# Microplastics in seafood

*Humans now produce over 322 million tonnes of plastic annually, with a projected doubling of production by 2035. Millions of tonnes of this plastic have entered the ocean, including trillions of microplastic particles (measuring less than 5 mm in length), and unknown quantities of nanoplastics (measuring less than 1 μm). Microplastics are found throughout marine food webs, and while human health risks from ingestion in seafood are currently considered low, many unknowns remain, and public concern about consuming microplastics in food is high.*

## Microplastics and their distribution in the ocean

Microplastics are generally defined as any plastic item less than 5 mm in length, when measured along its longest dimension[1]. Some microplastics are directly manufactured and are referred to as "primary microplastics" (e.g. many cosmetic products include microplastic "beads"). Other microplastics result from larger plastic items fracturing and degrading into smaller pieces, and are referred to as "secondary microplastics"[1]. Microplastics including microfibers are ubiquitous in the environment, found in soil, freshwater, air and the ocean[2,3].

Methods for estimating the full extent of microplastic pollution in the ocean are still being developed, but one study estimated 15 trillion to 51 trillion microplastic particles were floating on the ocean's surface at the time[4,5]. Microplastics have been found in all ocean basins, on coastlines, floating on the water surface and at great depths. According to models, the highest concentrations of microplastics are found in the Mediterranean and the North Pacific Ocean, although some rivers have concentrations of microplastics that are orders of magnitude higher than any recorded in the ocean[1,6].

In some cases, it has been possible to link the prevalence of microplastics to specific industries, including the seafood industry. Key examples include the particularly high levels of expanded polystyrene (EPS) microplastics along shorelines in southern Korea[7], which are thought to be linked to widespread use of EPS for aquaculture farms and buoys. Similar patterns have been found in parts of Japan and Chile, where dominance of EPS microplastics overlaps with areas of intense coastal aquaculture development[8].

## Microplastics in seafood

The ocean has long been considered a primary sink of plastic pollution, and substantial effort has focused on identifying microplastics in the stomach contents and tissues of marine species. Over 750 marine fish species and over 200 marine invertebrates have been found to ingest microplastics[9], although numbers for these and terrestrial species will certainly increase as researchers study more species (See full list of species and studies in Reference 9 (Santos et al. 2021)). While most fish species are gutted prior to human consumption, lowering risk of microplastic ingestion, sardines, anchovies and some other small pelagic species are consumed in their entirety, as are mussels, oysters and some other marine invertebrates[1]. Identification of plastics in species across marine food webs underscores that ingestion occurs not only directly, but also trophically (i.e. as species consume prey that already has microplastics in its tissues or digestive system)[10].

The health impacts of microplastic ingestion have been notoriously difficult to determine. This is due, among other things, to the difficulty of testing impacts in a laboratory setting. The ocean contains microplastics that span a wide diversity of chemical compositions, differences in shape and size, and covered with organic biofilms that form as the microplastic particle interacts with the surrounding environment[4]. All of these conditions are difficult to mimic in a laboratory setting, where researchers often depend on highly simplified microplastic compositions at far higher concentrations than are known to exist in the environment. Loss of mobility, slower growth, physical damage and less effective reproduction are among the effects that have

