Impact of Synthetic Materials on Animals

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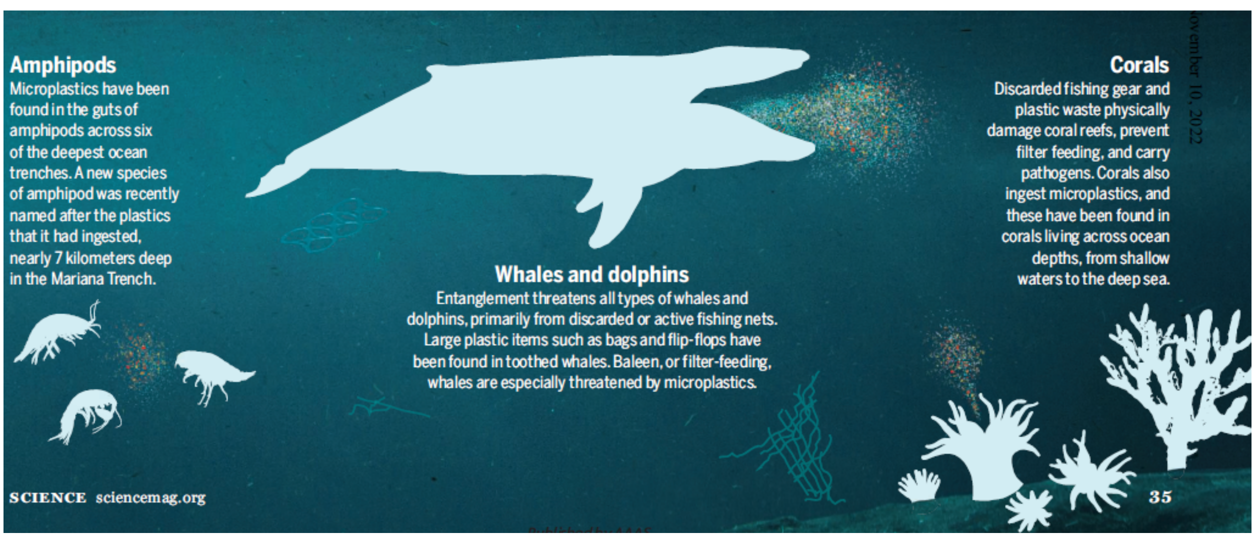

Figure 1. Science Magazine released a special issue focusing on the harms that synthetic materials have on animals and ecosystems. (Science, 2021, https://doi.org/10.1126/science.abj9099)

By 2050, it's estimated the weight of all plastic in the oceans will outweigh fish

Highlights

➤ Fossil fuel-derived ***synthetic fibers***,[1] which are nonrenewable and nonbiodegradable, currently comprise approximately 60%[2] of materials used by the fashion, automotive, and home goods industries and are projected to comprise approximately 70% of materials by 2030.[3]

➤ Synthetic materials contain microplastics, which accumulate and persist in ecosystems for hundreds of years, as well as toxins that poison ecosystems, harm animals, and fuel climate change.

➤ Microplastics are proliferated around the globe by air, rain, lakes, rivers, and oceans, and are found in nearly every aquatic environment tested for their presence, including in deep sea trenches, remote lakes, and Antarctica.

Defining material terms

Next-gen materials are more sustainable, humane alternatives for:

- **animal-derived** leather, silk, wool, down, fur, and exotic skins, which are sourced from more than 3.7 billion non-insect animals and 1 trillion insects each year; and
- **synthetic materials**, which are primarily sourced from petrochemicals.

Next-gen materials use a variety of biomimicry approaches to replicate the aesthetics and performance of their animal-derived and synthetic counterparts. They can be derived from plants, algae, fungi, microbes, cultured animal cells, recycled materials, and other sustainable sources.

➤ Fibers from synthetic textiles contribute approximately 35% of the microplastics that enter our waterways.

➤ Microplastics cause **pain, suffering, and death** to aquatic invertebrates, fish, birds, mammals, flying insects, soil invertebrates, and other animals by reducing their food intake, stunting their growth, decreasing their reproductive capabilities, and more.

➤ Once microplastics enter ecosystems, they are impossible to adequately remove using current technologies.

➤ The prevalence of microplastics across taxa (microbial flora and fauna) and trophic (variable temperature ecosystems) levels harms trillions of sentient beings.[4]

➤ Without the availability of sustainable, cruelty-free alternatives, fashion brands and other companies replace synthetics with "natural" animal-derived materials that are sourced from the harming or killing of more than 1 trillion animals each year.

➤ For the health of our planet and future generations, it is critical that both synthetic and animal-derived materials are replaced with sustainable and humane next-gen materials.

Synthetics are pervasive and circulating throughout all of Earth's systems

The synthetic materials we wear and use every day in our clothes, cars, and homes contain chemically stable microplastics (<5 mm) that can exist in the environment for hundreds of years or longer. These microplastics contain harmful substances, including antimicrobials, hydrocarbons, and flame retardants,[5] and attract persistent organic pollutants such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), and polycyclic aromatic hydrocarbons (PAHs).[6]

Microfibers originating from synthetic textiles are shed in large quantities during the process of laundering clothes. A 2021 review of **microfibers from synthetic textiles** found them to be the "**most abundant microplastic forms found in the environment**" and stated that they "are released in massive numbers from textile garments during home laundering via sewage effluents and/or sludge."[7]

Once shed by synthetic materials, microplastics are proliferated around the globe by rain, lakes, rivers, air, ocean currents, and ocean circulation patterns. They have been found in the Amazon River and estuaries, deep sea trenches, remote lakes, Swiss Alps snow, Arctic ice, and all major oceanic basins.[8] In 2017, the United Nations estimated that as many as 51 trillion (500 times as many stars estimated to be in our galaxy) particles of microplastic are in the world's seas and oceans alone.[9]

