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Persuasive scientific article

The effects of plastic pollution on marine ecosystems

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Abstract

This paper is a summary report prepared by WWF that stated how the plastic pollution is affecting the global ocean, the impacts are on marine species and ecosystems, and how these trends are likely to develop in future. The paper explains a serious and rapidly deterioration condition that needs instant and intensive international action. 1) Common definitions, methods, standards and regulations for an effective and organized global effort to combat plastic pollution throughout the plastic life cycle, including specific circularity requirements and prohibitions for certain plastic products that pose elevated risks to the environment. such as some single-use plastic products or intentionally added micro-plastics. 2) A clearly formulated vision to eliminate the direct and indirect entry of plastics into nature, based on the precautionary principle and the recognition of the devastating impacts of plastic pollution. 3) Several key global regions–including areas in the Mediterranean, the East China and Yellow Seas and Arctic sea ice–have already exceeded plastic pollution thresholds beyond which significant ecological risks can occur, and several more regions are expected to follow suit in the coming years.

Keywords: Plastic; Microplastic; Ocean; Biodiversity; Marine pollution.

1. Introduction

1.1. A watershed environmental crisis

Plastic pollution is everywhere in the ocean, and levels have risen exponentially. The UN has called it a "planetary crisis." (MacLeod *et al*., 2021) or watershed environmental crisis. From the poles to the most remote islands, and from the surface of the sea to the deepest

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trench of the ocean, the problem of plastic pollution has grown exponentially and is already a widespread problem that will increase even if current corporate and government commitments are met (Borrelle *et al*., 2020). In response, urgent global and systemic action is needed. Plastic pollution is a relatively new threat. Plastic came into widespread use after World War II. However, the mass of the entire plastic produced so far is twice the combined biomass of all land and marine animals (Elhacham *et al*., 2020).

Production has skyrocketed in the last two decades, between 2003 and 2016 the same amount of plastic was produced as in all previous years combined. In 2015, 60% of all plastic ever produced had already become waste and a significant part has ended up in the oceans.4 it is estimated that it varies widely, but it is believed that between 86 and 150 million metric tons (MMT) of plastic have accumulated in the oceans to date,5 with a steadily increasing trend. An estimated MMT of plastic pollution leaked into the ocean from land in 2010, while a recent study suggests this has risen to 19-23 MMT in 2016 (Schnurr *et al*., 2018; Geyer *et al*., 2017; Ocean Conservancy, 2015; Jambeck *et al*., 2015) (Figure 1).

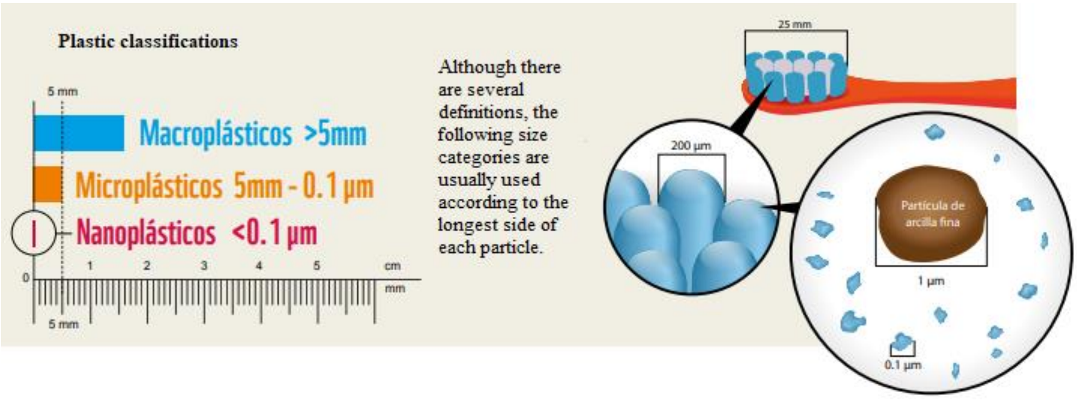

Figure 1. Nanoplastic particles (ten times smaller than fine clay)

Plastic pollution in the oceans is not evenly distributed (Figure 2). It focuses at a planetary level include the five great oceanic gyres (where the well-known “garbage patches” of floating macroplastics are concentrated), coastal and marine areas close to the main emission sources—such as the mouths of large rivers that cross centers settlements, coral reefs, and mangroves—and the deep seabed, especially submarine canyons. Where does all the plastic accumulated in the oceans come from? Some of the sources are known, but not all. A major driver is the rise of single-use plastics: in 2015, packaging generated half of all plastic waste (González-Fernández *et al*., 2021).

