POSITION BRIEFING

FAUNA & FLORA INTERNATIONAL

Alternative plastic: Is it the answer to ending marine plastic pollution?

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Executive summary

This briefing considers the environmental fate and impact, feasibility of use, and potential drawbacks associated with bioplastics, bio-based, biodegradable, oxo-(bio)degradable and compostable plastics, which are often referred to as 'alternative plastics' and which are increasingly being put forward as solutions to the problem of marine plastic pollution.

This paper is intended to be an accessible introduction to the topic, and explores some of the implications that any material switches may have on the marine environment.

In response to the impact of plastic pollution on biodiversity, and marine biodiversity in particular, Fauna & Flora International has been working on the issue of marine plastic pollution since 2009, with the primary aim of developing practicable solutions to eliminate sources of plastic pollution as far upstream as possible. In developing solutions it is important to consider ways in which alternative plastics may perpetuate existing environmental threats and further burden already struggling waste management infrastructure, as well as reflecting on the compatibility of their use with circular economy principles.

We conclude that there is no 'silver bullet' alternative to plastic, that more attention must be paid to the most suitable materials for specific applications, and that there is an overriding need to reform single and wasteful resource use. Further research and development is needed to identify a material that meets key criteria to be truly considered an 'environmentally friendly' alternative to plastic. In the absence of sustained behaviour change that moves away from linear, single use models, the switch to alternative plastics simply risks reinforcing a culture of disposability, unfettered production and resource consumption, and continued pollution of the environment. As with other materials, measures that facilitate a sustainable transition to a more circular economy for plastic are needed to prevent the loss of this valuable resource to the environment.

	Feedstock?	Does it fully and reliably biodegrade in the marine environment?	Potential impacts on marine biodiversity?	Can existing systems effectively manage it at end of life?	Is use compatible with circular economy principles?
Conventional plastic	Fossil fuels	No	Physical and chemical	Yes, depending on the product and polymer	Yes, if designed to be recovered, refilled, re-usable or recyclable
Bio-based plastic	Minimum % organic feedstocks, sometimes combined with fossil fuels.	No	Physical and chemical	Yes, depending on the product and polymer	Yes, if designed to be recovered, refilled, re-usable or recyclable
Biodegradable plastic	Fossil fuels or organic feedstocks	No; it depends on specific conditions	Physical and chemical, until decomposition	No; it could contaminate waste streams	No; it is designed to break down
Oxo-(bio) degradable plastic	Fossil fuels or organic feedstocks	No; it depends on specific conditions	Physical and chemical, until decomposition	No; it could contaminate waste streams	No; it is designed to break down
Compostable plastic	Fossil fuels or organic feedstocks	No; it depends on specific conditions	Physical and chemical, until decomposition	Maybe; it requires specific conditions	No; it is designed to break down

Introduction

Plastic's versatility and relatively low production costs make it a highly useful material for a range of applications in modern life, and production has increased exponentially since the 1950s. If current rates continue, production levels are predicted to have doubled on 2017 figures by 2040[1]. As production rates soar, so too does the volume of plastic waste generated. It is estimated that only 9% of plastic ever produced has been formally recycled[2]; much of the rest is disposed of after just one use. Where mismanaged, plastic waste is likely to end up in our environment, with a 2015 study suggesting up to 12.7 million metric tonnes of plastic currently enters the ocean every year, where it will never completely break down[3]. Based on business-as-usual scenarios, this amount is predicted to rise to 29 million tonnes or more by 2040[4].

In the marine environment, plastic pollution can have serious impacts on biodiversity, ranging from entanglement in larger plastic items (such as discarded fishing nets); ingestion of smaller plastic pieces that results in choking, gut perforations, or pseudo-satiation (a false feeling of fullness that can lead to starvation)[5]; the introduction of hazardous substances into marine food chains, if plastics transfer toxins to the animals that eat them[6]; and an increase in coral reefs' susceptibility to disease[7], which poses concerns for the long-term viability of the fragile ecosystems they support.

With an estimated 12.2 million tonnes of plastic entering the marine environment every year[8], the importance of reducing our consumption and production of unnecessary plastic has been increasingly acknowledged across governments, governing bodies[9] and other stakeholders. Public pressure to end the flow of plastic pollution to our oceans has been growing, and responsible businesses and policy makers are therefore looking to alternative materials that could provide the same benefits as plastic, but without its associated negative environmental impacts. A range of alternatives to conventional plastics, such as so-called bio-based, biodegradable, compostable or oxo-degradable plastics, are increasingly commonly used. Recognition of the need to reduce society's dependence on fossil fuels is driving a move towards bio-based plastics, while concerns regarding the need to avert pollution are often behind calls for biodegradable or compostable plastics, which are either perceived as, or presumed to be, less harmful should they end up in the environment. This brief paper will examine these alternatives from the perspective of their potential impact on marine biodiversity, whether they offer a solution to the plastic pollution problem and whether their use raises other potential problems or concerns. In order to do so, we will consider the following questions:

What are the different types of alternative plastics?

