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Focus

# Microplastics in corals: An emergent threat

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ABSTRACT

This article seeks to present a summary of knowledge and thus improve awareness of microplastic impacts on corals. Recent research suggests that microplastics have a variety of species-specific impacts. Among them, a reduced growth, a substantial decrease of detoxifying and immunity enzymes, an increase in antioxidant enzyme activity, high production of mucus, reduction of fitness, and negative effects on coral-Symbiodiniaceae relationships have been highlighted in recent papers. In addition to this, tissue necrosis, lower fertilization success, alteration of metabolite profiles, energetic costs, decreased skeletal growth and calcification, and coral bleaching have been observed under significant concentrations of microplastics. Furthermore, impairment of feeding performance and food intake, changes in photosynthetic performance and increased exposure to contaminants, pathogens and other harmful compounds have also been found. In conclusion, microplastics may cause a plethora of impacts on corals in shallow, mesophotic, and deep-sea zones at different latitudes; underlining an emerging threat globally.

## 1. Threats to corals

Prolonged warming, ocean acidification, deoxygenation, weakening of benthic-pelagic coupling, high intensity and frequency of heat waves, and marine pollution have caused mass mortality of reef-building corals in the ongoing Anthropocene (Altieri et al., 2017; Eyre et al., 2018; Rossi et al., 2019; Hughes et al., 2018, 2020). These multiple stressors drive severe degradation, loss of diversity and oversimplification of shallow-water coral reefs (<30 m depth) (Hoegh-Guldberg et al., 2017), mesophotic coral ecosystems (~30–150 m depth) (Rocha et al., 2018; Soares et al., 2020), and even cold-water coral ecosystems of the deep sea (Boolukos et al., 2019; Hebbeln et al., 2019), leading to large-scale degradation of marine animal forests (sensu Rossi, 2013) worldwide. In addition to these different stressors, microplastics have become another understudied and recently emergent threat to coral reefs (Lartaud et al., 2020). Pollution concern from microplastics has increased rapidly during the last few decades due to the significant increase of macroplastics in marine waters that degrade to smaller-sized particles. Moreover, they enter the marine environment as a primary microplastics from their inappropriate disposal (Reichert et al., 2018; Akdogan and Guven, 2019; Hale et al., 2020). Even more difficult to detect and quantify are the nanoplastics (from 100 nm to 0.1 μm, Piccardo et al., 2020), which potentially represent a threat at the cellular level and are less studied than microplastics (Gopinath et al., 2019).

## 2. Definition of microplastics

A recent attempt to put a clearer language framework around plastic debris, categorizes microplastics as between 1 μm and 1 mm in size, as measured by the maximum length (Hartmann et al., 2019). Other definitions consider microplastics to be as large as 5 mm (e.g., Arthur et al., 2009; GESAMP, 2015; Frias and Nash, 2019). Microplastics may be further categorized by their chemical composition, solid state, solubility, shape and structure (e.g., spheres, foams, fibers, fragments, films, flakes etc), color (which can affect ingestion rates in some organisms), and origin (Hartmann et al., 2019). The chemical composition of microplastics varies widely and encompasses many forms including polyethylene, polypropylene, polyvinyl chloride, polystyrene, and

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polyethylene terephthalate (Akdogan and Guven, 2019; Franzellitti et al., 2019).

## 3. Source of microplastics

Microplastics originate from multiple sources. It has been estimated that between 1.15 and 2.41 million tonnes of plastics flows from rivers to the oceans annually (Lebreton et al., 2017), with packaging being a major contributor to riverine plastic debris (Schwarz et al., 2019). Land-based sources are estimated to comprise approximatively 80% of marine plastic debris, with ocean-based sources such as fishing the remaining 20% (Li et al., 2016). Microplastics can also be transported in the atmosphere for distances approaching 100 km (Allen et al., 2019) and found in places like the Antarctic sea ice (Kelly et al., 2020). Microplastics maybe primary (i.e., they are manufactured as microplastics) or secondary (i.e., they result from degradation of macroplastics) (Hale et al., 2020). Density and surface area affect how microplastics are sedimented and/or resuspended, but ocean bottoms provide the ultimate microplastic sink (Schwarz et al., 2019). Microplastics are increasingly being reported from reef environments, both close onshore and offshore, with riverine input from coastal cities and activities, local intensive fisheries, and trade winds as hypothesized as sources (Critchell et al., 2019; Jensen et al., 2019; Huang et al., 2019). Microplastics can be transferred from ocean to beach (Schwarz et al., 2019) so it is not a one-way transport.

