Current trends of microplastic pollution in the marine environment

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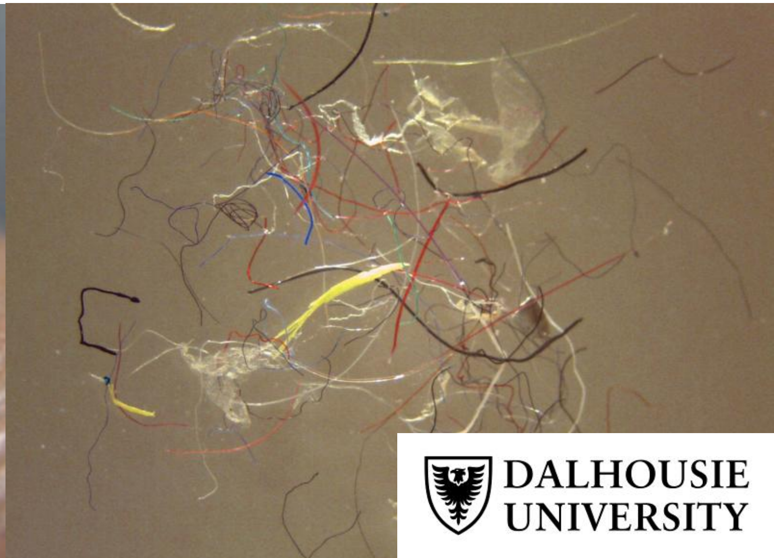
Types of microplastic pollution

- **Microplastics <5 mm**
  - Secondary microplastics (degraded macroplastics)
  - Primary microplastics (manufactured microbeads <1 mm)
  - Microfiber plastics



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Origin of the “microplastic” term in 2004

Lost at Sea: Where Is All the Plastic?

Richard C. Thompson,[1]* Ylva Olsen,[1] Richard P. Mitchell,[1] Anthony Davis,[1] Steven J. Rowland,[1] Anthony W. G. John,[2] Daniel McGonigle,[3] Andrea E. Russell[3]

Millions of metric tons of plastic are produced annually. Countless large items of plastic debris are accumulating in marine habitats worldwide and may persist for centuries (*1–4*). Here we show that microscopic plastic fragments and fibers (Fig. 1A) are also widespread in the oceans and have accumulated in the pelagic zone and sedimentary habitats. The fragments appear to have resulted from degradation of larger items. Plastics of this size are ingested by marine organisms, but the environmental consequences of this contamination are still unknown.

Over the past 40 years, large items of plastic debris have frequently been recorded in habitats from the poles to the equator (*1–4*). Smaller fragments, probably also plastic, have been reported (*5*) but have received far less attention. Most plastics are resistant to biodegradation, but will break down gradually through mechanical action (*6*). Many “biodegradable” plastics are composites with materials such as starch that biodegrade, leaving behind numerous, nondegradable, plastic fragments (*6*). Some cleaning agents also contain abrasive plastic fragments (*2*). Hence, there is considerable potential for large-scale accumulation of microscopic plastic debris.

To quantify the abundance of microplastics, we collected sediment from beaches and from estuarine and subtidal sediments around Plymouth, UK (Fig. 1B). Less dense particles were separated by flotation. Those that differed in appearance to natural particulate material (Fig. 1A) were removed and identified with Fourier Transform infrared (FT-IR) spectroscopy (*7*). Some were of natural origin and others could not be identified, but about one third were synthetic polymers (Fig. 1C). These polymers were present in most samples (23 out of 30), but were significantly more abundant in subtidal sediment (Fig. 1D). Nine polymers were conclusively identified: acrylic, alkyd, poly (ethylene:propylene), polyamide (nylon), polyester, polyethylene, polymethylacrylate, polypropylene, and polyvinyl-alcohol. These have a wide range of uses, including clothing, packaging, and rope, suggesting that the fragments resulted from the breakdown of larger items.

To assess the extent of contamination, a further 17 beaches were examined (Fig. 1B). Similar fibers were found, demonstrating that microscopic plastics are common in sedimentary habitats. To assess long-term trends in abundance, we examined plankton samples collected regularly since the 1960s along routes between Aberdeen and the Shetlands (315 km) and from Sule Skerry to Iceland (850 km) (*7*) (Fig. 1B). We found plastic archived among the plankton in samples back to the 1960s, but with a significant increase in abundance over time (Fig. 1E). We found similar types of polymer in the water column as in sediments, suggesting that polymer density was not a major factor influencing distribution.

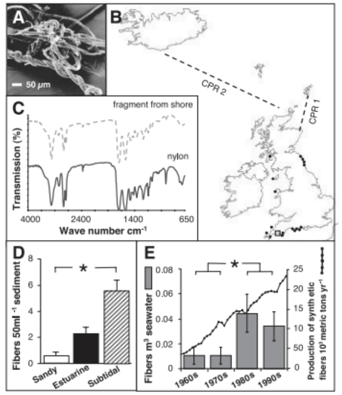

Fig. 1. (**A**) One of numerous fragments found among marine sediments and identified as plastic by FT-IR spectroscopy. (**B**) Sampling locations in the northeast Atlantic. Six sites near Plymouth (□) were used to compare the abundance of microplastic among habitats. Similar fragments (●) were found on other shores. Routes sampled by Continuous Plankton Recorder (CPR 1 and 2) were used to assess changes in microplastic abundance since 1960. (**C**) FT-IR spectra of a microscopic fragment matched that of nylon. (**D**) Microplastics were more abundant in subtidal habitats than on sandy beaches (*, $F_{2,3} = 13.26$, $P < 0.05$), but abundance was consistent among sites within habitat types. (**E**) Microscopic plastic in CPR samples revealed a significant increase in abundance when samples from the 1960s and 1970s were compared to those from the 1980s and 1990s (*, $F_{3,3} = 14.42$, $P < 0.05$). Approximate global production of synthetic fibers is overlain for comparison. Microplastics were also less abundant along oceanic route CPR 1 than along CPR 2 ($F_{1,24} = 5.18$, $P < 0.05$).

It was only possible to quantify fragments that differed in appearance from sediment grains or plankton. Some fragments were granular, but most were fibrous, ~20 μm in diameter, and brightly colored. We believe that these probably represent only a small proportion of the microscopic plastic in the environment, and methods are now needed to quantify the full spectrum of material present. The consequences of this contamination are yet to be established. Large plastic items can cause suffocation and entanglement and disrupt digestion in birds, fish, and mammals (*3*). To determine the potential for microscopic plastics to be ingested, we kept amphipods (detritivores), lugworms (deposit feeders), and barnacles (filter feeders) in aquaria with small quantities of microscopic plastics. All three species ingested plastics within a few days (*7*) (fig. S1).

Our findings demonstrate the broad spatial extent and accumulation of this type of contamination. Given the rapid increase in plastic production (Fig. 1E), the longevity of plastic, and the disposable nature of plastic items (*2*, *3*), this contamination is likely to increase. There is the potential for plastics to adsorb, release, and transport chemicals (*3*, *4*). However, it remains to be shown whether toxic substances can pass from plastics to the food chain. More work is needed to establish whether there are any environmental consequences of this debris.

References and Notes

1. P. G. Ryan, C. L. Moloney, *Nature* **361**, 23 (1993).
2. M. R. Gregory, P. G. Ryan, in *Marine Debris*, J. M. Coe, D. B. Rogers, Eds. (Springer, Berlin, 1996), pp. 48–70.
3. J. G. B. Derraik, *Mar. Pollut. Bull.* **44**, 842 (2002).
4. E. J. Carpenter, S. J. Anderson, G. R. Harvey, H. P. Miklas, B. P. Bradford, *Science* **178**, 749 (1972).
5. J. B. Colton, F. D. Knapp, B. R. Burns, *Science* **185**, 491 (1974).
6. P. P. Klemchuck, *Polym. Degrad. Stab.* **27**, 183 (1990).
7. Materials and methods are available as supporting material online on *Science* Online.

8. We thank C. Hoare, R. Ticehurst, G. Mandair, and F. Birembaut for help with sample collection and analysis. Supported by the Leverhulme Trust, UK.

Supporting Online Material
www.sciencemag.org/cgi/content/full/304/5672/838/DC1
Materials and Methods
Fig. S1
References and Notes

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Thompson, R.C. et al.(2004). *Science*, *304*(5672), 838-838.

REVIEW SUMMARY

MICROPLASTICS

Twenty years of microplastic pollution research—what have we learned?

Richard C. Thompson*, Winnie Courtene-Jones, Julien Boucher, Sabine Pahl, Karen Raubenheimer, Albert A. Koelmans

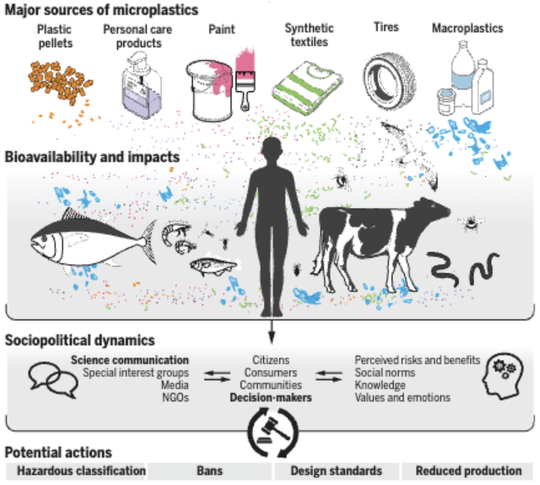
BACKGROUND: The term microplastic was first used to describe microscopic fragments of plastic debris (~20 μm in diameter) in a publication in 2004. On the basis of this paper and earlier work, it was evident that small fragments of various common plastics—including acrylic, polyamine (nylon), polypropylene, polyester, polyethylene, and polystyrene—were present in coastal environments around the United Kingdom and along the eastern seaboard of the United States and that their abundance had increased substantially since the 1960s. There was evidence that microplastics were bioavailable to invertebrates and fish but only speculation on the key sources and the potential for harmful effects.

ADVANCES: Microplastics, now widely defined as pieces ≤5 mm in size, are recognized as a highly diverse set of globally important contaminants. Multiple sources are now confirmed, including primary microplastics in cosmetics and paint as well as the pellets and flakes used to make plastic products, along with secondary microplastics generated by the abrasion of larger items during use, including textiles and tires, and the fragmentation of larger debris in the environment. Microplastics can be redistributed by wind and water and have since been reported in diverse locations, from the sea surface to deep-sea sediments, from farmland to our highest mountains, and in sea ice, lakes, and rivers. They have been detected in 1300 aquatic and terrestrial species, from invertebrates at the base of the food web to apex predators, with evidence of impacts at all levels of biological organization, from cellular to ecosystem. Microplastics are pervasive in the food we eat, the water we drink, and the air we breathe. They have been detected in multiple tissues and organs of the human body, with emerging evidence of potential effects.

This rapidly unfolding scientific evidence, together with individual, social, and societal drivers of change, is leading to policy outcomes that include national-level regulations, such as the prohibition of microplastics in cosmetics by multiple countries and a mandate in France requiring that filters be installed in washing machines to intercept microfibers, as well as multinational policies, including the EU Marine Strategy Framework Directive and the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) legislation on intentionally added microplastics.

OUTLOOK: Emissions of microplastics to the environment are estimated to be between 10 and 40 million tonnes per year, and under business-as-usual scenarios, this amount could double by 2040. Even if it were possible to immediately halt emissions, quantities would continue to increase because of the fragmentation of legacy items. Modeling predictions indicate the potential for wide-scale environmental harm within 70 to 100 years, but detailed risk assessments are limited because exposure and effect data are incomplete. This is especially true for human health effects. Although we anticipate greater clarity over the next few years, public risk perception is also a key driver of actions and is often influenced by a wider range of factors than objective risk assessment; for example, German consumers recently rated microplastics in food as being their top environmental health concern.

Can we afford the externalized costs of microplastics that are already understood, and if not, which criteria should guide interventions and what is essential, in the context of societal needs and desires? A whole-system approach from extraction to remediation will be key to creating material flows that satisfy human needs with minimal environmental impact. Twenty years of science defining microplastic pollution now brings a tangible opportunity for international action as part of the United Nations Environment Programme draft global plastics treaty. Together with reductions in primary polymer production, measures will be needed to reduce emissions and pollution along the entire life cycle of plastics, including dedicated provisions on microplastics. However, there is a high risk of unintended consequences if interventions are implemented without appropriate evaluation. ■



Microplastic pollution: Sources, impacts, and actions. Twenty years of research focused on microplastic pollution has identified their multiple sources, wide-scale environmental distribution, bioavailability, and impacts. This evidence, together with the associated sociopolitical dynamics, has started to drive actions on a global scale. NGOs, nongovernmental organizations.

The list of author affiliations is available in the full article online.
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READ THE FULL ARTICLE AT https://doi.org/10.1126/science.adl2746

Thompson, R.C. et al.(2024). *Science*, *386*(6720), eadl2746.

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Environmental Science & Technology

Feature

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pubs.acs.org/est

Are We Speaking the Same Language? Recommendations for a Definition and Categorization Framework for Plastic Debris

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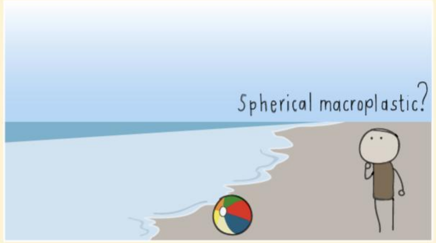
ABSTRACT: The accumulation of plastic litter in natural environments is a global issue. Concerns over potential negative impacts on the economy, wildlife, and human health provide strong incentives for improving the sustainable use of plastics. Despite the many voices raised on the issue, we lack a consensus on how to define and categorize plastic debris. This is evident for microplastics, where inconsistent size classes are used and where the materials to be included are under debate. While this is inherent in an emerging research field, an ambiguous terminology results in confusion and miscommunication that may compromise progress in research and mitigation measures. Therefore, we need to be explicit on what exactly we consider plastic debris. Thus, we critically discuss the advantages and disadvantages of a unified terminology, propose a definition and categorization framework, and highlight areas of uncertainty. Going beyond size classes, our framework includes physicochemical properties (polymer composition, solid state, solubility) as defining criteria and size, shape, color, and origin as classifiers for categorization. Acknowledging the rapid evolution of our knowledge on plastic pollution, our framework will promote consensus building within the scientific and regulatory community based on a solid scientific foundation.