In a study spanning four years, The Global Microplastics Initiative collected 2,677 water samples across every ocean and continent to research microplastics pollution in aquatic ecosystems. Its research resulted in the largest and most diverse dataset documenting microplastic pollution on a global scale. It found, "[o]n average, global water samples contained 11.8 pieces of microplastic per liter. Open ocean samples contained on average higher concentrations of the pollutant than did coastal samples, with polar regions containing the highest averages. Across studies, **microfibers, as opposed to other types of microplastics, were dominant: microfibers composed 91% of marine particles, 92% of freshwater particles, and 80% of Gallatin [River] particles**."[10]

The 2017 publication Primary Microplastics in the Oceans: A Global Evaluation of Sources by the International Union for Conservation of Nature and Natural Resources (IUCN) reported a more conservative estimate that 35% of microplastic pollution is from microfibers, most of which are derived from synthetic textiles.[11]

MII predominantly focuses on microplastics' impacts on marine animals because the majority of microfibers from synthetic materials are shed into aquatic ecosystems, yet microplastics are found in nearly every environment scientists test for their presence. A 2019 scientific study noted that, "[t]he fate of microplastics in the environment seemingly has no boundaries, and they have become ubiquitous in ecosystems globally. The type, size, shape, and color of microplastics are important factors that inform their fate in the environment and in biota."[12]

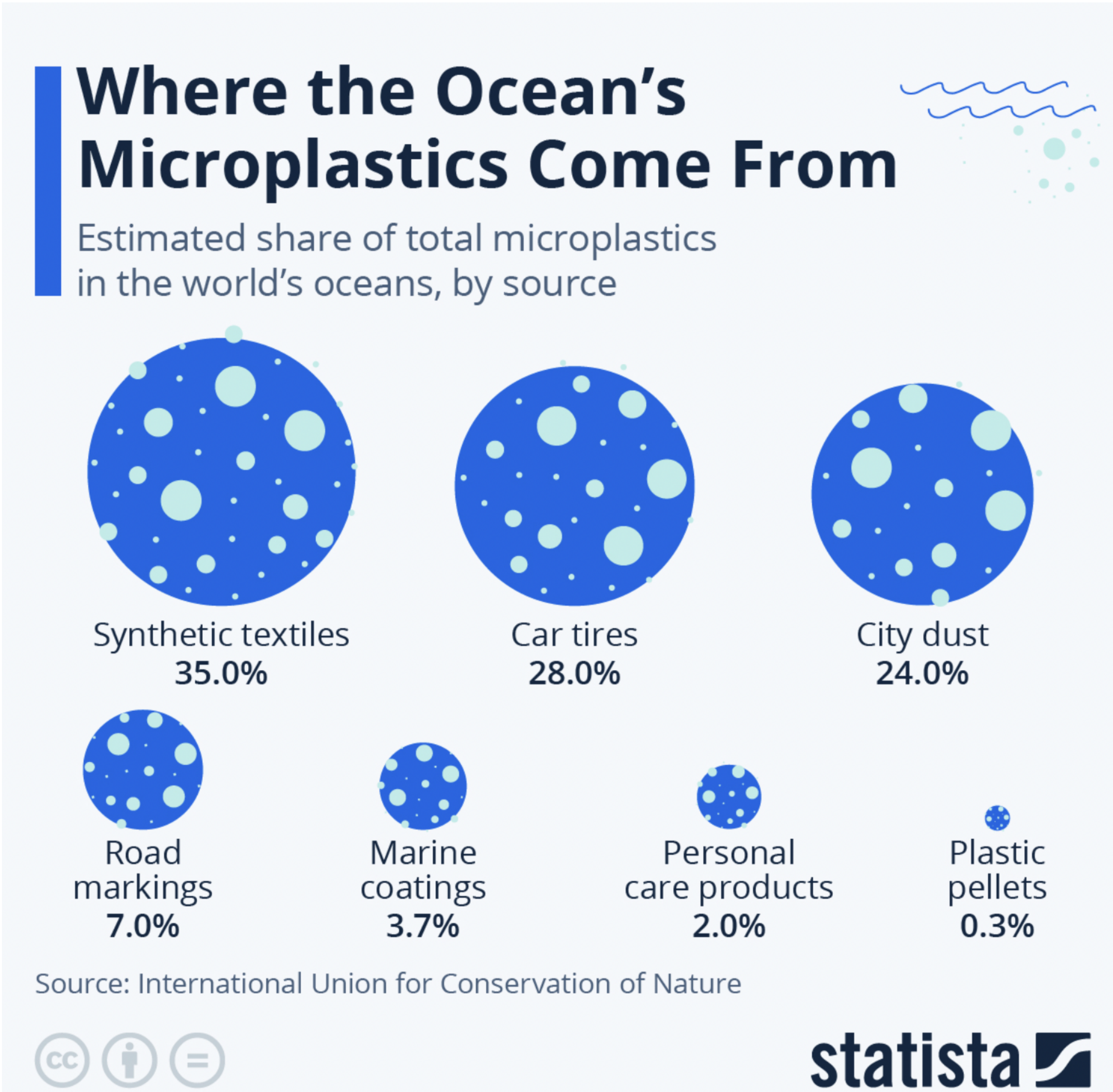

Figure 2. According to the IUCN, synthetic textiles are the number one source of microplastics in oceans (Statista, 2022, bit.ly/3UZa8co)

Thousands of species and trillions of animals are known to ingest synthetics

As summarized in the graphics below, direct evidence reveals that animals across terrestrial, freshwater, and marine ecosystems ingest plastics. This includes thousands of individual species of fish, birds, invertebrates, mammals, reptiles, and amphibians. Considering the research in this space is still relatively new, researchers expect that this may greatly underestimate the true nature of plastic ingestion across the animal kingdom, with terrestrial and freshwater ecosystems understudied compared to the marine environment.