## 4. Microplastics as an emergent threat

Attention given to the impact of macroplastics on corals has recently been growing (Bidegain and Paul-Pont, 2018; Lamb et al., 2018; Lartaud et al., 2020). However, the multiple impacts that microplastics may have on scleractinian corals is largely understudied (Hankins et al., 2018; Reichert et al., 2018; Montano et al., 2020; Huang et al., 2020). One concern is whether the accumulation of microplastics, in addition to global warming and heat waves, may affect coral-algae symbiotic relationships (Okubo et al., 2018; Orte et al., 2019; Lanctôt et al., 2020) and consequently lead to additional coral bleaching (Syakti et al., 2019), causing further mortality of these eco-engineer species. These tiny particles may act together with several human stressors (Axworthy and Padilla-Gamiño, 2019) to amplify the susceptibility of corals. They also increase the risk of decline of these habitat-forming species that underpin the structure and function of shallow-water, mesophotic, and cold-water reefs by interfering in their food balance (Hall et al., 2015). This is especially worrying considering that corals and their structurally complex forests, as suspension feeders, are potential sinks (Martin et al., 2019; Corona et al., 2020) for microplastics worldwide. Although literature regarding these and other impacts of microplastics has been growing rapidly in the last few years, with findings even in quite remote or unexpected areas (e.g., Garcia et al., 2020; Kelly et al., 2020), this information remains largely unknown by administrative agencies, stakeholders, non-governmental organizations, and governments, as well as the private sector. This happens despite significant concern in the media, in society, and from multiple stakeholders, about the ecotoxicological impacts on corals (Allen et al., 2017; Hankins et al., 2018; Rist and Hartmann, 2018). In this framework, a synthetic review is crucial and timely. Therefore, this focus article seeks to present a short summary of current knowledge and research and thus improve awareness of microplastic impacts on habitat-forming scleractinian corals, which form the cornerstone of reefs.

## 5. Interaction of corals and microplastics: adhesion and ingestion

Microplastics may affect corals passively by adhering to the coral surface (Allen et al., 2017; Hankins et al., 2018; Martin et al., 2019; Procter et al., 2019), which is an important mechanism of microplastic induced-stress on corals. Adhesion was shown to be 40 times more effective in removing microplastics from the water than ingestion in three species of coral in the Red Sea (Martin et al., 2019). Martin et al. (2019) investigated the effects of microplastics on three reef-building corals (*Acropora hemprichii*, *Pocillopora verrucosa* and *Goniastrea retiformis*). The first two coral species are branching species with small-sized polyps, while *G. retiformis* is a massive coral with large polyps (i.e., 2–3 mm). Similarly, in the mushroom coral *Danafungia scruposa*, common in the Maldives reefs, adhesion removed ~98%, while ingestion removed only ~2% of microplastics (Corona et al., 2020). These results indicate that despite growth, coral form, distinct distribution of species and polyp size, passive adhesion may be an important mechanism. This also suggests that corals are efficient sinks of microplastics in the oceans owing to their rugose and complex skeletons that trap microplastics transported by sea currents (Martin et al., 2019; Corona et al., 2020). Microplastics may interfere with coral functioning. Microplastics have been found to affect coral cleaning mechanisms (direct interaction, overgrowth, mucus production) and interact with feeding mechanisms (i.e., interaction with mesenterial filaments, ingestion, and egestion) depending on the species and the size of coral polyps. In this way, high microplastic concentrations may be especially harmful to stress-sensitive coral species (Reichert et al., 2018) and small polyps (Hankins et al., 2018; Tang et al., 2021).