What are their potential physical and chemical impacts on marine biodiversity?

How confident can we be that those designed to biodegrade will reliably do so in the marine environment?

What potential impacts will they have on existing waste management infrastructure?

What potential impacts do their feedstocks and methods of production have?

How do these alternatives fit into aspirations for a future circular economy?

1 Materials

The word 'plastic' is used to describe a wide range of synthetic, semi-synthetic, or bio-based materials made up of various polymers (chains of linked molecules made of carbon and hydrogen, often with additional elements such as oxygen, nitrogen, and chlorine). Plastic is officially defined as *'a material consisting of a polymer to which additives or other substances may have been added, and which can function as the main structural component of final products, with the exception of natural polymers that have not been chemically modified'*[10]. It is important to note that all plastics are made of polymers, but not all polymers are plastic.

The terms synthetic and bio-based refer to the feedstock used to make the plastic: synthetic polymers are made with crude oil or natural gas, whereas bio-based polymers are partially or wholly derived from organic matter such as corn, sugarcane, wood, and bamboo. Despite their different feedstocks, bio-based plastics can have identical chemical structures to synthetic (or 'conventional') plastic, and when littered in the environment can cause the same damaging effects.

Plastics are generally lightweight with varying degrees of strength, and can be molded, cast and extruded into an extremely wide range of shapes, films, foams or fibres. The most widely produced and used plastics are: polyethylene terephthalate (PET or PETE), polyolefins (polyethene, PE, or polypropylene, PP), polyvinyl chloride (PVC), polystyrene (PS) and others including acrylic, nylon, and polycarbonates[11].

Below are key terms we will use in this briefing/paper to differentiate between different types of plastic.

1.1 CONVENTIONAL PLASTIC

Conventional plastic refers to synthetic or petroleum-based plastics, derived from fractions of crude oil and natural gas.

1.2 ALTERNATIVE PLASTICS

Alternative plastic refers to all non-conventional plastics, including but not limited to bioplastic, bio-based, biodegradable, compostable and oxo-degradable plastic.

1.2.1 **Bioplastic or bio-based plastics:** These terms are often used interchangeably, though there are differences between them. Bioplastic can be defined as a plastic that is either bio-based, biodegradable, or has both properties[12], though there are some slightly conflicting definitions. Therefore this briefing will refer specifically to bio-based plastic or biodegradable plastic (see next paragraph), to permit differentiation between the two. Bio-based plastic is made in part or in full from feedstocks other than petroleum products, known as biomass - some form of plant or animal matter. In most cases this means bio-based plastic is at least partly derived from plant materials, either organic waste, or plant matter grown specifically to be used as feedstock. For example, sugar cane can be processed to produce ethylene, which is then used to manufacture polyethylene (used for applications such as food packaging)[13]. Bio-based polylactic acid (PLA), polyethylene terephthalate (PET) and polytrimethylene teraphthalate (PTT) made from corn or other biomass can be used to make fibres for textiles[14]. The structure and performance of bio-based plastics is either identical or very similar to that of conventional plastics.

1.2.2 **Biodegradable plastics:** The term biodegradable plastic refers to plastics that are capable of breaking down to the basic components of water, biomass and gas, with the aid of microorganisms[15]. Under the right conditions, the material will degrade either completely or partially back to hydrogen, oxygen and carbon molecules. Biodegradable plastics can be made from both renewable (i.e. bio-based) or fossil fuel feedstocks. Their biodegradability is dependent on the additives used during production and the conditions of the environment in which they end up.

1.2.3 **Compostable plastics:** Compostable plastic is defined as 'capable of undergoing biological decomposition in a compost site as part of an available program, such that the material is not visually distinguishable and breaks down into carbon dioxide, water, inorganic compounds, and biomass, at a rate consistent with known compostable materials'[16]. Compostable plastics can be made from renewable feedstocks, fossil fuel, or a combination of the two. For example, polylactic acid (PLA) made from a blend of corn starch and petroleum-derived polymers is used to make bags for the collection of food waste[17], with the aim that the bag and its contents can be composted together and break down entirely within four weeks in certain industrial settings. For at-home and other non-industrial settings, compostable plastic must be able to degrade at lower temperatures, and this will typically require longer dwell times in the compost heap[18]. There are internationally recognised standards for labelling plastic items as compostable in specific environments (e.g. the harmonised European standard EN13432, and US-based international standard ASTM D6400). It should be noted, however, that these standards are for the raw polymer, and do not take into account the effects chemical additives (e.g. for colour or performance) may have on degradation times.

1.2.4 **Oxo-degradable plastics:** Oxo-degradable and oxo-biodegradable plastics are conventional plastics to which chemicals are added to accelerate the oxidation and fragmentation of the material under the action of UV light and/or heat, and oxygen. The oxidation process enables a faster conversion of polymers into microplastic fragments (oxo-degradation), but it does not mean that the plastic will fully break down into composite parts as in the case of biodegradation: this is the second stage of the process, in which the microplastic material chemically decomposes into small-chain organic chemicals but which only occurs in specific conditions unlikely to be replicated in highly variable natural environments. The fragmentation process and any subsequent biodegradation depends on multiple criteria, including the fragment size, the quantity of additives, and the environmental conditions to which the material is subjected (e.g. temperature, biotic factors) - conditions that vary significantly in practice.

