frontiers FOR YOUNG MINDS

BIODIVERSITY
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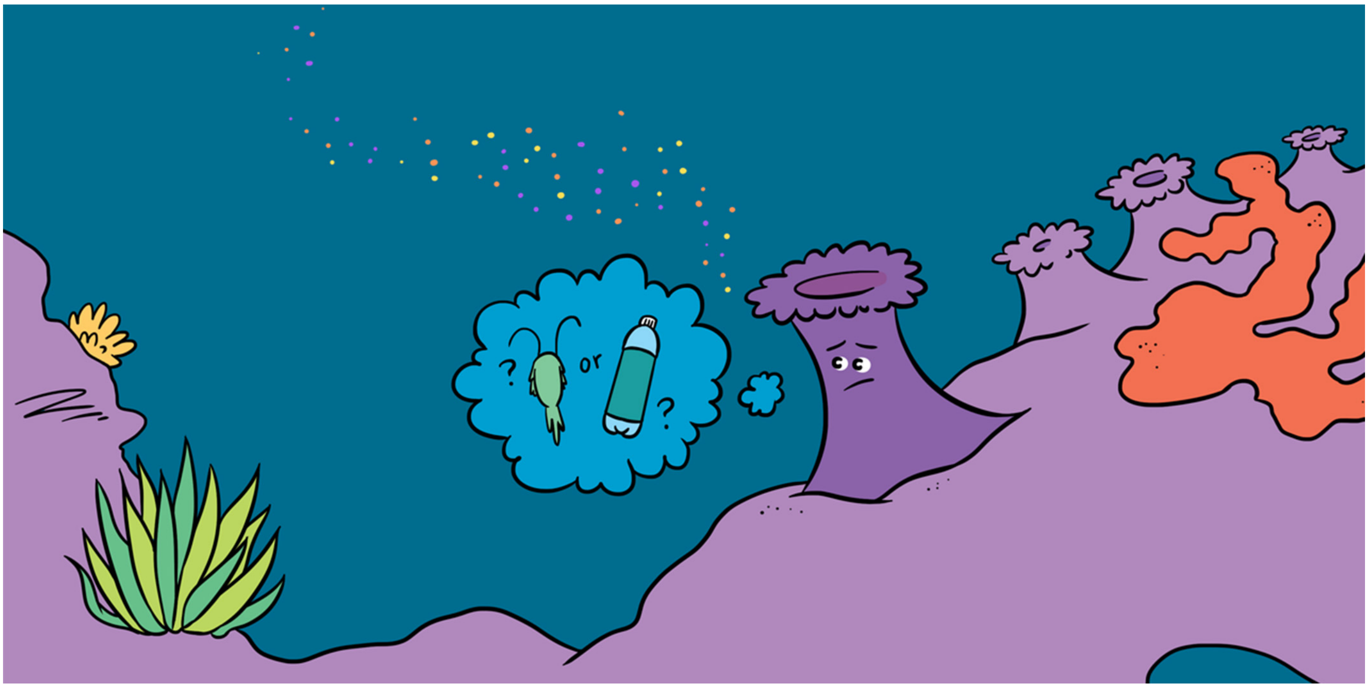

THE INVISIBLE THREAT: HOW MICROPLASTICS ENDANGER CORALS

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ANHAD
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Coral reefs are one of the most endangered habitats due to climate change, but not enough attention has been paid to how plastic pollution affects coral reef health. Plastics are massively produced worldwide for many purposes and they degrade very slowly, breaking down into tiny, invisible particles of 5 mm or less, called microplastics. When these tiny particles reach coral reefs, they harm corals by constantly rubbing on them through the action of waves and currents. Corals may also ingest microplastics and get a false sense of "fullness," which results in the coral not feeding on nutritious food. Within the coral, microplastics may block the gut and cause internal damage. Also, microplastics, which are already made of chemicals, can pick up pollutants and harmful microorganisms from the seawater and transfer them to the coral. A reduction of microplastics pollution is therefore urgent.

POLYP

Each of the tiny animals that make up coral reefs. Polyps can live individually (like mushroom corals) or in large colonies that create an entire reef structure.

OCEAN ACIDIFICATION

The ocean is becoming more acidic (like lemon juice) as its water absorbs carbon dioxide from the atmosphere. Carbon dioxide is produced by factories, cars, or used fuels like coal or oil. This change in the properties of ocean water can be harmful for plants and animals.

