Microplastics in the Ocean and their Consequences: Coral Reef Case Study

Saanvi N Prakash

1. Introduction

Humans have become more and more dependent on plastic since its boom in popularity in the 1950s (Matsuguma et al. 2017). This reliance is causing an increase in the concentration of microplastics, toxins and toxic chemicals entering the environment. Microplastics are plastic fragments less than 5 mm in length (Wright, Thompson, and Galloway 2013; Cole et al. 2011). These particles are a major source of marine pollution and a great danger to environmental health due to their high absorption potential and high surface area to volume ratio (Hale et al. 2020; Cole et al. 2011). Microplastics can absorb toxic chemicals present in the water such as pesticides and heavy metals which are harmful to sea life. For every 500,000 biological or mineral particles in the ocean, there is estimated to be 1 microplastic particle (Cole et al. 2011). The consistent use of this versatile, cheap and lightweight plastic along with inefficient waste management methods allows for a great deal of plastic and microplastic waste to enter the ocean. At the current rate of plastic production, microplastic concentrations in the ocean may double by 2030 (Hale et al. 2020).

Plastics and microplastics are both directly and indirectly transferred into the ocean through improper waste disposal, runoff, rain or wind (Hale et al. 2020). Contaminated water flows from drainage systems and landfills directly into the ocean or into rivers which flow into oceans (Thompson et al. 2004). In addition to this, increased coastal development and urbanization has led to the direct entry of plastics into the ocean. Lastly, coastal tourism and commercial fishing cause large quantities of discarded fishing gear, nylon netting and plastic bags to enter the water (Andrady 2011; Cole et al. 2011). All these sources of plastic increase the number of secondary microplastics in the ocean, which as discussed later on, are a type of microplastic that can be very harmful to the environment.

Microplastics have been classified into two major types: primary and secondary. Primary microplastics are plastics that are created to be smaller in size (Zitko and Hanlon, 1991). Some examples are micro beads and plastic pellets that are used in most cosmetic products and engines or machinery for cleansing and scrubbing (Hale et al. 2020). Secondary microplastics are formed through the breakdown and fragmentation of larger plastic products. They are also known as “user” plastics as high concentrations are obtained through poor waste management or littering (Cole et al. 2011). Primary and secondary microplastics constitute about 80% of marine litter (Andrady 2011).

Bioaccumulation can be defined as the gradual absorption or accumulation of microplastics in an organism (Bryan and Lewis 1979). The rate of the entry of microplastics into an organism is greater than the rate at which it is excreted or egested, which causes this bioaccumulation (Bryan and Lewis 1979). Continuous bioaccumulation leads to biomagnification, which is the movement of microplastics through the food chain. Microplastics move from organisms present in the benthic zone, or the ocean floor, to organisms in the pelagic zone, or the water column. As organisms higher up in the food chain consume organisms lower down in the food chain, they ingest their preys’ microplastics, which gradually leads to the accumulation of microplastics in these higher trophic level organisms, i.e, organisms in the pelagic zone (Bryan and Lewis 1979; Gray 2002). The estimated increase in microplastic concentrations would lead to increased bioaccumulation and biomagnification (Susanti, Mardiastuti, and Wardiatno 2020).

One of the main reasons for the high rate of bioaccumulation is microplastics' high consumption potential. Microplastics come in many sizes, colors and shapes, and their shape and density determine their abundance and availability (Wright, Thompson, and Galloway 2013). Many marine organisms are not selective about the type of food they consume. Detritivores, for example, are one of the least-selective bottom feeders and thus consume small, low density microplastics present in the benthic zone (Wright, Thompson, and Galloway 2013; Thompson et al. 2004). They are only selective when it comes to size and therefore consume microplastic particles having the same size as their prey. Due to the high quantities of microplastic they consume, detritivores are known as "primary microplastic consumers" (Wright, Thompson, and Galloway 2013). Secondary and tertiary consumers eventually prey upon primary microplastic consumers, starting the movement of microplastics up the food chain. For example, sharks and spider crabs feed on echinoderms who have consumed microplastics, starting the process of biomagnification (Ali and Khan 2019). Eventually humans consume these higher trophic level microplastic consumers, causing microplastics to accumulate in humans (Ali and Khan 2019; Cole et al. 2011).