2 Issues of concern

Many plastic alternatives present the same potential harm to biodiversity as conventional plastics if they reach the environment. There may also be other unintended impacts on biodiversity from some alternatives, resulting from their methods of production or the effects of their use on the potential for much-needed systemic change in our patterns of consumption and production.

2.1 PHYSICAL HARM TO BIODIVERSITY

There are still many unknowns regarding the impacts of plastic pollution on biodiversity and ecosystems, both terrestrial and marine. Once in the marine environment, products made of alternative plastic don't biodegrade immediately, if at all, and still pose a risk of physical harm to wildlife in many of the same ways as conventional plastic[19]. Estimates suggest that over 800 species are known to be affected by plastic pollution[20], with research indicating that 56% of cetaceans and 52% of turtles[21] are likely to have ingested plastic debris, while in the North Pacific alone, fish ingest 12,000 to 24,000 tonnes of plastic each year[22]. It is estimated that plastic waste kills up to a million seabirds worldwide annually through entanglement or ingestion[23]; 59% of seabird species examined for plastic ingestion between 1962 and 2021 were recorded as having eaten pieces of plastic, with the proportion of species affected predicted to rise to 99% by 2050.[24]

So why do alternative plastics present a similar risk of harm? As mentioned above, the chemical structure of alternative plastics can be identical to conventional plastics, meaning they won't necessarily break down readily in the marine environment, or even if they do, this process takes time. This means that their use in lieu of conventional plastics would not completely remove the threat posed to biodiversity by entanglement, ingestion, or other physical risks. In order to fully degrade, these plastics require specific conditions unlikely to be found in the heterogeneous marine environment (see 2.3 below).

A further potential concern is that anywhere this degradation does occur, it is possible that the original plastic item may break down into many smaller pieces of microplastic before fully degrading to the component hydrogen, oxygen and carbon molecules, thus increasing its bioavailability, i.e. making it possible for a greater range of species at various stages of the food chain to ingest the plastic fragments as they become smaller and more numerous in the marine environment. Further research is required to understand if this is the case.

To demonstrate the risks posed to marine life by alternative plastics, a lab experiment exposed conventional high density polyethylene, oxo-degradable plastic and biodegradable PBAT/starch blend (commercially known as Mater-Bi™) to the gastrointestinal fluids of sea turtles for over a month. Polyethylene and oxo-degradable plastic degraded negligibly, and the biodegradable PBAT/starch blend degraded by 4.5–8.5%, much slower than the 100% degradation that the manufacturers reported would occur at an industrial composting site[25]. The scientists concluded that all of the fragmented materials would still present a serious risk of gastrointestinal tract blockage to the sea turtle.

2.2 PRESENCE AND ACCUMULATION OF TOXIC CHEMICALS

The production of plastics with the wide variety of functions and characteristics seen today requires widespread use of a multitude of chemical additives[26]. Research suggests that these chemicals are often toxic, the degree to which being further complicated by the sheer variety and combination of additives used in the production of plastic[27]. The process of manufacturing bio-based and biodegradable plastics can use more chemicals than are used in conventional plastics (sometimes significantly more), and testing suggests bio-based and biodegradable plastics cause a similar, if not greater degree of toxic contamination in organisms exposed to them when compared with conventional plastics[28].

In addition to the chemicals inherently contained in plastics, once in the sea, some plastics may adsorb further hydrophobic chemical pollutants from the water around them, concentrating them on their surface with increased exposure over time. The surface area-to-volume ratio of microplastics results in elevated adsorption rates and surface concentrations of persistent, and often bio-accumulating, environmental toxins relative to levels in the surrounding seawater[29]. If microplastic particles – whether made of conventional or alternative plastic – are consumed by wildlife, the risk comes not only from the physical impacts outlined in 2.1 above, but also from toxicological exposure as the plastics become a vector for chemical contaminants (intrinsic and surface), introducing them to the bodies of any organism that ingests them[30]. In this sense, in the marine environment alternative plastics are likely to pose an identical threat to conventional plastics.

2.3 CONDITIONS REQUIRED FOR DEGRADATION AND COMPOSTING

Biodegradable and compostable plastic often only breaks down when exposed to high temperatures above 50°C[31,32], for a prolonged period (typically, three months to disintegrate and six months to 'fully' biodegrade back to component molecules in industrial settings[33]). Most plastic products currently labelled as biodegradable only truly biodegrade in the special conditions of industrial facilities (e.g. controlled temperatures, CO_2 levels, and with specific microorganisms present). This means they are extremely unlikely to break down in the natural environment, and in particular the marine environment, where these conditions rarely, if ever, occur.