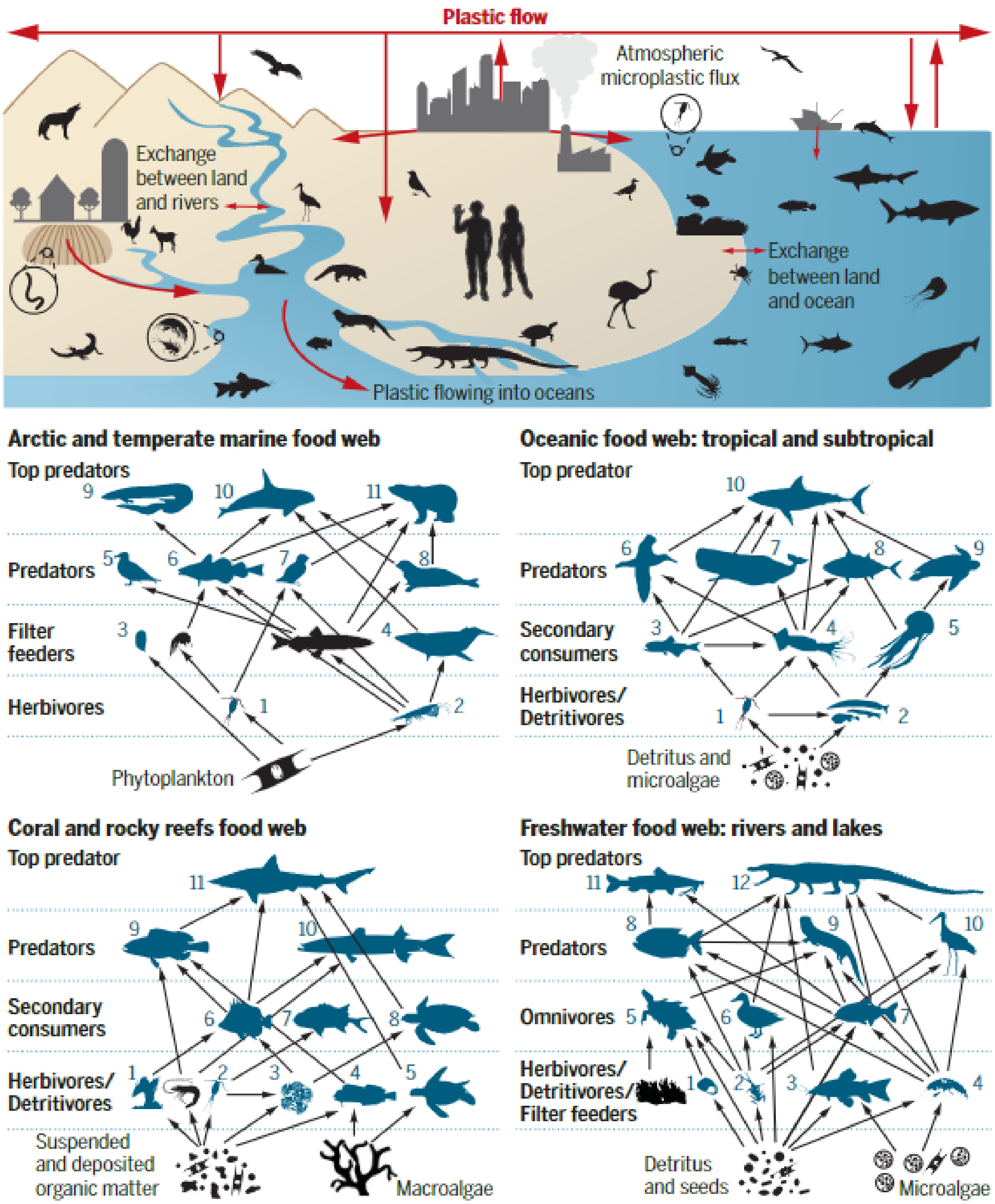

Figure 3. "Plastic flux and accumulation in the environment are shown by red arrows. Plastics are circulating through all Earth systems and have been affecting animals with diverse niches and ecological traits. All depicted animals have a record of plastic ingestion." Santos et al., Science 373, 56–60 (2021)

