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remain resilient to the impacts of larger scale, longer term stressors. This means improving local water quality, preventing damage from destructive fishing practices, including seagrasses in Marine Protected Areas, preventing overexploitation of seagrass fisheries and mitigating stress from coastal development. Bold steps are required to ensure the recovery and restoration of these habitats, but the cumulative effect of multiple small-scale actions can work towards a brighter future for these underappreciated undersea gardens.

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Quick guide

Marine microplastics

Tamara Galloway* and Ceri Lewis

What are microplastics? Unless you've been out of contact with global media for a while, you will have heard of microplastics. Microplastics is a word coined to describe the vast tide of microscopic plastic debris that is now found throughout the world's oceans. Wherever we look, from beaches and coastlines, to subtropical oceanic gyres, polar ice caps and even the deepest parts of the ocean, we find microplastics. Microplastics (<1 mm in size and with no lower size limit) are formed by the fragmentation of larger plastic items, ropes and synthetic fabrics through the mechanical action of wind and waves or by sunlight-induced photo-oxidation. They are also made up of items manufactured to be small, such as the microbeads added to cosmetics and shower gels as exfoliators to make skin feel soft and that then wash down the drain into the wastewater system, or the tiny particles generated by 3D printers or used in paints and coatings that reach the oceans through a similar route.

Plastics are synthetic polymers, which make up around 25% of the output of the global chemical industry, with around 4,000 different formulations in current manufacture, worth billions to the global economy. Plastics are wonderful materials; lightweight and durable, cheap to manufacture and non-toxic. They can be made into endless colours, shapes and materials (Figure 1) depending on the addition of dyes, plasticisers, hardeners, softeners, UV screens and antimicrobial agents, allowing us to manufacture many of the constituents of daily modern life that we take for granted: plastic bags and bottles, packaging materials, computer screens, plant pots, construction materials, clothes, medical disposables and even medicines themselves.

The term 'microplastics' therefore refers to a complex mixture of shapes and sizes, fragments, fibres and particles made from a multitude of polymer types and chemical additives. Unsurprisingly, it is our favourite plastics in terms of global tonnage that also form the major constituent of marine debris. Polymers that are less dense than seawater, like polyethylene and polypropylene, are more likely to float on the ocean surface, whilst polymers with a greater density, such as polyvinylchloride and polystyrene, settle in the water column or accumulate on the ocean floor.

How much is too much? Think of a number, any number, multiply it by a million and you are probably not even close to the amount of plastic currently in the oceans. Globally, we produce around 300 million tonnes of plastic per year, of which around 50% is intended for single use before being discarded. Conservative estimates suggest that there are over 5 trillion individual pieces of plastic floating on the ocean surface — that's a million pieces for each human being living on the planet! These eye-watering numbers don't include the tiny fragments at the nanoscale that form as microplastics break down to form nanoplastics, since we're not yet able to measure this size range in the environment. It has been suggested that there is now enough plastic to form a permanent and distinct layer in the fossil record. Interestingly, fibres outnumber fragments and beads, at the sea surface, in sediments and in the bodies of marine animals. Black and blue fibres are more common than any other colour.

What harm do they do? Just because microplastics are in the oceans, doesn't mean that they are doing any harm. Plastic is safe, right? The problem is that microplastics have accumulated in immense quantities in locations and in a form that was never envisaged when they were manufactured, and so most of the tests that have been performed to guarantee their safety in consumer items are inappropriate for determining their risk to marine life.

Does size matter? Microplastics raise concern because their small size overlaps with the preferred prey items of many marine animals, including indiscriminating filter, suspension and detritus feeders near the base of the food web, allowing these particles to be ingested along with, or instead of, normal food. Field studies have revealed microplastics in the guts or tissues of hundreds of marine species, including planktonic species from surface waters such as copepods and larval fish, and in

Figure 1. Plastic items found in marine debris collected from beaches across the southwest coastline of England, UK.
(Photo courtesy of Tracey Williams, UK, www.facebook.com/groups/lostatseagroup)

bivalves, crustaceans, and worms from the ocean floor. Microplastics are also found in the guts of larger animals, such as sea turtles, and in the scat of seals and other marine mammals. Whether they got there through direct ingestion or through consumption of contaminated prey is not yet known, but transfer of microplastics from prey to predator has been demonstrated in laboratory studies.

How about other effects on marine ecology? As things become smaller, so their relative surface area increases, providing a larger area for interaction with the outside environment. The hydrophobic nature of plastic attracts other substances, including organic and plant matter, bacteria, chemical contaminants and metals that adsorb onto the surface. Following ingestion, these substances can potentially transfer to the tissues of animals. The jury is out over the relative contribution that microplastics make to the transfer of contaminants to marine species compared to direct transfer across the skin or ingestion of contaminated food, since many hazardous persistent organic pollutants, such as organochlorine pesticides or polyaromatic hydrocarbons, are also prevalent in seawater. An intriguing possibility is that microplastics are selective in what else they bind, preferentially accumulating certain chemicals or substances deliberately secreted or exuded by marine life, including signalling molecules, pheromones and predator–prey infochemicals. When combined with the buoyancy and persistence of microplastics and their tendency to be moved long distances across the ocean surface through the action of wind, currents and tides, the resulting widespread distribution of these selected substances could alter ecological processes in many ways.

What are the consequences? If levels of microplastic contamination are sufficiently high, chronic exposure studies in the laboratory suggest a consistent pattern of adverse effects. Ingesting microplastics leads to altered feeding behaviours, leaving animals with lower lipid stores which then reduces growth and reproductive output. Carry-over effects in the next generation include reductions in offspring quality and growth rates. Other reported adverse effects relate to the uptake of particles across the gut and across cell membranes, triggering apoptosis and the upregulation of stress and damage repair pathways. Far fewer studies have been able to extrapolate from these findings to higher levels of biological organisation, and none to date have been able to identify populations in the wild that have been adversely affected. In part, this is due to the technical challenges of identifying microplastic-contaminated animals *in situ*. It is also challenging to link cause and effect against the backdrop of degraded marine habitats and multiple anthropogenic stressors to which many populations and communities are subjected.

What would it take to do things differently? Microplastics are, on the face of it, an easy problem to solve. It is a problem entirely generated by our own behaviour. We could simply stop throwing plastic into the oceans. Achieving this aim is less straightforward. Complex problems relating to patterns of consumer use, societal behaviour and waste-disposal infrastructure across developed and developing nations remain a barrier to international agreements. The technological achievements that brought us plastic in the first place could offer us the solution. Biodegradable biopolymers, which degrade completely to non-toxic monomers, changing fashions in reusable containers and consumer preference for more thrifty use and sustainable packaging can all make a difference. Societal pressure is potentially the most compelling of these. By improving ocean literacy, i.e. teaching people more about how the oceans function and the human behaviours that threaten them, we might stand more chance of achieving the UN Sustainable Development Goal of conserving the oceans for future generations.

Where can I find out more?

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