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Editorial: Effects of microplastics on ecosystem functioning of eukaryotic marine microbes

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Editorial on the Research Topic
Effects of microplastics on ecosystem functioning of eukaryotic marine microbes

Overview

Microplastics (MPs) are increasingly being reported from all the components of most aquatic ecosystems including littoral, pelagic, benthic, deep-sea environment, seabed sediments, wastewater effluents, and even in Antarctic fjords. Given the continued increase in the consumption, production, and persistence of polymers, the MP quantity is likely to surge exponentially with lessening size in aquatic ecosystems (Jahnke et al., 2017). Thus, MPs are increasingly becoming contaminants of serious concern in the marine ecosystem globally. At present we are far from a full understanding of the ecological consequences of MPs – their contamination, accumulation and interactions with marine organisms, especially eukaryotic microbes (EM). EM play a critical role in carbon transfer via multiple routes by ingesting bacteria, fungal spores, phytoplankton and zooplankton, and are in turn ingested by planktivorous fish and invertebrates. Grazing on fungal spores functions as a different phytoplankton → fungi → EM (mycoloop) route, whereas grazing on bacteria constitutes a second pathway as dissolved organic matter (DOM) → bacteria → EM → necton (microbial loop) route. Both routes play an important role in returning DOM to higher organisms via its incorporation into bacterial and fungal biomass and connecting the classical algae-based food chain. The size range of MPs overlaps with the dietary niche size of EM in marine ecosystems. Therefore, inevitably MPs are easily ingested by size-selective grazers, indirectly via ingestion of MP-contaminated natural prey, and incidentally via feeding process while ingesting a natural prey. Being indigestible particles, MPs bring down the intake of natural diet, leading to a lower energy gain at organismic level, and affecting prey–predator relationships at community level.

The hydrophobic MP surface can sorb harmful chemicals and stressors, and can act as an ideal site for colonization of pathogens and invasive strains before being ingested by marine organisms. MPs directly interact with all the components of microbial loop and mycoloop, in addition to their influence on the algae-based trophic pathway. MPs affect different microeukaryotic groups differentially (Figure 1), for instance, MPs influence (i) algae by penetrating algal cells, decreasing chlorophyll absorption and decreasing photosynthesis rate; (ii) zooplankton by direct ingestion, by interfering with their feeding process, through clogging and entangling appendages, and also by transferring pathogens, parasites and toxicants; (iii) fungi by providing artificial substrate for growth and colonization (Kettner et al., 2017); and (iv) their infection by chytrid on cyanobacterium *Planktothrix agardhii* (Schampera et al., 2021), altering outcomes of host–parasite interactions. The aggregation of MPs around the host and parasite constitutes a physical barrier, limiting direct contact between the host and parasite; it also provides substrate for microbial colonization leading to biofilm formation, which causes biofouling, thereby enhancing the bioavailability of MPs for zooplankton and ichthyoplankton. Copepods, being the most dominant metazoans play an ecologically relevant role in sinking of MPs along with their fecal pellets in the ocean in form of marine snow (Cole et al., 2016; Rodríguez-Torres et al., 2020). This is likely to influence the outcome of interactions among eukaryotic microbes and affect prey–predator dynamics. The physical and biological effects of MPs might also adversely impact global ocean oxygenation similar to that of climate warming (Oschlies et al., 2018) with implications for general ecosystem functioning (Schulze and Mooney, 1993). An alteration in any level of the ecosystem (community, population and individuals) would affect nutrient cycling also. This Research Topic is germane in the present scenario of global MP pollution. We have included four papers by leading authors highlighting the latest advances reviewing various aspects of MP pollution and their effects at all levels of biological organization in marine environment. To advance our knowledge about ecological consequences of MPs on the ecosystem functioning of EM in the marine ecosystem, we present research on MP effects on the diversity and demography of marine eukaryotic microbes (protists, fungi, and zooplankton), their ecological functioning and outcomes of prey–predator interactions.

Highlights of articles featured in the Research Topic

Thery et al. compare the effect of biodegradable and non-biodegradable MP on the microbiota of copepod *Euretimora affinis* after four generations of chronic exposure to single-use polymers (low-density polyethylene and biodegradable polymer-polybutylene adipate terephthalate (PBAT)). Their study, based on 16S rRNA gene high-throughput sequencing suggests that MPs rapidly affect the copepod-associated microbial community, with the effects persisting for generations regardless of plastic origin. This paper also concludes that the biodegradable PBAT, may not be an ideal alternative to non-biodegradable plastics, in terms of their