CORAL BLEACHING

Many corals live with algae, which give them their vibrant color. However, the coral tissue is white. When corals lose their algae after a stress, only the white tissue remains, and this is called coral bleaching.

Coral reefs are among the richest, but at the same time most endangered, habitats on Earth. Reefs are composed of thousands of small sac-like organisms called **polyps** that secrete an exterior skeleton with a specific shape and color and group into coral colonies, also with different shapes and colors (Figure 1). When many of these coral colonies come together, a coral reef is formed. Home for more than 25% of all marine species and with more than 850 million people depending on them for livelihoods and tourism, the health of coral reefs is closely monitored. In the last decades, coral reefs have been highly challenged due to climate change, primarily by the rising seawater temperature and **ocean acidification**. Oceans are becoming more acidic because they absorb the excessive amounts of carbon dioxide that humans release into the atmosphere. These challenges cause corals to expel the microscopic algae living inside their cells (Figure 1), losing their vibrant colors and turning white—a process called **coral bleaching**. Coral bleaching can ultimately kill the corals. Recent forecasts indicate that more than 75% of coral reefs will be severely bleached in the next 50 years due to temperature increase alone. Coral health may be worsened if corals face additional challenges [1], including plastic pollution. Because plastics continue to accumulate in the oceans, we must look with more attention into the harm they are causing to corals.

BIG LITTLE ENEMIES

Since the development of the first synthetic plastic in 1907, plastic production has increased by 200-fold and there is now ∼275 million tons of plastic waste spread throughout the world. Up to 70% of the litter in many areas of the ocean is plastic, and up to 12.7 million tons of plastics are added to the oceans each year (Figure 2). By 2025, at least 155 million tons of plastics are expected to accumulate in the oceans [2]. Because it takes plastics 500–1,000 years

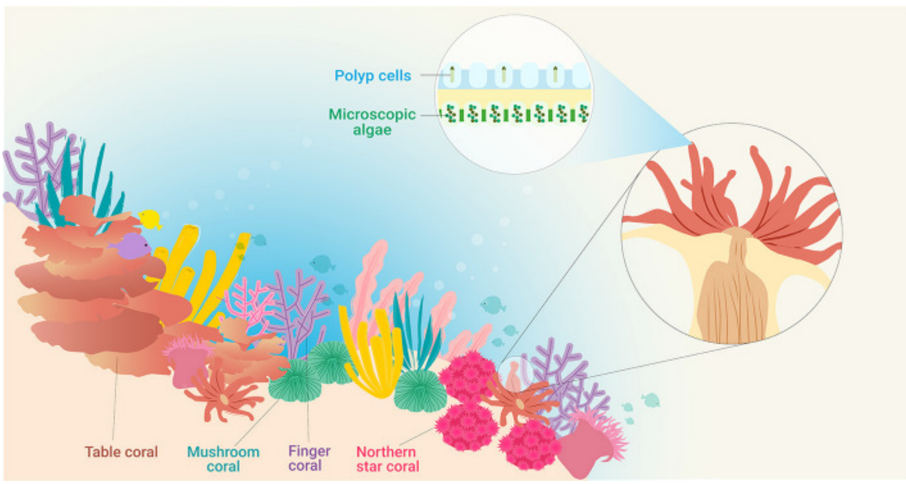

Figure 1

Figure 1

The tiny polyps aggregate in colonies, usually referred to as "corals," of varied colors and shapes. In a reef, mushroom, table, finger, and northern star corals can be found. Microscopic algae are usually found inside the cells of coral polyps.

