A SCIENTIFIC SUMMARY

WHAT WE KNOW AND

Plastic pollution in the ocean

WHAT WE DON'T KNOW ABOUT

PRODUCED BY
Plastic and Ocean Platform

EDITED BY
thecamp

Summary

what is thecamp?

Open since October 2017 in Aix-en-Provence, France, thecamp is a base camp for exploring the future. It's a new focal point and meeting point that welcomes all kinds of explorer communities. A space where expeditions are planned to sound out and invent the future in a collaborative way.

Dedicated to emerging technologies (virtual reality, robotics, artificial intelligence, biotechnology) and social innovation (collective intelligence, sustainable economic models, shared governance), thecamp is a place for inspiration, exchanges, creation and experimentation on a large scale.

The future that thecamp wants to explore brings with it radical changes. It's a future in which we no longer think in a linear but a systemic way. In which we reinvent new ways of getting around, of using the planet's resources, of communicating, of growing, new ways of evolving and thinking about the world. It's a future in which people live together according to new paradigms, applying sustainable economic models, using collective intelligence to interconnect knowledge and disciplines, adopting disruptive and agile forms of governance.

what is waves ?

ECLECTIC COLLABORATIONS TO ELEVATE
THE HUMAN CONDITION

To address the challenges of our times and find concrete solutions that serve the general interest, thecamp launched the "waves" program which initiated this Ocean project.

"waves" brings together major groups, NGOs, politicians, artists, militants, public citizens, children...
We want to re-invent imageries, perceptions and pave the way for new paradigms shaping the world of tomorrow. That's why waves brings together forces working towards a same objective, building them into a strong, organized collective movement.

Each year, a few projects in line with development objectives from the UN, the OECD and the World Economic Forum are selected. Waves then operates in two phases of 6 months each: one for reflection and networking on and off campus; one for action and concrete applications on the field.

waves Manifest

1. Waves is aimed solely at social and environmental issues.
2. Its philosophy can be likened to a wave or a popular movement, always growing and irresistible.
3. A wave doesn't belong to thecamp. We are starting a movement in the hope that it spreads far and wide.
4. We encourage collaboration rather than competition and prefer success as a group to individual achievement.
5. A wave's value lies in its ability to bring together varied profiles, from expert to novice, scientist to campaigner, retired person to student, CEO to second grade...
6. All our projects are documented and open-source.
7. We dare to make a stand and propose a different vision, even if it breaks with convention.
8. Since no two waves are identical, we do not have a protocol but principles and values to which we are faithful.
9. There are already countless world-changing projects focusing on the subjects we deal with. Our role is not to replace them, but to link them together.
10. Everybody can join a wave. Let's do something bigger together.

Introduction

Plastic pollution is pervasive in world oceans and has gained large attention by the media, the public and the governments. The urgency of this issue was recognized by nearly 200 countries that signed in December 2017 in Nairobi the U.N. draft Resolution on Marine Litter and Microplastics. It encourages Member States and stakeholders to take action but despite acknowledging the problem, the resolution does not contain any legally binding agreement.

Meanwhile plastic litter continues to accumulate in world oceans. It has been estimated that 8 million tons (Mt) of plastic waste reaches the ocean each year, and with no action that volume is projected to double by 2030, and double again by 2050.

In order to tackle this issue, NGOs, startups, activists, public and private decision makers need correct information about the reality of plastic pollution in the sea, its impacts on marine ecosystems and human health.

Among the large quantity of information available, it is difficult to differentiate exaggerated alarms from miracle solutions, while taking into account unknown but potential risks of plastic pollution. Scientific evidence shows a complex reality.

In order to increase overall scientific literacy on plastic pollution, the associated risks and the possible solutions, thecamp, the new innovation campus located in Aix-en-Provence, France, has created the Plastic and Ocean Platform with the view of bringing together and promoting collaboration between scientists, NGOs and plastic experts.

The goal of the Platform, supported by the Intergovernmental Oceanographic Commission of UNESCO, is to facilitate the exchange of information and provide a clear and comprehensible overview of the current scientific knowledge and understanding about plastic pollution and the way to fight it. This information will be shared widely to the media, the general public and the decision makers.
As of today, more than 30 international research scientists and 20 NGOs have contributed to the Plastic and Ocean Platform. We are now expanding this network.

The first production of the Plastic and Ocean Platform is a state of the art on what is known and what is not known about plastic pollution. Following a collective work with the NGOs, the scientists have produced a **scientific summary** that gives synthetic answers to the most common questions the public is asking on the reality of plastic pollution and its consequences.

The summary focuses on three themes:

- Sources, distribution and fate of plastic pollution in the ocean;
- Impacts of marine pollution on marine ecosystem and environmental and human health;
- Analysis of proposed measures to address plastic pollution in the ocean.

It also provides references to the scientific literature on which the information is based.

Scientific research continues and as new information will become available, new versions of this scientific summary will be made. This evolving common vision should be a basis to build new collaborations and science-based actions.

