

Plastic pollution in rivers and lakes—An indicator of an even bigger consequence of global change?

Over the past five or so years, the presence of plastic waste in the marine environment has received increasing publicity and has become a symbol of the effects of human life on the planet. Plastic pollution offers convincing images that symbolize the damaging nature of human activity in the Anthropocene. Powerful images of shark or whale stomachs packed with plastic bags or turtles with plastic wound round their necks have stirred the public and brought home the message that our use of plastic for so many things has a serious downside. Plastic bags in shark stomachs are highly visible, but the influence of plastic on the marine ecosystem is possibly even more damaging when microplastics are considered. Whales, sharks and all the teleosts we catch and eat are ultimately dependent on plankton although this link is not direct for top predators. There are now many examples of the influence of microplastics on the feeding habits of copepods, chaetognaths and other planktonic animals (<http://www.planktonpundit.org>). For this life form, a stomach full of microplastics is functionally the same as a shark stomach full of plastic bags.

The presence of microplastics in the marine environment is not new. An analysis of samples taken by the Continuous Plankton Recorder Survey, which has been sampling the Northeast Atlantic since the 1950s, has shown an increasing incidence of microplastic particles over the past 60 years (Edwards et al., 2009; Ostle et al., 2019; Thompson et al., 2004).

What is forgotten in the furore over plastic in the sea is that one of the main routes it takes to the sea is down rivers, which receive the processed and unprocessed waste from human activity. The presence of microplastics in the freshwater habitat has been less publicized, but its effects on the fish and other life must be as invidious as it is in the sea, perhaps even more so. A recently published study by Hou et al. (2021) has examined the alimentary canals in preserved museum specimens of four species of freshwater fish widely distributed in the United States. They find that microplastics were absent in samples taken before 1950 but have increased thereafter. This is clear evidence of how industrialization and our increasing reliance on oil-based products can be traced back to the guts of fish. Our plastic bags, once broken up into small particles, are the mistaken food items of young fish, thereby accumulating in the food web.

In this issue, Parker et al. synthesize information on the occurrence of microplastics in freshwater fish and explore the effects on the biochemistry, physiology and behaviour of a range of species. They summarize and collate information from studies in 20 countries and from around 18 species of fish from a wide range of families.

This comprehensive survey shows how plastic pollution in freshwaters is a pervasive and global issue. Plastics can be traced even to the most remote ecosystems, implying a diffuse aerial spread.

After realizing how pervasive microplastics are in the freshwater environment, the obvious next step is to develop a rigorous ecotoxicological and ecological research programme to study the biological and ecological consequences of microplastics (Parker et al., 2021, this issue). It is likely that the effects will be less sensational than the recent claim, now retracted, that plastic load increased mortality of perch (*Perca fluviatilis*, Percidae) in the presence of pike (*Esox lucius*, Esocidae) (for a report, see Enserink 2017). It is instead very likely that microplastics exert their effects predominantly at a sublethal level, changing energetics, behaviour and possibly fostering disease. Such effects in turn are likely interacting with other pervasive anthropogenic threats, such as global warming, to ultimately cause population-level consequences through altered mortality or reproduction. The next decade of research will expand our understanding.

Before this research becomes available, there is another benefit deriving from our appreciation of the widespread nature of plastic pollution. The increasing understanding of microplastic pollution in freshwater and other ecosystems serves as a publicly visible warning that we live in the Anthropocene and that our massive reliance on fossil fuels, oil and coal is creating serious issues, including global warming, that each of us is responsible for. In the context of climate change, one could recruit microplastic distribution in the ecosystem as a visible indicator of global warming.

While marine fish can respond to global warming and other threats by range expansion, many freshwater fish are trapped in their ecosystems. Adaptation to thermal and other local changes is possible through evolution, but only within limits (Morgan et al., 2020). If an ecosystem such as in a lake or an upstream river section is becoming too warm or too polluted, there is no possibility for cold-water-adapted fish to adapt in the short term and there is limited opportunity for range expansion, resulting ultimately in extinction as the worst possible outcome. The “microplastic invasion” documented by Parker et al. (this issue) carries with it a warning about the vulnerability of freshwater systems and freshwater fish in particular to global change drivers—effects that we as a scientific community are only beginning to understand.

A key issue for policymakers may be how to persuade industry and individuals to use less plastic and if they must use it, to find acceptable ways for it to be dealt with once it is no longer required. If we are to reduce the influence of plastics on the marine and freshwater habitats and their biota, then education and proper incentives

for each individual to deal responsibly with waste become the priority. Some of these incentives will be costly. There is little merit in being horrified at a shark stomach full of plastic if people so affected are not prepared to take responsibility for proper waste disposal or better waste avoidance. Ultimately, lakes and rivers are sinks to everything we do in our private households, be it using plastics or antibiotics—in the end they all trace back in fish. This outlook might worry people enough to initiate action.

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