1. INTRODUCTION

Plastic pollution is a substantial environmental problem. Plastic debris, that is, plastic items occurring in natural environments without fulfilling an intended function, is persistent, mobile, and ubiquitous in terrestrial and aquatic environments, including urban, rural, and remote locations. Large plastic litter is readily visible and adversely affects wildlife species through entanglement, ingestion, and lacerations.[1] Microscopic plastic debris

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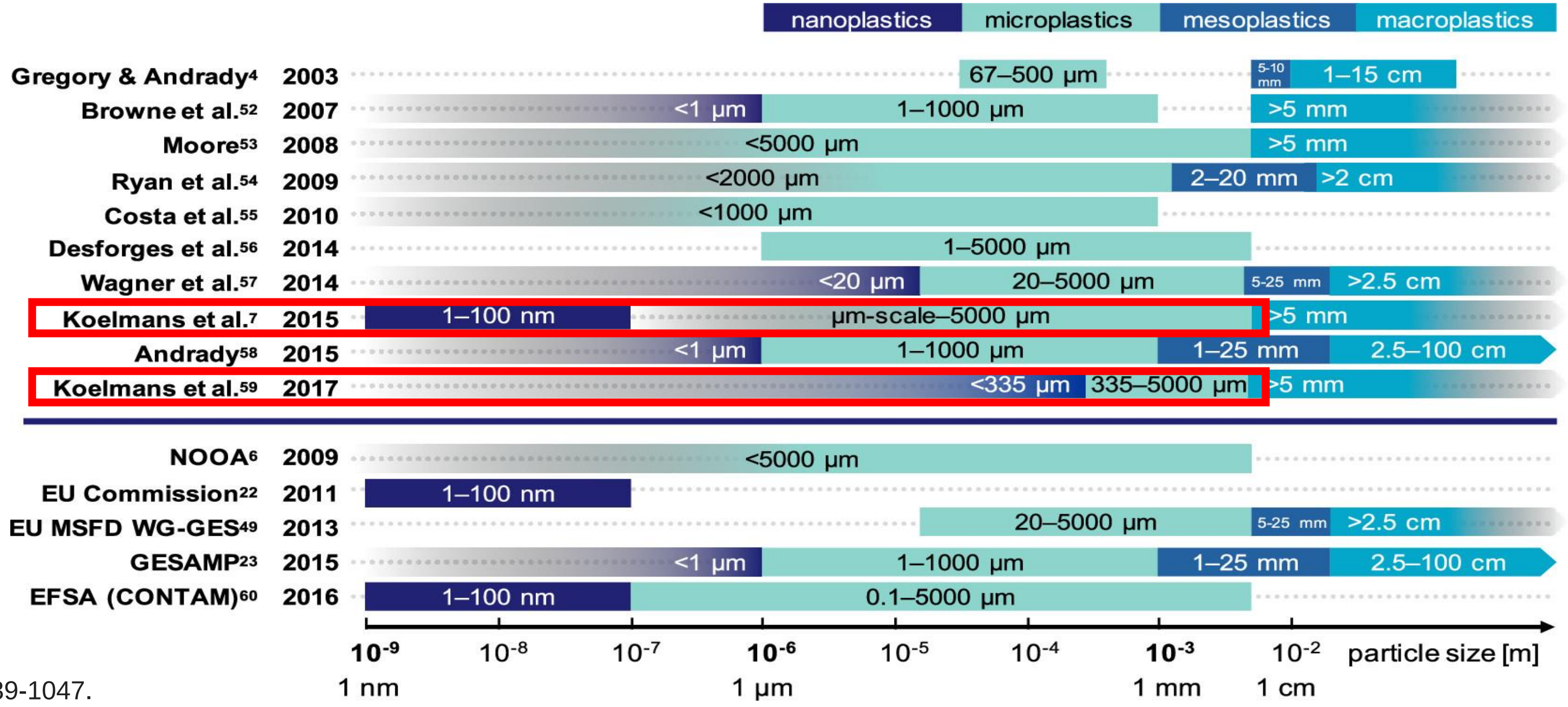
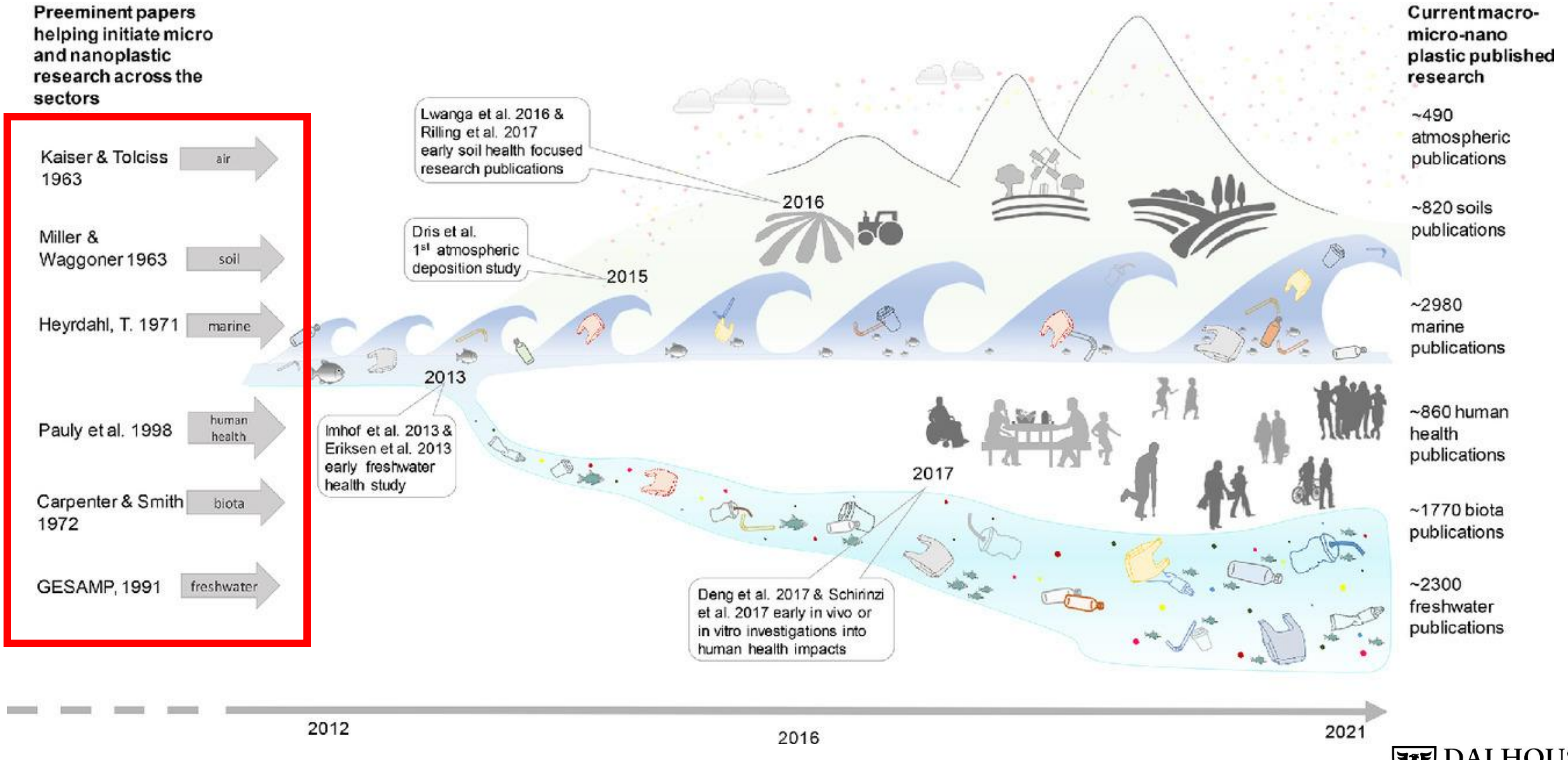


Hartmann, N.B. et al. (2019). *Environmental Science and Technology*, *53*(3), 1039-1047.

Microplastic pollution is <u>not just</u> a marine problem



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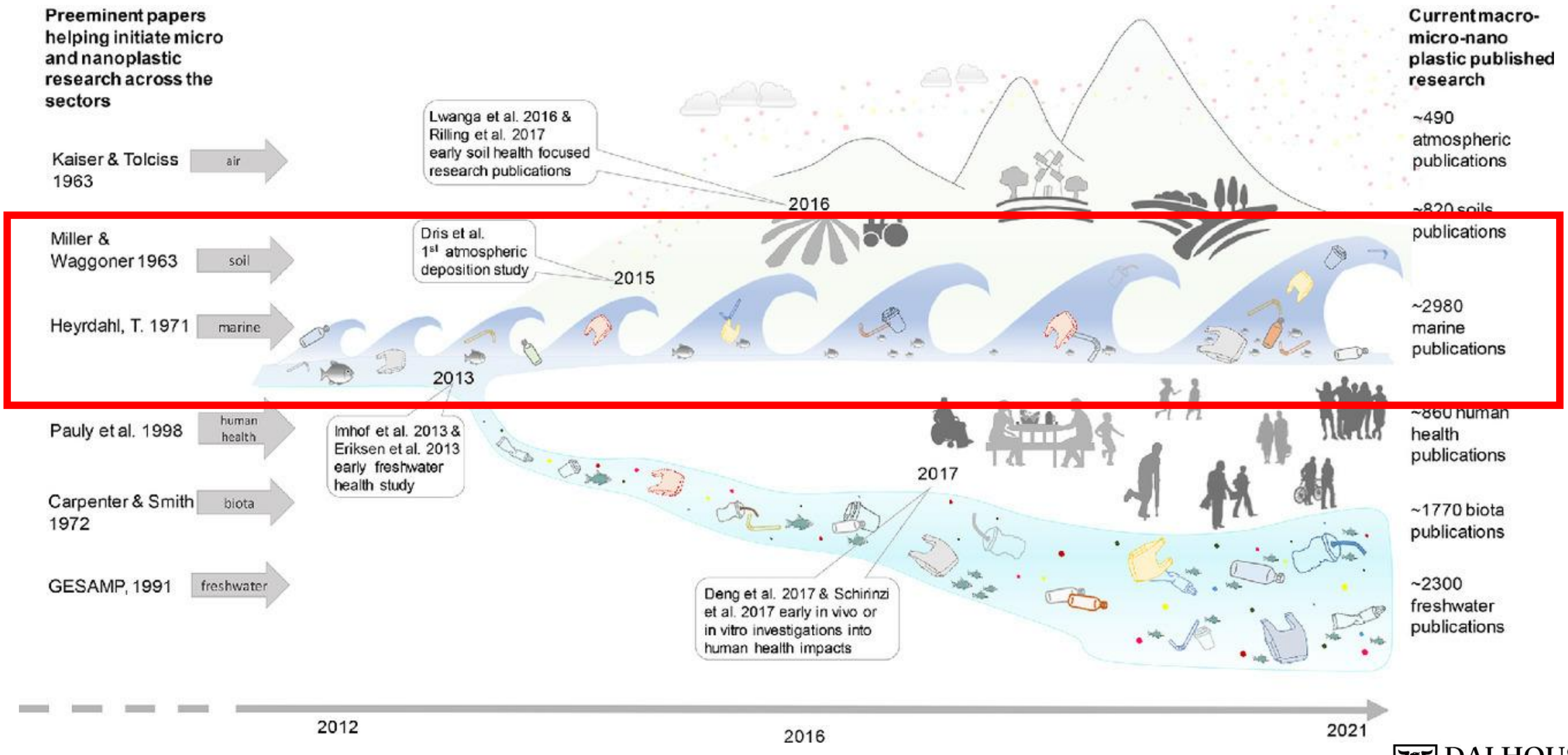
Allen et al. (2022). *Journal of Hazardous Materials Advances*, 6, 100057. https://www.sciencedirect.com/science/article/pii/S2772416622000146

Microplastic pollution is <u>not just</u> a marine problem



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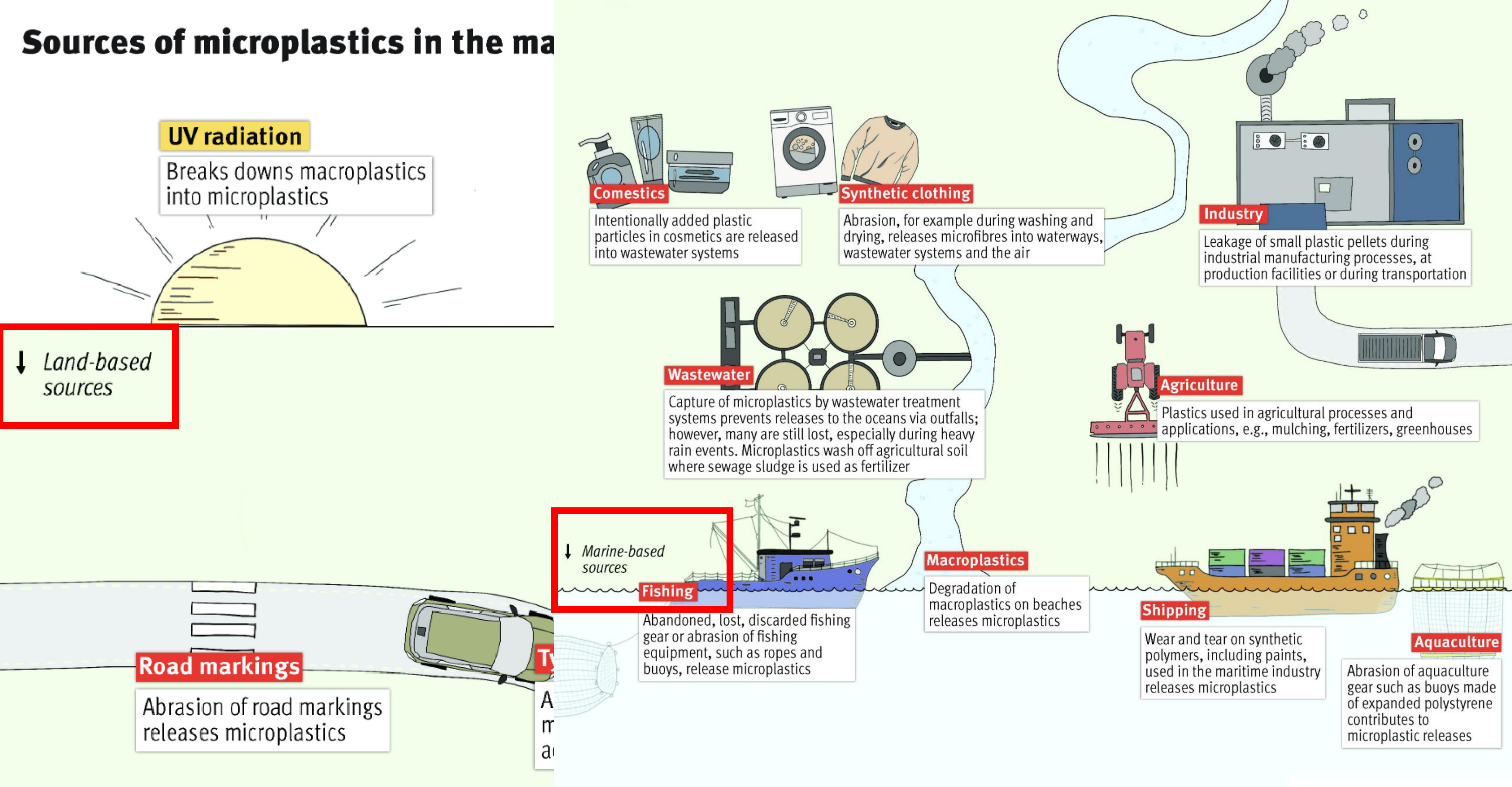
Allen et al. (2022). *Journal of Hazardous Materials Advances*, 6, 100057. https://www.sciencedirect.com/science/article/pii/S2772416622000146



Source: Waldschläger et al. (2020). Illustration by GRID-Arendal.
UNEP (2021). Drowning in plastics – Marine Litter and Plastic Waste Vital Graphics.