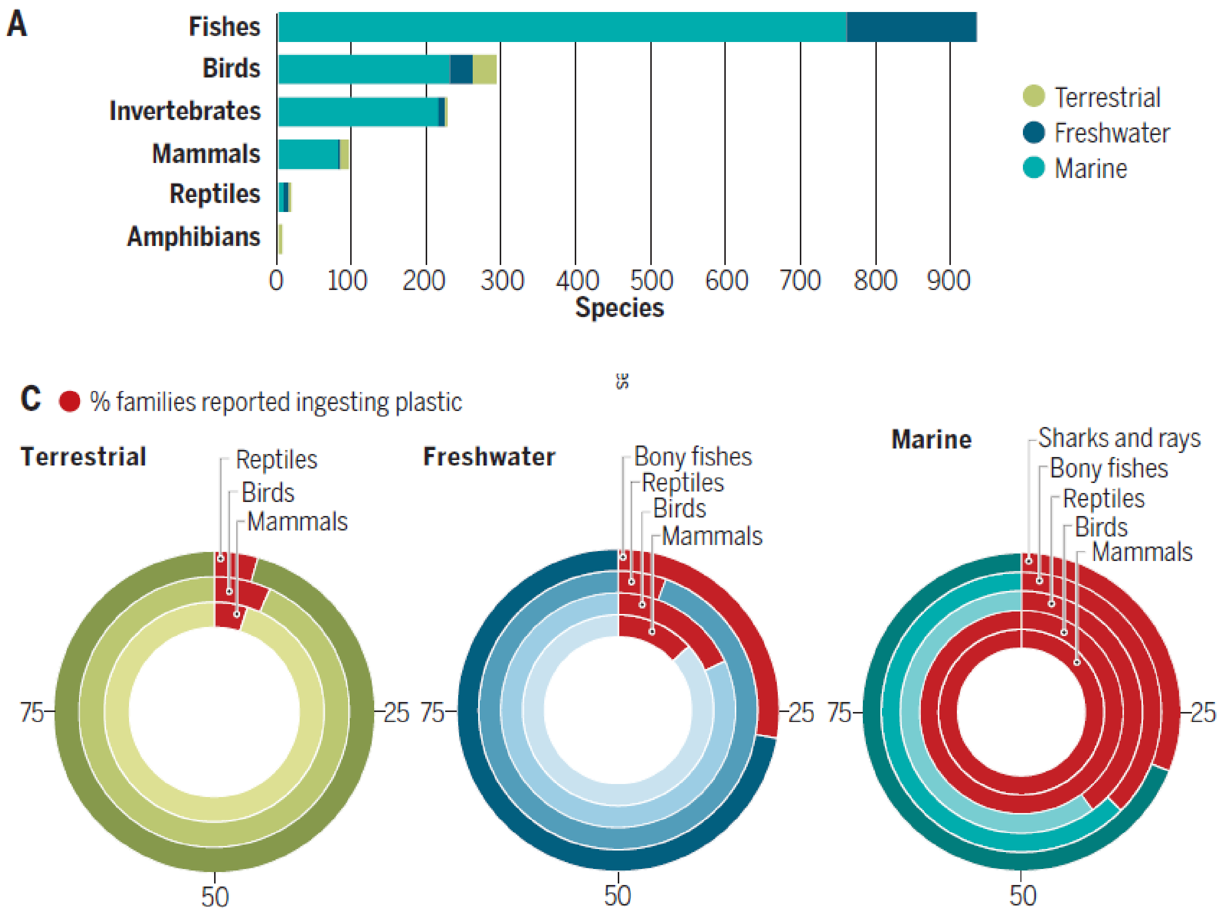

Figure 4. Top: Number of animal species reported in the literature from 1980 until early 2021 ingesting plastics (macro- and microplastics) across terrestrial, freshwater, and marine ecosystems. Bottom: Percentage of vertebrate families with plastic ingestion (red bars) reported for at least one species in the terrestrial, freshwater, and marine systems. Santos et al., Science 373, 56–60 (2021)

It is currently difficult to measure the number of individual animals who absorb synthetic waste. But looking just at fish, about a third of all tested fish have contained microplastics. With over 3 trillion fish on our planet, that's 1 trillion fish who may be ingesting microplastics. According to scientific research, the proportion of fish consuming plastic has doubled across all species within the last decade, from an average of 15% to 33% of fish sampled.[13] Factor in thousands of other animal species, and the numbers of animals consuming microplastics appear to be staggering.

A publication titled *Studies of the effects of microplastics on aquatic organisms* concluded that, “[t]he widespread distribution of MPs[14] in aquatic ecosystems (Lusher et al., 2013) and broad range of physicochemical properties make a wide range of aquatic organisms potentially susceptible to these emerging contaminants.”[15] It cites research studies that “ingestion may be due to an inability to differentiate MPs from prey [or] ingestion of organisms of lower trophic levels containing these particles (e.g. plankton containing MPs)” or through direct adherence to organisms. A significant amount of microplastic ingestion is not accidental; rather, it is a result of plastic debris mimicking food sources for animals. According to one scientific study, "[p]lastic ingestion can be considered as an evolutionary trap, where the sudden appearance of plastics in the environment…mimic cues of food items."[16]

While the long-term impacts of microplastics on animals and the environment are not yet fully understood, their prevalence across taxa (microbial flora and fauna) and trophic (variable temperature ecosystems) levels are recognized as contributors to pollution, harm, and suffering for trillions of animals.[17]

Microplastics harm animals who consume them in myriad ways

Microplastics harm animals who consume them in myriad ways, including by reducing their food intake, delaying their growth, altering their behaviors, decreasing their reproductive capabilities, causing inflammation and oxidative damage, poisoning them with toxins, and leading to premature death.

A literature review titled *Harmful effects of the microplastic pollution on animal health* described the harms caused by microplastics to invertebrates, fish, and mammals (pages 6-16).[18] It summarized, "[t]he number of published studies considering the effects of microplastic particles on aquatic organisms is considerable. In aquatic invertebrates, microplastics cause a decline in feeding behavior and fertility, slow down larval growth and development, increase oxygen consumption, and stimulate the production of reactive oxygen species. In fish, the microplastics may cause structural damage to the intestine, liver, gills, and brain, while affecting metabolic balance, behavior, and fertility; the degree of these harmful effects depends on the particle sizes and doses, as well as the exposure parameters."