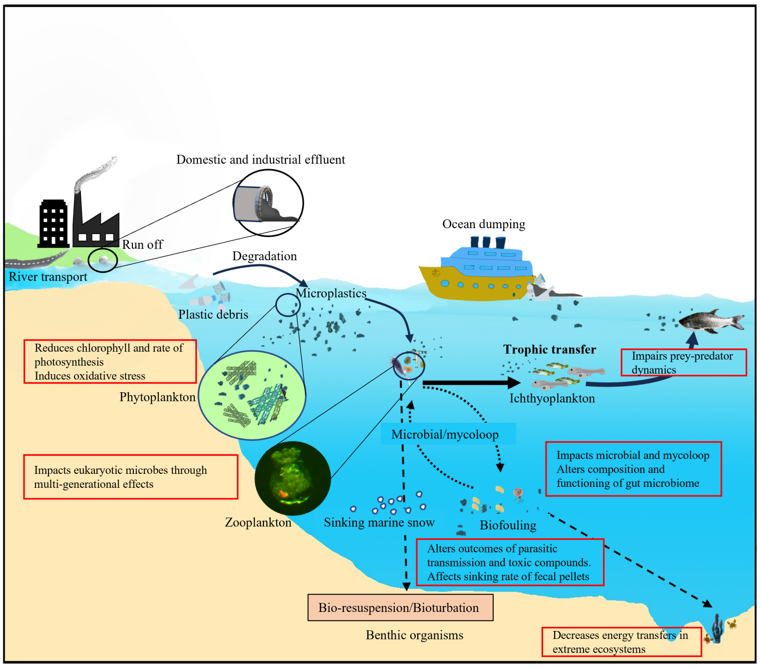

FIGURE 1
Schematic presentation of the effects of microplastics on ecosystem functioning of eukaryotic marine microbes via reduction of photosynthesis rate, induction of oxidative stress, reduction of carbon transfer through microbial loop, intervention of fungal activities through mycoloop, alteration of gut microbiome composition, functioning and alteration of prey–predator dynamics.

effects on microbiota. It highlights the self-resilient ability of the microbial community following the removal of MP from the system.

Muthu et al. evaluate the effects of polyethylene MP contamination on physical, and biochemical characteristics of the ventiferous crab *Xenograpsus testudinatus* and on its gut microbiota using the 16S rDNA gene full-length sequencing. Benthic deposit feeders like *X. testudinatus* inhabit the immediate vicinity of hydrothermal vents and utilize for their survival the zooplankton and other associated microbiota killed by vent plumes. This paper presents preliminary evidence on the presence of MPs in the shallow-water hydrothermal vent crab *X. testudinatus* and their potential impacts on the crab's microbiome. MP contamination increases the concentration of Proteobacteria and Bacteroidetes, whereas, it decreases the concentration of Firmicutes and Tenericutes. The alterations in crab's microbiome and their function raise concerns and point to the unanswered question of whether changes in the gut microbiota would affect the environmental microbial communities and the community structure of shallow-water hydrothermal vents.

Sharma et al. elucidate MP-mediated alterations in prey–predator interactions between tropical estuarine calanoid *P. annandalei* and its prey (rotifers and ciliates) using functional response approach. These authors reported that the presence of MPs alters outcomes of prey–predator interaction within eukaryotic microbes as the behavioral response of predator to prey density is affected by the MPs. Lower consumption of natural prey, slower ingestion rate, and altered functional response type due to MP contamination are reported in this paper. The reduced predation rate was attributed to pseudo-satiation due to MPs ingestion, leading to malnutrition and MP accumulation in copepod biomass.

Yadav and Kumar critically reviewed existing literatures on various interaction types among eukaryotic microbes with an emphasis on zooplankton–fungi interactions. This paper concludes that the MPs alter the complex ecological interaction (fungi–phytoplankton–zooplankton) impeding energy flow through the mycoloop and microbial loop (Figure 1). They suggest that MPs become part of the eukaryotic community and affect organisms at all trophic levels, from bacteria to piscivorous fish. However, the outcome of interactions among various microbial compartments of aquatic food webs are altered by MP and this alteration is modulated by the more complex interactions shaped by bacterivory, algivory, and predatory protists, rotifers, crustaceans and benthos. The paper identifies the research gap and highlights the need for future research to understand MP-mediated changes in the marine ecosystems.

All four articles in this Research Topic shed light on the far-reaching effects of MP on energy flow through various pathways of marine food web, through altering copepod microbiome, through transfer of chemicals from ambient water to aquatic biota, dispersal and transfer of epiplastic microbes, via blocking, choking gut lumen and through entanglement in marine ecosystems including extreme systems like hydrothermal vents.

Author contributions

RK: Conceptualization, Writing – original draft, Writing – review & editing. RD: Visualization, Writing – review & editing. JA-P: Resources, Validation, Writing – review & editing. DK: Conceptualization, Writing – review & editing. J-SH: Supervision, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

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