THE PROBLEM OF MICROPLASTICS IN OUR MARINE ENVIRONMENT

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Plastic debris is a widespread pollutant of the marine environment. Step on to any beach around the world and you will almost certainly find plastic litter. Not only is this plastic an eyesore, but it also poses a distinct threat to marine life and in turn human wellbeing. However, research is now suggesting that it is microscopic sized plastic, the plastic we don't readily spot, that we should be really concerned about (Figure 1).

Figure 1: Small plastic litter visible amongst the strand line on an otherwise pristine beach, Cockleridge, Devon. © Dr. Penelope Lindeque

PLASTIC IN OUR SOCIETY AND IN OUR SEAS

Large-scale production of plastics began in the 1950s, since which there has been an exponential growth of plastic production, with over 300 million metric tons currently manufactured globally each year. Plastic can be of vast benefit to society, providing a durable and low-cost material with widespread application. However, plastic is increasingly used to manufacture single-use, throwaway products, such as food packaging and drinks bottles, or to replace natural materials traditionally used in fishing gear, fabrics, or personal care products. Unfortunately, society has been slow to comprehend the pervasiveness and durability of plastic litter and waste management strategies have been equally slow to emerge. Through beach littering, road runoff, sewage, and illegal dumping, it is estimated that up to 10% of manufactured plastic ends up in the marine environment where it may take centuries to degrade. As a result plastic litter is increasingly emerging as a threat to marine life, ecosystems and potentially human health.

MICROPLASTICS

The effect that larger plastic debris has on wildlife is well documented. However, in recent years it has become apparent that microscopic plastic litter – termed "microplastics" – may pose an equal threat to marine life. Microplastics describe particulates and fibres, <5 mm in diameter, of various shapes, size, colour and polymer. Microplastics originate from two sources:

i) primary microplastics are manufactured to be of a microscopic size, and include small plastic resin pellets (nurdles or mermaid's tears) used to manufacture plastic goods, and extremely small plastic beads used as exfoliates in shower gels, toothpastes and industrial abrasives; and

ii) secondary microplastics which are derived from the degradation of larger plastic litter through exposure to ultraviolet radiation from the sun, abrasion or by the action of washing synthetic nylon or polyester clothing which can release thousands of plastic fibres into wastewater.

Microplastic debris has been identified in the water column and sediments of marine and freshwater ecosystems across the globe, including freshwater and glacial lakes, rivers, polar icecaps and deep sea sediments. Recent estimates suggest there are currently over 5 trillion bits of plastic floating within our oceans, the majority of which are microscopic in size, however this is likely to be a gross underestimate. According to recent studies there's much less microplastic observed in the sea surface compared to estimates of plastic production, release and expected rates of fragmentation. So where is this missing microplastic? Hypotheses put forward to explain this shortfall include accelerated fragmentation to nanoparticles, biodegradation, ingestion by organisms, sinking due to biofouling and settling in marine aggregates. In addition, sampling of microplastics with a traditionally used 335 micron net may be unrepresentative. We have recently made a comparison of microplastic abundance sampled with different size nets which clearly indicates that the smaller the net size used for sampling the more mircoplastics are found. In Plymouth Sound, for example, >16,000 anthropogenic fibres per cubic metre have been recorded following heavy rainfall and an ebbing tide using a 100 micron net.

Sampling is currently biased towards the collection of larger plastics from surface waters of the subtropical gyres in the open ocean where plastics are known to accumulate. However, sources of plastics are largely centred on urbanized areas and it is here in these highly biologically productive coastal environments that interactions between microplastics and small marine organisms are most likely to occur, suggesting that these coastal areas should be given greater attention (Figure 2; Clark, Cole, Lindeque et al., 2016).

SMALL PLASTIC, BIG RISK?

Owing to their small size and abundance, microplastics are readily consumed by marine organisms. Microplastic debris has been identified in the stomachs of over 200 different species, including seabirds, turtles, fish, shellfish and barnacles. Evidence indicates that microplastics can be directly ingested, or transferred to other organisms through the consumption of prey, animal carcasses, faeces or biotic material containing plastic. Ingestion of microplastic debris can result in gut blockages and anecdotal evidence indicates they can lead to mortality in whales, fish, turtles and seabirds.