Suspension feeding organisms will have different procedures and clearance rates depending on their feeding (passive or active) strategy (Arossa et al., 2019; Hall et al., 2015). In fact, microplastics may also affect corals via direct ingestion of seston (Hall et al., 2015). Microplastics may be captured, ingested, and partially or totally egested depending on the quantity and type of microplastic, phagostimulants, and the coral species (Hall et al., 2015; Allen et al., 2017; Hankins et al., 2018; Reichert et al., 2018; Montano et al., 2020). Corals probably lack a selection mechanism to allow the polyps to discern between food items (e.g., plankton) and microplastics when they occur simultaneously in the marine environment (Savinelli et al., 2020). Habitat-forming corals can thus easily mistake microplastics for their natural prey, and ingest them and all the annexed plasticizer additives. For example, Montano et al. (2020) reveal that >95% of corals (*Pocillopora verrucosa*, *Porites lutea* and *Pavona varians*) sampled in Maldivian reefs were contaminated, with a maximum of 172.4 ng/g, a value 7-fold higher than found in a previous study. They focused on five phthalate esters (PAEs) namely dibutyl-phthalate (DBP), benzylbutyl-phthalate (BBzP), diethyl-phthalate (DEP), Bis(2-ethylhexyl)-phthalate (DEHP), and dimethyl-phthalate (DMP) and concluded that these contaminants can represent a novel, and ubiquitous, form of contamination in scleractinian corals (Montano et al., 2020).

Experimental feeding tests have revealed that corals cannot distinguish microplastics from their natural preys while in other cases they select some microplastics (Hall et al., 2015). In addition, recent investigations have found microplastics in the mesenteric tissue within the coral gut cavity (Rotjan et al., 2019). Where these organisms ingest energetically non-profitable seston or particles from non-organic origin, the energy budget may be unbalanced and the energy invested in respiration, growth or reproduction may be affected in the overall input-output equilibrium. Coral species respond differentially to microplastics (Lartaud et al., 2020). Since thermal stress and bleaching in some corals lead to an increase in heterotrophy, these species may have an increased risk of ingesting microplastics (Axworthy and Padilla-Gamiño, 2019). Ingestion of microplastics may be considered a ‘double jeopardy’ to the corals because they may suffer a nutritive loss by eating nonnutritive particles (i.e. microplastics) and may spend energy ingesting and egesting those microplastics (Rotjan et al., 2019).

## 6. Overview of direct impacts

Recent research suggests that microplastics have a plethora of negative species-specific impacts on corals (Table 1), some of which