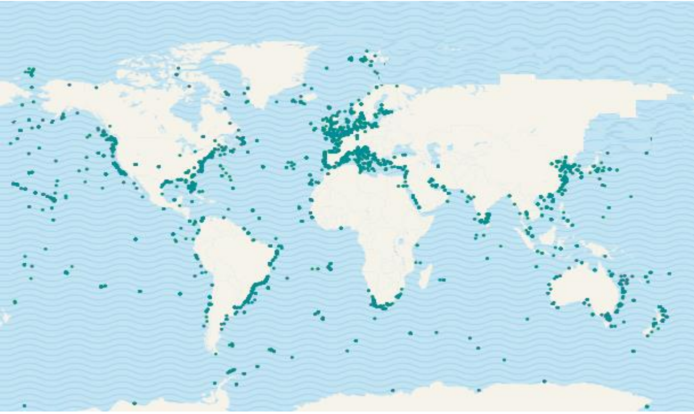

Figure 2. Map of interactions between plastic pollutants and marine life. The dots on the map show 1,511 locations reported in 851 studies (Litterbase).

According to a 2018 estimation, 60-95% of plastic pollution in the oceans are single-use plastics (Morales-Caselles *et al*., 2021). Land-based sources near coasts and rivers generate most of the plastic pollution that reaches the oceans. A recent analysis estimated that Europe emits 307-925 million disposable items into the ocean each year and that 82% of these are plastic (Evangeliou *et al*., 2020). There are also significant marine sources. Another study estimates that at least 22% of marine debris comes from the fishing sector (MacLeod *et al*., 2021). Air is also a vector for plastic pollution: tire wear and vehicle brakes are a significant source of microplastic emissions (Lebreton *et al*., 2019) as are wind-scorched plastic surfaces, waste processing, roads, and agriculture.

2. The growth of Micro-plastics

As plastics continue to break down in the oceans, the threats they pose are multiplying. Due to the difficulty of collecting plastic from the oceans and its prolonged permanence in the environment once it enters the sea it is almost impossible to remove it. Furthermore, once it enters the ocean, plastic continues to break down: Macro-plastics become micro-plastics and then nano-plastics, making their recovery even more difficult. Even if all sources of plastic pollution reaching the ocean were stopped today, this degradation process would mean that the mass of microplastics in oceans and beaches would more than double between 2020 and 2050 (Pew, 2020).

The evidence does not point to the sources of plastic pollution stopping or diminishing in the near future. Although projections under a business as usual scenario vary considerably, they all predict substantial growth in waste generation. The plastics industry has invested US$180 billion in new factories since 2010 (Lebreton *et al*., 2019). Plastics production is expected to more than double by 2040 and plastic pollution in the oceans is expected to triple (Everaert *et al*., 2018). This could result in an increase of 400 % in the concentrations of macroplastics in the oceans between 2020-2050 (Everaert *et al*., 2020), and an increase by 2100 of 5,000% in the amount of microplastics in the oceans (Peeken *et al*., 2018).

A microplastic concentration level of 1.21 × 105 objects per cubic meter has been proposed as a limit above which significant ecological risks occur (Tekman *et al*., 2021). This threshold has already been exceeded in certain sources of pollution, including the

Mediterranean, the of East China, the Yellow Sea (Yoshikawa and Asoh, 2004) and in the ice of the Arctic Ocean (Parga Martínez *et al.*, 2020). The ecological risks of pollution by microplastics on the surface of the oceans are expected to expand considerably towards the end of the 21st century (Naidoo and Glassom, 2019). Even the optimistic scenarios foresee significant increases, while the most unfavorable scenarios warn that dangerous pollution thresholds will be exceeded in a sea area greater than twice the area of Greenland.

3. Interactions with nature

Plastic pollution in the oceans harms marine biological life through entanglement, ingestion, suffocation, and chemical contamination. Plastic pollution is already present everywhere in the ocean and almost all marine species have faced it (Figure 2). A conservative estimate based on current studies suggests that a total of 2,141 species have faced plastic pollution in their natural environments.