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History of marine microplastic pollution

Atlantic Ocean Pollution and Biota Observed by the 'Ra' Expeditions

THOR HEYERDAHL, Ph.D. (Oslo)

Kon-Tiki Museum, Oslo, Norway; Colla Micheri, Laigueglia, Italy

ABSTRACT

On two voyages virtually across the Atlantic Ocean in papyrus raft-ships in 1969 *and* 1970, *surface pollution was observed from very close quarters. Visible pollution was recorded during six days of the eight weeks' sailing in* 1969 *and on forty of the first forty-three days of sailing in* 1970, *although the remainder of that voyage was in relatively clean water. The pollution was mainly in the form of floating asphalt-like material, mostly in tiny lumps but sometimes up to fist size, though other forms were also observed. The older lumps were often beset with living barnacles and Algae, while quantities of dead coelenterates were in some places observed floating among them. Continued indiscriminate use of the world's oceans as a dumping-ground for durable human waste seems likely to have very serious and perhaps irreversible effects on their productivity.*

experiment with *Ra I*, created such wide interest that a more systematic survey with daily records and a wider range of samples were planned for the second crossing, on board *Ra II*.

As the water in the latitudes of our observations is not stagnant but is constantly on the move from east to west at an average speed of 0·5 knots, it is of some importance to repeat even the sparse observations recorded from *Ra I*. For the bulk of the surface water encountered on its move westwards in 1969 had already joined the Gulf Stream and was thus on its way back to northern Europe by the time we made our new observations in 1970.

On two voyages across the Atlantic Ocean in papyrus raft-ships in **1969** and **1970**, surface **(plastic)** pollution was observed by **Heyerdahl (1971)**

Heyerdahl, T. (1971). Atlantic Ocean pollution and biota observed by the 'Ra'expeditions. *Biological Conservation*, *3*(3), 164-168.

History of marine microplastic pollution

Plastics on the Sargasso Sea Surface

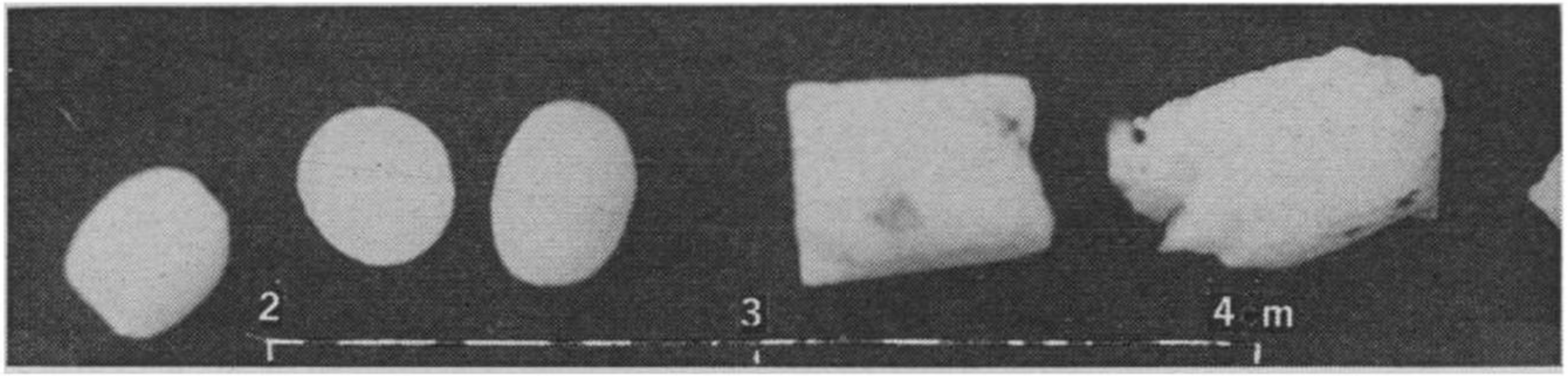

Fig. 1. Typical plastic particles from tow 2. White pellets are on the left.

Carpenter and Smith (1972) reported of weathered **tiny plastic particles (2.5 to 5 mm**) in the Sargasso Sea

Carpenter, E.J., & Smith Jr, K.L. (1972). Plastics on the Sargasso Sea surface. *Science*, *175*(4027), 1240-1241.

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History of marine microplastic pollution

Letter | Published: 04 January 1974

Quantitative Tar and Plastic Waste Distributions in the Pacific Ocean

C. S. WONG, DAVID R. GREEN & WALTER J. CRETNEY

Nature **247**, 30–32 (1974) | Cite this article

Wong et al. (1974) reported widespread **tiny plastic particles (1 to 5 mm)** in 21 of 36 tows along 35° N in the **Pacific Ocean** as small round, colourless pellets weighing 20 to 50 mg each

Wong, C.S., Green, D.R., & Cretney, W.J. (1974). Quantitative tar and plastic waste distributions in the Pacific Ocean. *Nature*, *247*(5435), 30-32.

History of marine microplastic pollution

Pergamon

Marine Pollution Bulletin Vol. 42, No. 12, pp. 1297–1300, 2001

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A Comparison of Plastic and Plankton in the North Pacific Central Gyre

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The potential for ingestion of plastic particles by open ocean filter feeders was assessed by measuring the relative abundance and mass of neustonic plastic and zooplankton in surface waters under the central atmospheric high-pressure cells of the North Pacific Ocean. Neuston samples were collected at 11 random sites, using a manta trawl lined with 333 u mesh. The abundance and mass of neustonic plastic was the largest recorded anywhere in the Pacific Ocean at 334 271 pieces km^2 and 5114 g km^2, respectively. Plankton abundance was approximately five times higher than that of plastic, but the mass of plastic was approximately six times that of plankton. The most frequently sampled types of identifiable plastic were thin films, polypropylene/monofilament line and unidentified plastic, most of which were miscellaneous fragments. Cumulatively, these three types accounted for 98% of the total number of plastic pieces. © 2001 Elsevier Science Ltd. All rights reserved.

harm to the animal. Less well studied are the effects of ingestible debris on fish, and no studies have been conducted on filter-feeding organisms, whose feeding mechanisms do not permit them to distinguish between debris and plankton. Moreover, no studies have compared the amount of neustonic debris to that of plankton to assess the potential effects on filter feeders.

Concerns about the effects of neustonic debris in the marine environment are greatest in oceanographic convergences and eddies, where debris fragments naturally accumulate (Shaw and Mapes, 1979; Day, 1986; Day and Shaw, 1987). The North Pacific central gyre, an area of high atmospheric pressure with a clockwise ocean current, is one such area of convergence that forces debris into a central area where winds and currents diminish. This study compares the abundance and mass of neustonic debris with the amount of zooplankton in this area.

TABLE 1

Abundance (pieces km^2) by type and size of plastic pieces and tar found in the North Pacific gyre.

Mesh-size (mm)	Fragments	Styrofoam pieces	Pellets	Polypropylene/ monofilament	Thin plastic films	Miscellaneous		
						Tar	Unidentified	Total
> 4.760	1931	84	36	16 811	5322	217	350	24 764
4.759–2.800	4502	121	471	4839	9631	97	36	19 696
2.799–1.000	61 187	1593	12	9969	40 622	833	72	114 288
0.999–0.710	55 780	591	0	2933	26 273	278	48	85 903
0.709–0.500	45 196	567	12	1460	10 572	121	0	57 928
0.499–0.355	26 888	338	0	845	3222	169	229	31 692
Total	195 484	3295	531	36 857	95 642	1714	736	334 270

Charles Moore et al. (2001) reported >300,000 plastic particles/km^2 (**<5 mm**) in trawls in the **North Pacific Ocean**

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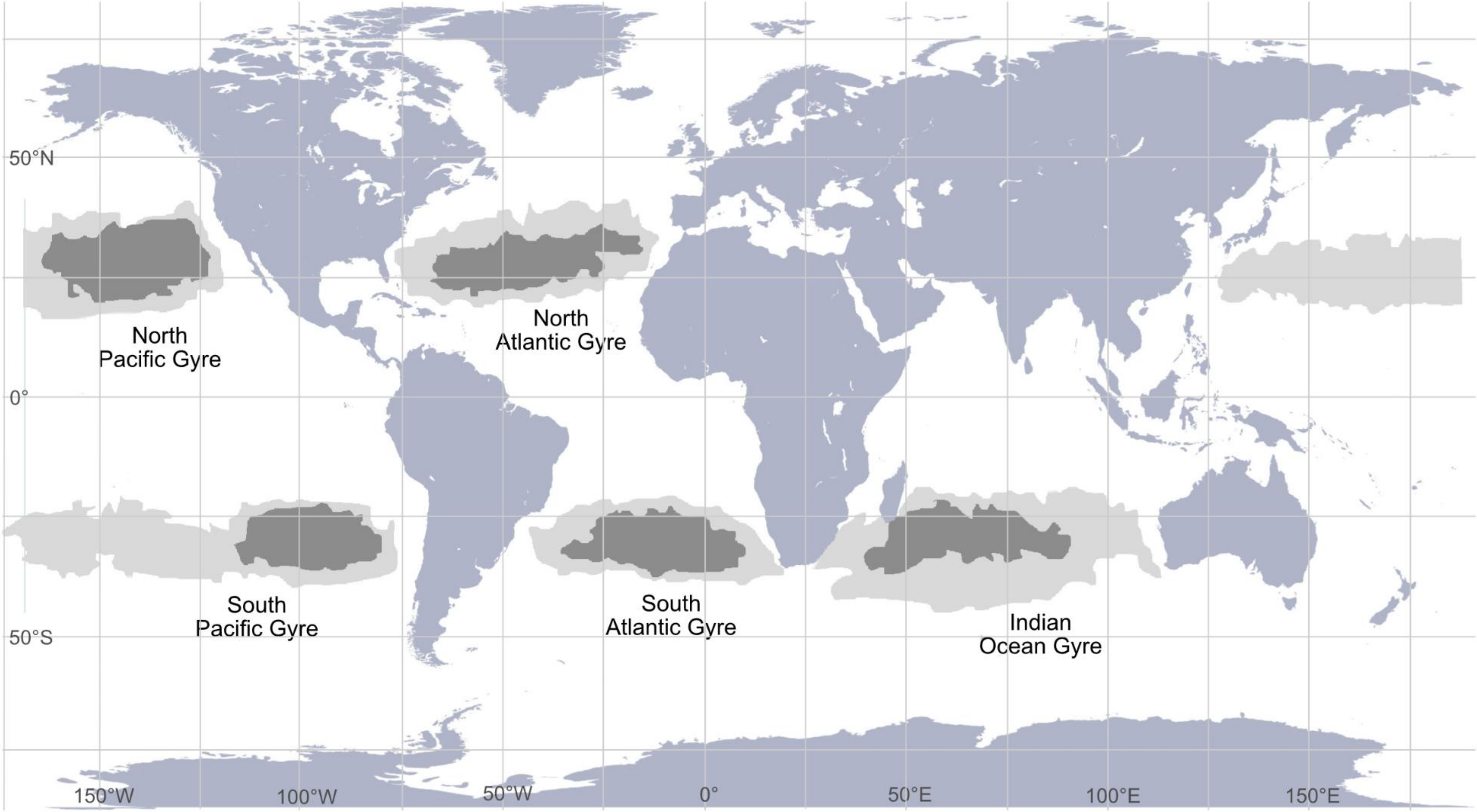
Moore, C.J. et al. (2001). A comparison of plastic and plankton in the North Pacific central gyre. *Marine Pollution Bulletin*, *42*(12), 1297-1300.

Location of the five major (micro)plastic gyres



Once in the marine environment does all the **plastic and microplastic pollution** float on the sea surface?

Andrade, H. et al. (2021). Oceanic long-range transport of organic additives present in plastic products: an overview. *Environmental Sciences Europe*, *33*, 1-14.