This executive summary is edited by thecamp - 550, rue Denis Papin – 13100 Aix-en-Provence, France – thecamp.fr
Coordination : Jean-Ronan Le Pen – Ocean project manager – jean-ronan@thecamp.fr
Review edits and rewriting : Tosca Ballerini – Marine biologist - toscaballerini@gmail.com

The lead authors of the executive summary:
Anthony Andrady - North Carolina State University - anthonyandrady@gmail.com
Matthew Cole - Plymouth Marine Laboratory - mcol@pml.ac.uk
François Galgani – Ifremer - francois.galgani@ifremer.fr
Mikaël Kedzierski - Université de Bretagne Sud - mikael.kedzierski@univ-ubs.fr
Maria-Luiza Pedrotti – Observatoire Océanologique de Villefranche-sur-Mer - pedrotti@obs-vlfr.fr
Alexandra Ter Halle – Université de Toulouse - ter-halle@chimie.ups-tlse.fr
Kim Van Arkel – Marine biologist - kim.vanarkel@raceforwater.org
Erik Zettler – NIOZ-Royal Netherlands Institute for Sea Research - erik.zettler@nioz.nl

Scientists involved in the Plastic and Ocean Platform:
Linda Amaral-Zettler - NIOZ-Royal Netherlands Institute for Sea Research ; Jennifer Brandon - University of California San Diego ; Stéphane Bruzaud - Université de Bretagne Sud ; Gael Durand - Labocea, Brest ; Enrik Enevoldsen - COI-Unesco ; Marcus Eriksen - 5 gyres ; Pascale Fabre - Université de Montpellier ; Maria-Christina Fossi - Università degli Studi di Siena ; Laura Frère - IUEM/Ifremer, Brest ; Carlo Giacomo Avio - Università Politecnica delle Marche ; Denis Hardesty - University of Tasmania ; Jenna Jambeck - University of Georgia ; Kara Lavender-Law - Sea Education Association ; Jeremy Mansui - Université de Toulon ; Emmanuel Nafrechoux - Université Savoie Mont Blanc ; Christian Schmidt - Helmholtz Centre for Environmental Research ; Richard Sempéré - Institut Méditerranéen d'océanologie ; Martin Thiel - Universidad Catolica del Norte, Chile ; Richard Thomson - Plymouth Marine Laboratory ; Chris Wilcox - University of Tasmania ; Pascal Wong-Wha-Chung - Université de Aix-Marseille

Organizations involved in the Plastic and Ocean Platform:
7th Continent Expeditions - Expédition Med – Innovations Bleues - Mer-Terre – Ocean Conservancy - Oceaneye – Oceans sans plastiques – Plastic Odyssey Expedition – Palana Environment – Pôle Mer Méditerranée - Race For Water - Surfers agains Sewage - Surfrider Foundation Europe – The Sea Cleaners – ZEA

Supported by the Intergovernmental Oceanographic Commission of Unesco

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source, *distribution* and fate of plastic pollution in the ocean

Q1: What are the sources of plastic pollution in the ocean?

Plastic represents today between 45 and 95% of marine litter (Ioakeimidis et al., 2014; Nicolau et al., 2016; Topçu et al., 2013). Because of their physical and chemical properties, plastic polymers are commonly used in a wide range of products and total plastic production has increased from 2 Million tons (Mt) per year in the 1950 to 380 Mt per year in 2015 (Geyer et al., 2017). Considering different types of plastics (polymer resins, synthetic fibers, and additives) it is estimated that a total of 8 billions tons of plastic materials have been manufactured since 1950 (Geyger et al., 2017). About 30% of this material is still in use, 10% has been incinerated and the remaining 60% (corresponding to 4900 Mt) has been discarded and is now landfilled or lost in the natural environment, including the ocean.

The largest inputs of plastic waste to the ocean come from coastlines of Asia, mainly China, and the United States (Jambeck et al., 2015). Data from 2010 show that the regions within 50 km from the coast concentrated 36% of the plastic waste produced worldwide (Jambeck et al., 2015). About one third of this plastic waste is mismanaged, which facilitates its transfer to the ocean. Among the average of 8.3 Mt (4.8 to 12.7 Mt) of the total plastic waste transferred to the ocean in 2010, the plastic input due to river transport, is evaluated between 1.15 and 2.41 Mt of plastics every year, corresponding between 9 and 50% of total plastic transport to the ocean (Lebreton et al., 2017). Around 90% of this input from river is estimated to come from only 10 rivers in the world (Schmitt et al., 2017).

In 2015, the three industrial sectors most responsible for plastic waste production were packaging (46.7%), textiles (13.9%) and the consumer-institutional product sectors (12.3%) (Geyer et al., 2017).

Q2: Are there real "Garbage Islands" or "Garbage Patches" in the ocean?

Garbage Island and Garbage Patch are popular terms used to refer to places in the ocean with high concentration of plastic corresponding to subtropical gyres, but there are no actual «islands» of garbage. These gyres are formed by wind-driven ocean circulation causing convergence zones where floating objects accumulate. Subtropical gyres tend to trap debris (of natural or of anthropogenic origin), as well as plankton and seaweed originating from sources along the gyre (Goldstein and Goodwin, 2013).

Data from circumnavigations and regional surveys shows that plastics and other waste have accumulated in five large subtropical gyres in the world's oceans (North and South Pacific, North and South Atlantic, and Indian Ocean) and that they may remain trapped in these gyres for many years (Cózar et al., 2014; Eriksen et al., 2013; Law et al., 2010). These accumulation areas are characterized by high concentration of plastic particles between 1 mm and 5 mm called microplastics that accumulate at the sea surface or are suspended throughout the water column. Despite the high concentration of microplastic particles, these zones are barely visible and for this reason the terms "island" or "patch" are inaccurate to describe them.