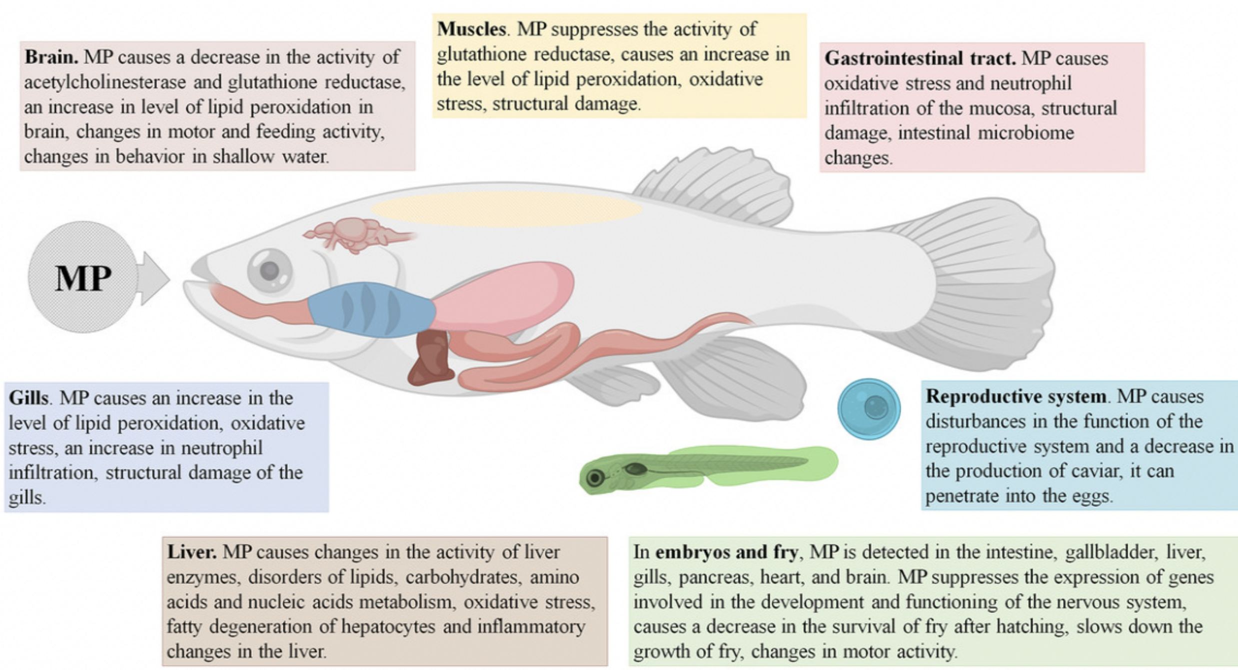

Figure 5. Harmful effects of microplastics on fish (Zolotova N, et.al. 2022)

Microplastics cause the most damage to ecosystems through harming keystone species[19]—*including some species of zooplankton, crabs, and coral*—all of whom serve critical functions for entire ecosystems.

Some species of zooplankton, which are primary consumers in marine ecosystems, have been proven to grow more slowly and lay fewer eggs as a result of consuming microplastics, thereby decreasing food available to entire ecosystems.[20]

Video of plankton ingesting microfiber

"{T}he sight of plankton ingesting plastic was a relatively common sight... {in the video} the fibre has made a loop inside the animal's gut, you can actually see the consequences of something as small as the arrow worm consuming microplastic."

Richard Kirby, Plankton Scientist

Microplastics in corals: An emergent threat found that microplastics have an abundance of negative impacts on keystone coral species, including "reduced growth, a substantial decrease of detoxifying and immunity enzymes...high production of mucus, reduction of fitness...tissue necrosis, lower fertilization success, decreased skeletal growth and calcification...coral bleaching... impairment of feeding performance and food intake...and increased exposure to contaminants, pathogens and other harmful compounds."[21] Coral reefs are among the most biodiverse marine ecosystems on Earth and vital for the survival of thousands of species; the impact their health has on entire ecosystems is therefore profound.

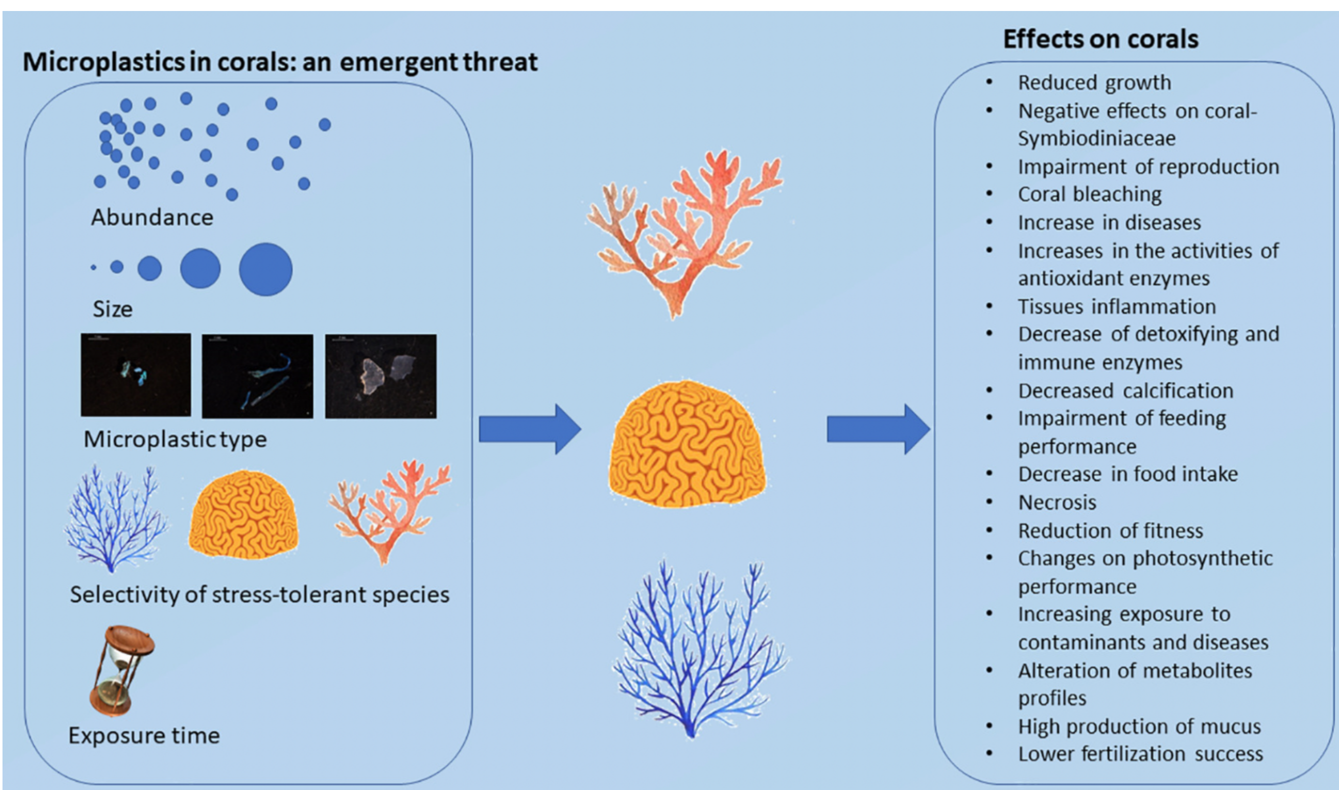

Figure 6. According to scientific research, microplastics' harm to coral represents "an emerging threat globally." (de Oliveira Soares, et. al. 2020)

Multiple scientific studies of keystone crab species have found that microplastics impair their shell selection, attacking behaviors, and defending behaviors, all of which are important for their survival. A review of studies about microplastics' impacts on crabs and other decapods (including prawns, shrimp, lobsters, and crayfish) stated that, "[n]umerous studies are available on the accumulation of microplastics in tissues such as the gills, hepatopancreas and gastrointestinal tract in these organisms.[22] Experimental studies have also highlighted the toxic effects of microplastics such as oxidative stress, immunotoxicity and reproductive and developmental toxicity in them."