Marine microplastics fate

IOP Publishing Environ. Res. Lett. 12 (2017) 114028 https://doi.org/10.1088/1748-9326/aa9500

Environmental Research Letters

LETTER

All is not lost: deriving a top-down mass budget of plastic at sea

CrossMark

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Keywords: plastic debris, microplastic, ocean modeling, fragmentation

Supplementary material for this article is available online

Abstract

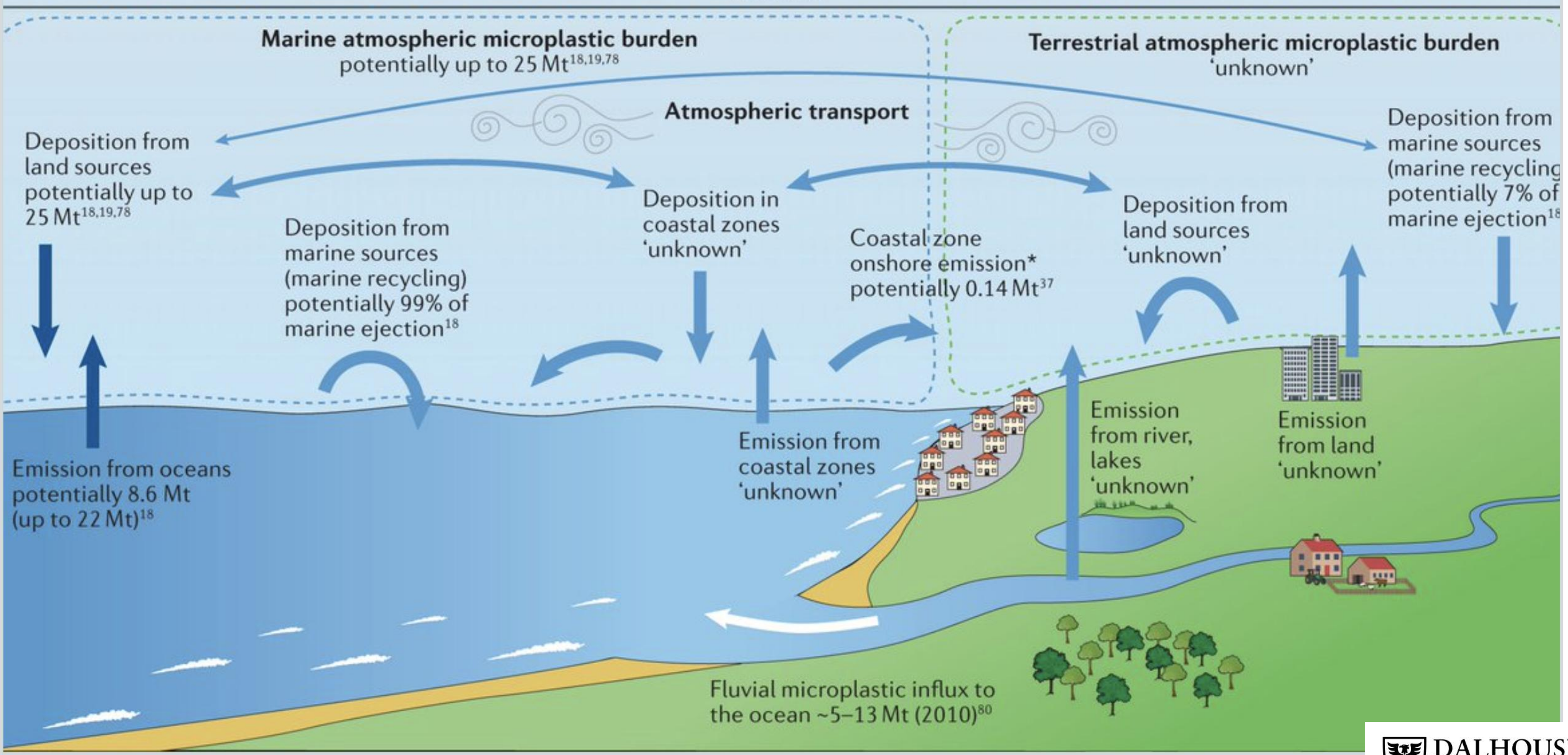
Understanding the global mass inventory is one of the main challenges in present research on plastic marine debris. Especially the fragmentation and vertical transport processes of oceanic plastic are poorly understood. However, whereas fragmentation rates are unknown, information on plastic emissions, concentrations of plastics in the ocean surface layer (OSL) and fragmentation mechanisms is available. Here, we apply a systems engineering analytical approach and propose a tentative 'whole ocean' mass balance model that combines emission data, surface area-normalized plastic fragmentation rates, estimated concentrations in the OSL, and removal from the OSL by sinking. We simulate known plastic abundances in the OSL and calculate an average whole ocean apparent surface area-normalized plastic fragmentation rate constant, given representative radii for macroplastic and microplastic. Simulations show that 99.8% of the plastic that had entered the ocean since 1950 had settled below the OSL by 2016, with an additional 9.4 million tons settling per year. In 2016, the model predicts that of the 0.309 million tons in the OSL, an estimated 83.7% was macroplastic, 13.8% microplastic, and 2.5% was < 0.335 mm 'nanoplastic'. A zero future emission simulation shows that almost all plastic in the OSL would be removed within three years, implying a fast response time of surface plastic abundance to changes in inputs. The model complements current spatially explicit models, points to future experiments that would inform critical model parameters, and allows for further validation when more experimental and field data become available.

Surface waters account for only **~1% of the global marine (micro)plastic budget**, implying that **most (micro)plastic pollution** entering the ocean **accumulates at the seafloor (Koelmans et al. 2017)**

But the sea surface and marine sediments are **not permanent sinks for marine microplastics**

Koelmans, A.A. et al. (2017). All is not lost: deriving a top-down mass budget of plastic at sea. *Environmental Research Letters*, *12*(11), 114028.

Marine-atmosphere microplastics



Allen, D. et al. (2022). *Nature Reviews Earth & Environment, 3*, 393–405, https://doi.org/10.1038/s43017-022-00292-x

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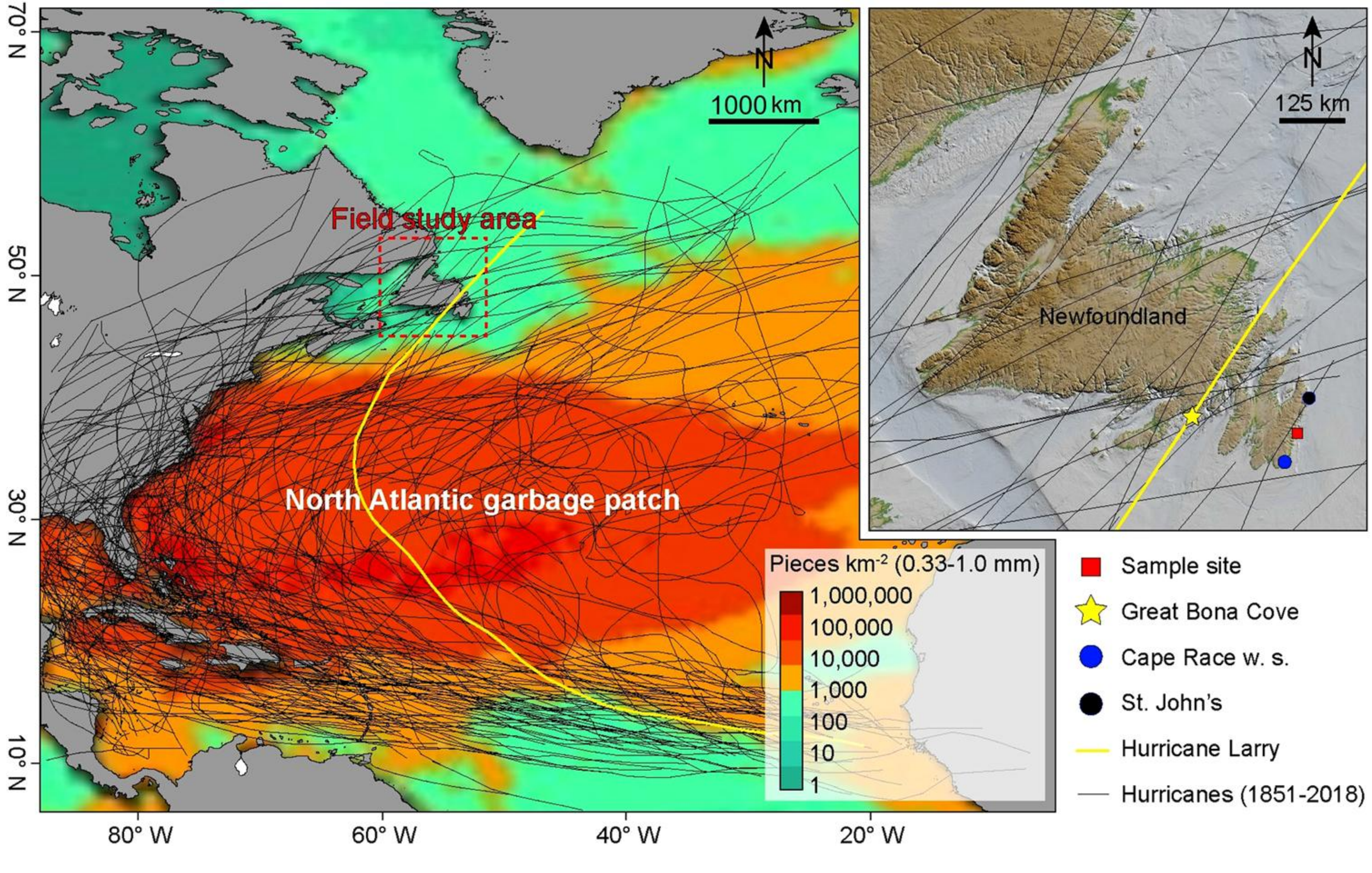
Marine-atmosphere microplastics



Transport and deposition of **ocean-sourced microplastic** particles by a North Atlantic hurricane

Ryan, A.C. et al. (2023). *Communications Earth & Environment, 4*, 442. https://doi.org/10.1038/s43247-023-01115-7

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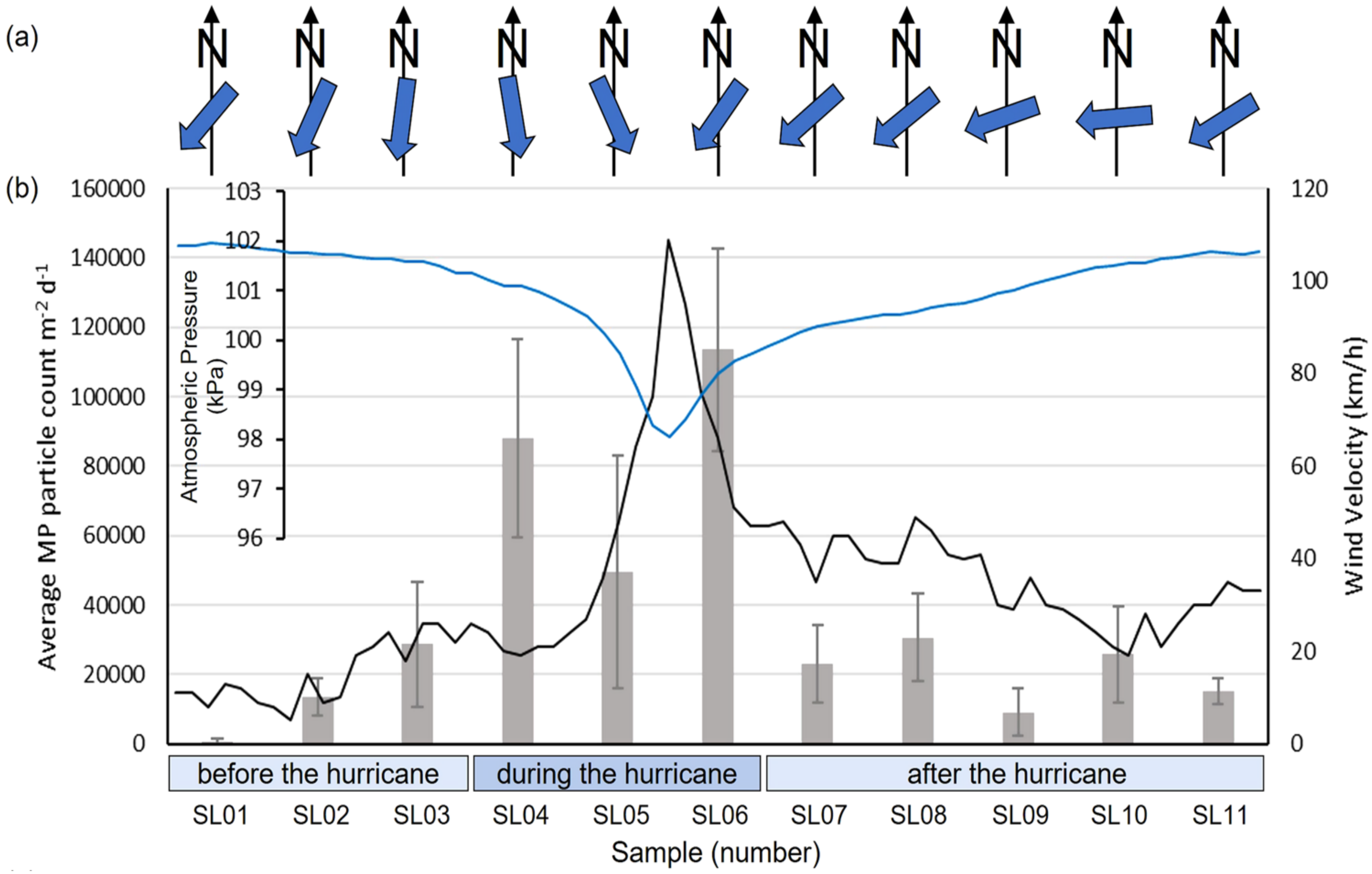
Marine-atmosphere microplastics