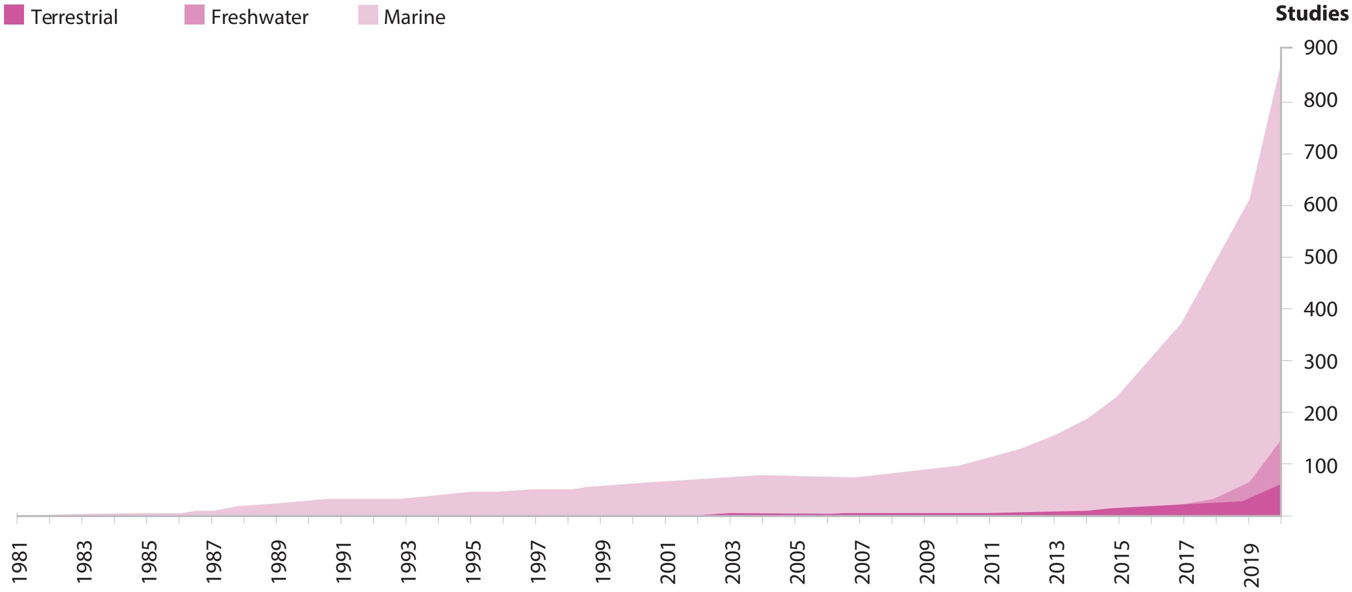


**Figure 1. Number of studies on plastic ingestion by system type (marine, freshwater and terrestrial) (Adapted from Santos et al. 2021)[9].**

been identified in such studies on zooplankton, a group of species that form the basis of marine food webs[4,11–13].

A primary concern related to microplastic ingestion is the suite of over 10,000 chemicals used to manufacture plastics[14], some of which are known or probable carcinogens and endocrine disruptors, as well as the contaminants that plastics adsorb or absorb from the environment. These include persistent organic pollutants (POPs) like polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), both of which are also considered persistent bioaccumulative toxic substances (PBTs). Consumption of such pollutants is linked to a wide range of negative impacts for the health and reproductive capacity of marine life as well as humans[15,16], and the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization have set maximum allowable tolerance levels for food products and packaging, as well as allowable human daily intake levels (e.g. for PCBs, 6 µg/kg per day)[1,17].

A 2017 FAO report on "Microplastics in Fisheries and Aquaculture" calculated a "worst-case scenario" for human consumption of contaminants from seafood, which considered a 225 g portion of Chinese bivalves. Samples of these bivalves had the highest observed level of microplastics in any seafood at the time, approximately four particles of microplastics per gram of tissue[1,18], resulting in ingestion of some 900 microplastic particles, weighing approximately 7 µg. Using best available data, the levels of ingestion of several well-studied contaminants (PCBs, PAHs, DDT) and plastic additives/monomers (Bisphenol A, PBDEs) from this meal were estimated to all fall well below 1% of allowable daily intake levels[1]. Another 2019