The study *Microplastic exposure and effects in aquatic organisms: A physiological perspective* provides a simple and clear illustration of the myriad molecular, cellular, systemic and other effects microplastics have on animals in aquatic ecosystems:[23]

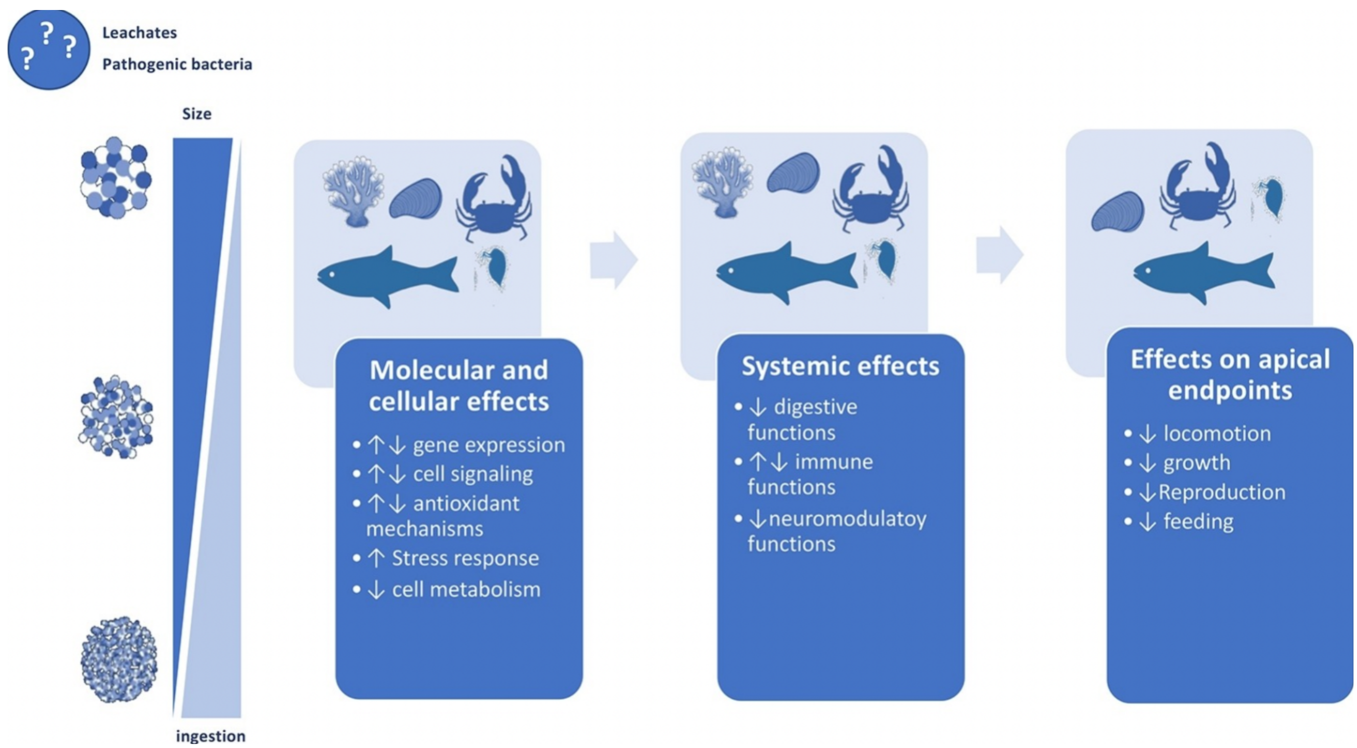

Figure 7. In the image above, an apical endpoint is an outcome for an animal (including altered locomotion, growth, reproduction, and feeding) that can result from exposure to a pollutant like microplastic and that indicates a diseased state for that animal. (Franzellitti S, et. al. 2019)

Microplastics are "magnets" for environmental toxins

While ingesting microplastics directly harms animals, microplastics can also act as sponges for other hazardous substance, such as additives that were intentionally included in the synthetic formulation (e.g., phthalates, well-known endocrine disrupting agents), or they can absorb and concentrate pollutants in the environment (e.g., petrochemical residues from oil rigs).[24] In one recent scientific study, researchers found that "even very low concentrations of environmental pollutants, which are non-toxic to humans, once adsorb to the microplastic result in significant increase in toxicity.[25] This is because **microplastics are a kind of 'magnet' for environmental pollutants**."

A research study of the ecotoxicological effects of microplastics in aquatic environments cited that there are **more than 200 organic chemicals related to microplastics**, including flame retardants, antimicrobials, DDEs, and PCBs. It also found that microplastics may absorb and concentrate other environmental toxins, and aquatic organisms who ingest them may serve "as environmental carriers and vectors of toxic chemicals which they can transmit to marine organisms and cause severe and adverse health effects."[26] The scientists who recently published *Research on the Influence of Microplastics on Marine Life* found similar toxicological effects of microplastics and concluded, "[a]t present, the pollution of marine microplastics has become more and more serious and has become a global pollution incident, but **there is a lack of effective treatment methods.**"[27] [28]

We cannot prevent microplastics from entering the environment once products are sold

There are currently no effective interventions for adequately removing microplastics once they are released into the environment. In many countries, microplastics are not filtered out by wastewater treatment processes. Even in countries that have the technological capabilities to remove the vast majority of microplastics during the wastewater treatment process, a large quantity of microplastics and nanoplastics still escape into ecosystems, where they may wreak havoc and persist for centuries. And while individuals with the means to do so can purchase products that decrease the amount of microplastics escaping their washing machines, these solutions require investments of time and money and are not a cost-effective, scalable, global solution to the unbounded planetary problem of microplastic pollution.