During the storm peak, **113,000 MPs/m²/day** were deposited

Most (65%) MPs were 2–10 µm

Most MPs were fragments

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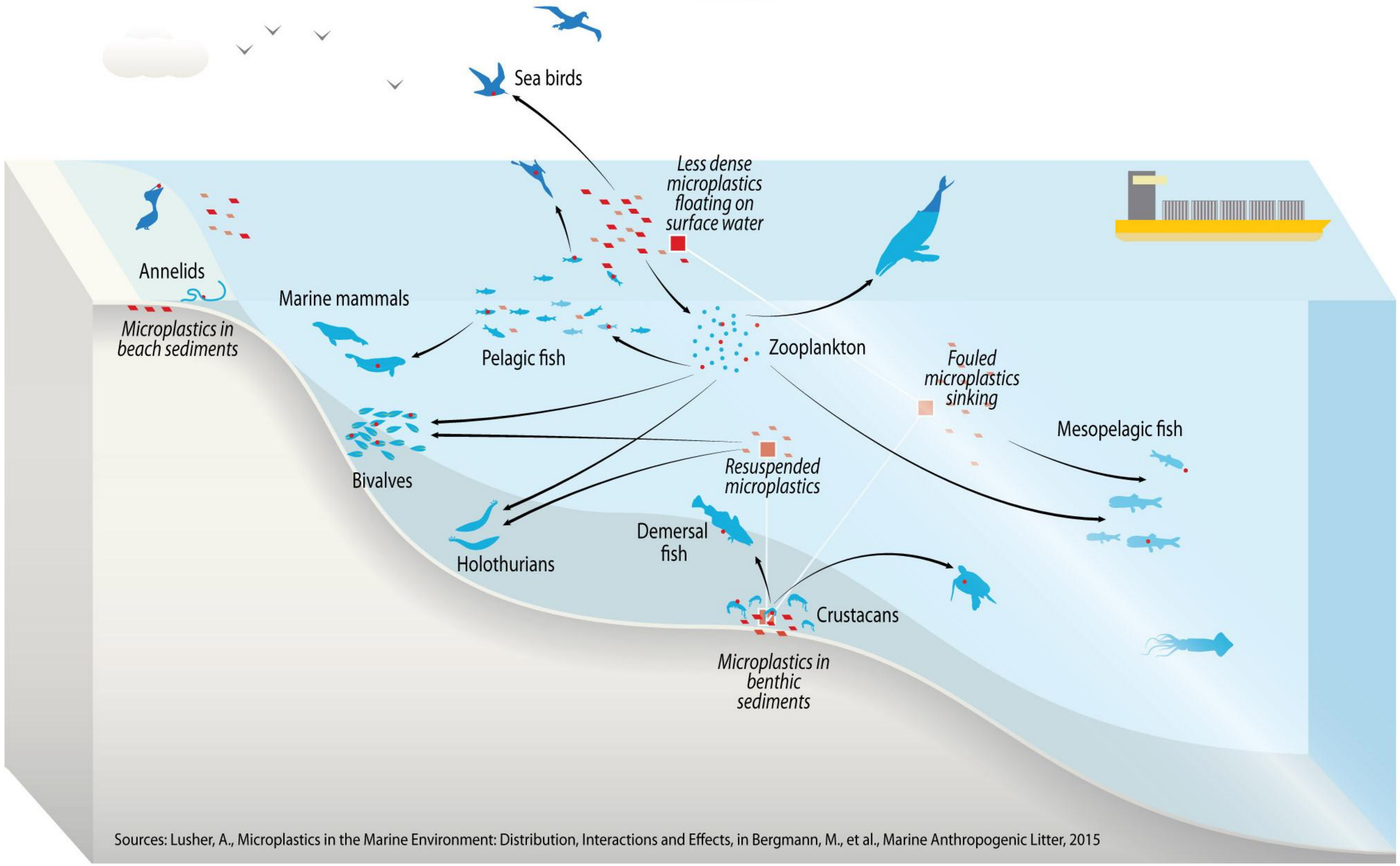
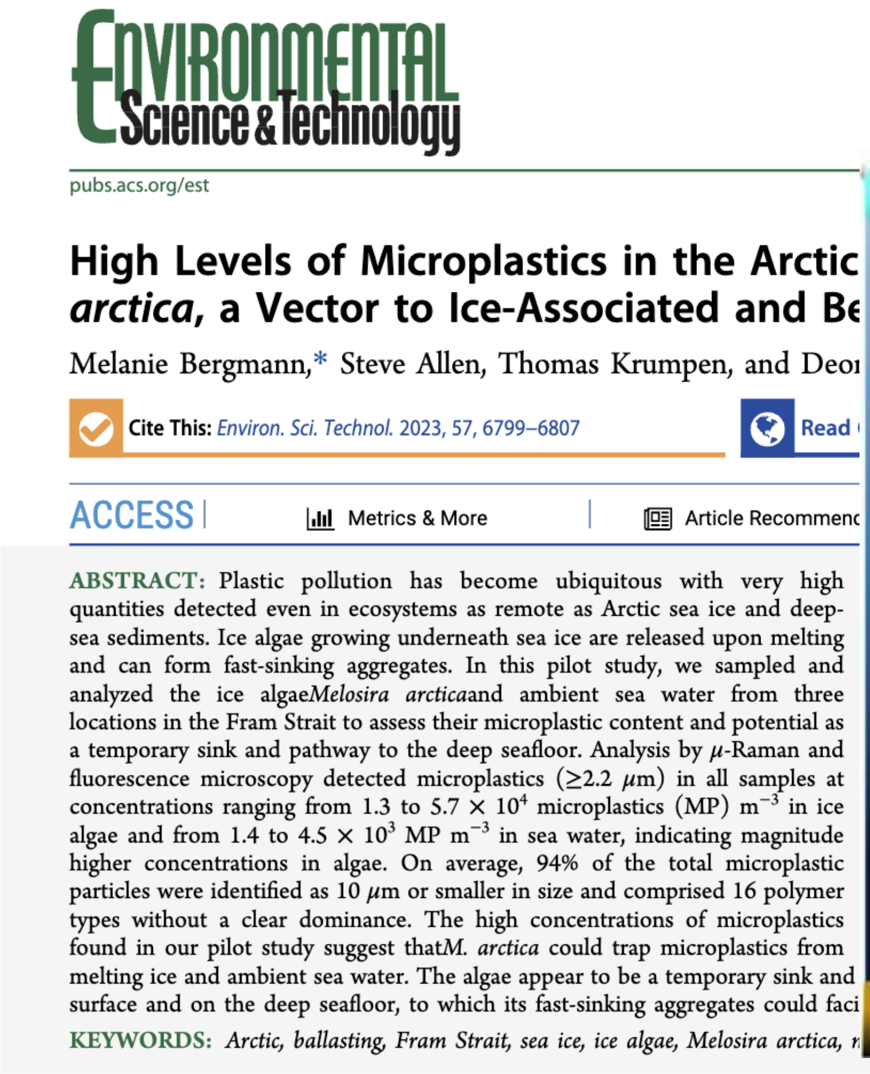
Ryan, A.C. et al. (2023). *Communications Earth & Environment, 4*, 442. https://doi.org/10.1038/s43247-023-01115-7

How marine microplastics enter the food web



Source: Maphoto/Riccardo Pravettoni (https://www.grida.no/resources/6904)

Microplastics in Arctic Sea Ice Algae



Environmental Science & Technology

pubs.acs.org/est

High Levels of Microplastics in the Arctic
***arctica*, a Vector to Ice-Associated and Be**

Melanie Bergmann,* Steve Allen, Thomas Krumpen, and Deo

Cite This: *Environ. Sci. Technol.* 2023, 57, 6799–6807 | Read

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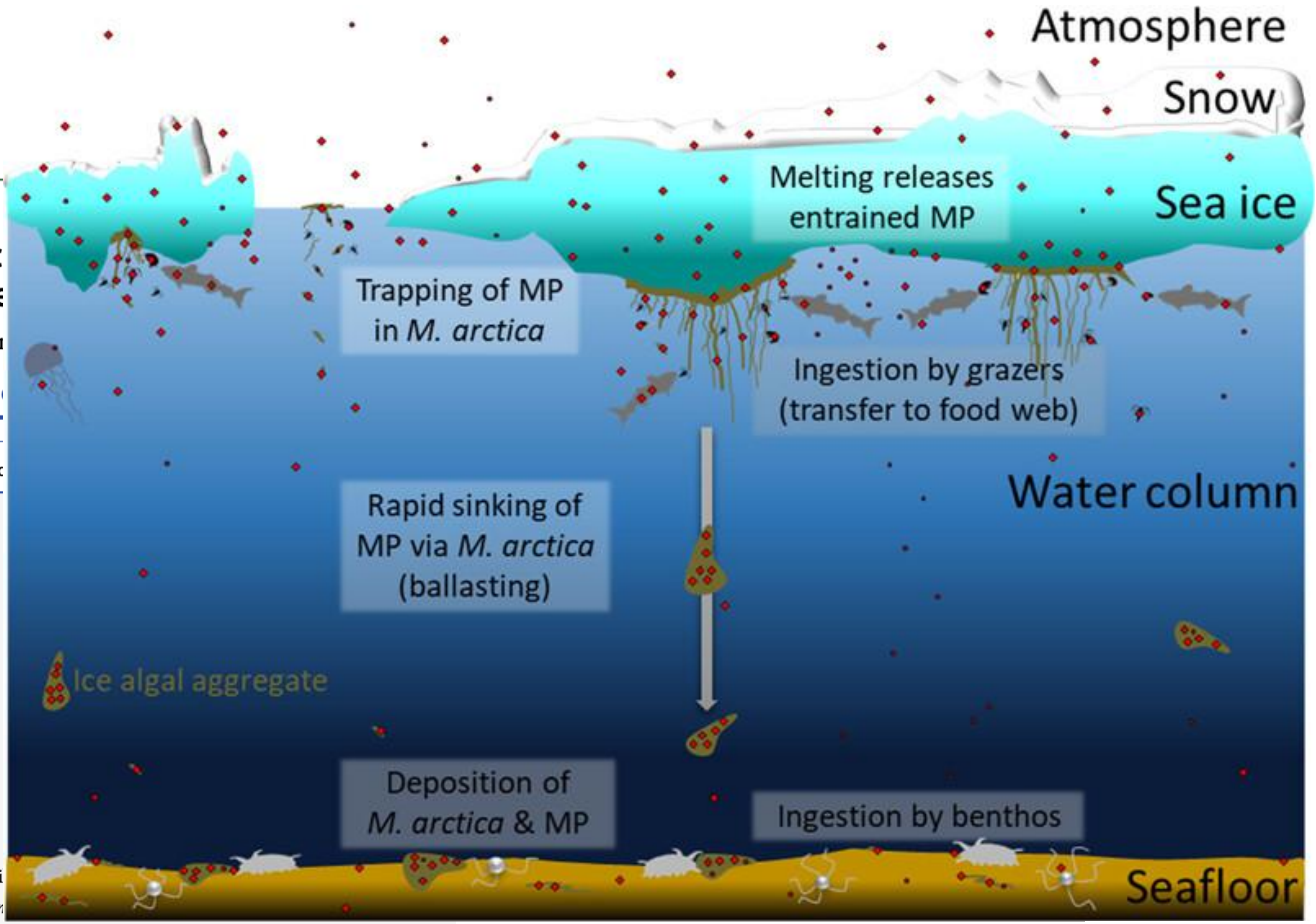
ABSTRACT: Plastic pollution has become ubiquitous with very high quantities detected even in ecosystems as remote as Arctic sea ice and deep-sea sediments. Ice algae growing underneath sea ice are released upon melting and can form fast-sinking aggregates. In this pilot study, we sampled and analyzed the ice algae*Melosira arctica*and ambient sea water from three locations in the Fram Strait to assess their microplastic content and potential as a temporary sink and pathway to the deep seafloor. Analysis by μ-Raman and fluorescence microscopy detected microplastics ($\geq$2.2 μm) in all samples at concentrations ranging from 1.3 to 5.7 × 10^4 microplastics (MP) m^{-3} in ice algae and from 1.4 to 4.5 × 10^3 MP m^{-3} in sea water, indicating magnitude higher concentrations in algae. On average, 94% of the total microplastic particles were identified as 10 μm or smaller in size and comprised 16 polymer types without a clear dominance. The high concentrations of microplastics found in our pilot study suggest that*M. arctica* could trap microplastics from melting ice and ambient sea water. The algae appear to be a temporary sink and surface and on the deep seafloor, to which its fast-sinking aggregates could faci

KEYWORDS: *Arctic, ballasting, Fram Strait, sea ice, ice algae, Melosira arctica, r*



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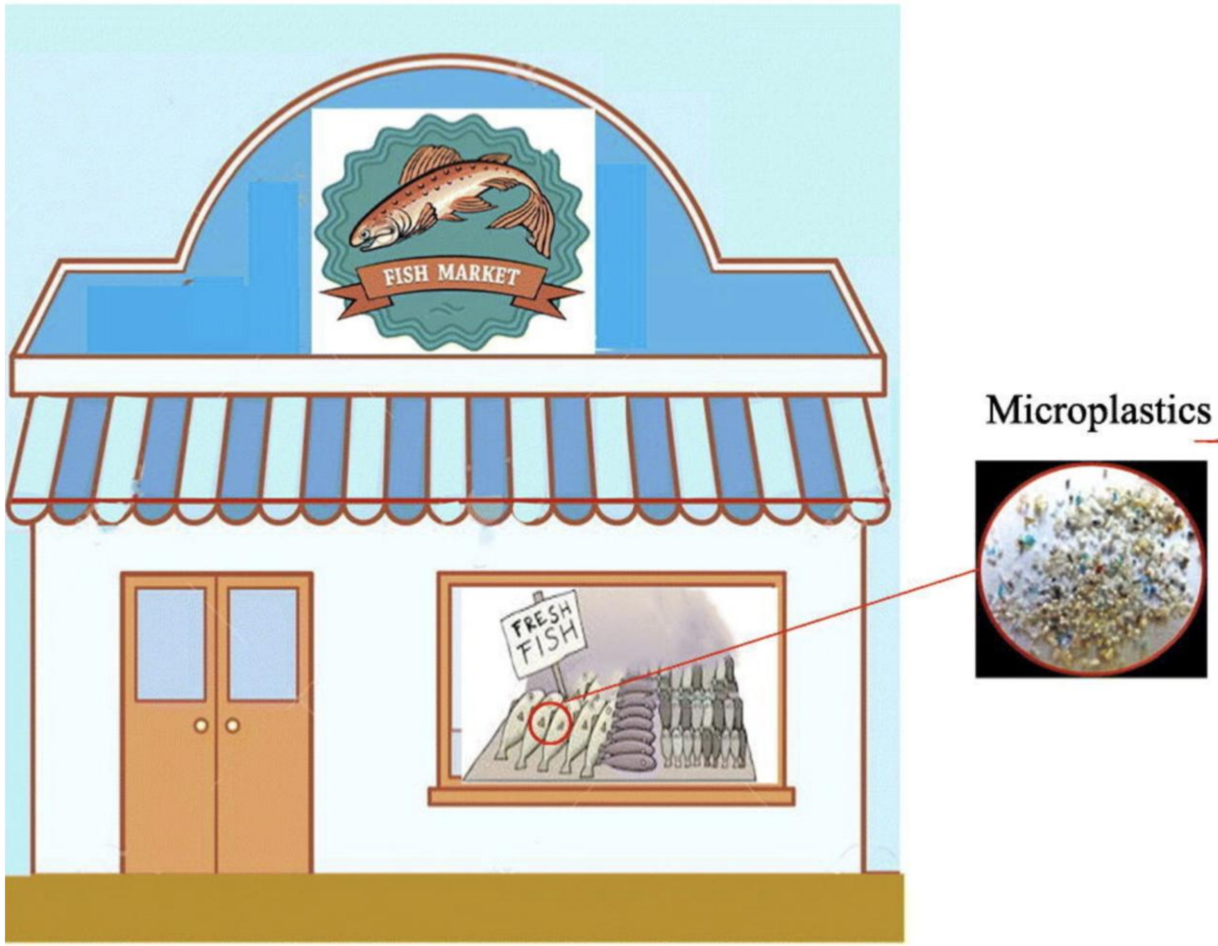
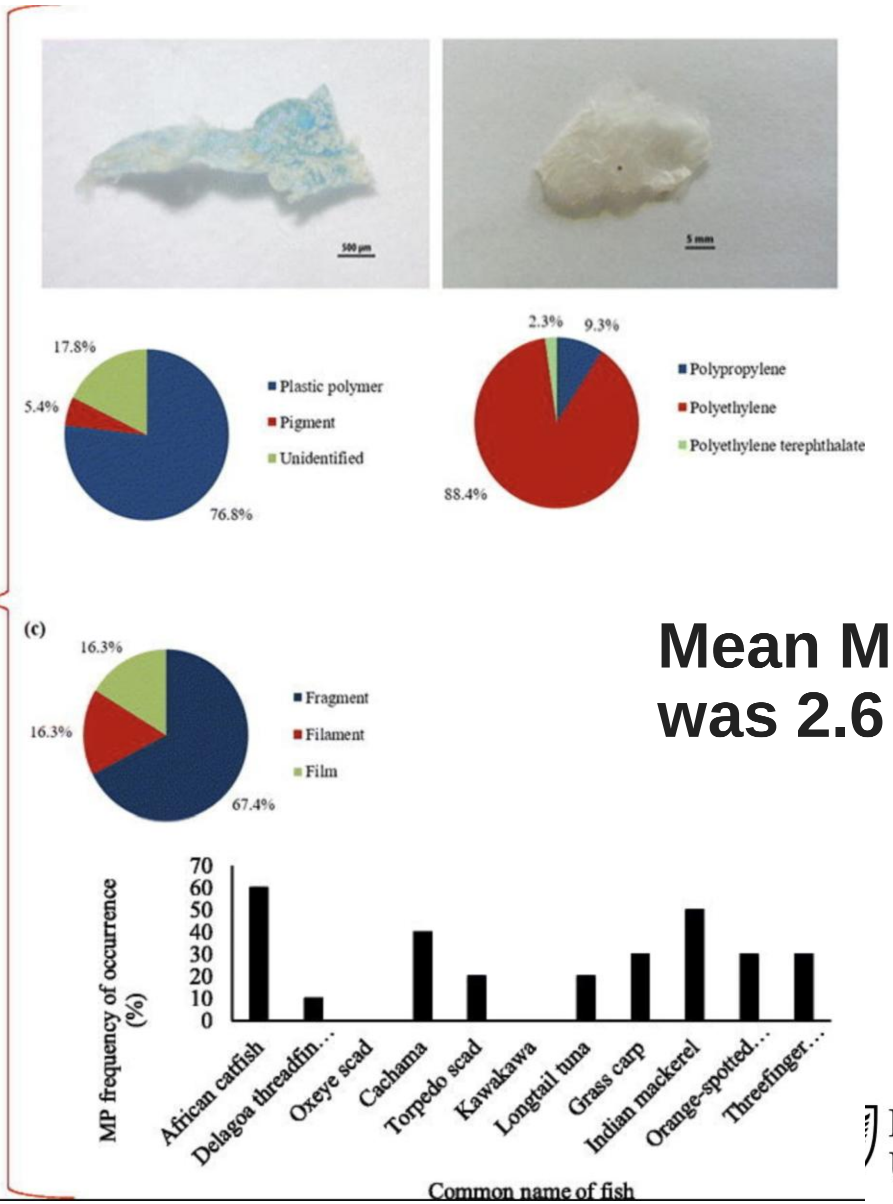
Bergmann, M. et al. (2023). *Environmental Science & Technology*, *57*(17), 6799-6807.