Variations in temperature, pH, and moisture, among other issues, all hinder the biodegradation process as they may inhibit the activity of microorganisms required to break down plastic. Biofouling on plastic items (including biodegradable plastics) in the marine environment quickly causes them to sink from surface waters to cooler waters, where exposure to ultraviolet light is prevented[34]. Suitable conditions for biodegradation are usually only achieved if products are appropriately captured for industrial composting and then adequately processed, including sufficient time for composting to take place.

LACK OF SUITABLE STANDARDS FOR BIODEGRADABLE PLASTICS IN THE MARINE ENVIRONMENT

Though certain standards exist for biodegradability (e.g. the standards on compostability mentioned in section 1.2.3), they are often specific to certain environmental conditions, and calls have been made for the development of more stringent standards applicable to a broader range of environments[i]. US standard ASTM D7081 was the Standard Specification for Non-Floating Biodegradable Plastics in the Marine Environment. It applied to products that achieved 20% biodegradation in the marine environment over six months[ii], by which point the product in question could have already had a serious impact on the marine environment, including lethal entanglement and ingestion[iii], and the remaining 80% would continue to pose those threats thereafter. It was not considered effective in reducing risks to the marine environment and was withdrawn without replacement in 2014[iiv].

i SAPEA, 2020 ii ASTM International, 2014 iii UNEP, 2015 iv ASTM International, 2014

Some biodegradable single-use plastics, such as those made from starch, may readily break down outside of industrial composting facilities. However, this makes them unsuitable for many plastic applications as they quickly begin decomposing when wet[35], so they do not represent a useful alternative to conventional plastics for many applications.

When disposed of in regular rubbish bins, biodegradable and compostable plastics will often be sent to landfill. In the anaerobic conditions often found in deeper landfill layers, biodegradable plastics can only be decomposed by anaerobic bacteria, which degrade the plastic into carbon dioxide and methane[36]. Methane is a greenhouse gas 34 times stronger at heat-trapping than carbon dioxide[37], and therefore increasing use of biodegradable plastics which are then sent to landfill could have the perverse impact of exacerbating climate change. Furthermore, many of the so-called biodegradable or compostable plastics, even those designed to be disposed of with food waste (like cornstarch-based food caddy liners) can't be broken down in organic waste processing facilities such as anaerobic digestion plants. Their use therefore disrupts the waste management process as they need to be removed and disposed of separately, often through incineration[38].

CASE STUDY: OXO-DEGRADABLE AND OXO-BIODEGRADABLE PLASTICS

Initially, oxo-degradable and oxo-biodegradable plastics were marketed as a solution to the problem of increasing plastic waste: if we added chemicals to help plastic break down to nothing but residue, the issue of accumulated plastic waste polluting the environment would be solved. But in real-world conditions, studies suggested that oxo-degradable plastics fail to fully break down within the short time frames claimed by their producers[i], resulting in partial degradation in which they fragment into microplastic pollution and remain in the environment, posing a continued threat to biodiversity. Furthermore, the additives used to achieve this effect may contain heavy metals whose environmental impacts are unknown[ii]. Concerned by this, in 2017 a broad coalition of businesses, NGOs, researchers and politicians called for a precautionary ban on all oxo-degradable products, which the EU subsequently introduced as part of its Single Use Plastics Directive[iii], giving individual member states until July 2021 to adopt the ban in their own legislation.

i. Ellen MacArthur Foundation, 2019 ii. UNEP, 2021 iii. European Parliament, 2019

2.4 CONTAMINATION OF WASTE STREAMS

'Bio-based plastic', 'plant-based plastic', 'bioplastic' and 'biodegradable plastic' are terms which are all easily confused, which may lead to incorrect disposal of products made from these materials[39]. If bio-based, biodegradable, or compostable plastic is disposed of in recycling alongside conventional plastics, it could compromise the quality and performance of the recyclate and the recycled plastic products and materials that are made from it[40]. Biodegradable plastic and compostable plastic contaminate conventional recycling even at extremely low concentrations (PLA contamination can compromise the structural integrity of recycled PET at concentrations of just 0.1%)[41], sometimes leading to the whole batch of recyclable materials being discarded to landfill or incineration. Conversely, wider use of compostable plastics could result in consumer confusion and risks higher incidences of non-compostable plastics being added to compost bins for kerbside collection (and indeed, home composting), where they would contaminate the compost batch, introduce microplastics to land where the compost is used, and subsequently increase the risk of run off and chemical contamination in waterways.

The UK's Department for Environment, Food and Rural Affairs and the United Nations Environment Programme have expressed concern regarding the growing use of compostable and biodegradable plastics without a corresponding increase in consumer understanding of how to dispose of these materials and the provision of appropriate treatment infrastructure to receive and process them[42,43]. Existing waste management infrastructure cannot deal with the different types of conventional plastic already in circulation, so introducing further types of alternative plastics requiring dedicated waste management streams and treatments will likely make matters worse.