The vast majority of these interactions were related to ingestion, entanglement, or choking. According to observations, there are 738 species that can colonize plastic surfaces and articles, which facilitates their movement to new areas. Several studies, both in the laboratory and in the field, have examined the interactions of 902 species with plastic under experimental conditions. These investigations include studies on the ingestion of microplastics of various sizes and the use of ghost nets to quantify entanglements. Other studies have gone beyond evaluating the interactions of these 902 species with plastics and have investigated the negative effects in detail. Some of these studies evaluated effects such as injury or mortality, mobility restrictions, feeding and growth disturbances, immune system responses, reproduction, and cell function. The observed effects were studied for 297 species and it was determined that 88% of them suffered adverse effects (Haetrakul *et al*., 2009). Although this percentage corresponds to a small sample of species and therefore cannot be understood at a general level, there is a clear trend that shows the negative impact of plastics on most marine life.

3.1. The main negative effects of plastics

3.1.1. Entanglements

Items such as abandoned, lost, or discarded fishing tackle ropes, nets, traps, and monofilament lines entangle marine animals, causing injury, suffocation, restricted mobility, and death. Birds use marine debris to build their nests, which can entangle them and their chicks. On Oahu, Hawaii, 65% of coral colonies were entangled with fishing line and 80% of these colonies were totally or partially dead (Wilcox *et al.*, 2015). Even in the remote and deep parts of the Arctic Ocean, up to 20% of sponge colonies they had entanglements with plastics, which have increased over time (Schuyler *et al*., 2015).

3.1.2. Ingestion

Plastic is ingested by marine animals of all kinds, from top predators to plankton at the bottom of the food chain (Figure 3). This can cause them serious injuries, affecting their food intake by generating a false sense of satiety, blocking their digestive system or causing internal injuries. For example, laboratory experiments have shown reduced growth in fish when their feed is contaminated with a large volume of microplastics (Kasteleine and Lavaleye, 1992). At the other extreme, a single plastic straw in the digestive system was the likely cause of death in fish. a whale shark in Thailand (Baird and Hooker, 2000). Plastics are widely ingested by seabirds, which has become a growing problem globally (Barros *et al*., 1990). It is estimated that up to 90% of seabirds (Lusher *et al*., 2018) and 52% of sea turtles today ingest plastics (Byrd et al., 2014). The ingestion of microplastics has also been discovered in many whales and dolphins that have stranded in a state of malnutrition (Prokić *et al*., 2019; De Stephanis *et al*., 2013). Some studies have shown alterations and reductions in food consumption, negative impacts on the growth (Balestri *et al*., 2017; Green *et al*., 2015). the immune system, fertility and reproduction, and alterations in cellular functions and behavior of the impacted species. Damage levels are directly related to exposure concentrations (Prüst *et al*., 2020).

3.1.3. Suffocation

Plastic pollution deprives humans of light, food and oxygen. corals, sponges, and animals that live on the seafloor and reduces the amount of oxygen and food available in the sediments (Hamlin *et al*., 2015). This can negatively impact ecosystems and accommodate pathogens in deteriorating marine life. Suffocation is particularly damaging on coral reefs and mangroves.

3.1.4. Chemical contamination

Although not all ingredients in plastic are harmful, some are and can leach into the marine environment (Muncke *et al*., 2020). Smaller plastic particles can pass through the cells of marine animals and some can reach the brain (Geyer *et al*., 2017).

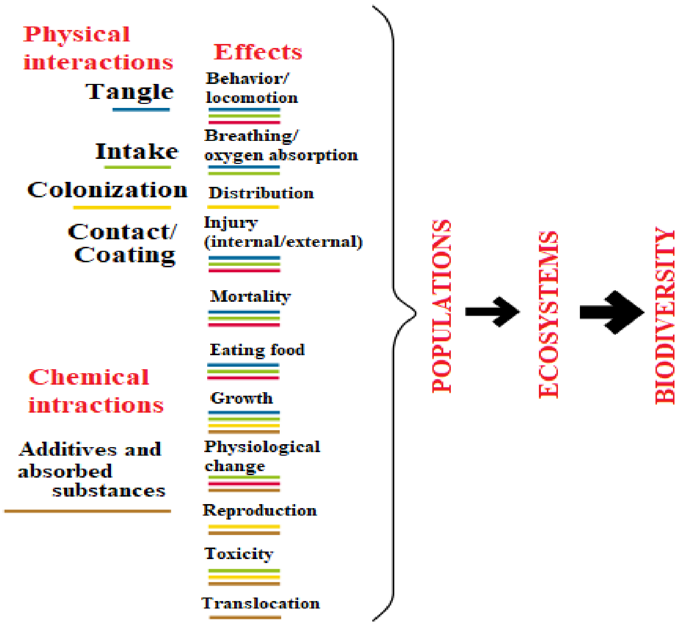

Figure 3. Diagram of the most frequently reported interactions and their effects on organisms (Litterbase). The colors represent the different types of interaction.