**Table 1**
Impacts of microplastics on scleractinian corals.

| Impact | Coral species | Microplastics concentration | Exposure time | Reference (s) |
|---|---|---|---|---|
| Reduced growth | *Acropora muricata*<br>*Heliopora coerulea* | $\sim$200 particles L$^{-1}$ or 0.25 mg L$^{-1}$ | 6 months | Reichert et al. (2019) |
| | | 350 particles L$^{-1}$ | 2 months | Chapron et al. (2018) |
| | *Lophelia pertusa* | 350 particles L$^{-1}$ | 5 months | Mouchi et al. (2019) |
| Significant decrease of detoxifying and immune enzymes | *Pocillopora damicornis* | 50 mgL$^{-1}$ or 9,0 × 10$^{10}$ particles L$^{-1}$ | 6, 12, 24h | Tang et al. (2018) |
| Increases in the activities of antioxidant enzymes and chlorophyll content | *Pocillopora damicornis* | 50 mgL$^{-1}$ or 9,0 × 10$^{10}$ particles L$^{-1}$ | 6, 12, 24h | Tang et al. (2018) |
| Alteration of coral metabolite profiles (increased levels of phosphorylated sugars and pyrimidine nucleobases) | *Stylophora pistillata* | 5 particles/mL and 50 particles/mL | 28 days | Lanctôt et al. (2020) |
| | *Acropora hemprichii* | 53 – 500 µm; 13645 ± 139 beads L$^{-1}$ or $\sim$ 0.2 g L$^{-1}$ | 28h | Martin et al. (2019) |
| High production of mucus | | | | |
| | *Porites lutea* | 37–163 µm;<br>$\sim$ 4000 particles L$^{-1}$ or 0,1 g L$^{-1}$ | 4 weeks | Reichert et al. (2018) |
| Symbiont chlorophyll content increased | | | 6, 12, 24h | Tang et al. (2018) |
| | *Pocillopora damicornis* | 50 mgL$^{-1}$ or 9,0 × 10$^{10}$ particles L$^{-1}$ | | |
| Reduction of fitness (impacted by plastic ingestion and adhesion) | *Danafungia scruposa* | 212- 1000 µm, 2,996 ± 5 beads or 0.57 ± 0.0001 g per 1.5 L | 2 days | Corona et al. (2020) |
| | *Astroides calycularis* | 20 particles per 15L | 30 min<br>90 min | Savinelli et al. (2020) |
| Significant decrease of detoxifying and immune enzymes | *Pocillopora damicornis* | 50 mgL$^{-1}$ or 9,0 × 10$^{10}$ particles L$^{-1}$ | 6, 12, 24h | Tang et al. (2018) |
| Tissue necrosis | *Acropora formosa* | 0.05 g. L$^{-1}$, 0.1 g. L$^{-1}$, and 0.15 g. L$^{-1}$. | 14 days | Syakti et al. (2019) |
| | *Pocillopora verrucosa* | $\sim$200 particles L$^{-1}$ or 0.25 mg L$^{-1}$ | 6 months | Reichert et al. (2019) |
| | | 37–163 µm;<br>$\sim$ 4000 particles L$^{-1}$ or 0,1 g L$^{-1}$ | 4 weeks | Reichert et al. (2018) |
| | *Pocillopora damicornis* | 37–163 µm;<br>$\sim$ 4000 particles L$^{-1}$ or 0,1 g L$^{-1}$ | 4 weeks | Reichert et al. (2018) |
| | *Acropora muricata* | $\sim$200 particles L$^{-1}$ or 0.25 mg L$^{-1}$ | 6 months | Reichert et al. (2019) |
| Coral bleaching | *Acropora formosa* | 0.05 g. L$^{-1}$, 0.1 g. L$^{-1}$, and 0.15 g. L$^{-1}$. | 14 days | Syakti et al. (2019) |
| | *Acropora humilis*<br>*Acropora millepora*<br>*Porites cylindrica* | 37–163 µm;<br>$\sim$ 4000 particles L$^{-1}$ or 0,1 g L$^{-1}$ | 4 weeks | Reichert et al. (2018) |
| | *Acropora muricata* | $\sim$200 particles L$^{-1}$ or 0.25 mg L$^{-1}$ | 6 months | Reichert et al. (2019) |
| Lower fertilization success | *Acropora tenuis* | 5 pieces L$^{-1}$ to 200 pieces L$^{-1}$ | 2, 5 h and 24 h | Berry et al. (2019) |
| | *Acropora humilis*<br>*Acropora millepora*<br>*Porites lutea*<br>*Porites cylindrical* | 37–163 µm;<br>$\sim$ 4000 particles L$^{-1}$ or 0,1 g L$^{-1}$ | 4 weeks | Reichert et al. (2018) |
| Overgrowth on microplastics (energy costs) | | | | |
| Ingestion, retainment within their gut cavity and egestion | *Dipsastrea pallida* | 0.395 g. L$^{-1}$,<br>0.197 g L$^{-1}$ (±0.2) and 0.24 g L$^{-1}$ (±0.13) | 48 h, 12 h and 3 h | Hall et al. (2015) |
| | *Montastraea cavernosa* | 30 mg L$^{-1}$ | 48 h | |
| | | | | Hankins et al. (2018) |
| | *Orbicella faveolata* | 30 mg L$^{-1}$ | 48 h | |
| | *Madrepora oculata* | 350 beads L$^{-1}$ | 5 months | Mouchi et al. (2019) |
| | *Pocillopora verrucosa* | 37–163 µm;<br>$\sim$ 4000 particles L$^{-1}$ or 0,1 g L$^{-1}$ | 4 weeks | Reichert et al. (2018) |
| | *Astroides calycularis* | 20 particles per 15L | 30 min<br>90 min | Savinelli et al. (2020) |
| Decreased feeding performance and food intake | *Astroides calycularis* | 20 particles per 15L | 30 min<br>90 min | Savinelli et al. (2020) |
| | *Desmophyllum pertusum* | 350 beads L$^{-1}$ | 5 months | Mouchi et al. (2019) |
| | *Montipora capitate*<br>*Pocillopora damicornis* | 2 particles mL$^{-1}$ | 10 days | Axworthy and Padilla-Gamiño (2019) |
| | *Astrangia poculata* | 0.1 g in 500 ml | 15 min | Rotjan et al. (2019) |
| Changes on photosynthetic performance | *Acropora muricata*<br>*Pocillopora verrucosa* | $\sim$200 particles L$^{-1}$ or 0.25 mg L$^{-1}$ | 6 months | Reichert et al. (2019) |
| | *Acropora formosa* | 0.05 g. L$^{-1}$, 0.1 g. L$^{-1}$, and 0.15 g. L$^{-1}$. | 14 days | Syakti et al. (2019) |
| | *Stylophora pistillata* | 5 particles/mL and 50 particles/mL | 28 days | Lanctôt et al. (2020) |
| Decreased skeletal growth rates and calcification | *Desmophyllum pertusum* | 350 beads L$^{-1}$ | 5 months | Mouchi et al. (2019) |
| | *Heliopora coerulea* | $\sim$200 particles L$^{-1}$ or 0.25 mg L$^{-1}$ | 6 months | Reichert et al. (2019) |