The full geographical extent and the amount of plastic trapped in the subtropical gyres are not yet determined, however, numerical model simulations allowed to estimate that 15 to 51 trillion microplastics particles float in the oceans (van Sebille et al., 2015). About one third of all this plastic (12 to 35 million tons) is though to be trapped in the Great Pacific Garbage Patch (GPGP) (Eriksen et al., 2014; Law et al., 2010).

Besides the subtropical gyres, high levels of plastic pollution have been found in other regions of world oceans. In the Mediterranean Sea, plastic concentration in surface waters varies between 100,000 to 1,000,000 particles by km2, a concentration similar to that found in the subtropical gyres (Pedrotti et al., 2016; Suaria et al., 2016) and that makes of this closed sea the sixth great accumulation zone for marine litter in the world (Cózar et al., 2015). Another region microplastic density comparable to that found in the tropical gyres is the Gulf of Bengal (Eriksen et al., 2014). Although in lower concentration, plastic pollution has also been recorded in regions previously considered pristine, such as the Greenland Sea and the Barents Sea in the Arctic (Cozar et al. 2017).

Q3: How much plastic is there in the ocean?

Using data on production and on analysis of end-of life for polymer resins, synthetic fibers and additives produced, it is estimated that every year, an average of 8 million tons (4-12 Mt) of plastic waste enter the ocean from land-based inputs (Jambeck et al., 2015). However, the ocean is under sampled and the overall amount of plastic present in different ocean compartments is currently unknown. Once plastics get into the ocean, they undergo several processes of

degradation (photodegradation, mechanical stress by the action of waves action, biodegradation by microorganism) that fragment large plastic items and lead to the formation of microscopic plastic particles.
Most of the data on the abundance and mass of plastic particles in the ocean have been collected with trawled nets that were originally developed to sample plankton at the surface of the ocean. These nets generally have a mesh size of 330 or 200 µm and do not efficiently sample smaller fragments. In addition, until recently researchers have focused their attention mostly on microplastics, fragments between 1 and 5 mm that are large enough to be counted by eye. Using observational data and ocean models, a first global estimation of the total amount of small plastic fragments floating at the surface of the oceans has been carried out and indicated that the total weight of plastic fragments (ranges between 93,000 and 236,000 Mt (van Sebille et al. 2015). This estimated amount of microplastic at the surface of the ocean represents approximately 1% of the 8 million Mt of plastic waste that are estimated to enter the ocean from land-based inputs each year (Jambeck et al., 2015). The difference between these estimates reflects the current lack of knowledge on the distribution at sea and of the fate of plastic once it enters the ocean.
Detection and quantification of smaller plastic fragments at the micrometric scale (between 1-1000 µm) and at the nano scale (smaller than 1000 µm) is more difficult and methods are still being developed and tested (Enders et al., 2015; ter Halle et al., 2017). For this reason, very few data are available on their abundance and it is not possible to estimate the mass of plastic fragments at the macrometric and nanometric scales in world oceans. However, one study conducted in the North Atlantic that considered size classes from 10 to 690 µm showed that micrometric plastic particles are much more abundant than microplastics (Enders et al. 2015).
Once in the water, plastic particles are soon colonized by marine organisms that create a biofilm at the surface of the plastic which can modify their floatability and favor their sedimentation (Lobelle and Cunliffe, 2011). The majority of microplastic particles found at the surface of the ocean are plastic polymers with a lower density than sea-water (such as polyethylene and polypropylene) that allows them to float at the surface. However, fragments of plastic from denser polymer types don't float and can be found in the water column and in the sediments. Currently, data are missing on plastic concentration in the water column and in sediments. Data from international coastal cleanup efforts (Ocean Conservancy), the annual beach clean in 2014 accounts for approximately 7,000 tons of trash. Added to estimates of microplastics at the surface of the ocean, (Eriksen et al.,2014) this represents approximately 3.0 to 3.5% of annual plastics that arrives to the ocean each year (Jambeck et al.,2015). Marine organisms such as plankton, filter feeders and fish are eating plastic particles (Cole et al., 2015; Van Cauwenberghe and Janssen, 2014), which might account for some of the discrepancies observed.

The challenges are to quantify how much is of the «missing plastic» in each of these marine reservoirs - the deep sea, the banks and the biota as we still don't know where more than 95% of ocean plastic debris ends up. Estimates of the amount of plastic that enters in each ocean compartment is necessary in order to be able to estimate the potential impacts of plastic pollution on marine ecosystems.

Q4: What is the average usage-time of plastic items?

The use lifetime of plastics varies depending on the industrial use sectors (Geyer et al., 2017). For packaging the average lifetime is generally half a year. For electrical and electronic, a textile, consumer and institutional products, the lifetime is between 1 and 10 years. Plastics used in transportation sectors, industrial machinery, building and construction are more durable with a lifetime comprised between 10 and 50 years (Geyer et al., 2017).

Q5: What is the persistence of plastics in the natural environments?