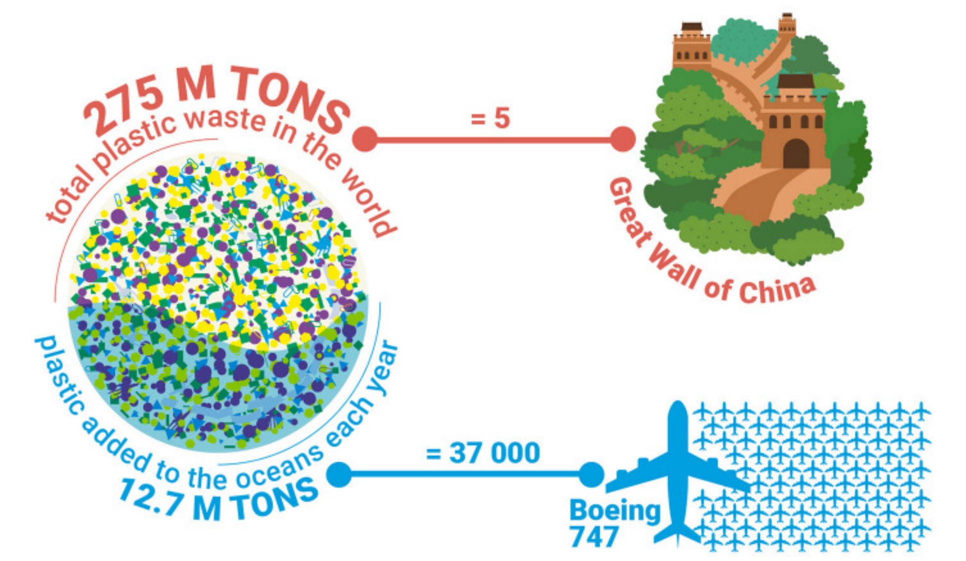

Figure 2

Figure 2

The amount of plastic waste found worldwide weighs five times as much as the Great Wall of China. The weight of plastic waste in the world's oceans is equal to that of 37,000 Boeing 747s.

to degrade and they never completely break down, all plastics created since 1907 still exist, even if they have degraded to smaller plastic particles, such as **microplastics** (<5 mm) or **nanoplastics** (<0.1 mm). The actions of waves and sunlight break down larger pieces of plastic in the oceans into microplastics and nanoplastics, but other tiny plastic particles, originating from clothing, car tires, and personal care products, may also end up in oceans via wastewater, road runoff, winds, and waterways.

MICROPLASTICS

Microplastics are tiny bits of plastic of <5 mm (smaller than an ant). Often, they are too small to be seen. They pollute water in many ways.

NANOPLASTICS

Nanoplastics are bits of plastic even smaller than microplastics. A billion nanoplastics can fit on the head of a pin.

In 2014, the oceans were estimated to contain 15–51 trillion microplastic particles [1], which can cause both physical and chemical harm to corals, and many other species, big and small. The increased abrasion (tissue scraping) by the plastic particles can wound the corals. These injuries may become infected by fungi or bacteria, killing some cells or even the entire coral. Each coral species reacts differently to microplastics. Scientists found that a mushroom coral removed microplastics from the water by capturing them from water currents and sticking them to its wrinkled skeleton [3]. Another study revealed that a species of finger coral tried to clean itself of microplastics [4]. In both cases, dealing with the microplastics requires increased energy expenditure that negatively affects corals. Finger corals and table corals also grow over the microplastics, incorporating them into their tissues [4], which occurs when the tiny particles are wrapped into the cell membrane. Nanoplastics have also been found in the brains, livers, and circulatory systems of other animals [5], clearly indicating that these tiny plastic particles can cross cell membranes and therefore may be a major risk for corals.

TINY PARTICLES, BIG IMPACT

ZOOPLANKTON

Tiny, free-floating animals that can be found in the oceans, seas, rivers, and ponds.

Microplastics are likely to be eaten by corals because they have a similar shape and size to microscopic organisms called **zooplankton** that live in the water. Under normal conditions, reef corals get most of their food from their partnership with the microscopic algae that they harbor in their cells (Figure 1). However, as coral bleaching becomes more severe and the corals lose their algae partners, some corals start ingesting more zooplankton, which they filter from the seawater. The risk of corals ingesting microplastics increases with increased feeding on zooplankton [1]. For instance, ~112 plastic particles were found in each polyp of wild northern star corals, 73.4% of which were fibers, coming mainly from clothes. In a lab experiment, northern star corals were fed with their favorite meal in the wild (brine shrimp eggs) mixed with similar-sized microplastic beads. The corals chose the microplastics, which inhibited further feeding on brine shrimp eggs [2]. Thus, one potential consequence of ingesting microplastics is a false feeling of "fullness" and subsequent reduction of real food intake, leading to low coral growth and decreased survival. Ingestion of microplastics may also cause blockages throughout the gut cavity of corals, as well as internal damage. Although several experiments have shown that corals clean off the microplastics within 6 h after intake, this requires spending a high amount of energy that can no longer be used for growth and survival.