2.5 PRODUCTION IMPACTS

The land and energy requirements to grow alternative feedstocks for bio-based plastics, and the subsequent manufacturing process, carry their own environmental concerns. Should the production and use of bio-based plastics continue to increase, there will be a corresponding increase in the demand for their feedstocks. If this cannot be met through second or third generation feedstock – such as organic waste, or unused agricultural byproducts (for example, the stalks of grain-producing plants), then more land will be required to grow first generation raw material (such as corn, rapeseed, and wood), increasing pressure on productive agricultural land which could otherwise be used to produce food[44]. Other impacts, such as energy consumption during feedstock production and material manufacture, the ecological effects of increased monoculture cropping, and the environmental problems associated with increased fertiliser and pesticide use[45] must be taken into account in a life-cycle analysis approach to fully understand the wider impacts of alternative plastics production.

Alternative plastics go through many of the same production phases as conventional plastics. As such, the raw material and building blocks for products are pre-production plastic pellets, powders and flakes (collectively referred to as 'pellets')[46]. Globally, pellet loss is estimated to contribute 230,000 tonnes of plastic pollution to the marine environment every year[47]. There is currently no reason to believe that the supply chain for alternative plastics has a better record at minimising spillage than that for conventional plastics, so alternative plastics cannot be considered part of a circular economy solution while pellet loss occurs throughout their supply chains, and where design and use is still intended to replace conventional, single-use plastic items.

2.6 PERPETUATING SINGLE-USE MODELS

The most commonly recorded plastic items in beach litter surveys are so-called single-use plastics, e.g. food packaging, plastic bottles and bags, and takeaway containers[48]. These items easily enter the environment because they are marketed as disposable and are frequently used 'on-the-go', where consumers may not have access to appropriate disposal methods, and because food contamination may render them unrecyclable. The belief that alternative plastics will break down in the environment faster than conventional plastics means that alternatives are often seen as a quick-fix 'solution' to the problem of single-use plastic pollution, and in one study consumers expressed a belief that biodegradable plastics were more environmentally-friendly than 'easily recyclable plastics'.[49] However, material switches simply reinforce negative behaviour and reliance upon single-use models, and further challenge the functioning of inadequate waste management infrastructure around the world, or complicate the introduction of such infrastructure where it is yet to be developed. This is equally true of non-plastic material alternatives, such as glass, paper, wood, and metal: if the manufacture and use of unnecessary single-use products can be avoided in the first place, this is preferable to switching to a different material, which avoids addressing the core issue of over-consumption and waste generation.

Even developed nations struggle to process their post-consumer plastic waste[50] with ageing or insufficient infrastructure. For example, the UK recycles less than 10% of everyday plastic packaging, and currently still relies heavily on incineration and the offshoring of waste to other countries, even though these approaches often result in further pollution problems[51]. According to the OECD, current global plastic recycling rates remain low in comparison to other materials (such as metal and glass), with only between 14–17% of all plastic recycled, 24% incinerated, and the remaining 58–62% ending up in landfill or the environment[52]. In the absence of appropriate infrastructure to capture and safely dispose of plastics appropriately, bio-based plastics are as likely as conventional plastics to escape to and pollute the environment.

Replacing products such as single-use plastic supermarket bags and takeaway cutlery with alternative materials, plastic or otherwise, perpetuates a throwaway consumer mentality and can be a distraction from reducing unnecessary plastic production and consumption. A further concern is that the prefix 'bio' (or 'plant-based') could suggest that these products present no, or reduced, harm to the environment. This could lead consumers to believe that 'bio-based', 'plant-based', or 'biodegradable' products or packaging are safe to litter and to be less careful with their disposal, thus exacerbating the problem of plastic pollution. A 2020 report noted that over 80% of consumers surveyed thought 'compostable' or 'biodegradable' packaging was the most environmentally-friendly compared to other kinds, while not being clear on what the terms actually meant[53], while another study highlighted that 'compostable bio-based packaging' held the most environmental appeal among consumers, but was disposed of incorrectly more frequently than other types of packaging[54]. Presenting consumers with clear instructions on what to do with alternative plastic products at end-of-life is of critical importance, but unlikely to result in a reduction in marine plastic pollution on its own, with current infrastructure and levels of consumer awareness.

Rather than a simple material switch, strategies to address systemic plastic pollution should follow the waste hierarchy principles, with an emphasis on waste avoidance in the first instance, followed by redesign of products and their packaging, and waste reduction, recapture, and recycling. Of course, where single-use is currently essential, we need to find the least harmful material, but alternative plastics don't yet equate to a reduced risk to marine biodiversity. Selecting the plastic applications that are currently essential and reducing the complexity of the materials used for these applications, by limiting their content to a minimal number of polymers and additives (e.g. avoiding the use of colourants in plastic), would help ensure they can be easily reused or recycled in destination countries and markets. This would increase the value of post-consumer plastic material and increase likelihood of recapture, reuse or recycling and a successful transition to a circular plastic economy.