Plastics materials are known for their stability and durability. This property made them very popular in a wide range of use (Webb et al., 2013). The counterpart is that they become persistent wastes once they have no more utility. Finally, if they end up in the environment they will persist decades or even longer. Once in the environment they undergo photodegradation, with temperature and oxygen they endure thermooxydative degradation, in the presence of water they undergo hydrolytic degradation and finally some microorganisms and organisms can biodegrade them (Andrady, 2011). The rate of plastic degradation is a function of the natural environmental characteristics where the plastic ends up. Furthermore, the degradation duration also varies as a function of plastic intrinsic properties and of additives. The characteristics (e.g. size, mass, shape) of the plastic artifacts can also have an important impact on the plastic degradation.

These different reasons make it difficult to give a global overview on the duration of plastics in natural environments. However, the study of different cases can give some indications on the degradation of plastic. In wet soil poly(ethylene terephthalate) bottles can persist between 35 and 180 years before their disaggregation in microplastics due the loss of intrinsic viscosity (Allen et al., 1994; Edge et al., 1991). The plastic degradation can be lower if the oxygen availability is limited (Massardier-Nageotte et al., 2006) or if humidity is low (Allen et al., 1988). In sea water, photodegradation, which generally starts the degradation process, is significantly reduced. Furthermore, lower temperature and oxygenation, a low hydrolysis rate and sometimes a lack of nutrients, as potassium and phosphorous, make sea environments less favorable to plastic degradation. Thus, even if the plastic degradation process can begin few weeks after the entering into the marine environment (Kedzierski et al., 2018), the full degradation process last between few decades and few centuries and probably far more in deep-sea conditions due to the absence of light, low temperature and oxygenation (Barnes et al., 2009; Ioakeimidis et al., 2016; Shaw and Day, 1994). As a comparison, natural organic materials such as wood or pollen, which have higher degradation rate than plastics, can be preserved over millennia in such environments (Blanchette et al., 1991; Boswijk et al., 2006; Haberle and Maslin, 1999).

Q6: Is the amount of plastics in the ocean increasing?

Plastics production reached 320 million tons in 2016 and is expected to steadily grow by an average of about 4 % each year (Plastics Europe, 2016). The constant increase in plastic production followed by a continuous supply of waste in oceans is expected to continue the long-term accumulation of plastic in marine ecosystems.

Available data show an increase in floating microplastics concentration in Atlantic Ocean the 1960s and 1970s, and 1980s and 1990s (Thompson et al., 2004), but nothing significant for the following decades in the main trash zones of the North Pacific and Atlantic (Law et al., 2010; Law et al., 2014). Despite the exponential production of plastics and therefore waste for several decades, the absence of accumulation of floating plastic over time can be explained by the multiple physical and biological processes explained above but also by the intrinsic properties of plastics that regulate their fate in aquatic systems.

It remains however difficult to predict the evolution of the pollution of the ocean surface in the long term because the zones sampled are not always the same, not all oceans / regions are sampled and the scientific community has not yet developed suitable analytical tools to measure the amount of plastic in the whole water column nor in the sediments.

2

Impacts of plastic pollution on marine ecosystems and environmental and human health

Introduction

Plastic pollution poses an increasing issue for marine life.
The risks to wildlife fall into one of three categories:

① Physical harm from plastic items (e.g. entanglement, irritation/blockage/perforation of the digestive system, suffocation/damage to benthic systems);

② Chemical harm from toxic chemicals associated with plastic (additives, persistent organic pollutants);

③ Biological harm from microorganisms that adhere to plastics.
Plastic is just one type of floating substrate in the ocean, but it is unique in a number of ways that make it particularly worrisome:

❶ the concentration is increasing rapidly and is difficult to control;

❷ it has toxic chemicals incorporated during manufacture and a hydrophobic surface that absorbs additional persistent organic pollutants;

❸ it is rapidly colonized by marine microbes including some harmful species; and

❹ it is very long-lived so that it can transport these toxic chemicals and harmful species long distances, potentially across entire ocean basins.

Q1: What animals eat marine plastic litter and why?

Animals including plankton, fish, shellfish, seabirds, turtles, and whales have all been shown to eat plastic in the wild; this may be due to indiscriminate ingestion of any particle, or active selection because the plastic looks, smells, or tastes like food (see Q.6 below). Plastic consumption can be direct (e.g. turtles may mistake plastic bags for their natural prey of jellyfish) or indirect (e.g. if a mussel eats some plastic, and then a crab eats that mussel, the crab will end up with the plastic in its stomach). Some plastic that is ingested may pass through the digestive system, but some is retained and may cause harm. Seabirds, turtles and whales washing up dead on beaches with stomachs full of plastic provide an indication of how bad plastic can be for marine life. While the effects of plastic on single organisms are quite well documented, the impact of accumulating plastic marine debris (including the smallest fragments of micro- and nanoscopic dimensions) on environmental and human health are still relatively unknown.

Q2: What are the effects of ghost fishing and other plastic debris on marine life entanglement?

In 2009, abandoned, lost or discarded fishing gear in the oceans was estimated at 640,000 tons, corresponding to 10% of all marine litter (Macfadyen et al., 2009). Abandoned or lost fishing gear (e.g. line, nets, traps) can continue to trap fish, and also entangle other animals, impairing their growth and reproduction and eventually causing them to starve or drown. At least 44 sea bird species, 9 cetacean species, 11 pinniped species, 6 turtle species and 31 invertebrate species have been documented to suffer entanglement in larger pieces of plastic debris (NOAA, 2014).