As microplastics continue to accumulate and persist in ecosystems across the globe, they may grow into an existential threat.

Figure 8. Microplastics of various forms under a microscope. The long fibers are microfibers derived from textiles. (Alex Aves/University of Canterbury. bit.ly/3Etw4GZ)

Recycling is also not a cost-effective, scalable, and global solution to preventing microplastic pollution. Though recycling is an option for some synthetic fibers, only a small percentage of the synthetic materials we wear and use is recycled, microplastics are still released during the process of recycling these materials, and recycling does not capture the microplastics released during wear and washing. In addition, recycling technology faces numerous challenges, including low efficiency of existing recycling technology, management of the underlying materials' toxicity, fiber shedding during recycling, transitional risk (increased emissions with increase in recycling facilities to meet demand), the resource intensiveness of the recycling process, and long-term dependency on virgin plastic production. To prevent the harms microplastics cause to countless animals and ecosystems, they must be eliminated from materials during the production process.

The research on this issue is continuing to evolve, but all signs point to dire consequences

The answer to this problem is not simply more research on the effects of microplastic on animals. A search within Google Scholar reveals over 20,000 individual scientific articles that contain the terms "microplastics" and "animals."

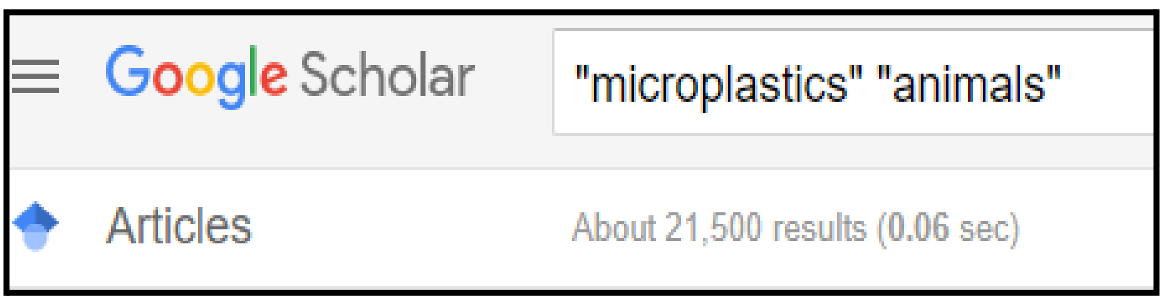

Figure 9. There has already been extensive research on microplastics and animals, and even more will continue to be conducted in the coming years.

Some will argue that a "wait and see" approach is needed to fully understand the scale and scope of microplastics' effects on animal well being. It is true that with any environmental crisis, continued research is necessary and warranted to fully comprehend the issue. However, research continually indicates that due to the pervasive, toxic, and bioaccumulative nature of microplastics, more and more animals will be exposed to these pollutants, and as environmental migration and dispersion along the food chain continue to progress, more animals will be harmed.

Time and time again, humanity has taken too little action while "waiting for more research." For example, the mid 20th century saw some of the worst occupational exposures to asbestos, a useful mineral with deadly consequences when inhaled. The evidence of the harm of asbestos was reported as early as 1899, but it took almost 100 years later for asbestos to be banned in many use cases. In fact, asbestos is still in use in the U.S. in certain applications.[29] During that century of heavy asbestos use, corporations argued for "more research" while millions of workers were exposed to asbestos, leading to >200,000 annual deaths worldwide.[30]

To avoid making the same mistakes with synthetics, we need to act now to find viable alternatives that are high performance, aesthetically appealing, affordable, scalable, sustainable, and that don't shed microplastics.

Without intervention, the use of synthetics or animal-derived materials will continue to grow

Synthetic textiles are expected to remain the number one source of primary microplastics globally in the coming decade as the industry grows. Synthetic materials comprise approximately 60% of materials used by the fashion, automotive, and home goods industries today and are projected to comprise 70% by 2030.

As research continues to surface about the environmental and animal welfare impacts of synthetics, brands and retailers are under pressure to reduce their reliance on these materials. In fashion especially, there is an increased push to equate synthetic materials with "plastics," necessitating a move back to "natural" products like leather, wool, and silk. Unfortunately, without providing sustainable, cruelty-free alternatives, this backlash against synthetics will likely lead to a resurgence in animal-derived materials, which are sourced from the harming or killing of more than 1 trillion animals each year.

Without the development of next-gen materials, significant numbers of animals will be harmed either through the prevalence of more microplastics or through the use of their skin, hair, fur, feathers, and silk.

Figure 10. Woolmark campaign claiming wool as sustainable, because it does not create microplastics. (https://www.woolmark.com/industry/sustainability/wool-is-a-sustainable-fibre/)

Next-gen materials are the solution to the synthetics crisis, offering viable alternatives that will not harm animals in any point in their life cycle

The only truly effective long-term solution to the irreversible harms of synthetic and animal-derived materials is to replace them with next-gen materials that replicate their positive aesthetic and performance properties while eliminating their negative externalities.

Material Innovation Initiative (MII) advances sustainable, animal-free next-gen materials and helps drive material innovation. We were founded on the premise that consumers do not buy materials because they come from animals or petrochemicals; they buy them based on their performance, aesthetic, price, and availability. If the market provides consumers with products that meet their needs, plus have the added benefits of being more sustainable and cruelty-free, consumers will purchase these products.