Conclusion

At this stage, current or proposed alternative plastics do not offer a solution to the marine plastic pollution problem. The research, reports and knowledge gaps synthesized in this briefing emphasize that without an adequate focus on moving away from single -use models, promotion of such alternatives risks perpetuating the same threats to biodiversity (physical harm, chemical toxicity, environmental persistence, and the impacts of production) while also reinforcing linear material flows instead of facilitating transition to a more circular economy.

When considering shifts away from conventional plastics, it is important to assess whether alternative plastics will have any less of an impact on biodiversity: not only due to their environmental fate at end of life, but also in the event their manufacture places greater demands on natural resources, or their use confuses consumers and compromises the efficiency of waste management infrastructure, and in circumstances where the promotion of single-use alternatives becomes a counterproductive distraction from the urgent need to better value and recover plastic materials.

Whilst we are supportive of further research and innovation, at the time of writing we cannot recommend a straightforward transition to any of the alternative plastics currently available, as there is no clear evidence to suggest they present an improvement over conventional plastics from the perspective of reliably protecting marine biodiversity. Instead, we would like to see efforts focused towards reducing current excessive over-production and consumption, making provisions for circularity, improving waste recapture and working towards Extended Producer Responsibility in terms of responsible product design, recyclability, and recycling rates. Innovators and policy-makers should focus on these principles regardless of what a material is made of, and consider that depending on its intended use, a more robust plastic product suitable for repeated re-use and eventual recycling may be better for the environment in the long term than a single-use product designed to fragment into microplastics.

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References

1. Reddy, S., Lau, W., *et al.* (2020). 'Breaking the Plastic Wave: Top Findings for Preventing Plastic Pollution'. Report by The Pew Charitable Trusts & SYSTEMIQ, Philadelphia, USA. Accessed July 2021. https://www.pewtrusts.org/en/research-and-analysis/articles/2020/07/23/breaking-the-plastic-wave-top-findings

2. Parker, L. (2019). A Whopping 91 Percent of Plastic Isn't Recycled. *National Geographic.* Accessed August 2021. https://www.nationalgeographic.org/article/whopping-91-percent-plastic-isnt-recycled/

3. Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Marine pollution. Plastic waste inputs from land into the ocean. *Science,* 347(6223), 768–771.

4. Reddy, S., Lau, W., *et al.* (2020). 'Breaking the Plastic Wave: Top Findings for Preventing Plastic Pollution'. Report by The Pew Charitable Trusts & SYSTEMIQ, Philadelphia, USA. Accessed July 2021. https://www.pewtrusts.org/en/research-and-analysis/articles/2020/07/23/breaking-the-plastic-wave-top-findings

5. Thiel, M., Luna-Jorquera, G., Álvarez-Varas, R., Gallardo, C., Hinojosa, I. A., Luna, N., Miranda-Urbina, D., Morales, N., Ory, N., Pacheco, A. S., Portflitt-Toro, M., & Zavalaga, C. (2018). Impacts of marine plastic pollution from continental coasts to subtropical gyres-fish, seabirds, and other vertebrates in the SE Pacific. In *Frontiers in Marine Science*, 5, 238.

6. Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M, & Watanuki, Y. (2013). Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics. *Marine Pollution Bulletin,* 69(1–2), 219–222.

7. Lamb, J. B., Willis, B. L., Fiorenza, E. A., Couch, C. S., Howard, R., Rader, D. N., True, J. D., Kelly, L. A., Ahmad, A., Jompa, J., & Harvell, C. D. (2018). Plastic waste associated with disease on coral reefs. *Science*, 359(6374), 460-462.

8. Sherrington, C. (2016). 'Plastics in the Marine Environment.' Report by Eunomia, Bristol, UK. Accessed August 21. https://www.eunomia.co.uk/reports-tools/plastics-in-the-marine-environment/

9. European Commission (2018). 'A European Strategy for Plastics in a Circular Economy.' Brochure by the European Commission. Accessed September 2021. https://www.europarc.org/wp-content/uploads/2018/01/Eu-plastics-strategybrochure.pdf

10. As defined in Article 3(5) of Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

11. Baheti, P. (2020) 'How is Plastic Made?' British Plastics Federation. Accessed August 2021. https://www.bpf.co.uk/plastipedia/how-is-plastic-made.aspx

12. European Bioplastics (2020). 'What are Bioplastics?' Accessed August 2021. https://www.europeanbioplastics.org/bioplastics/

13. Plastics Europe (2018). 'Bio-based Plastics.' Accessed September 2021. https://www.plasticseurope.org/en/about-plastics/what-are-plastics/large-family/bio-based-plastics

14. Textile Exchange, (2018). 'Quick Guide to Biosynthetics' Report. Textile Exchange, Lamesa, USA. Accessed July 2021. https://store.textileexchange.org/product/quick-guide-to-biosynthetics/

15. SAPEA, Science Advice for Policy by European Academies. (2020). Biodegradability of plastics in the open environment. SAPEA, Berlin, Germany. Accessed August 2021. https://www.sapea.info/wpcontent/uploads/bop-report.pdf

16. *ibid*

17. BASF (2011). 'Tear-resistant Waste Bags For Compost.' Accessed July 2021. https://www.basf.com/gb/en/media/science-around-us/tear-resistent-waste-bags-for-compost.html

18. European Bioplastics (2018). 'Home Composting of Compostable Bioplastics.' Position paper. https://docs.european-bioplastics.org/publications/pp/EUBP_PP_Home_composting.pdf

19. O'Brine, T., & Thompson, R. (2010). Degradation of Plastic Carrier Bags in the Marine Environment. *Marine Pollution Bulletin*, 60(12), 2279-2283.