Q3: What are the effects of microplastics on marine organisms?

Microplastics can interfere with the ability for an animal to feed, and this in turn can have an impact on their ability to function normally, grow and reproduce. Many laboratory studies indicate a negative effect of microplastics on the health of the individual used for laboratory experiments. In oysters, polystyrene microparticles caused a reduction in energy uptake and allocation, reproduction, and offspring performance (Sussarellu et al. 2016). In copepods, polystyrene microplastics incited reduced algal feeding with negative consequences for survival and egg hatching success (Cole et al. 2016). In sediment-dwelling worms, polyvinylchloride microplastics caused a reduction in energetic reserves and functionality (Wright et al. 2015). Through its impact on organisms, plastic may alter the functioning of marine ecosystems. For example, animals have vitally important roles in transferring carbon down to the ocean depths and in aerating sediments; scientists are concerned that high levels of microplastic pollution could impact the ability for these animals to carry out these functions.

Q4: What are the effects of nanoplastics on marine organisms?

Nanoplastics (fragments of plastic with at least one dimension smaller than 100 nm) can be found in the water as single particles or aggregates of particles. Research on nanoplastics is still scarce and it is currently unclear what health risks they represent for marine organisms. The available data show some evidence that once ingested, these particles can pass from the intestines into an animal's circulatory system and generate an immune response (von Moos et al. 2013). In one laboratory experiment nanoparticles were able to pass into the food web, from algae, to zooplankton and then to fish, where they entered the brain and incited behavioural disorder (Mattson et al. 2017). In nature, animals are likely exposed to low concentrations of plastic nanoparticles during their whole life-time.

Q5: What are the chemical hazards related to plastic?

Plastics contain a mix of chemicals added during their manufacture to give them special properties, such as flame-retardance or anti-microbial resistance. In addition to these additives, microplastics have been shown to adsorb or "mop up" man-made chemical pollutants including POPs (Persistent Organic Pollutants) commonly found in the environment. These additives and POPs include harmful chemicals such as flame-retardants (various types of compounds), DDT (dichloro diphenyl trichloroethane, was one of the first synthetic insecticides that was banned in Europe and the US), PCBs (polychlorinated biphenyls), PAHs (polycyclic aromatic hydrocarbonsand other persistent organic pollutants. There are concerns that after ingestion, the additives and POPs might be released, causing a toxic risk to the animals that consumed the plastic. Transfer and accumulation of harmful chemicals associated with plastic has been demonstrated in laboratory experiments and it is expected to occur within marine food webs. However, it is unclear to what extent this occurs in the ocean and whether the concentration of toxic chemicals associated with plastic are significant relative to other sources such as polluted water or contaminated food. Consequently, the trophic transfer and accumulation (biomagnification) of toxic chemicals associated with plastic in the ocean is probable but difficult to assess at this stage.

Q6: Does plastic carry invasive species and diseases

Plastic is a persistent material that can travel long distances in the oceans carried by currents. Immersed in seawater, plastic within hours will begin to develop a microbial biofilm, which in turn increases the likelihood of settlement by other organisms, as well as ingestion by animals that use smell and taste in selecting food. Plastic marine debris has been shown to transport and transfer several types of organisms, including algae that can produce harmful algal blooms (HAB), diseases (including potential human pathogens) and parasites. It was estimated that human litter more than doubles the rafting opportunities for marine organisms, facilitating the dispersal of non-indigenous species. For example, of the nearly 300 species, mainly invertebrates, that reached the shores of the U.S. Pacific Northwest following the 2011 East Japan earthquake and tsunami, most arrived attached to the remains of manmade structure floating across the Pacific Ocean (Carlton et al., 2017). The transport of HAB species on plastic was observed via microscopy in the Mediterranean as early as 2003 Masó et al.), and has been confirmed with molecular results from other areas of the ocean. Outbreaks of HABs affecting wild caught and aquaculture shellfish is increasing globally and presents a real threat to food security, food safety, and economies of shell fishermen. More recently, the presence of Vibrio bacteria and other potential pathogens (sometimes in high concentration) has been noted on plastic (Zettler et al. 2013, Viršek et al. 2017). Unlike contamination from toxic chemicals, where low concentrations on plastic make the impact uncertain, with microbial contamination, a relatively small number of bacteria introduced to an organism can multiply quickly and cause infection. Most marine bacteria (including many types of Vibrio) are harmless, but several species can cause disease in humans, finfish, shellfish, crustaceans, and corals. Plastic in the ocean shows a significant correlation with coral disease: 89% of corals with trapped plastic had visual signs of disease, compared to a 4% disease rate for corals without plastic (Lamb et al. 2018). Aquaculture facilities may be particularly at risk to plastic-borne pathogens because animals are crowded and stressed, and disease is one of the major sources of loss in aquaculture facilities. In addition, much of the gear used in modern aquaculture practices including nets, floats, lines, and cages are constructed of or contain plastic. Many invertebrates from crabs to marine insects are associated with plastic marine debris, so the potential to transport other organisms such as parasites is possible but unknown. Most plastic marine litter originates on land and before reaching the ocean moves through some of the most polluted waters on our planet, such as urban rivers and coastal waters off areas with high human populations. The prevalence of harmful organisms on plastic and the survival of human pathogens from sewage treatment plants once they reach marine systems are unknown.