The ideal next-gen material is derived from renewable, animal-free inputs such as cellulose, chitin, proteins, or biosynthetics, and this material is able to safely return to nature as nutrients, rather than pollutants. Thus across the life cycle, next-gen materials are poised to have much lower environmental footprints, and avoid contributing to the plastic pollution crisis.

The MII team conducts research, shares knowledge, and facilitates connections to profoundly shift the way materials are produced and to foster a global market for sustainable products across the fashion, automotive, and home goods industries. We envision a world where the materials we interact with every day, from our shoes to our car seats, are produced in a way that allows the planet, animals, and future generations to thrive.

Endnotes

1. Common synthetic fibers include acetate, acrylic, lyocell, nylon, polyester, polypropylene, PVC, rayon, and spandex.

2. Boucher, Julien, and Damien Friot. *Primary microplastics in the oceans: a global evaluation of sources*. Vol. 10. Gland, Switzerland: Iucn, 2017.

3. "Fossil Fashion: The hidden reliance of fast fashion on fossil fuels." Changing Markets Foundation, 2021. https://changingmarkets.org/wp-content/uploads/2021/01/FOSSIL-FASHION_Web-compressed.pdf

4. A taxon is a biological classification into which related organisms are classified; for example, a kingdom, phylum, class, order, family, genus, or species. The trophic level of an organism is the position it occupies in a food web.

5. United Nations Environment Programme and Caribbean Environment Programme. 2015. Plastics and Microplastics - Factsheet July 2015. https://wedocs.unep.org/20.500.11822/28420

6. Teuten, Emma L., Jovita M. Saquing, Detlef RU Knappe, Morton A. Barlaz, Susanne Jonsson, Annika Björn, Steven J. Rowland et al. "Transport and release of chemicals from plastics to the environment and to wildlife." Philosophical transactions of the royal society B: biological sciences 364, no. 1526 (2009): 2027-2045.

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8. Barrows, A. P. W., Sara E. Cathey, and Christopher W. Petersen. "Marine environment microfiber contamination: Global patterns and the diversity of microparticle origins." Environmental pollution 237 (2018): 275-284. https://doi.org/10.1016/j.envpol.2018.02.062.

9. United Nations Environment Programme and Caribbean Environment Programme. 2015. Plastics and Microplastics - Factsheet July 2015. https://wedocs.unep.org/20.500.11822/28420

10. The Gallatin River, which originates in Yellowstone National Park, is one of the major tributaries of the Missouri River.

11. Boucher, Julien, Friot, Damien. (2017). Primary Microplastics in the Oceans: A Global Evaluation of Sources. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources.

12. Rochman C, et. al. (2019). Rethinking microplastics as a diverse contaminant suite. Environmental Toxicology and Chemistry Volume 38, Issue 4 p. 703-71

13. Alexandra McInturf and Matthew Savoca, "Hundreds of Fish Species, Including Many that Humans Eat, are Consuming Plastic," The Conversation. February 2021. https://theconversation.com/hundreds-of-fish-species-including-many-that-humans-eat-are-consuming-plastic-154634

14. "MP" is an abbreviation for microplastic.

15. de Sá, Luís Carlos, Oliveira, Miguel, Ribeiro, Francisca, Lopes Rocha, Thiago, Norman Futter, Martyn. Studies of the effects of microplastics on aquatic organisms: What do we know and where should we focus our efforts in the future? Science of The Total Environment, Volume 645, 2018, pp. 1029-1039.

16. Santos et al., Science 373, 56–60 (2021)

17. A prominent effective altruism research organization has found that all animal species it has researched, including aquatic and soil invertebrates, are sentient; the research isn't published yet.

18. Zolotova N, Kosyreva A, Dzhalilova D, Fokichev N, Makarova O. 2022. Harmful effects of microplastic pollution on animal health: a literature review. PeerJ 10:e13503 DOI 10.7717/peerj.13503 (2022)

19. A keystone species is defined in the dictionary as a species on which other species in an ecosystem largely depend, such that if it were removed the ecosystem would change drastically.

20. Yu, Sing-Pei Yu, Matthew Cole Cole, and Benny KK Chan. “Effects of microplastic on zooplankton survival and sublethal responses.” Oceanography and Marine Biology, Chapter 7 (2020).

21. de Oliveira Soares, Marcelo, Matos, Eliana, Lucas, Caroline, Rizzo, Lucia, Allcock, Louise, Rossi, Sergio. Microplastics in corals: An emergent threat, Marine Pollution Bulletin, Volume 161, Part A, 2020.

22. D'Costa, AH. Microplastics in decapod crustaceans: Accumulation, toxicity and impacts, a review. Science of The Total Environment, Volume 832, 2022.

23. Franzellitti S, Canesi L, Auguste M, Wathsala R, Fabbri E. Microplastic exposure and effects in aquatic organisms: A physiological perspective. Environmental Toxicology and Pharmacology, Volume 68, 2019.

24. Tel-Aviv University. "Microplastics increase the toxicity of organic pollutants in the environment by a factor of 10, study finds." ScienceDaily. February 2022.
www.sciencedaily.com/releases/2022/02/220216112233.htm

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27. You Li et al. Research on the Influence of Microplastics on Marine Life. 2021 IOP Conf. Ser.: Earth Environ. Sci. 631 012006

28. For more information about the toxicological effects of microplastics on fish, see: Espinosa Ruiz, Cristóbal & Esteban, Maria & Cuesta, Alberto. (2016). Microplastics in Aquatic Environments and Their Toxicological Implications for Fish. 10.5772/64815.

29. Luus, Kristina. "Asbestos: mining exposure, health effects and policy implications." McGill Journal of Medicine: MJM 10, no. 2 (2007): 121.

30. Furuya, Sugio, Odgerel Chimed-Ochir, Ken Takahashi, Annette David, and Jukka Takala. "Global asbestos disaster." International journal of environmental research and public health 15, no. 5 (2018): 1000.