include reduced growth, a significant decrease of detoxifying and immunity enzymes, an increase in antioxidant enzyme activity, high production of mucus, reduction of fitness, and negative effects on coral-Symbiodiniaceae relationships. In addition to this, tissue necrosis, lower fertilization success, alteration of metabolite profiles, energetic costs, decreased skeletal growth and calcification, and coral bleaching have been observed in the presence of microplastics (Table 1). Furthermore, impairment of feeding performance and food intake, changes in photosynthetic performance and increased exposure to contaminants, pathogens and other harmful compounds have also been observed (Table 1).

Some effects appear to be species-specific (Table 1). For example, while reduced growth was detected in *Acropora muricata* and *Heliopora coerulea* when exposed to microplastics; the growth of *Porites lutea* and *Pocillopora verrucosa* remained unchanged. Photosynthetic activity has been evaluated in the above-mentioned four coral species exposed to microplastics, reporting an alteration of photosynthetic performance in both *A. muricata* and *P. verrucosa* but not in *P. lutea* and *H. coerulea* (Reichert et al., 2019). These effects will be especially deleterious in stress-sensitive species at distinct depths and are dependent on the type of microplastic they may potentially ingest. For example, low-density polyethylene (LDPE) was shown to affect coral polyps of *Acropora formosa* via either direct interaction or through photosynthesis perturbation. This exposure leads to bleaching and necrosis in this staghorn coral, which thrives in tropical shallow-water reefs (Syakti et al., 2019). Furthermore, LDPE impairs prey capture and growth rates of *Desmophyllum pertusum*, a habitat-forming deep-sea coral (Mouchi et al., 2019). It also causes decreased skeletal growth rates and calcification in the same species (Chapron et al., 2018). However, LDPE does not affect another important cold-water coral, *Madrepora oculata*, which seems to be more resistant to this stressor (Mouchi et al., 2019).