An increase in the abundance of microplastic concentration is harmful to the food chain in other ways, for example, the fall or rise in the population of species present in the pelagic zone and coral reef degradation (Smith et al.; Wright et al.). One way in which microplastics cause a decrease in populations is through the ingestion or excretion of microplastics. Organisms may die or have problems reproducing, causing a reduction in their population. Some species, such as rafting species which attach themselves to floating objects in the pelagic zone, may also use floating microplastic particles as a surface to lay their eggs causing an increase in their population (Wright, Thompson, and Galloway 2013; Susanti, Mardiastuti, and Wardiatno 2020; Thiel and Gutow, n.d.). In addition to this, increasing concentrations of microplastics put coral reefs at high risk (John et al. 2022). Corals may have the ability to egest microplastics which could decrease bioaccumulation, but it is a highly energy-intensive process. Energy required for growth and photosynthesis is lost, leading to stunted growth and coral bleaching (Susanti, Mardiastuti, and Wardiatno 2020; John et al. 2022). This degradation would affect the health of coral reefs which would in turn impact their ability to harbor or feed organisms that rely on the reef. In this article, as part of my case study, we will be discussing the impacts on microplastics on overall water quality, corals and coral reefs.

2. Microplastics in Coral Reefs: Case Study

Coral reefs play an important role in global oceans. Coral reefs harbor over 835 different species and generate a significant fraction of the Earth's oxygen, and are characterized by high productivity due to the high rate of photosynthesis (Rubec 1988). Corals contain symbiotic algae called zooxanthellae (Ciereszko, n.d.). The presence of this photosynthetic zooxanthellae, specifically within coral polyps, provides them with nutrients to sustain their rich biodiversity as well as maintain the food chain (Adey and Goertemiller 1987). Coral reefs are, therefore, referred to as the rainforests of the sea (Knowlton 2001). The reefs also provide many ecosystem services such as acting as a carbon sink and a barrier to protect coastlines from storms. Additionally, they provide many recreational and economic opportunities, like spear-fishing, reef harvesting and tourism (John et al. 2022; Knowlton 2001; Pavlowich and Kapuscinski 2017; Spurgeon 1992). People living in coastal communities depend on these opportunities for their livelihood (Hoegh-Guldberg, Pendleton, and Kaup 2019). The income generated through SCUBA diving fees and harvested reef product sales, for example, sustains about 450 million people globally (Spurgeon 1992; Nakajima et al. 2022).

Microplastic accumulation in coral reefs causes large concentrations of microplastics to directly enter the food chain (John et al. 2022). As a benthic ecosystem, coral reefs harbor many benthic organisms. As previously mentioned, animals present in the benthos act as primary microplastic consumers (Jaubet et al. 2021). Small, high density microplastics accumulate within coral reefs because they resemble the prey that these organisms consume. As these benthic organisms are ingested by those at higher trophic levels, bioaccumulation occurs (de Smit et al. 2021). The damage caused by microplastics that travel through the food chain could lead to the death of marine fauna. This in turn may lead to a loss in biodiversity within coral reefs (Nakajima et al. 2022).

There are 2 main types of corals. The first are scleractinian species, which are corals with a skeletal structure; these are often referred to as hard corals. The second are non-scleractinian, which are corals without a skeletal structure; these are often referred to as soft corals (Epstein and Kingsford 2019). Typically, hard and soft species of corals interact differently with microplastics. While many hard corals can egest microplastics that they have ingested, soft corals often lack this ability and rather ingested microplastics will migrate into coral tissues (Reichert et al. 2018). These consumption and cleaning mechanisms are highly energy-intensive processes with consequences such as tissue necrosis, coral bleaching and attachment of microplastic particles (Stafford-Smith and Ormond 1992; Reichert et al. 2018; Rotjan et al. 2019).