3.2. Harmful plastic chemical contaminants

3.2.1 Endocrine disruptors

These particles interfere with hormones, altering the reproduction, development, and behavior of various types of marine life (Tekman *et al*., 2020) Even some plastics labeled as safe for food storage can be highly toxic to aquatic animals and people (Brandon *et al*., 2020).

3.2.2 Persistent Organic Pollutants

These long-lasting substances, such as polychlorinated biphenyls (PCBs), affect the health of organisms and the environment (Cole *et al*., 2013). Because they do not break down, they can travel long distances on wind and water, creating long-lasting impacts far from their source.

4. Contaminating the food chain

Ingested plastic moves up the marine food chain. It is increasingly common to find it in the food that humans consume. Laboratory and field studies have shown that plastic ingested by marine animals can work its way up the marine food chain-just like its chemical contaminants (Figure 4 and Figure 5).

Studies have confirmed the presence of microplastics in the water column and their incorporation into aggregates that sink to the seabed (Wieczorek *et al*., 2019). Plankton and other small organisms that make up the bottom of the marine food chain consume these microplastics. particles as they sink to the bottom (Qu *et al*., 2018). Alterations in the efficiency of biological processes due to the ingestion of plastics can affect the amount of food that reaches the seabed, often causing changes in ecosystems on the seabed where food is not abundant. A recent study demonstrated this phenomenon by exposing a group of salpids to concentration levels of microplastics expected in the future (Zeytin *et al*., 2020).

There is widespread concern about the potential dangers of nanoplastics, about which little is known to date. The survival rate of the water flea Daphnia magna was dramatically reduced when exposed to nanoplastics and in some cases the population studied reached mortality rates of 100%. The study found that these nanoplastics crossed the blood-brain barrier of fish that consumed these water fleas, causing behavioral changes such as reduced feeding rates and mobility (Karami *et al*., 2018). As these impacts propagate along the food chain, food, can harm the general functioning of the ecosystem.

Despite a recent increase in research on the impact of plastics on organisms, it is surprising how little we know about their potential impacts on human health. However, it can be said that people are inhaling and ingesting them. For example, Atlantic mussels and oysters have been shown to ingest microplastics in most of their natural habitats and those to which they have been introduced (Lamb *et al*., 2018). Similarly, researchers have found that four in 20 brands of canned sardines and sprats contain plastic particles (Tang *et al*., 2021).

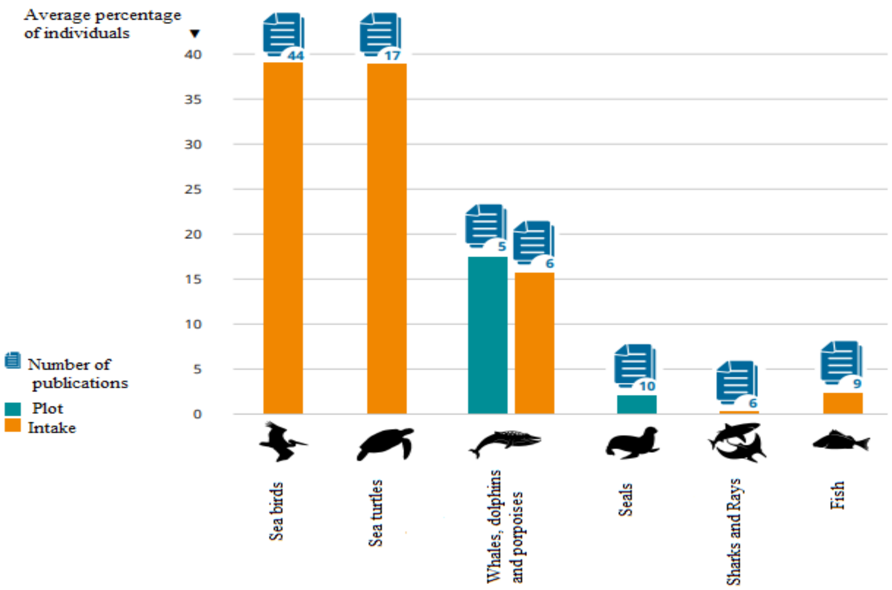

Figure 4. Average percentage of individuals that had interactions with macroplastics. The organisms examined are classified into taxa. Information comes from 105 studies on flagship megafauna and macroplastic entanglement and ingestion (Litterbase). The blue symbols above the bars show the total number of studies supporting the value of each bar.