Q7: Does marine litter represent a public health issue?

Marine litter, beached or floating, is considered a public health issue. Beside the disturbance to humans associated with propeller fouling and blocked intake pipes, debris may affect humans directly from a molecular (toxicity) to an individual level. Pieces of glass, metal fragments, discarded syringes and medical waste may harm beach users. In some areas, up to 4% of reported injuries due to hypodermic needles occur on beaches. However, evaluating harm is difficult as many incidents go unrecorded. Entanglement can also pose a threat to swimmers, and divers who can become entangled in submerged or floating debris such as fishing nets and ropes. Loss of life resulting from ship damage by propeller entanglement has also been recorded, and incidents of injury to maritime workers may be much higher, considering the frequency of coast guard call outs and ship maintenance works arising from blocked intakes, entangled propellers or collision with larger debris items. Floating debris represents a navigation hazard and has been implicated in many accidents, some resulting in fatalities (UNEP, 2016).

Q8: Is there a health hazard for humans eating seafood?

Microplastic have been found in the guts of marine species (including samples taken from commercial markets) that humans consume as food (e.g. shellfish, fish), but it is unknown whether this presents any measurable hazard to humans at current levels of contamination, particularly given the many other sources of exposure to toxic chemicals in modern life (food, air, and water). Human ingestion of plastic via seafood is probably more common for shellfish and small fish that are eaten whole, including the gut, and less frequent for large fish of which generally only the flesh is eaten. More recently the potential risk of nanoplastics (<100 nm in at least one dimension) in seafood is being recognized. Compared to microplastics, nanoplastics have an increased mobility in the tissues of living organisms and their larger surface to volume ratio increases the potential concentration of harmful chemicals they can absorb. The marine distribution and impact of plastic nanoparticles are relatively unknown, but these tiny particles have been shown to translocate to the lymph and possibly to the brain and other tissues of marine organisms. This presents an unknown risk to marine organisms as well as to humans who consume seafood.

Conclusions

The increasing quantity of plastic in the ocean poses many potential risks to humans and marine organisms, ranging from toxic chemicals to harmful organism that attach to drifting plastic and can cause diseases. However, we do not know yet the relative risk posed by these threats or whether plastic marine debris is harming marine organisms or humans via toxic chemicals or diseases. We tend to be most concerned about risks to humans, but we are just one species that may be negatively impacted by the increasing amount of environmental plastic. The more scientists search, the more marine species we realize are interacting with and potentially impacted by plastic marine debris. We know that plastic in the ocean impacts hundreds of species; many of these are of direct importance as food and especially protein sources, while others such as corals and other invertebrates provide important ecosystem functions that maintain balance and indirectly benefit society. Because of the lack of information about the impact of environmental plastic on environmental and human health, an important priority should be to assess the plastic-associated risk for environmental and human health.

3

Analysis of proposed measures to address plastic pollution in the ocean

Q1: Is biodegradable plastic good for the oceans?

The term 'biodegradable' describes a material that, under certain circumstances and with the help of micro-organisms, can biodegrade into natural components (water, carbon dioxide and / or methane, new biomass). The speed of degradation of a material depends its chemical composition, its morphology and external conditions like light, temperature, presence of oxygen and quantity and type of micro-organism involved (i.e. bacteria /fungi).

Biodegradable plastic, as defined in most of the world, requires specific conditions such as heat and soil-dwelling microbes and bacteria to fully biodegrade. Such conditions do not exist in many ocean environments, and therefore plastic that might otherwise be biodegradable in industrial composters does not biodegrade once it enters the marine environment. Both "industrially compostable" and "home compostable" materials are clearly defined whereas the term "biodegradable packaging" is very broad and not informative.

Q2: Is there hope for new types of plastics to solve plastic pollution in the ocean?

The term 'bioplastics' is often loosely used to refer to plastics that are bio-based, biodegradable, compostable or all of these things. To prevent confusion, it is necessary to clearly distinguish a material's origin from its available after-use options.

The term 'biodegradable' describes a material can biodegrade into natural elements with the help of micro-organisms. The term 'compostable' describes a material that is suitable for the after-use pathway of home composting or industrial composting and follows officially defined criteria for the respective environment. The term 'bio-based' describes a material that is wholly or partly derived from biomass resources. Not all bio-based plastics are compostable. Some bio-based plastics are designed for the technical cycle and can be recycled, others are designed for the biological cycle and are industrially compostable; others are both recyclable and industrially compostable. In addition, not only bio-based plastics are compostable. There also some types of fossil-based plastics that are industrially compostable.

Oxo-degradable, oxo-biodegradable or Pro-oxidante Additive Containing (PAC) plastics are conventional plastics commonly used in carrier bags, which also include additives designed to promote the oxidation of the material to the point where it embrittles and fragments. This may be followed by biodegradation by bacteria and fungi at varying rates depending upon the environment. A study conducted for the European Commission (EUNOMIA, 2017) showed that this type of plastics is not suitable for any form of composting in the absence of oxygen. PAC plastic can in fact biodegrade under certain circumstances in the open environment, but there is doubt as to whether they do so fully of within a reasonable time period in practice. As of today, there is insufficient assurance that PAC plastic will biodegrade in the marine environment and there remains a risk that plastic fragments may persist either indefinitely, or for long enough to cause significant environmental damage. PAC plastics are more likely to fragment than conventional plastic, which is thought to exacerbate the issues related to microplastics.