## 7. Indirect effects

Microplastics, with their very high surface area to volume ratio associated with their small size, provide a surface to which toxicants may adsorb (Caruso, 2019). Thus, any contact with microplastics, be it internal or external, may have detrimental toxicological effects on the coral and its tissues that have to still be explored. Besides the direct effects cited above and in Table 1, microplastics may also have indirect effects on coral health when their exposure to chemical contaminants, bacteria, and viruses increases. In this way, microplastics tend to adsorb hydrophobic organic pollutants and aqueous metals (e.g., phthalic acid esters, metals, antibiotics) (Naik et al., 2019; Saliu et al., 2019; Yu et al., 2020), indirectly potentially leading to negative effects on coral health. Microplastic exposure can compromise the anti-stress capacity and immune system of some corals (e.g., *Pocillopora damicornis*) (Tang et al., 2018) (Table 1). They may also be colonized by pathogenic microorganisms to form biofilms (Curren and Leong, 2019). Microplastics provide a new substrate on which certain dominant bacteria, that are not free-living in seawater, may grow. These bacteria include *Vibrionaceae*, *Rhodobacteraceae*, and *Flavobacteriaceae* (Feng et al., 2020), which are implicated in tissue damage of corals, the *Vibrio* species being the major pathogens of coral bleaching. Additionally, harmful *Pseudomonas* and *Vibrio cholerae* can also be found on the microplastics' biofilm (Feng et al., 2020), increasing the probability of coral disease and mortality.

## 8. Effects on endosymbionts

Microplastics may also indirectly affect dinoflagellates and, consequently, the coral-Symbiodiniaceae symbiosis that is important to the survival of mixotrophic corals (Tremblay et al., 2015; Okubo et al., 2018; Lanctôt et al., 2020; Tang et al., 2021). Even the symbionts that provide most of their autotrophic nutrition (i.e., photosymbiotic corals in shallow-water and mesophotic depths) can be negatively affected. In this way, microplastics may reduce the growth and density of algal cells, and negatively affect detoxification activity, nutrient uptake, as well as photosynthesis. Moreover, they may also raise oxidative stress, apoptosis level, and ion transport in some key endosymbionts (i.e., *Cladocopium goreaui*) (Su et al., 2020). On the other hand, Tang et al. (2018) found no significant changes in the density of symbiotic zooxanthellae in the coral *Pocillopora damicornis* but instead its chlorophyll content increased significantly after 12 h of microplastic exposure. Tang et al. (2018) also reported minimal impact on the abundance of the endosymbiont (*Symbiodinium* clade C now formally *Cladocopium* spp.) (LaJeunesse et al., 2018) and its major photosynthate translocation transporters in a short-term evaluation. Similarly, Reichert et al. (2019) found no changes in symbiont densities or chlorophyll content in *Acropora muricata*, *Pocillopora verrucosa*, *Porites lutea*, and *Heliopora coerulea*. Interestingly, Rocha et al., 2020 found that high concentrations of microplastics (10 mg $L^{-1}$) increased photosynthetic efficiency by adhering to the epidermis. However, high microplastic exposure affected the photosynthetic efficiency of the coral symbiont (*Stylophora pistillata*). These findings support the hypothesis that microplastics disrupt host-symbiont signaling in this coral (Lanctôt et al., 2020). All these studies are short-term experiments in which the authors suggest caution because it is not known what this means in terms of long-term physiological and ecological effects. Recently recognized indirect effects illustrate the need for further investigation of the species-specific impacts on distinct symbionts (LaJeunesse et al., 2018), corals, and long-term physiological and ecological analyses (Lartaud et al., 2020).