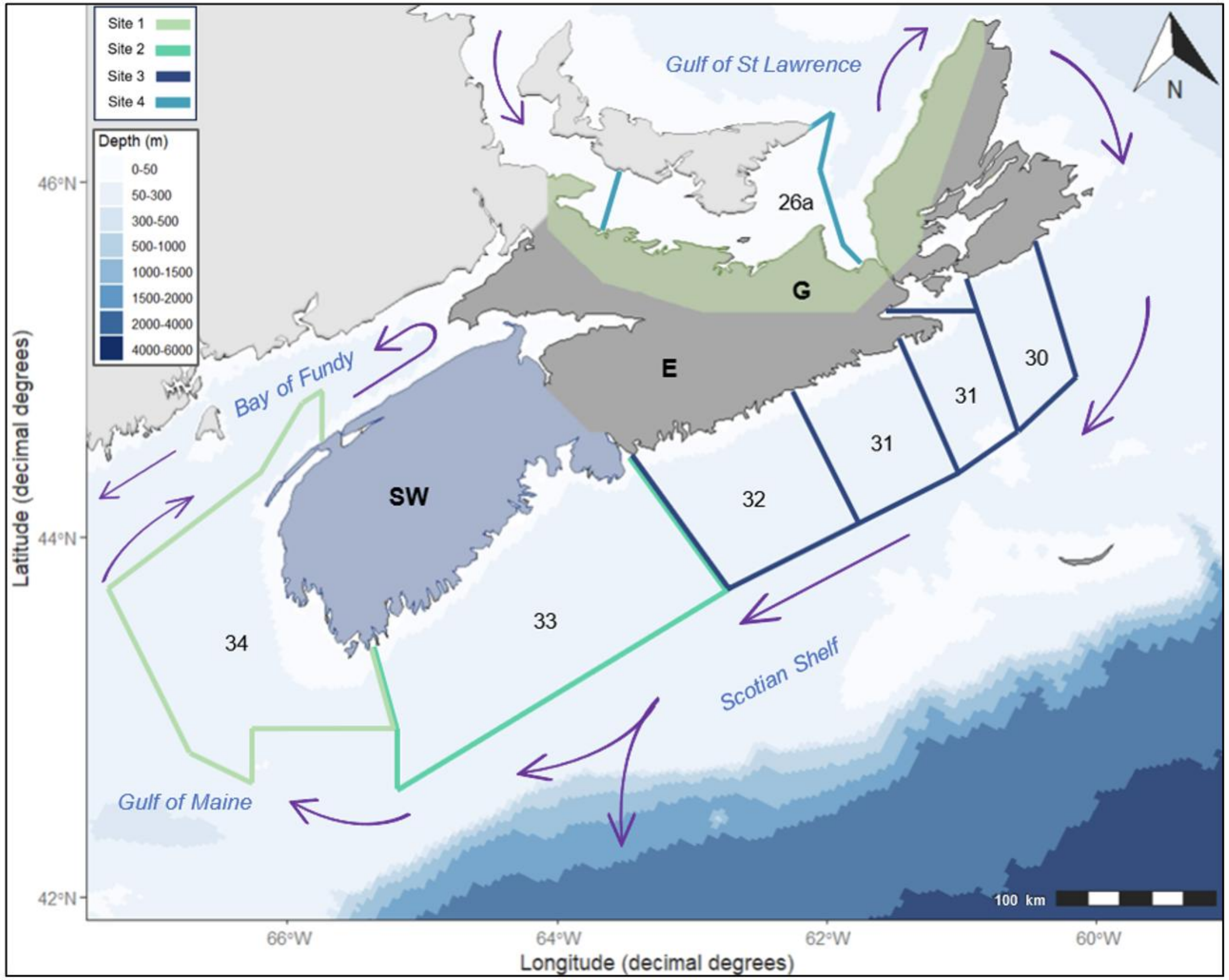
Microplastic ingestion by commercial fish

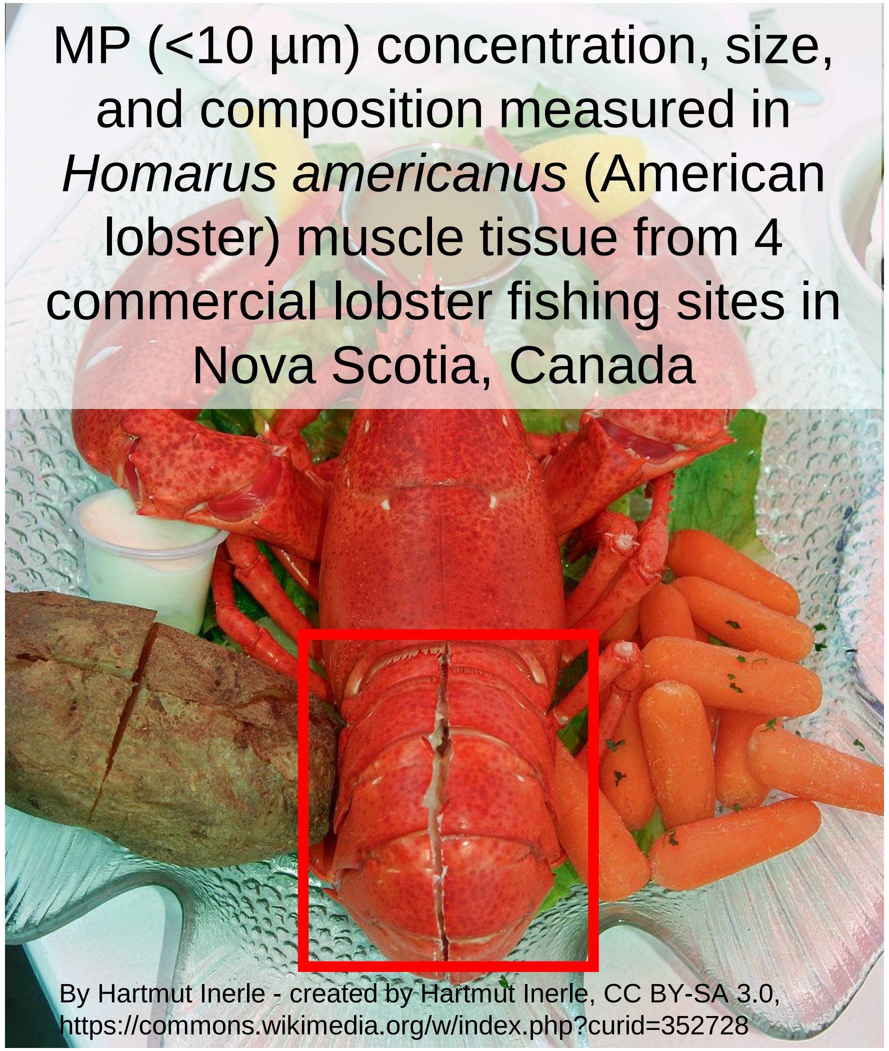




Mean MP size was 2.6 mm

Microplastic internalization by lobster





MP (<10 µm) concentration, size, and composition measured in *Homarus americanus* (American lobster) muscle tissue from 4 commercial lobster fishing sites in Nova Scotia, Canada

LeBlanc, A. et al. (unpublished).

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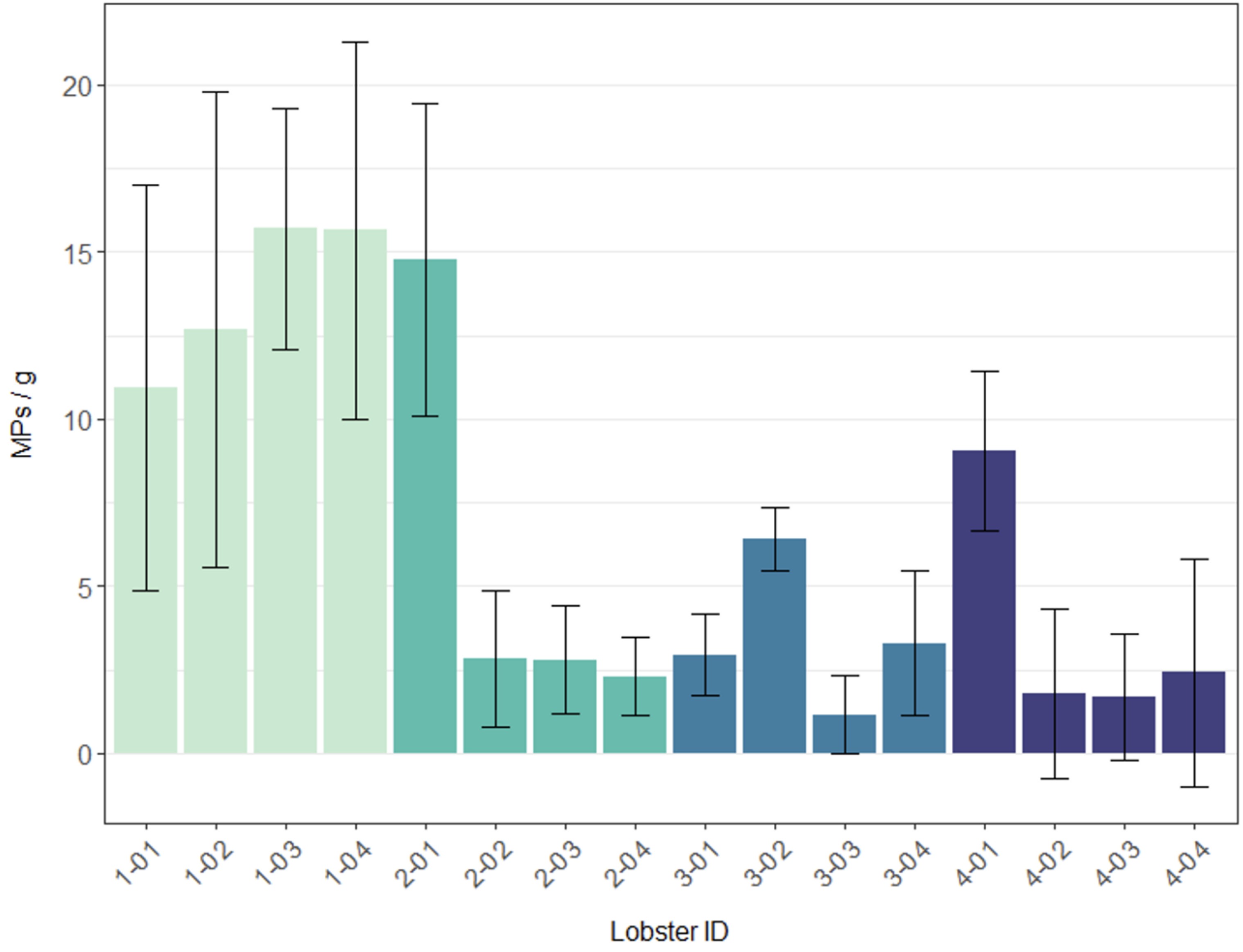
Microplastic internalization by lobster



Mean MP concentration per lobster

All lobsters contained MPs

Significantly higher concentrations in the SW region

LeBlanc, A. et al. (unpublished).