ADSORB

The sticking of molecules from a gas, liquid, or dissolved solid to a surface, such as the surface of a plastic particle.

Microplastics can also harm corals in other ways. Micro- and nanoplastics can contain large amounts of toxic chemicals. Many of these chemicals are added during the production of plastics, but micro- and nanoplastics may also **adsorb** toxic pollutants from the ocean water, due to their porous and rough surfaces [5]. Thus, micro- and nanoplastics surfing the oceans can increase the uptake of pollutants by corals, and these toxic pollutants can then be transferred to other organisms along the food web. In addition, toxic chemicals may leak from the tiny plastic particles when they are inside corals, causing toxins to accumulate in the corals, posing an additional risk to their growth, reproduction, and survival. An experiment showed that hood coral polyps pulled in after being exposed to chemicals leaked from plastics [6]. This action reduces the uptake of pollutants by the coral, but it also reduces food intake, photosynthetic rate, and oxygen exchange with the surrounding seawater. Thus, coral exposure to micro- and nanoplastics can also mean exposure to dangerous pollutants.

WOLVES IN SHEEP'S CLOTHING

Corals catch zooplankton by relying on the signals these tiny organisms emit into the seawater. So, corals are more likely to ingest micro- and nanoplastics when these particles are covered by biological materials, such as algae, fungi, and bacteria [3]. This

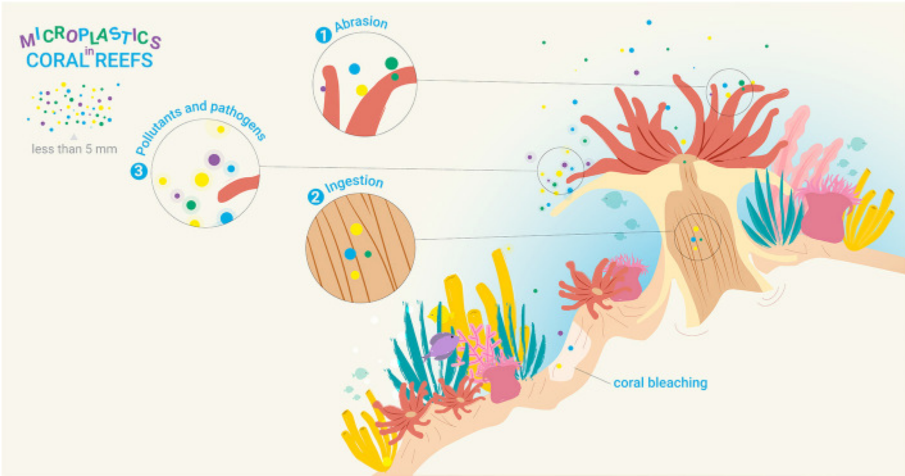

Figure 3

Figure 3

Microplastics can harm corals in three major ways: (1) Abrasion, which may wound the coral and, if wounds become infected by fungi or bacteria, lead to coral disease or even death; (2) Ingestion, which may lead to a false perception of "fullness" and thus to a reduction of food intake jeopardizing coral growth and survival; and (3) transfer of pollutants (toxic chemicals) and pathogens (harmful microorganisms in the biofouling) from the plastic particles to the coral cells. Toxic chemicals transferred to corals include those the plastic particle is made of but also those adsorbed from the water column.

BIOFOULING

Aquatic organisms can build up on surfaces and structures exposed to seawater. This is biofouling, most often composed of tiny algae and bacteria.

coating of organisms, which is called **biofouling**, is highly nutritional for corals that can digest it, and biofouling increases the time that micro- and nanoplastics stay inside the coral. Plastic particles not covered by biofouling are more easily recognized as alien particles and more readily spat off. However, biofouling may also contain harmful microorganisms and therefore plastic particles may serve as disease carriers in the ocean. Although these studies are still in their early stages, when lab-raised corals were fed microplastic beads covered with disease-causing bacteria, the particles were spat off within 48 h, but the corals still became ill and died.

