing nets in Puget Sound and the Northwest Straits: patterns and threats to marine fauna. Marine Pollution Bulletin, 60(1), pp.39-50.

24. Wilcox, C., Heathcote, G., Goldberg, J., Gunn, R., Peel, D. and Hardesty, B.D., 2015. Understanding the sources and effects of abandoned, lost, and discarded fishing gear on marine turtles in northern Australia. Conservation biology, 29(1), pp.198-206.

25. Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C. and Kaminuma, T., 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environmental science & technology, 35(2), pp.318-324.

26. Rochman, C.M., 2016. The role of plastic debris as another source of hazardous chemicals in lower-trophic level organisms. In Hazardous Chemicals Associated with Plastics in the Marine Environment (pp. 281-295). Springer, Cham.

27. Mathalon, A. and Hill, P., 2014. Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia. Marine pollution bulletin, 81(1), pp.69-79.

28. Alonso-Magdalena, P., Ropero, A.B., Soriano, S., García-Arévalo, M., Ripoll, C., Fuentes, E., Quesada, I. and Nadal, Á., 2012. Bisphenol-A acts as a potent estrogen via non-classical estrogen triggered pathways. Molecular and cellular endocrinology, 355(2), pp.201-207.

29. Lithner, D., Larsson, Å. and Dave, G., 2011. Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. Science of the Total Environment, 409(18), pp.3309-3324.

30. Lusher, A., Hollman, P. and Mendoza-Hill, J., 2017. Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms and food safety. FAO Fisheries and Aquaculture Technical Paper, (615).

31. Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear (No. 523). Food and Agriculture Organization of the United Nations (FAO).

32. Acoleyen, M., Laureysens, I., Lambert, S., Raport, L., van Sluis, C., Kater, B., van Onselen, E., Veiga, J. and Ferreira, M., 2013. Marine litter study to support the establishment of an initial quantitative headline reduction target. Final report–SFRA0025.

33. Acoleyen, M., Laureysens, I., Lambert, S., Raport, L., van Sluis, C., Kater, B., van Onselen, E., Veiga, J. and Ferreira, M., 2013. Marine litter study to support the establishment of an initial quantitative headline reduction target. Final report–SFRA0025.

34. Masó, M., Garcés, E., Pagès, F. and Camp, J., 2003. Drifting plastic debris as a potential vector for dispersing Harmful Algal Bloom (HAB) species. Scientia Marina, 67(1), pp.107-111.

35. Arias-Andres, M., Klümper, U., Rojas-Jimenez, K. and Grossart, H.P., 2018. Microplastic pollution increases gene exchange in aquatic ecosystems. Environmental pollution, 237, pp.253-261.

36. Yang, Y., Liu, G., Song, W., Ye, C., Lin, H., Li, Z. and Liu, W., 2019. Plastics in the marine environment are reservoirs for antibiotic and metal resistance genes. Environment international, 123, pp.79-86.

37. Royer, S.J., Ferrón, S., Wilson, S.T. and Karl, D.M., 2018. Production of methane and ethylene from plastic in the environment. PloS one, 13(8), p.e0200574.

38. Worm, B., Lotze, H.K., Jubinville, I., Wilcox, C. and Jambeck, J., 2017. Plastic as a persistent marine pollutant. Annual Review of Environment and Resources, 42, pp.1-26.

39. Worm, B., Lotze, H.K., Jubinville, I., Wilcox, C. and Jambeck, J., 2017. Plastic as a persistent marine pollutant. Annual Review of Environment and Resources, 42, pp.1-26.

40. http://marinelitternetwork.com/the-partnership/

41. https://sustainabledevelopment.un.org/partnership/?p=7462

42. https://cloma.net/english/

43. https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/

44. https://www.coastalcleanupdata.org

45. https://www.ghostgear.org

46. Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear (No. 523). Food and Agriculture Organization of the United Nations (FAO).

47. Good, T.P., June, J.A., Etnier, M.A. and Broadhurst, G., 2010. Derelict fishing nets in Puget Sound and the Northwest Straits: patterns and threats to marine fauna. Marine Pollution Bulletin, 60(1), pp.39-50.

48. https://www.theoceancleanup.com

49. Stafford, R. and Jones, P.J., 2019. Viewpoint–Ocean plastic pollution: A convenient but distracting truth?. Marine Policy, 103, pp.187-191.

50. Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear (No. 523). Food and Agriculture Organization of the United Nations (FAO).

51. http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx
52. Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear (No. 523). Food and Agriculture Organization of the United Nations (FAO).
53. https://www.nationalgeographic.com/environment/2018/11/china-ban-plastic-trash-imports-shifts-waste-crisis-southeast-asia-malaysia/
54. https://www.reuters.com/article/us-malaysia-waste-imports/malaysia-to-curb-imports-of-plastic-waste-minister-idUSKCN1N028P
55. https://www.ft.com/content/06b5a136-ce09-11e8-b276-b9069bde0956
56. https://www.independent.co.uk/environment/india-plastic-waste-ban-recycling-uk-china-a8811696.html
57. https://www.cbsnews.com/news/recycling-after-chinas-plastic-ban-american-cities-face-recycling-crisis/
58. http://time.com/5560105/european-union-plastic-ban/
59. https://www.nationalgeographic.com/environment/2019/04/plastic-bag-bans-kenya-to-us-reduce-pollution/
60. https://www.nytimes.com/2018/07/04/world/africa/somalia-shabab-plastic-bags.html
61. https://www.nationalgeographic.com/environment/2019/04/plastic-bag-bans-kenya-to-us-reduce-pollution/
62. Stafford, R. and Jones, P.J., 2019. Viewpoint–Ocean plastic pollution: A convenient but distracting truth?. Marine Policy, 103, pp.187-191.
63. Tiller, R., Arenas, F., Galdies, C., Leitão, F., Malej, A., Romera, B.M., Solidoro, C., Stojanov, R., Turk, V. and Guerra, R., 2019. Who cares about ocean acidification in the Plasticene?. Ocean & Coastal Management, 174, pp.170-180.
64. Novacek, M.J., 2008. Engaging the public in biodiversity issues. Proceedings of the National Academy of Sciences, 105(Supplement 1), pp.11571-11578.
65. Stafford, R. and Jones, P.J., 2019. Viewpoint–Ocean plastic pollution: A convenient but distracting truth?. Marine Policy, 103, pp.187-191.
66. Tiller, R., Arenas, F., Galdies, C., Leitão, F., Malej, A., Romera, B.M., Solidoro, C., Stojanov, R., Turk, V. and Guerra, R., 2019. Who cares about ocean acidification in the Plasticene?. Ocean & Coastal Management, 174, pp.170-180.
67. Schmidt, C., Krauth, T. and Wagner, S., 2017. Export of plastic debris by rivers into the sea. Environmental science & technology, 51(21), pp.12246-12253.
68. Eriksen, M., Lebreton, L.C., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G. and Reisser, J., 2014. Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. PloS one, 9(12), p.e111913.
69. Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear (No. 523). Food and Agriculture Organization of the United Nations (FAO).

Authors: Robert Blasiak and Patricia Villarrubia-Gómez

Affiliation: Stockholm Resilience Centre

Acknowledgements: The authors acknowledge support from the Walton Family Foundation, the David and Lucile Packard Foundation, and the Gordon and Betty Moore Foundation.

Graphics and layout: Jerker Lokrantz/Azote

Printed on 100% recycled, FSC certified paper.