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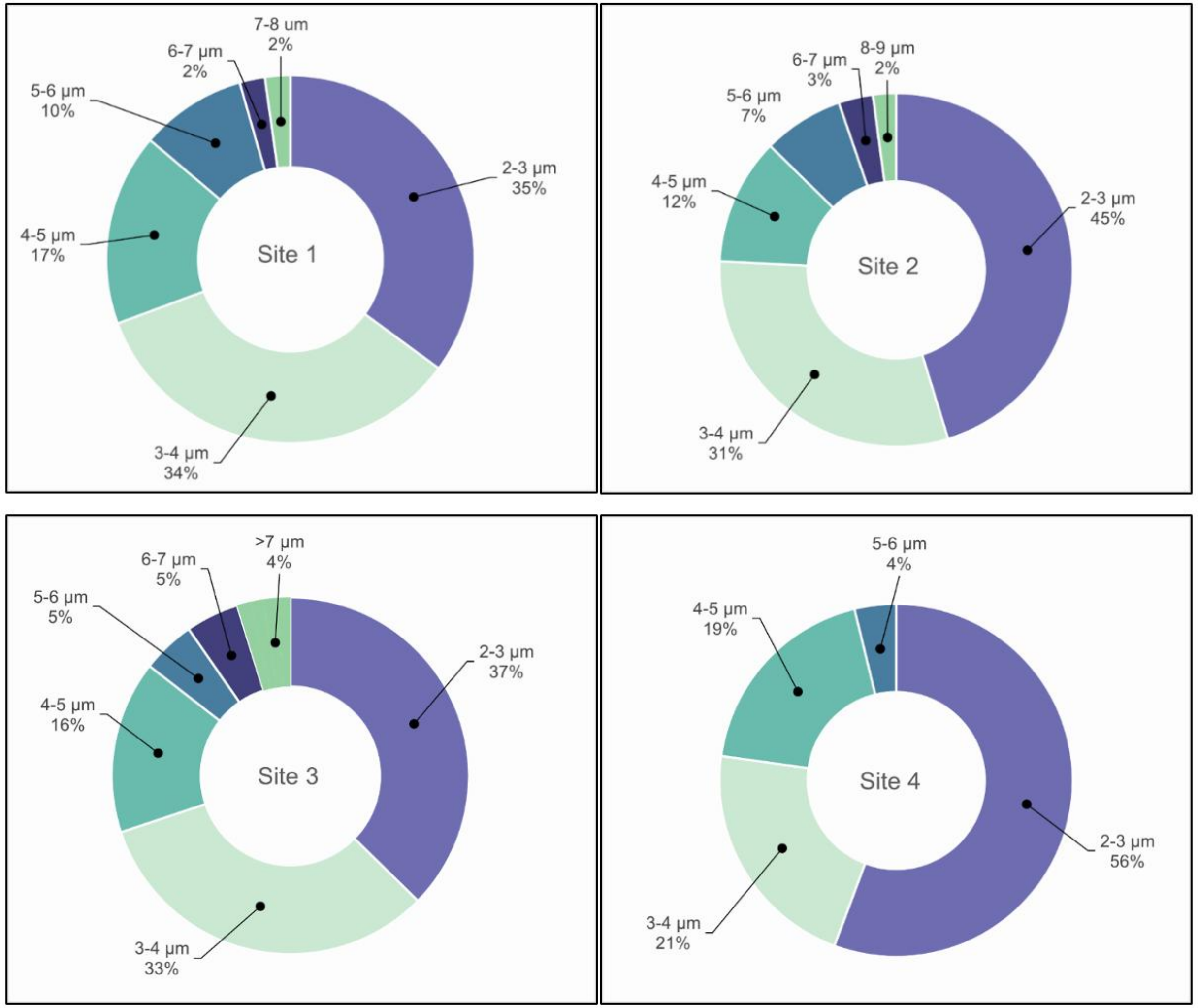
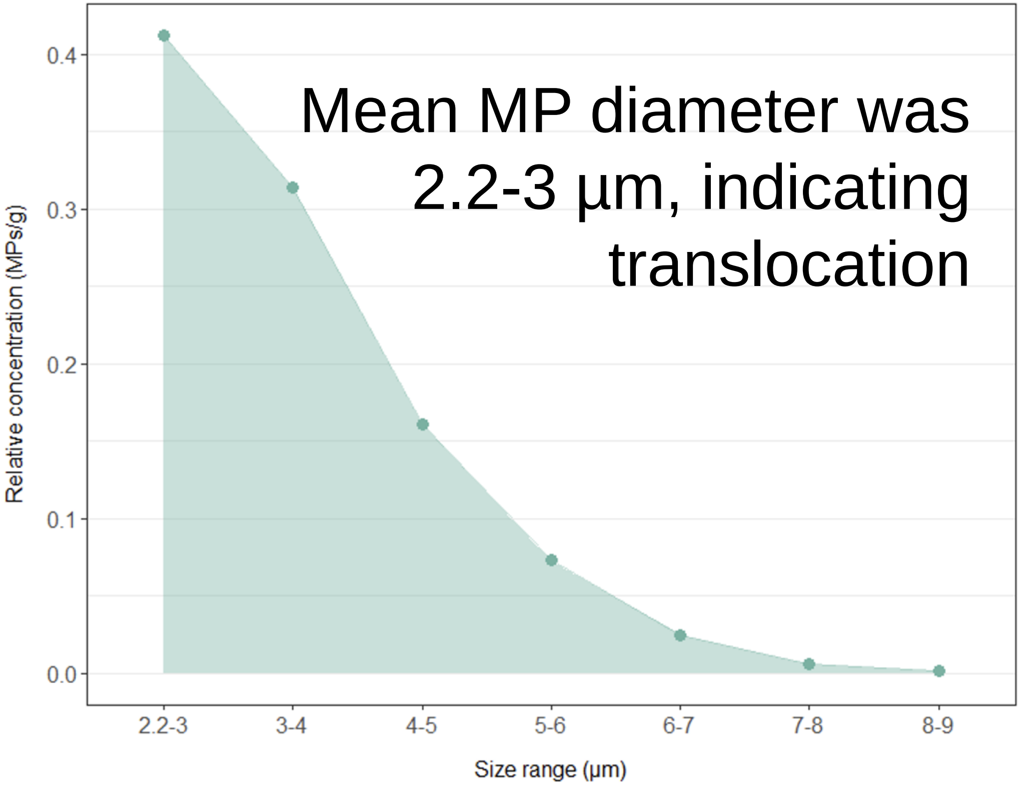
Microplastic internalization by lobster



Relative size distribution per sample site



Mean MP diameter was 2.2-3 µm, indicating translocation

Size distribution across samples (n = 482)

LeBlanc, A. et al. (unpublished).

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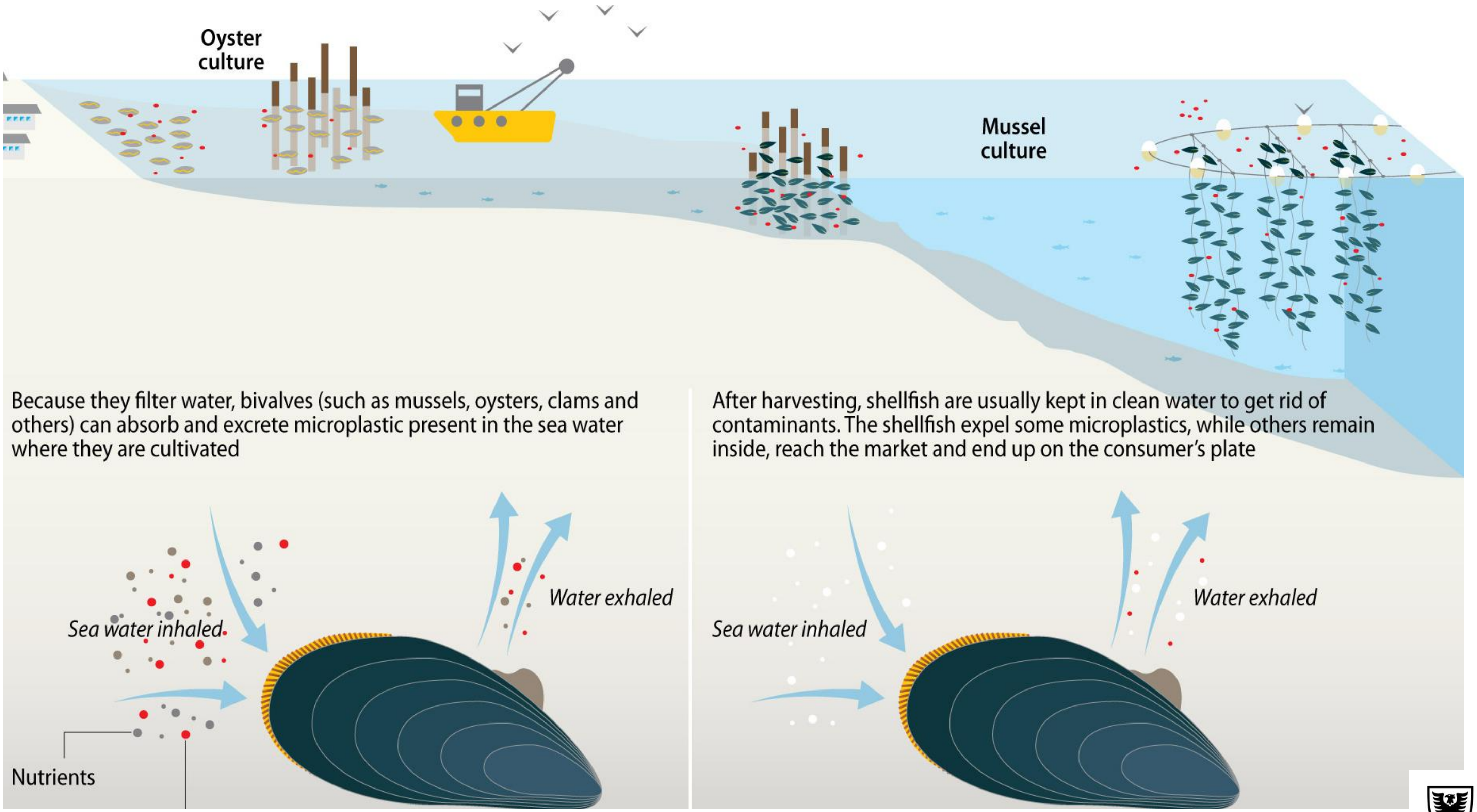
Microplastics in bivalves



Source: Maphoto/Riccardo Pravettoni (https://www.grida.no/resources/6915)

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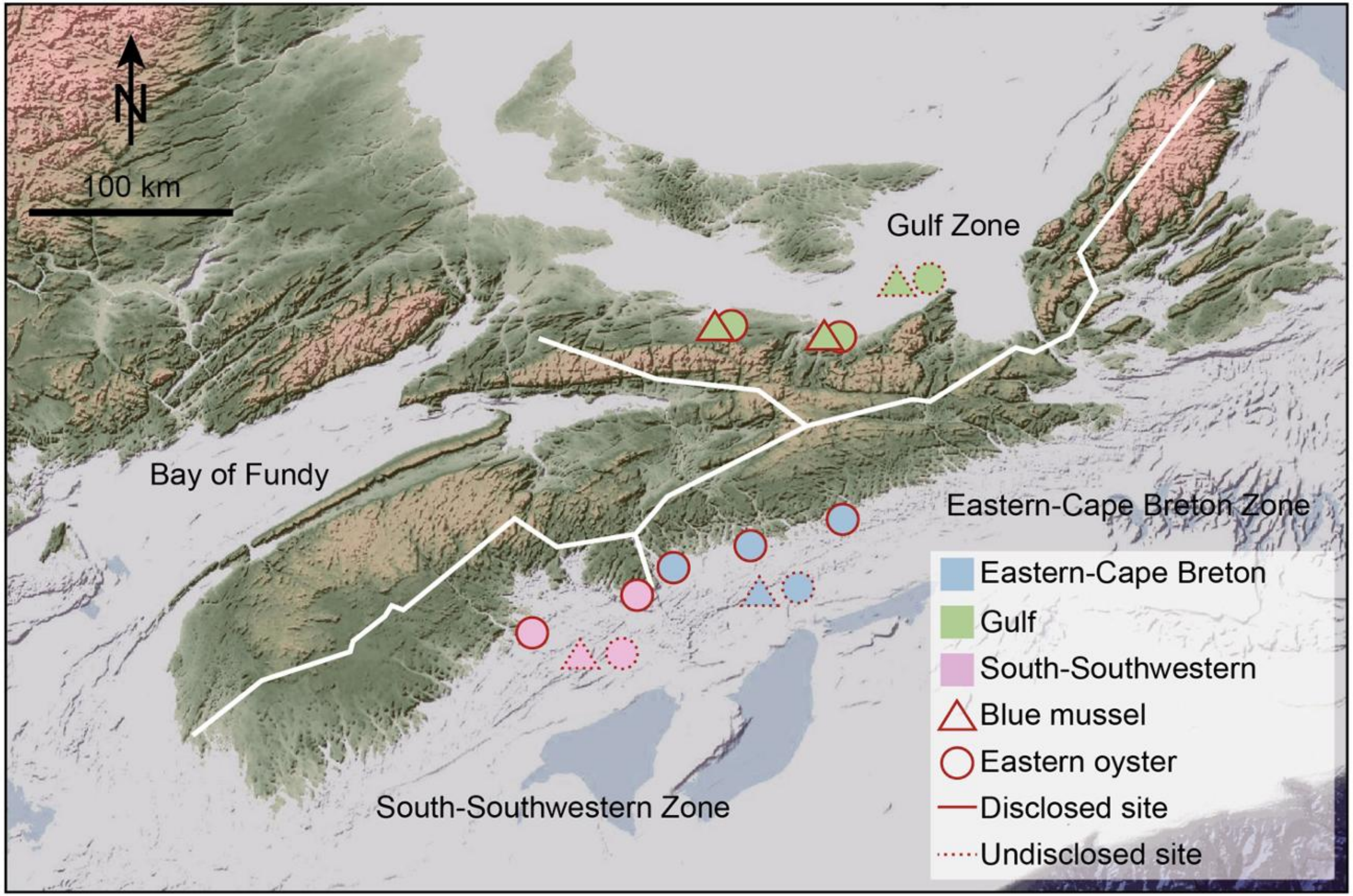
Microplastics in mussels and oysters



MP concentration, size, and composition measured in Blue mussels and Eastern oysters in Nova Scotia, Canada

Saunders, D. et al. (unpublished).