KEEPING THE OCEANS HEALTHY WITHOUT PLASTICS

Overall, the ingestion of micro- and nanoplastics affects corals in many ways (Figure 3): it reduces feeding on nutritious prey and increases the energy spent on spitting out or cleaning off the plastic particles; it increases corals' exposure to pollutants stuck to the plastic particles or released in nearby seawater; and it increases corals' exposure to harmful microorganisms. All these negative effects are not restricted to the corals—they affect all living creatures in lakes, rivers, and oceans. Moreover, if a fish eats a coral contaminated with plastic particles it also becomes contaminated; and this will be repeated all the way up in the food web, eventually reaching humans.

Plastic, as well as the pollutants and harmful microorganisms they may carry, would not be found in the oceans if plastic waste was not there to begin with. Reducing plastic production and plastic waste are therefore critical for improving the health and survival of coral reefs and will also be important for improving our own health. So how can you help? The easiest and most direct way is by reducing your use of single-use plastics: refuse straws, bags, and takeout cutlery and containers, if these items are made of plastic. If and when you do use plastics, please recycle them. If you are looking for a more hands-on action, participate in or even organize a cleanup at your local beach or waterway: you will be amazed by the number of plastic particles you will be preventing from reaching the ocean.

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CONFLICT OF INTEREST: JM was employed by company Scite – Science Crunchers.

The remaining 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.

YOUNG REVIEWERS

ANHAD, AGE: 11
Hello my name is Anhad and I like writing about topics (sometimes). I also love watching TV and playing video games on my console and also love hanging out with my friends and family. I like watching Netflix in my free time and cooking.

ASHIMA, AGE: 14
Hi, I am Ashima. I like to read fiction books and swim. I love to study. My favorite subject is mathematics. Quadratic functions are my favorite topic in mathematics.

MANAN, AGE: 13
Hello, my name is Manan. I love playing basketball, swimming, and video games and I also love to hang out with my friends. I love to learn everything associated with technology and science, and I want to know more about animals. My favorite animal is a dog. I am also interested in nature and flowers. I love to hike.

MARIA, AGE: 14
Hi, my name is Maria and I am from Poland. I absolutely love biology, especially solving tasks in genetics and cell metabolism. In my spare time I enjoy reading books and playing with my cat Roxi. I am keen on ballet. I train regularly at the Dance Conservatory. I really love it!

SANSKRITI, AGE: 14
Hello, my name is Sanskriti. I am 14 years old and am going into ninth grade. I love Computer Science and hope to see more girls showing interest in that field in the next few years.

AUTHORS

VANESSA BEDNARZ

Vanessa is a marine biologist investigating how corals respond to environmental disturbances, such as chemical pollutants leaching from plastic waste. Vanessa conducts aquarium experiments with corals to better understand how pollutants affect the health, fitness, and physiology of the coral and its symbiotic partners. When not working, Vanessa loves spending time at the sea, on mountain hikes with her dog, or playing the violin.

MIGUEL LEAL

Miguel is a marine biologist at the University of Aveiro (Portugal). His passion for marine biology started when he first saw a coral reef. He studied marine biology and focused most of his research on studying marine invertebrates, such as corals, addressing the questions of what they eat, when they eat, and how their food affects their functioning. Miguel has a large variety of scientific interests and has worked on multiple topics from ecology and evolution to aquaculture and marine biotechnology.

ERIC BÉRAUD

Eric is a marine biologist and a diver. His passion for biology started with his discovery of the underwater world. He studied sciences, ecology, and ecotoxicology, and focused his research on the symbiosis of corals. More particularly, Eric tries to understand how changes in the environment influence coral symbiosis.

JOANA FERREIRA MARQUES

Joana is a marine biologist and data cruncher at Scite. Her passion for biology started late in her teens, driven by the need to understand the life-long relationships of organisms, particularly when one organism does not seem to benefit, such as in parasitism. Joana recently moved from the lab bench to the office desk, to help resolve another complicated matter—how to turn complex datasets into simple texts or schemes that fit on a sticky note.

CHRISTINE FERRIER-PAGÈS

Christine is a marine biologist who has worked for more than 20 years on corals and coral reefs. She started in marine biology with the study of the tiniest organisms in the sea (the microbes), and then moved to bigger animals, such as corals. Her passion however is for one of the largest animals on earth, the elephants. *ferrier@centrescientifique.mc