Q3: Is it feasible to clean up the Ocean?

Following the increased public attention on the issue of plastic pollution in the ocean, numerous ideas and projects have seen the day that propose to recover plastic from the ocean. Some of the initiatives include ocean clean up arrays, various types of plastic eating drones and of vessels that propose to remove plastic litter from the surface of the ocean. These methods only target surface floating plastic fragments and generally are not able to collect plastic particles smaller than 1 cm. This means that they leave out more than 99% of plastic estimated to be in the ocean. None of these methods has yet been proven.

By-catch and the unintended killing of passively floating organisms that can't swim away is an issue around any cleanup proposal and there is concern that these methods may cause more harm than good.

Using data on production and on analysis of end-of life for polymer resins, synthetic fibers and additives produced, it is estimated that every year, an average of 8 million tons (4-12 Mt) of plastic waste enter the ocean from land-based inputs (Jambeck et al., 2015). The amount of plastic that can be removed by ocean arrays, plastic eating drones and vessels is an infinitesimal part of all the plastic that enters the ocean.

Q4: Is marine litter recoverable?

Various plastic recycling technologies are available or under development. Although these technologies can be effective for recycling industrial and domestic waste plastics, some technical and economic issues arise when applying these methods to treat plastic marine litter, especially for material and chemical recycling.
Technical issues: Since marine litter includes various plastic types, the collected litter must be sorted into the same plastic types for recycling; Even for the same plastic types, the composition or quantity of additives used may differ among plastic manufacturers. In this case, recycling must be conducted separately; Materials of some plastic marine litter are difficult to identify, making it hard to select the appropriate recycling method; Painted and specially coated plastic must be pretreated (i.e. removal of painting and coating) prior to recycling; Foreign objects, such as sand, dirt and marine organisms, must be removed prior to recycling; The quality of some plastic marine litter may be unsuitable for recycling due to degradation by marine environment exposure, including ultraviolet radiation.
Economic issues: There is a general lack of recycling plants; It is difficult to sustain a constant supply of plastic marine litter; It requires time and effort (i.e. additional cost) to separate recyclable and non-recyclable plastics; It requires time, effort (i.e. additional cost) and experience to sort plastic into different types; It requires time and effort (i.e. additional cost) to untangle and remove foreign objects from fishing nets and rope; Some plastics incur high transportation costs; The price differences between recycled and virgin material are narrowing (i.e. less incentive in using recycled material); Other treatment methods are often less time consuming and costly.
Contrary to material and chemical recycling, thermal recycling of plastic marine litter does not require rigorous sorting, and plastics can be mixed with other wastes. However, some general issues still remain such as: Plastics with high moisture and salt content are unsuitable for incineration because of possible damage to the furnace; Some plastics (e.g. plastics coated with flame retardant) may emit harmful chemical substances when incinerated; Further treatment of incineration ash is required in some cases.

Q5: Are there bacteria and worms that can degrade plastic?

The larvae of the greater wax moth (*Galleria mellonella*), can eat polyethylene, which along polypropylene is the main type of plastic found in waste. One worm can eat about 2 mg of plastic a day. You'd need billions of caterpillars eating constantly all year round to deal with the plastic problem. As their name says, these moths eat wax and specifically they love wax from which bees make their honeycombs, so they can devastate bee colonies.
In 2016 a team of Japanese scientists identified and named a bacterium (*Ideonella sakaiensis*) existing in the wild that can feed on PET (polyethylene terephthalate), another common plastic which is used to make bottles for soft drinks and water. The bacterium seems to feed exclusively on PET and breaks it down using just two enzymes. It must have evolved the capability to do this because the plastics were only invented in the 1940s.
The bacteria could be brewed up in fermentation vats that would dissolve plastics or it might be possible to extract the particular enzymes the caterpillars use and put them to work on their own – a kind of concentrate of gastric juices. But these options have not yet been tested or experimented.

Q6: What is the Plastic Circular Economy?

The concept of a circular economy (CE) has been first raised by two British environmental economists David W. Pearce and R. Kerry Turner in 1989. In "Economics of Natural Resources and the Environment, they pointed out that a traditional open-ended economy was developed with no built-in tendency to recycle", which was reflected by treating the environment as a waste reservoir. Circular economy is a model in which recycling is a valuable activity which imply a closed loop to severely restrict both the use of new raw materials and the production of residual waste.
The report "New Plastic Economy" (WEF et al. 2016) addresses the circular economy to plastic demonstrating that the linear economic system is more polluting with all its point of leakage along the supply chain compared to the circular system. Also, the report was the first of its kind to consider the economic and business opportunity for the transition to a restorative, circular model for plastics.

Q7: what are the short-term and long-term measures to stop plastic pollution in the ocean?