Figure 3: Polystyrene microplastics ingested during laboratory experiments and visible in the intestinal tract of the marine copepod, Calanus helgolandicus. © Dr Matthew Cole

There is growing evidence that plastic debris can act like a magnet to other pollutants, including pesticides and industrial contaminants, present within the water; if eaten, there

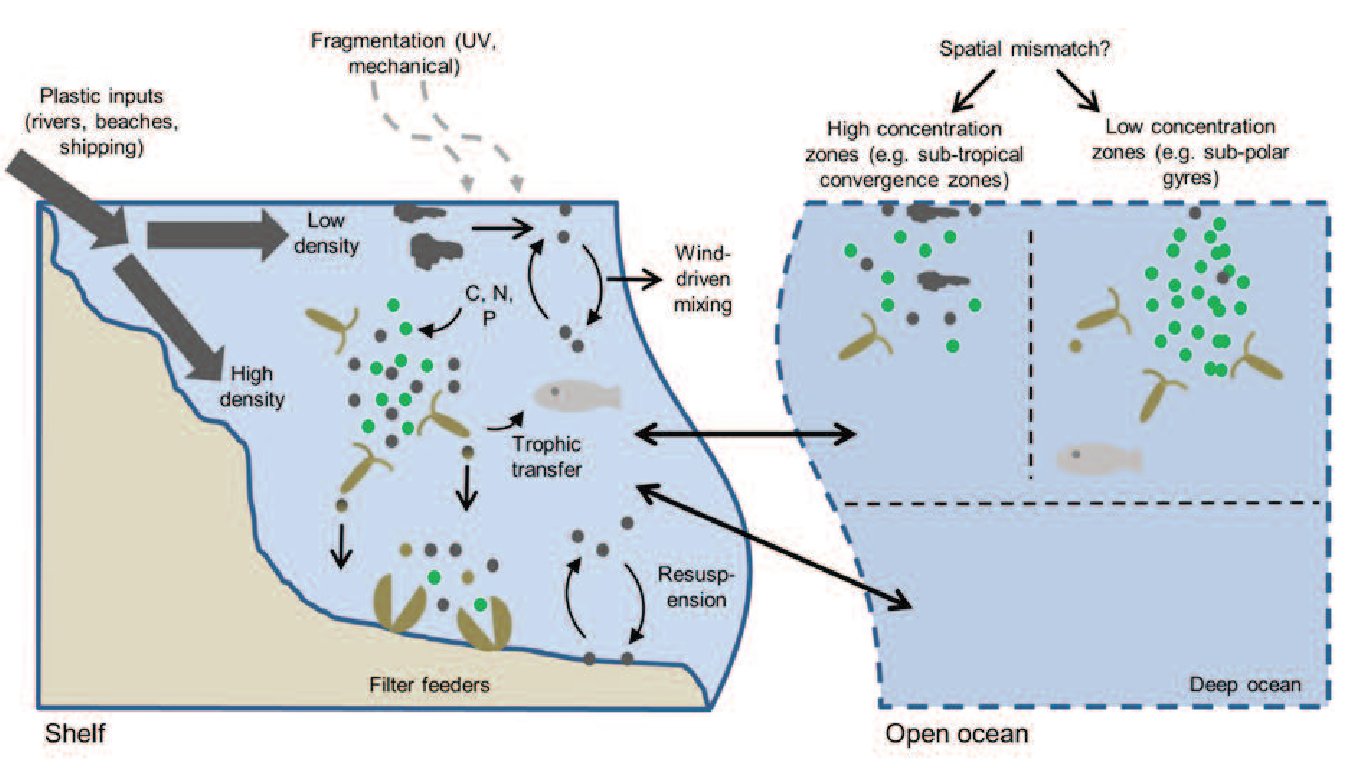

Figure 2: Schematic showing hypothesised regions and modes of interaction between microplastics (dark grey), small planktonic prey items (green) and other marine organisms (brown and light grey). Open ocean: known areas of high plastic accumulation (e.g. sub-tropical convergence zones) have low primary productivity meaning less energy is available to fuel the growth of consumers. Consequently, biological interactions with these organisms are expected to be less frequent. Shelf seas: areas with generally high levels of biological productivity that are often close to sources of plastic input, where we predict biological interactions will be more frequent (From Clark, Cole, Lindeque et al., 2016).

is concern such plastics might release these toxic compounds to the animal.