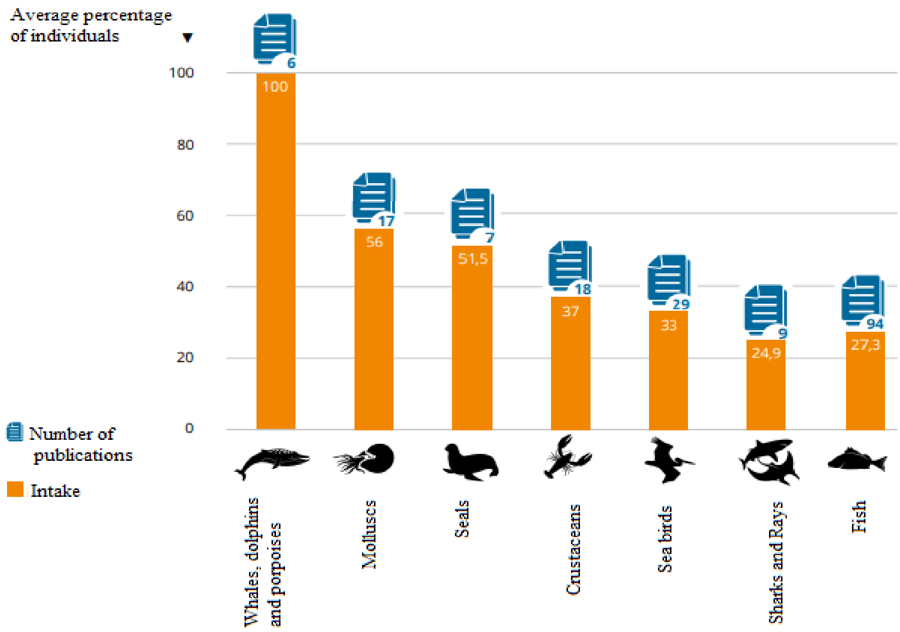

Figure 5. Average percentage of individuals who ingested microplastics. The organisms examined are classified into taxa. The information comes from 180 studies on the ingestion of microplastics (Litterbase). The blue symbols above the bars show the total number of studies supporting the value of each bar.

5. Key marine ecosystems at risk

Plastic pollution is having a greater impact on coral reefs and mangroves. Although plastic pollution is a growing phenomenon that has already reached all corners of the ocean, certain key marine and coastal ecosystems are at particularly high risk because they currently face several additional threats. These ecosystems, coral reefs and mangroves being notable examples, provide essential services for people and marine life. Therefore, when plastic negatively impacts its operation, people also suffer direct effects.

Plastic poses a threat of alarming scale to coral reefs, which are already in crisis due to global warming. It is estimated that in 2010 there were 11.1 billion pieces of plastic entangled in the coral reefs of the Asia-Pacific region (Luo *et al*., 2021), and that this type of pollution will grow 40% by 2025. It is particularly worrying that the entangled corals had a probability of get sick 20 to 89 times more (Suyadi and Manullang, 2020).

Lost or abandoned fishing gear, known as ghost gear, also poses a significant threat to corals around the world and can remain entangled in reefs for decades, suffocating, breaking and engulfing structures and even killing entire reefs (van Bijsterveldt *et al*., 2021; Martin *et al*., 2019; Angiolillo *et al*., 2015). has shown that corals accumulate microplastics in and on their polyps, which impacts the corals themselves and the algae with which they have symbiotic relationships. In addition, it can alter the community structures of the reefs (Tang et al., 2021).

Mangroves, which are often located near river mouths, provide many coastal communities with food security and flood control, among other services. Their complex root systems trap and accumulate plastic pollution, turning them into plastic sinks. Some of the highest debris density measurements in the world have been recorded in mangrove areas, where high pollution levels are associated with low levels of mangrove health (Song *et al*., 2021; Tekman *et al*., 2017; Debrot *et al*., 2013; Smith, 2012).