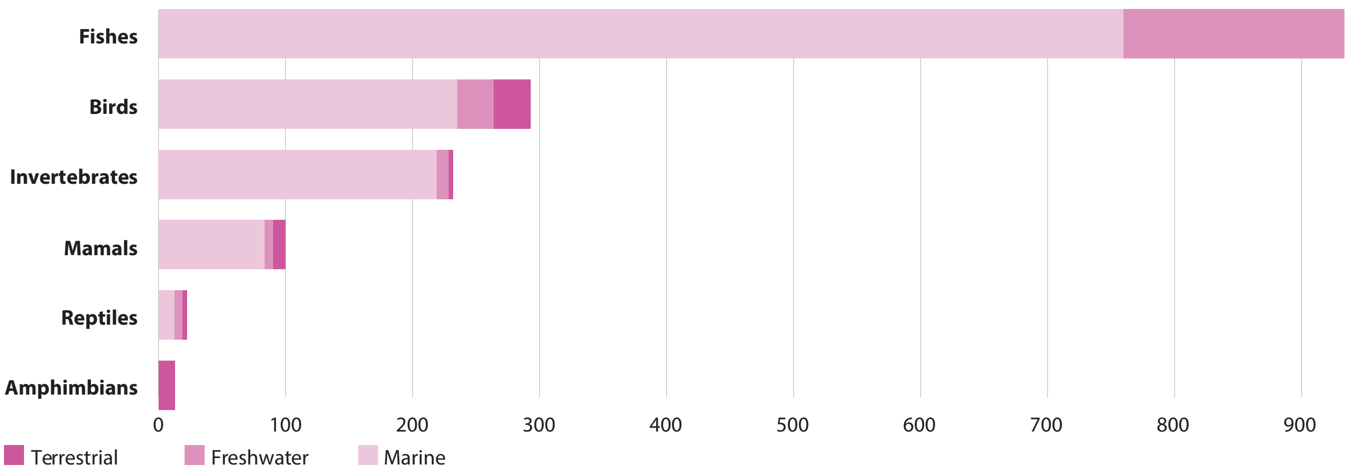


**Figure 2** Number of species in which plastic ingestion has been identified, organized by species group and ecosystem (Adapted from Santos et al. 2021).[9]

review found that human's primary consumption of microplastic is not through food, but rather through airborne consumption while breathing[19].

## Research frontiers and projections

Many uncertainties remain about the impacts of microplastics on marine life and human health. One particular concern is nanoplastics (i.e. microplastics measuring less than 1 µm), which may cross into cells, be passed from mother to offspring[20], and even cross the blood-brain barrier of humans[4]. Studying nanoplastics is extremely challenging due to their small size, and their presence in seawater wasn't conclusively observed until 2017[21]. Researchers have noted the urgent need for standardized methodologies to systematically and inexpensively collect, identify and classify microplastics and nanoplastics.

A recent editorial in the journal *Nature* noted that researchers do not believe that current levels of microplastics and nanoplastics in the environment are affecting human health[4]. Surveys of public opinion, however, suggest that the public is deeply concerned about microplastics – a 2020 study by the German Federal Institute for Risk Assessment, for instance, found that 63% of respondents were concerned about microplastics in their food[22–24]. Moreover, microplastic levels are expected to rise dramatically alongside the continued growth in plastic production. According to one estimate, by 2040 approximately 10 million tonnes of plastic pollution – annually – could be in the form of microplastics[4,25]. This estimate only includes primary microplastics, and does not include secondary microplastics generated through the degradation and fracturing of larger plastics into microplastics, which will continue.

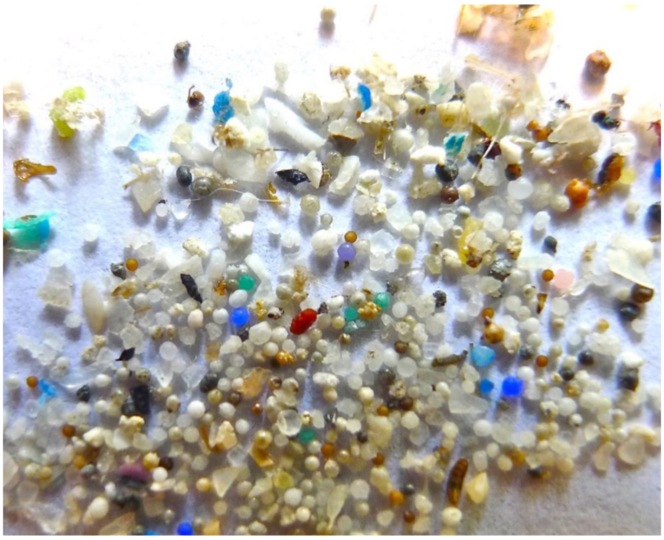

**Figure 3** Microplastics (reproduced courtesy of Oregon State University CC BY-SA 2.0)

### Key references for further reading:

GESAMP (2015). **"Sources, fate and effects of microplastics in the marine environment: a global assessment"**

Lim, XiaoZhi. (2021) **"Microplastics are everywhere —but are they harmful?"** Nature: 22-25.

