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REVIEW

Surfing and dining on the "plastisphere": Microbial life on plastic marine debris

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ABSTRACT

Plastic marine debris represents a global threat for the marine environment, having serious consequences for the ocean, the wildlife and the human health. While the plastics distribution, fate, persistence and toxicity mechanisms for the marine fauna have been more studied in the last decade, small efforts have been devoted to identify and characterize marine microbes that colonize plastic and microplastic debris in the ocean, and their potential to degrade plastics. Here we review the knowledge on the microbial biodiversity and degradation mechanisms of marine plastic debris, and present data, based on metagenomic analyses, on the distribution patterns of genes potentially involved in microbially-mediated plastic degradation in coastal locations across the global ocean. Most studies on plastic-colonizing microbes have focused on seawater rather than sediment, with most studies underlining striking differences in composition between assemblages attached to plastic particles and those in the surrounding environment. The diversity of microbes attached to plastic is high, and the core epiplastic microbial assemblages include often hydrocarbon-degrading bacteria, as well as prokaryotic and eukaryotic phototrophs. Several marine microbes have shown to be able to degrade or deteriorate plastic in the laboratory, or to grow on plastic as the only source of carbon, while indirect evidences suggest that microbially-mediated degradation of recalcitrant plastics also occur in the ocean, though at very low rates. Metagenomic analyses show that plastic degradation-related genes are present in microbial assemblages in several coastal ocean sites, with relative abundance related to the magnitude of plastic pollution at each site. Further research is required to study microbial plastic-degraders in the marine ecosystem, to decipher and exploit the potential of microbial consortia to degrade or mineralize plastic compounds, and to better understand the fate and residence times of plastic waste in the ocean.

Key words: Plastics; microbes; metagenomics; biodegradation.

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PLASTICS IN THE OCEAN

Plastic is today recognized as the most abundant form of man-made debris in the sea (Barnes *et al*., 2009), with the mass of land-based plastic waste entering the ocean recently estimated to be in the range 4.8 to 12.7 million metric tons per year (Jambeck *et al.*, 2015). Early reports on the occurrence of plastics in the marine environment can be traced back to the 70s: Carpenter and Smith (1972) reported on the presence of an average 3500 plastic particles per square kilometer in the Sargasso Sea surface, collected through a neuston net in an area located far from obvious pollution sources from land. The authors speculated that the source of the particles could have been the dumping of waste from cities or by the cargo and passenger ships, given that some of the sampled areas were within major shipping lanes from Europe to America. Later on, Gregory and Ryan (1997) reported that plastics accounted for a significant proportion (from 60 to 80%) of the total debris encountered in the seas of the Southern Hemisphere. Since then, a number of papers have increasingly documented the presence and spread of plastic debris across the marine environment (Galgani *et al.*, 2000; Moore *et al.*, 2001; Moore *et al.*, 2002; Willis *et al.*, 2017; Worm *et al.*, 2017). However, the threat of plastics to the marine environment has been ignored for a long time, and it is only in more recent years that its serious consequences for the ocean, the wildlife and the human health have started to being recognized (Derraik, 2002).

Plastic debris occurs along the coastlines (Browne *et al.*, 2010), at the sea surface (Law *et al.*, 2014) and on the sea floor (Stefatos *et al.*, 1999; Galgani *et al.*, 1996; Claessens *et al.*, 2011; Cau *et al.*, 2017), and even in remote areas such as the open ocean surface far from land (Cozar *et al.*, 2014). Plastic reaches the ocean both in the form of large visible debris ("macro") that is larger than 1-5 mm, or in the form of small particles or fragments called "micro-plastics" (having dimensions typically <1-5 mm) (Browne *et al.*, 2010), despite globally accepted definitions for these categories are yet to be established. In a recent review that compared the methodologies used in 68 studies for the quantification of microplastics in the marine environment, Hidalgo-Ruz *et al.* (2012) highlighted that most of them reported two main size ranges of microplastics, 500 µm-5 mm and 1-500 µm, or fractions thereof that are retained on filters, confirming that there is still not a universally adopted size range to define