Our investigations into the risks microplastics pose to marine life have centred on zooplankton, small marine animals ubiquitous throughout our seas, which provide an essential link between primary producers (small marine plants such as algae) and higher trophic levels such as commercially important fish species and whales. Research conducted at Plymouth Marine Laboratory with the University of Exeter has demonstrated that a range of zooplankton, common to the Northeast Atlantic, including copepods (Figure 3), the larvae of bivalves (mussels, oysters etc.) and juvenile decapods (crabs, lobsters etc.), all have the capacity to ingest microplastics (Cole, Lindeque et al., 2013). Tiny plastics can also get trapped on the appendages of these animals, potentially affecting their movement and ability to detect predators and prey.

To better understand the consequence of microplastic ingestion in zooplankton we conducted in-depth experiments on copepods, a dominant group of zooplankton. Compared with microplastic free controls, copepods exposed to polystyrene microplastics ingested fewer algae and also showed a shift in preference to smaller algae prey, resulting in a 40% reduction in energy consumed (Cole, Lindeque et al., 2015). Over time, microplastic exposed copepods showed reduced reproductive outputs and survival. Similar adverse health effects have been observed in fish, polychaete worms, mussels and oysters.

The problem of microplastic ingestion by zooplankton however, doesn't end there. Recent studies have also shown that microplastics egested within copepod faecal pellets result in the pellets having less structural integrity (Cole, Lindeque et al., 2016). Additionally, if the egested microplastics were low density (e.g. polystyrene) then the faecal pellets sank more slowly. It is postulated this will increase the chances of them being eaten by other marine animals, resulting in the movement of the plastics through the food chain. The problem is two-fold; first moving the plastics through the food chain further disperses their potential to have negative effects, and secondly, this may reduce the organic matter reaching the seabed and increase the amount of particulate matter in the water column, with possible repercussions for wider marine ecological processes, and even the oceans climate control capacity.

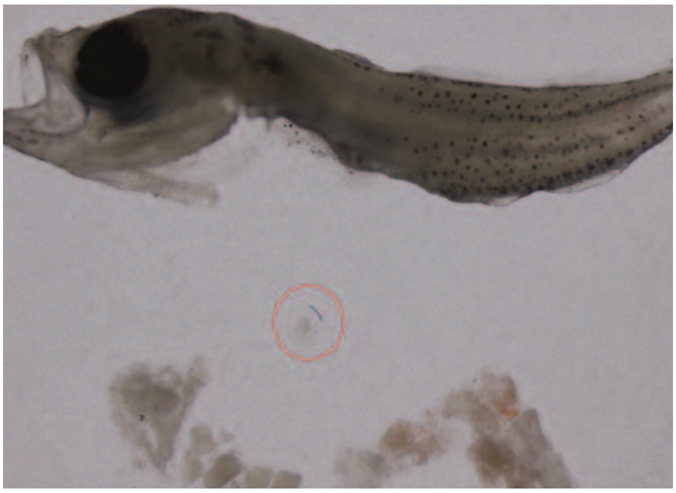

Figure 4: Whiting Merlangius merlangus (12 mm) post-larval stage caught at Station L5, Western English Channel (http://www.western channelobservatory.org.uk/) with a blue fibre (310µm x 30µm) dissected from the intestinal tract. © Madeleine Steer

Beyond the laboratory, and in the marine environment itself, it is currently unclear to what extent zooplankton will be affected by microplastic pollution. To address this knowledge gap at the Plymouth Marine Laboratory we have been undertaking an annual sampling programme based around the Western Channel Observatory http://www.western channelobservatory.org.uk/ (English Channel) to determine the extent of ingestion by zooplankton, including fish larvae, in the natural environment (Figure 4). Results from the laboratory and field based studies are being used in conjunction with mathematical models to determine the impact of microplastics on zooplankton and marine ecosystems; including the potential to affect the food chain.

ACTION IS URGENTLY NEEDED

With rates of manufacture rapidly increasing and long degradation times, marine plastic litter is expected to be a growing issue over the next century. While we don't yet know the full extent of the impact of microplastics on the health of the marine environment or humans, the growing body of evidence suggest microplastic pollution is a contaminant of environmental and economic concern. Working with the Ellen MacArthur Foundation, and funding from Players of People's Postcode Lottery, the Plymouth Marine Laboratory are now reviewing all current literature on marine plastics, with the aim of determining the likely global impact on human wellbeing. This ground-breaking research is anticipated to encourage manufacturers, innovators, legislators and consumers to work towards a circular economy and the prevention of plastic litter entering the marine environment.

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