20. Convention on Biological Diversity (2016). 'Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity.' Technical Series No.83. Secretariat of the Convention on Biological Diversity, Montreal, Canada. Accessed August 2021. https://www.cbd.int/doc/publications/cbd-ts-83-en.pdf

21. Schuyler, Q. A., Wilcox, C., Townsend, K. A., Wedemeyer-Strombel, K. R., Balazs, G., van Sebille, E., & Hardesty, B. D. (2016). Risk analysis reveals global hotspots for marine debris ingestion by sea turtles. *Global Change Biology*, 22(2), 567-576.

22. Center for Biological Diversity (2019). 'Ocean Plastics Pollution.' Accessed August 2021. https://www.biologicaldiversity.org/campaigns/ocean_plastics/

23. Reddy, S. (2018). Plastic Pollution Affects Sea Life Throughout the Ocean. Pew Charitable Trusts, Philadelphia, USA. Accessed September 2021. https://www.pewtrusts.org/en/research-and-analysis/articles/2018/09/24/plastic-pollution-affects-sea-life-throughout-the-ocean

24. Wilcox, C., van Sebille, E., & Hardesty, B. D. (2015). Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proceedings of the National Academy of Sciences of the United States of America*, 112(38), 11899–11904.

25. Müller, C., Townsend, K., & Matschullat, J. (2012). Experimental degradation of polymer shopping bags (standard and degradable plastic, and biodegradable) in the gastrointestinal fluids of sea turtles. *Science of the Total Environment*, 416, 464-467.

26. Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., & Purnell, P. (2018). An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. In *Journal of Hazardous Materials*, 344, 179-199.

27. Zimmermann, L., Dierkes, G., Ternes, T. A., Völker, C., & Wagner, M. (2019). Benchmarking the in Vitro Toxicity and Chemical Composition of Plastic Consumer Products. *Environmental Science and Technology*, 53(19).

28. Zimmermann, L., Dombrowski, A., Völker, C., & Wagner, M., (2020). Are bioplastics and plant-based materials safer than conventional plastics? In vitro toxicity and chemical composition. *Environment International,* 145, 106066.

29. O'Donovan, S., Mestre, N. C., Abel, S., Fonseca, T. G., Carteny, C. C., Cormier, B., *et al* (2018). Ecotoxicological effects of chemical contaminants adsorbed to microplastics in the Clam Scrobicularia plana. *Frontiers in Marine Science*, 5, 143.

30. Avio, C. G., Gorbi, S., Milan, M., Benedetti, M., Fattorini, D., D'Errico, G. et al. (2015). Pollutants bioavailability and toxicological risk from microplastics to marine mussels. *Environmental Pollution,* 198, 211-222.

31. UNEP (2018). 'Single-Use Plastics: A Roadmap for Sustainability.' United Nations Environment Programme. (Rev. ed., pp. vi;6)

32. Tokiwa, Y., Calabia, B. P., Ugwu, C. U., & Aiba, S. (2009). Biodegradability of plastics. In *International Journal of Molecular Sciences* (Vol. 10, Issue 9).

33. European Bioplastics (2016). 'What are the Required Circumstances for a Compostable Product to Compost?' Accessed July 2021. https://www.european-bioplastics.org/avada_faq/what-are-therequired-circumstances-for-a-compostable-product-to-compost/

34. UNEP (2015). 'Biodegradable Plastics and Marine Litter. Misconceptions, Concerns and Impacts on Marine Environments.' United Nations Environment Programme, Nairobi, Kenya.

35. Axion Group (2016). 'Are Biodegradable Plastics Better for the Environment?' Axion Group. Accessed July 2021. https://axiongroup.co.uk/news/biodegradable-plastics-better-environment/

36. Cho, H. S., Moon, H. S., Kim, M., Nam, K., & Kim, J. Y. (2011). Biodegradability and biodegradation rate of poly(caprolactone)-starch blend and poly(butylene succinate) biodegradable polymer under aerobic and anaerobic environment. *Waste Management*, 31(3), 475-480.

37. Myhre, G., Shindell, D., Bréon, F.-M., Collins, W., Fuglestvedt, J., Huang, J. *et al*. (2013). Anthropogenic and Natural Radiative Forcing. In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* [T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, & P. M. Midgley (eds.)], Cambridge University Press, Cambridge, UK.