Lusher, A.L.; Hollman, P.C.H.; Mendoza-Hill, J.J. 2017. **Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms and food safety. FAO Fisheries and Aquaculture Technical Paper.** No. 615.

OECD. 2022. **Projections of plastic leakage to the environment by 2060**.

## References


1. Lusher, et al. "Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms and food safety." FAO (2017).
2. Rochman, et al. "Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption." Scientific Reports (2015).
3. Smith, et al. "Microplastics in Seafood and the Implications for Human Health." Current Environmental Health Reports (2018).
4. Lim, X. "Microplastics are everywhere — but are they harmful?" Nature (2021).
5. Sebille, et al. "A global inventory of small floating plastic debris." Environmental Research Letters (2015).
6. Windsor, et al. "A catchment-scale perspective of plastic pollution." Global Change Biology (2019).
7. Heo, et al. "Distribution of small plastic debris in cross-section and high strandline on Heungnam beach, South Korea." Ocean Science Journal (2013).
8. Kershaw, P. "Sources, fate and effects of microplastics in the marine environment: a global assessment." (2015).
9. Santos, et al. "Plastic ingestion as an evolutionary trap: Toward a holistic understanding." Science (2021).
10. Athey, et al. "Trophic transfer of microplastics in an estuarine food chain and the effects of a sorbed legacy pollutant." Limnology and Oceanography Letters (2020).
11. Botterell, et al. "Microplastic ingestion in zooplankton from the Fram Strait in the Arctic." Science of the Total Environment (2022).
12. Walkinshaw, et al. "Microplastics and seafood: lower trophic organisms at highest risk of contamination." Ecotoxicology and Environmental Safety (2020).
13. Bucci, et al. "What is known and unknown about the effects of plastic pollution: A meta-analysis and systematic review." Ecological Applications (2020).

14. Wiesinger, et al. "Deep Dive into Plastic Monomers, Additives, and Processing Aids." Environmental Science and Technology (2021).
15. Carpenter, D. "Polychlorinated Biphenyls (PCBs): Routes of Exposure and Effects on Human Health." Reviews on Environmental Health (2006).
16. Kim, et al. "A review of airborne polycyclic aromatic hydrocarbons (PAHs) and their human health effects." Environment International (2013).
17. JEFCA. "Safety evaluation of certain food additives and contaminants, supplement 1: non-dioxin-like polychlorinated biphenyls, prepared by the eightieth meeting of the Joint FAO/WHO Expert Committee on Food Additives" (2016).
18. Li, et al. "Microplastics in commercial bivalves from China." Environmental Pollution (2015).
19. Cox, et al. "Human Consumption of Microplastics." Environmental Science and Technology (2019).
20. Pitt, et al. "Maternal transfer of nanoplastics to offspring in zebrafish (Danio rerio): A case study with nanopolystyrene." Science of the Total Environment (2018).
21. Ter Halle, et al. "Nanoplastic in the North Atlantic Subtropical Gyre." Environmental Science and Technology (2017).
22. Catarino, et al. "Risk posed by microplastics: Scientific evidence and public perception." Current Opinion in Green and Sustainable Chemistry (2021).
23. German federal Institute for Risk Assessment (BfR). "BfR-verbraucher MONITOR." (2020).
24. Soares, et al. Public views on plastic pollution: Knowledge, perceived impacts, and pro-environmental behaviours. Journal of Hazardous Materials (2021).
25. Lau, et al. "Evaluating scenarios toward zero plastic pollution." Science (2020).

Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship

Stockholm University

Beijer Institute of Ecological Economics

Kungl. Vetenskaps-Akademien
The Royal Swedish Academy of Sciences

Global Economic Dynamics and the Biosphere
The Royal Swedish Academy of Sciences

Pentland

Lancaster University

Stanford | Center for Ocean Solutions

Walton Family Foundation

the David & Lucile Packard Foundation

**Author:** Robert Blasiak

**Affiliation:** Stockholm Resilience Centre, Stockholm University

**Reviewed by:** Zoie Diana (Duke University), David Santillo (University of Exeter) and John Virdin (Duke University)

**Acknowledgements:** The author acknowledges support from the Walton Family Foundation and the David and Lucile Packard Foundation.

**Graphics and layout:** Evelina Jonsson/Azote