## 9. Deep-sea corals

The effects of microplastics on cold-water corals have been neglected. Woodall et al. (2014) were the first to propose the deep sea as a likely sink for microplastics, following their findings showing that microplastics, in the form of fibers, were up to four orders of magnitude more abundant in deep-sea sediments from the Atlantic Ocean, Mediterranean Sea, and Indian Ocean than in contaminated sea-surface waters (Woodall et al., 2014). In recent years, this hypothesis has been confirmed by high levels of microplastics found in Atlantic (Woodall et al., 2014), Mediterranean (Sanchez-Vidal et al., 2018), Arctic (Bergmann et al., 2017), SW Indian (Woodall et al., 2014), and Southern Ocean (Van Cauwenberghe et al., 2013) sediments, and in Atlantic deep waters (Courtene-Jones et al., 2017). High levels of microplastics have been found in the water and sediment (Peng et al., 2018; Peng et al., 2020), and in Lysianassoidea amphipods (Jamieson et al., 2019), from deep-ocean trenches in the Pacific, reinforcing the idea of the deep sea as the ultimate microplastic sink. In this way, thermohaline-driven currents, which build extensive seafloor sediment accumulations, could control the distribution of microplastics and create hotspots with the highest concentrations (Kane et al., 2020). This could lead to profound consequences for deep-water corals.

Lacking Symbiodiniaceae symbionts, deep-water corals are wholly heterotrophic, and thus potentially susceptible to all the impacts through adhesion and ingestion seen in their shallow water counterparts. Species-specific impacts have already been noted in *Desmophyllum pertusum* but not in *Madrepora oculata* (see earlier), which indicate that microplastics could potentially promote benthic community shifts with the selection of resistant species in both shallow-water and cold-water reefs. While there are few data on deep-water scleractinians, other deep-water cnidarians including zoanthids, alcyonaceans, pennatulaceans, and actinarians, have been observed to ingest microplastics (Taylor et al., 2016) and further studies could confirm whether microplastic ingestion is widespread in deep-water biogenic and geogenic reefs. In this framework, microplastics together with warming, acidification, macroplastics, and weakening of the benthic-pelagic coupling may jeopardize the resilience of cold-water coral ecosystems and their associated reef biodiversity (Taylor et al., 2016; Chapron et al., 2018; La Beur et al., 2019).

## 10. Conclusions

Microplastics may cause a plethora of species-specific impacts on habitat-forming corals in shallow, mesophotic, and deep-sea regions at different latitudes; underlining an emerging threat globally. This concern is highlighted by the increase of microplastics in the world's oceans in the ongoing Anthropocene. Moreover, the role played by corals as a sink of microplastics and their interaction with other stressors may affect the health, growth, and reproduction of the habitat-forming (or ecoengineering) (sensu Jones et al., 1994) species, having thus a long-term effect on population dynamics. We need to understand how these particles that give nothing from a nutritional point of view, are affecting the "main builders" from an energetic point of view. Further investigations at different bathymetric ranges are needed to understand the role of corals as an important global component of microplastic sinks and how, in the long term, this may be a clear disadvantage to their performance. Moreover, to date, most of the research demonstrating the impacts of microplastics has been done in the laboratory (Table 1), mainly restricted to the level of organisms or below (e.g., organs, tissues, or cells) and field research is scarce. Therefore, it is recommended that the laboratory research be conducted under environmentally realistic microplastic concentrations (Reichert et al., 2018; Garcia et al., 2020; Lanctôt et al., 2020) to provide useful information for conservation and management. In this way, future research may integrate investigations on toxicological and ecotoxicological effects in the laboratory with field research (Huang et al., 2020; Tang et al., 2021) at all the biological hierarchical levels (e.g., organs, organism, population, reef community and ultimately the ecosystem). Information on the effects of microplastics on corals in distinct reefs worldwide will improve knowledge on stress-tolerant and stress-sensitive species. This information is important to predict not only reef community changes but also the future seascapes of coral reefs in the Anthropocene.

## CRediT authorship contribution statement

**Marcelo de Oliveira Soares:** Conceptualization, Writing - original draft, Writing - review & editing, Methodology, Formal analysis, Supervision. **Eliana Matos:** Conceptualization, Writing - original draft, Writing - review & editing, Methodology, Formal analysis. **Caroline Lucas:** Writing - original draft, Writing - review & editing, Formal analysis. **Lucia Rizzo:** Writing - original draft, Writing - review & editing, Formal analysis. **Louise Allcock:** Conceptualization, Writing - original draft, Writing - review & editing, Formal analysis. **Sergio Rossi:** Conceptualization, Writing - original draft, Writing - review & editing, Formal analysis, Methodology.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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