38. The Oxo-biodegradable Plastics Association (2020). 'Rejects 'compostable' plastic and paper.' Accessed July 2021. https://www.biodeg.org/rejects-compostable-plastic-and-paper/

39. UNEP (2015). 'Biodegradable Plastics and Marine Litter. Misconceptions, Concerns and Impacts on Marine Environments.' United Nations Environment Programme, Nairobi, Kenya.

40. Alaerts, L., Augustinus, M., & Van Acker, K. (2018). Impact of Bio-Based Plastics on Current Recycling of Plastics. *Sustainability,* 10(5), 1487.

41 Peake, L., Riston, J., & Cripps, I. (2020). *'Fixing the system: Why a circular economy for all materials is the only way to solve the plastic problem.'* Green Alliance Report. Accessed September 2021. https://green-alliance.org.uk/resources/Fixing_the_system.pdf

42. Defra (2021). 'Consultation on consistency in household and business recycling collections in England.' Consultation Document, May 2021. Accessed August 2021. https://consult.defra.gov.uk/waste-and-recycling/consistency-in-household-and-business-recycling/supporting_documents/Recycling%20Consistency%20Final%20Consultation_May%202021.pdf

43. UNEP (2021). 'From Pollution to Solution: A global assessment of marine litter and plastic pollution.' United Nations Environment Programme, Nairobi, Kenya.

44. Brizga, J., Hubacek, K., & Feng, K. (2020). The unintended side effects of bioplastics: Carbon, land, and water footprints. *One Earth*, 3, 45–53.

45. Peake, L., Riston, J., & Cripps, I. (2020). 'Fixing the system: Why a circular economy for all materials is the only way to solve the plastic problem.' Green Alliance Report. Accessed September 2021. https://green-alliance.org.uk/resources/Fixing_the_system.pdf

46. e.g. http://www.bioplasticxh.com/news/biodegradable-plastic-pellets-suppliers,25.html

47. Hann, S., Sherrington, C., Jamieson, O., Hickman, M., & Bapasola, A. (2018). 'Investigating options for reducing releases in the aquatic environment of microplastics emitted by products.' Eunomia & ICF report for the European Commission.

48. Ocean Conservancy (2018). 'Building a Clean Swell' Report. Accessed August 2021. https://oceanconservancy.org/wp-content/uploads/2018/07/Building-A-Clean-Swell.pdf

49. Dilkes-Hoffman, L., Ashworth, P., Laycock, B., Pratt, S., & Lant, P. (2019). Public attitudes towards bioplastics – knowledge, perception and end-of-life management. *Resources, Conservation and Recycling,* 151, 104479.

50. Laville, S. (2021). Twenty firms produce 55% of the world's plastic waste, report reveals. *The Guardian.* Accessed August 2021. https://www.theguardian.com/environment/2021/may/18/twenty-firmsproduce-55-of-worlds-plastic-waste-report-reveals

51. Greenpeace (2021). What really happens to your plastic recycling? Accessed July 2021. https://www.greenpeace.org.uk/news/plastic-recycling-export-incineration/

52. OECD (2018). Improving plastics management: Trends, policy responses, and the role of international co-operation and trade. OECD Environment Policy Paper No. 12. Accessed August 2021. https://www.oecd.org/environment/waste/policy-highlights-improving-plastics-management.pdf

53. Benson, I. (2020). Plastic alternatives may cause greater environmental harm, says new report. *Resource*. Accessed July 2021. https://resource.co/article/plastic-alternatives-may-cause-greater-environmental-harm-says-new-report

54. Taufik, D., Reinders, M. J., Molenveld, K., & Onwezen, M. C. (2020). The paradox between the environmental appeal of bio-based plastic packaging for consumers and their disposal behaviour. *Science of the Total Environment*, 705, 135820.

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i SAPEA, Science Advice for Policy by European Academies. (2020). Biodegradability of plastics in the open environment. SAPEA, Berlin, Germany. Accessed August 2021. https://www.sapea.info/wpcontent/uploads/bop-report.pdf

ii/iv. ASTM International (2014). ASTM D7081-05 Standard Specification for Non-Floating Biodegradable Plastics in the Marine Environment (Withdrawn 2014). Accessed August 2021. https://www.astm.org/d7081-05.html

iii. UNEP (2015). Biodegradable Plastics and Marine Litter. Misconceptions, Concerns and Impacts on Marine Environments. United Nations Environment Programme, Nairobi, Kenya.

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i. Ellen MacArthur Foundation (2019). Oxo Statement. Accessed October 2021. https://emf.thirdlight.com/link/kfivzcx91l81-86a71k/@/preview/1?o

ii. UNEP (2021). From Pollution to Solution: A global assessment of marine litter and plastic pollution. United Nations Environment Programme, Nairobi, Kenya.

iii. European Parliament (2019). Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. Accessed October 2021. https://ec.europa.eu/environment/topics/plastics/single-use-plastics_en

Plastic bag on a coral reef. Credit: whitcomberd/Adobe Stock

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