In a recent study of mangrove areas in Java, a density of 2,700 pieces of plastic per $100m^2$ was quantified, and in several locations the plastic covered up to 50% of the forest surface (Werner *et al*., 2016). In one experiment, completely rooted mangroves Plastic covers had lower leaf area indices and survival rates (Landos *et al*., 2021). Furthermore, efforts to rehabilitate degraded mangrove areas may be less effective when plastic suffocates seedlings and seedlings (Gunderson *et al*., 2016). Plastic contamination has been discovered at more than 10 km deep in the Mariana Trench, the deepest place on the planet (Orr *et al*., 2020). Conditions in the trench are stable and the debris can remain intact for centuries. In some cases, a solid artificial substrate is created in the mud on the deep seafloor that the organisms can colonize (Kroeker *et al*., 2017). Although in such cases the plastic generates benefits for these species, its presence can alter the community structure of native ecosystems (McComb and Cushman, 2020; Ceballos *et al*., 2015).

6. Root cause investigation

Addressing the causes of plastic pollution before it occurs is much more effective than removing it afterwards. As with the climate crisis, this problem affects the entire planet: levels of plastic pollution are continually increasing and therefore only systemic and global solutions will succeed. It is encouraging that public attention is turning to this problem and that calls have been added to turn the tide, through decisive international action, before plastic pollution overwhelms and impedes the resilience of a critical number of species and marine ecosystems (Jackson, 2008; Ceballos *et al*., 2015).

Collection and removal is often proposed as a solution to plastic pollution in the ocean. In the same way that certain groups have promoted carbon capture technology to alleviate climate change, large-scale technologies are increasingly being promoted to remove plastic pollution from the oceans (Schmaltz *et al*., 2020; Helinski *et al*., 2021). They are futuristic technological solutions with results that have not yet been proven and, even if their feasibility is demonstrated at a theoretical level, their widespread use would probably have significant economic costs and would not reverse the problem of plastic pollution. In addition, the impact of removal on marine ecosystems has not been assessed: such removal solutions may cause more harm than good if they increase the mortality of marine life bycatch and if they consistently remove substantial amounts of biomass in the middle of an ocean with limited food, especially when implemented on a large scale. They also likely have a significant environmental footprint and would almost certainly not be able to remove the smaller plastic. There are certain methods of removing microplastics, but currently most of them are only used in wastewater treatment.

A much more far-reaching approach is to simply prevent plastic waste from entering the environment, which also implies a large reduction in the primary production of plastics. This approach would have additional benefits, including reduced resource use and pollution from manufacturing, transportation, and plastic waste disposal. After decades of delay, the world is finally beginning to come together to act collectively and decisively on the climate crisis. The global plastics crisis should also be a matter of urgency for everyone. There is no time to lose: the action must start now (Hohn *et al*., 2020; Padervand *et al*., 2020).

The treaty must include:

- A clearly formulated vision to eliminate the direct and indirect entry of plastics into nature, based on the precautionary principle and the recognition of the devastating impacts of plastic pollution.
- A global goal to reduce plastic pollution that is ambitious, shared, time bound and legally binding.
- Clear, measurable and time-bound national reduction targets
- determined that in aggregate reach the global reduction target.
- The obligation to develop and implement ambitious and effective national action plans for the prevention, control and removal of plastic pollution.
- Shared definitions, methods, standards and regulations for an efficient and coordinated global effort to combat plastic pollution throughout the plastic life cycle, including specific circularity requirements and prohibitions for certain plastic products that pose elevated risks to the environment. such as some single-use plastic products or intentionally added microplastics.
- The explicit prohibition of certain actions contrary to the object and purpose of the treaty, including the deliberate dumping of plastic waste in river systems and inland waters.

- An agreed measurement, reporting and verification scheme to monitor plastic pollution releases and phase-out progress at national and international levels.
- A specialized and inclusive international scientific body, with the mandate to assess and monitor the scale, scope and sources of plastic pollution, harmonize scientific methodologies and compile current and advanced knowledge to support decision-making and implementation.
- A global financial and technical agreement, as well as assistance in technology transfer, to support all parties in the effective implementation of the treaty.
- A commitment to update, review and develop these measures and obligations over time.

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