According to UNEP the most urgent short-term solution to reducing plastic inputs into the ocean is the improvement of wastewater and solid waste collection and management. This is especially true in developing economies. Reducing mismanaged plastic waste mainly requires implementing adequate infrastructure and waste management practices as well as educating behaviours of consumers. Technologies are readily available and the challenge is more a political and financial one.
On the longer term, a more sustainable solution will be moving towards a more circular economy, in which waste is designed out of the production and use cycle, and society adopts more sustainable consumption patterns. For example: reduce the use of single-use plastic items, and phase out microbeads in cosmetics and other products where it can be substituted with non-harmful alternatives. Closing the plastic tap will require design and implementation of both technological, behavioural and policy solutions considering plastics and products over their whole lifecycle to reduce plastic losses during production, use, maintenance or end of life of products and releases to the world ocean. This eco-design approach requires a systemic lifecycle management approach and dialogue with all stakeholders from product design to urban infrastructure planning both from private and public sectors (UNEP 2016 a, b).

4

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Sources, distribution and fate of plastic pollution in the ocean

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5

Key messages

Sources, distribution and fate of plastic pollution in the ocean

1 Among the 8 billion tons of plastic produced since 1950, 60% have been discarded in landfills or in the natural environment. In some compartments of the marine environment, plastic represents up to 95% of marine litter.

2 Plastic waste from land represents the predominant contributor of marine plastic litter; it has been estimated that an average of 8,3 million tons of marine plastic stems from land-based sources each year. The amount of plastic waste discarded directly into the marine environment is difficult to ascertain.

3 Rivers act as conduits between the land and sea, and have been estimated to contribute 1.15–2.41 million tons annually; around 90% of this input from rivers is estimated to come from 10 rivers in the world.

4 Once in the environment, plastic can break down into smaller pieces—including large microplastics (1 – 5 mm) small microplastics (25 μm – 1 mm) and nanoplastics (<1000 nm). Currently, we have very few data about small microplastic occurrence in the ocean, as for nanoplastic data are even scarcer.

5 Plastic microbeads manufactured as exfoliating particles in cosmetics will invariably end up in wastewater, and can eventually find their way out into the ocean. However, secondary microplastics can derive from a vast range of sources, including tire wear, paints, synthetic clothing and the degradation of larger plastic.

6 There are five zones of high accumulation of plastic debris in correspondence of subtropical oceanic gyres (North and South Pacific, North and South Atlantic, and Indian Ocean). Other zones with high plastic concentration, not stable but variable in time, have been found in the Mediterranean Sea and the Gulf of Bengal.

7 Labelling the subtropical gyres as "garbage patches" or the "seventh continent" is misleading. These regions coalesce large numbers of microplastics floating at the sea surface or suspended throughout the water column, however they are barely visible to the naked eye and do not form a solid continuous mass.

8 It has been estimated that 1% of the plastic that entered the ocean is today present at the sea surface as large microplastics. The rest might have broken down into smaller particles, have been ingested by marine organisms, have been redeposited on shores or has sunk in the water column and it is now resting at the seabed.

Impacts of plastic pollution on marine ecosystems, environmental and human health

9 All marine ecosystems are affected by plastic debris. The physical effects (suffocation, entanglement, ingestion) depend on the size of the animal and the size of the plastic.

10 Microplastics are usually excreted after ingestion but laboratory experiments have shown that at high doses microplastics are retained within an animal's intestinal tract and can transfer from a prey organism to a predator. Experiments have also demonstrated that nanoplastics can pass across cellular membranes and might translocate to tissues. It is currently unclear to what extent these phenomena might occur in the marine environment, where the observed concentrations of plastics are lower than in the experimental settings.

11 Plastics contain a suite of toxic additives and can accumulate persistent organic pollutants from their surroundings. Small doses of these chemicals can affect the hormonal balance in animals and can accumulate up the food chain. It is currently unknown to what extent plastics contribute to contamination of marine organisms in respect to seawater, the main source for persistent organic pollutants and other toxic chemicals.

12 Negative effects of plastic on individuals may have consequences at the ecosystem level. For example, reduced growth, reproduction and survival can limit population size. These populations can have vital roles in carbon fluxes in the ocean-atmosphere system and for populations (including humans) depending on them.

13 Plastic debris can transport microorganisms and invertebrates over long distances. Rafting on plastic can facilitate dispersal of potentially invasive species outside of their natural environment. Plastic can also transport pathogenic microorganisms and offer a substrate over which they can concentrate over time.

14 The effects of plastic pollution on human health are relatively unknown. There is widespread evidence of seafood being contaminated by microplastic, and nano- and microscopic plastics are prevalent in the air we breathe, but the effects this might have on humans are untested.

How to get rid of the plastic pollution in the ocean?

15 The degradation time for plastics varies greatly, being dependent on the intrinsic physiochemical characteristics of the plastic, environmental parameters such as light intensity, temperature, salinity and humidity, and the presence of micro-organisms (fungi and bacteria). This complexity makes it difficult to predict plastic degradation rates in the natural environment. Estimates of plastic degradation times in the marine environment vary between a few years and a few centuries; in some cases (in sediment, in cold water, without light, without oxygen) the degradation of certain plastics might take much longer.

16 There is limited scientific evidence regarding degradation rates of plastic that is commercialized as "biodegradable" under different conditions in the marine environment and it is unknown whether this type of plastic causes less harm to marine organisms than conventional plastic.

17 It is practically impossible to extract plastic from the ocean on a large scale.

18 Efforts to control plastic pollution in the ocean need to address in priority land-based sources of waste by implementing action plans to reduce plastic discharge to the ocean around the world.

WHAT WE KNOW AND

Plastic pollution in the ocean

WHAT WE DON'T KNOW ABOUT