Hard corals, corals that dominate reefs, are known to egest the microplastics they consume. For example, a study on a Caribbean hard coral *Montastraea cavernosa* found that this coral species egested 75% of all ingested microplastics (Hankins, Duffy, and Drisco 2018). However, microplastic egestion is a highly energy intensive process which has been shown to interfere with many processes, including those of the process of coral growth or coral skeleton development, also known as coral calcification (Hankins, Duffy, and Drisco 2018). In addition to this, continued egestion has been shown to cause irreversible damage such as tissue necrosis (Luna, Biavasco, and Danovaro 2007). Lastly, continuous egestion may affect corals' feeding which consequently impacts other important coral functions. For example, corals found in the Indo-Pacific region, such as *Pocillopora verrucosa* and *Acropora muricata,* showed a decline in their rate of photosynthesis (Reichert et al. 2018). However, other scleractinian species found in the same region, such as *Porites lutea* and *Heliopora coerulea,* did not react negatively to microplastic egestion and did not show a decline in the rate of photosynthesis or any other physiological process. This ability can benefit future coral reef health as they will most likely become one of the most prominent coral species in reefs (Zhou et al. 2022).

Even though they are less prominent on reefs, soft corals contribute towards a great deal of marine biodiversity. They are sources of food and shelter for marine organisms (Poulos et al. 2013). They are more prone to damage compared to hard coral (Poulos et al. 2013). As a more delicate species, they usually lack the ability to egest microplastics, which often causes consumed particles to remain within the coral structure (Poulos et al. 2013). For example, *Coelogorgia palmosa*, a soft coral found in the Indian Ocean, exhibited abnormal mucus production along with shrinking tentacles when put in contact with microplastics (Vencato et al. 2021). A button polyp, *Hexacorallia zoantharia*, showed a similar reaction even though it is present in the Northern Red Sea. More mucus was produced as a defense mechanism against the microplastic (Jiang et al. 2021; Vencato et al. 2021). This is dangerous as mucus can store pathogens and act as a medium for their growth (Brown and Bythell 2005). Accumulation of harmful bacteria may interfere with asexual coral reproduction—such as budding or fragmentation—and photosynthesis (Miller and Ayre 2004; Pait et al. 2014).

Another major factor contributing to coral reef degradation is microbes present on microplastics (Yang et al. 2020). It is observed that older microplastics present in coral reefs have rougher surfaces due to UV light exposure. These older microplastics, thus, have a larger surface area for microbes to accumulate on and form biofilms (Miao et al. 2019; Yang et al. 2020). The continued formation of secondary microplastics means that most microplastics present in the ocean are of older origin. This provides microbes with sufficient time to form biofilms. For example, several *Arcobacter* species, pathogens that affect the human intestine, were found to have higher concentrations on microplastic biofilms in comparison to other natural sources such as wood pellets (Wells et al. 2016; Yang et al. 2020). Because microplastics increase the rate at which pathogens enter corals, this allows pathogens to pass through the food chain more readily. This adds to the bioaccumulation cycle and poses an additional threat to marine biodiversity (Kirstein et al. 2018). This is why it is crucial to control microplastic production, waste management and improve coral reef conservation tactics.

3. Conclusion

Increased plastic and microplastic production and its inefficient management has many ill effects on various ecosystems. Some of these effects include bioaccumulation and biomagnification of microplastics, which can lead to the destruction of corals and their rich biodiversity. Microplastics affect organisms from the lowest trophic level–such as benthic organisms present in coral reefs—to the highest trophic level, us humans. Microplastics move through the different trophic levels to reach us, presenting themselves in our food and water. Even though microplastics and their effects have been researched more extensively over the past few years, many questions still remain unresolved. For example, it is still unknown if toxins released by microplastics travel through the food chain (Thompson et al. 2004). Additionally, with the rising global population, the continued destruction of corals will negatively impact future generations. Since corals provide us with almost half the Earth's oxygen, the damage caused by their destruction could lead to poor air quality. The diminished growth or death of corals could also impact their ability to act as a natural barrier against flash floods (Rubec 1988). Corals serve as vital habitats for many fish globally, and many coastal communities rely on these fish as a food source. A decline in these ecosystem services would, in turn, impact the future economy. Thus, it is important to maintain the biodiversity within coral reefs, not only to save the oceans but also us humans.

As corals continue to ingest or egest microplastics, the more their populations will dwindle. While there are coral species unaffected by microplastics, as previously mentioned in this case study, it is crucial to understand how they are resistant to microplastics and their toxins. Studying coral defense mechanisms would help with coral reef conservation. Future work on microplastics should contribute towards coral reef conservation and focus on controlling marine microplastic pollution.

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