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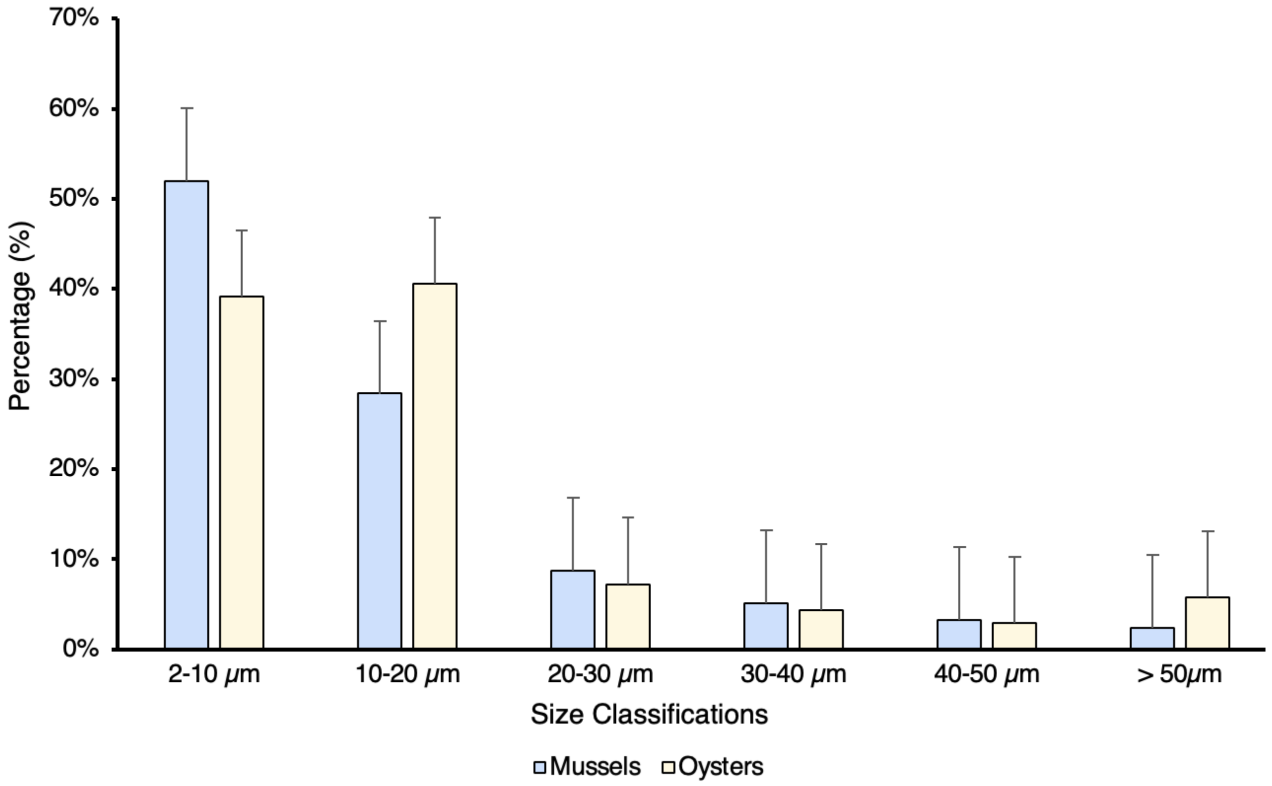
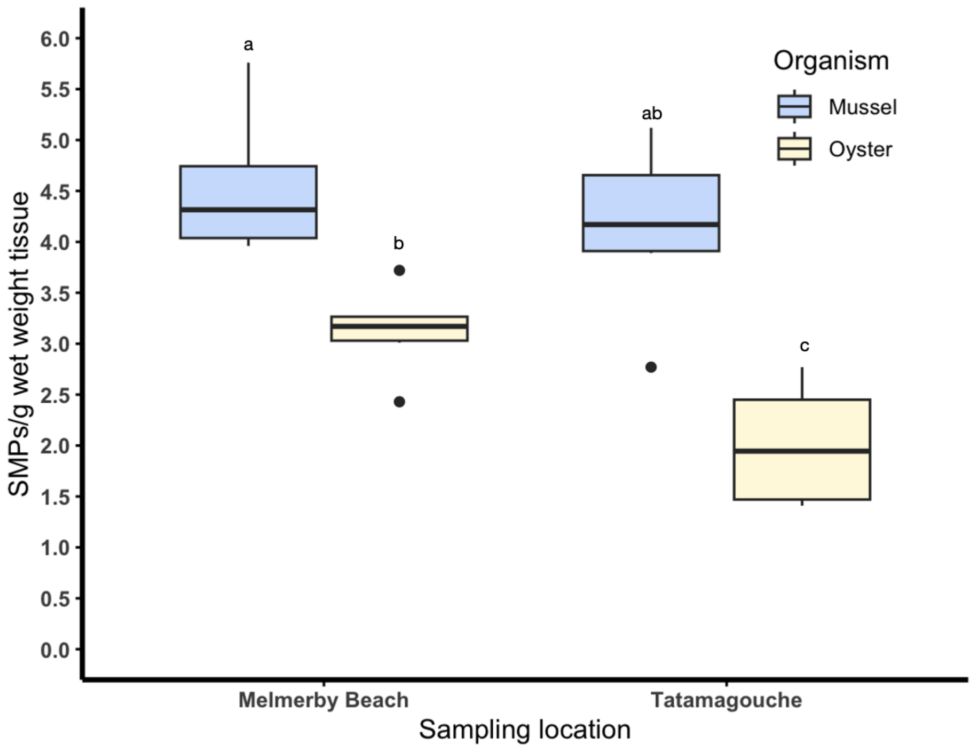
Microplastics in mussels and oysters



Mean percentage of MPs (±SD) across size categories in Blue mussels (blue bars) and Eastern oysters (yellow bars) from Nova Scotia



Microplastic concentration in mussels (blue) and oysters (yellow) from Nova Scotia. Different letters indicate statistically significant differences between sites ($p<0.05$)

Saunders, D. et al. (unpublished).

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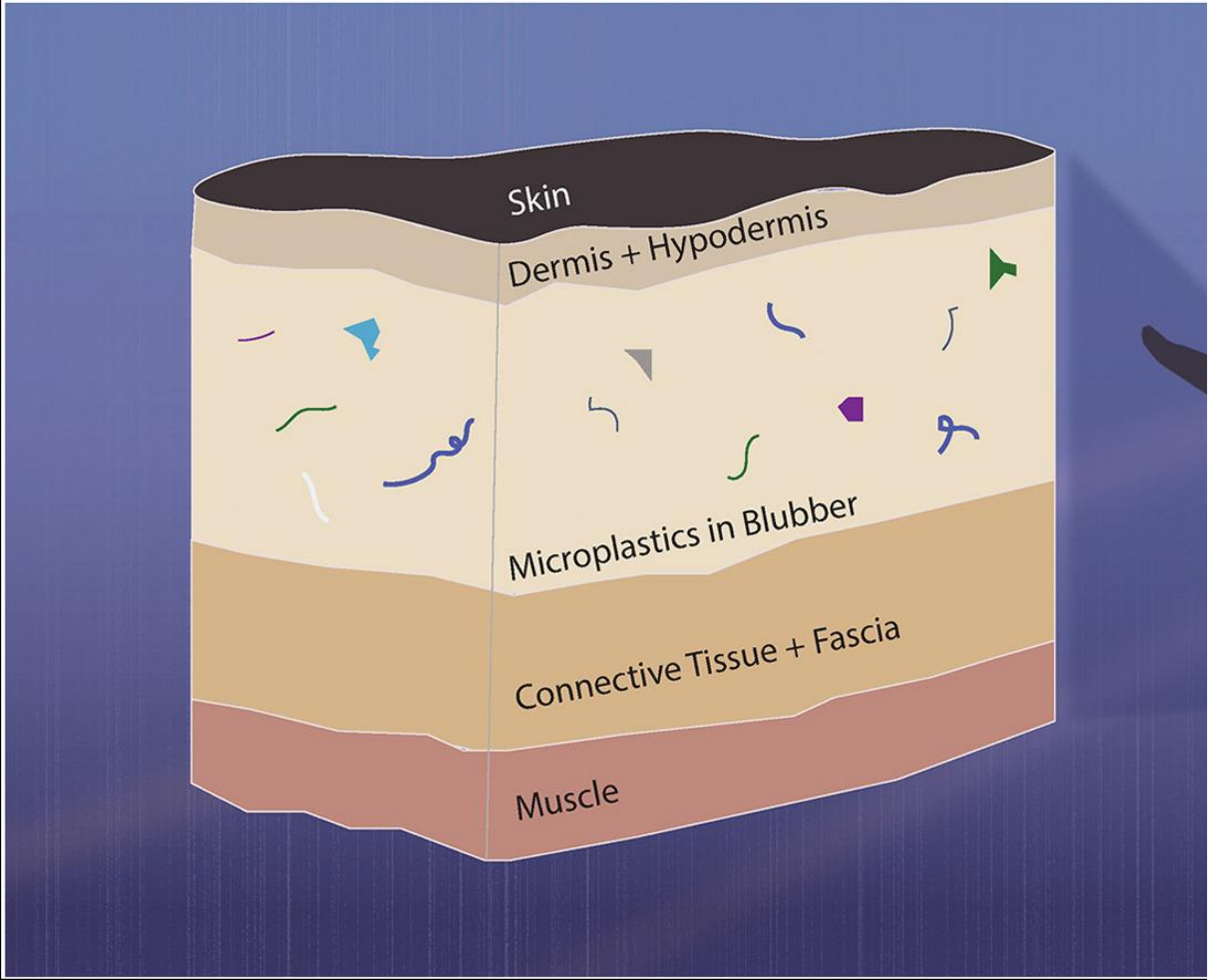
Microplastics in marine mammal blubber



Internalized microplastics translocate to marine mammal organs, notably blubber

Samples containing microplastics spanned over two decades

68% of samples contained at least one microplastic particle

Most common polymer and shape observed were polyethylene and fibers, respectively

Merrill, G.B. et al. (2023). Microplastics in marine mammal blubber, melon, & other tissues: Evidence of translocation. *Environmental Pollution*, *335*, 122252.

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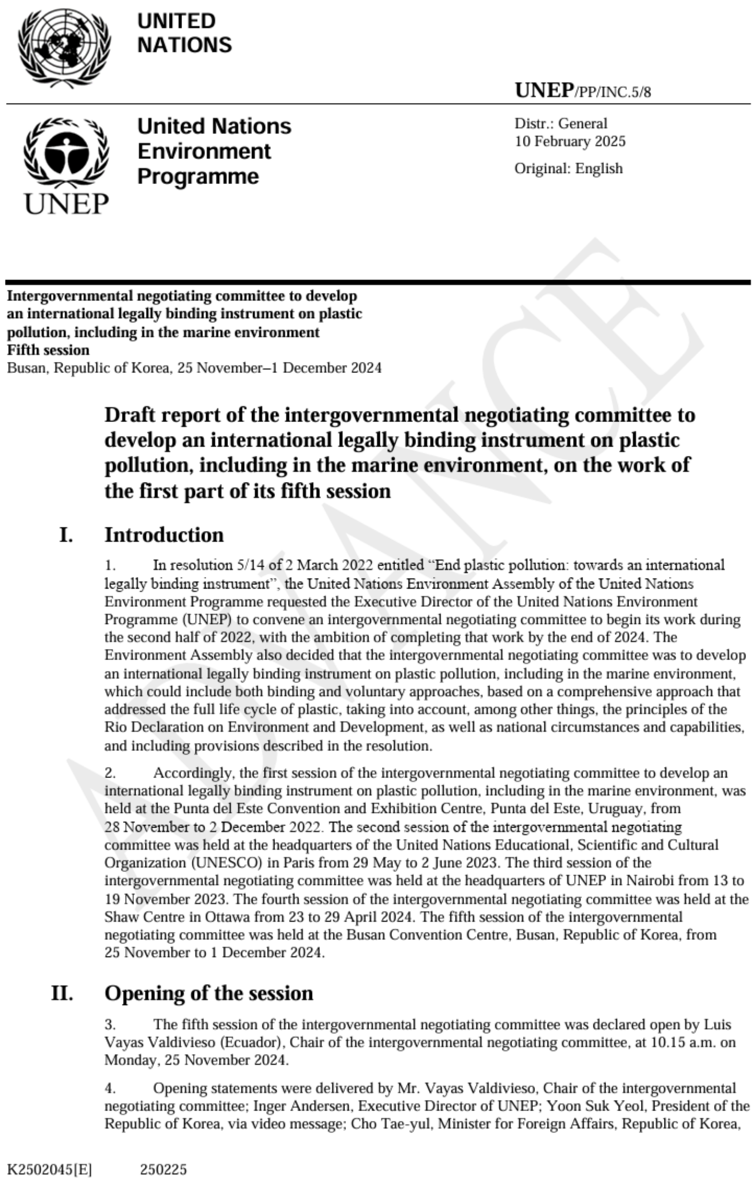
But what effective solutions can help reduce marine microplastic pollution?

Global plastics treaty?


UNITED NATIONS

UNEP/PP/INC.5/8

United Nations Environment Programme

UNEP

Distr.: General
10 February 2025

Original: English

Intergovernmental negotiating committee to develop an international legally binding instrument on plastic pollution, including in the marine environment
Fifth session
Busan, Republic of Korea, 25 November–1 December 2024

Draft report of the intergovernmental negotiating committee to develop an international legally binding instrument on plastic pollution, including in the marine environment, on the work of the first part of its fifth session

I. Introduction

1. In resolution 5/14 of 2 March 2022 entitled "End plastic pollution: towards an international legally binding instrument", the United Nations Environment Assembly of the United Nations Environment Programme requested the Executive Director of the United Nations Environment Programme (UNEP) to convene an intergovernmental negotiating committee to begin its work during the second half of 2022, with the ambition of completing that work by the end of 2024. The Environment Assembly also decided that the intergovernmental negotiating committee was to develop an international legally binding instrument on plastic pollution, including in the marine environment, which could include both binding and voluntary approaches, based on a comprehensive approach that addressed the full life cycle of plastic, taking into account, among other things, the principles of the Rio Declaration on Environment and Development, as well as national circumstances and capabilities, and including provisions described in the resolution.

2. Accordingly, the first session of the intergovernmental negotiating committee to develop an international legally binding instrument on plastic pollution, including in the marine environment, was held at the Punta del Este Convention and Exhibition Centre, Punta del Este, Uruguay, from 28 November to 2 December 2022. The second session of the intergovernmental negotiating committee was held at the headquarters of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in Paris from 29 May to 2 June 2023. The third session of the intergovernmental negotiating committee was held at the headquarters of UNEP in Nairobi from 13 to 19 November 2023. The fourth session of the intergovernmental negotiating committee was held at the Shaw Centre in Ottawa from 23 to 29 April 2024. The fifth session of the intergovernmental negotiating committee was held at the Busan Convention Centre, Busan, Republic of Korea, from 25 November to 1 December 2024.

II. Opening of the session

3. The fifth session of the intergovernmental negotiating committee was declared open by Luis Vayas Valdivieso (Ecuador), Chair of the intergovernmental negotiating committee, at 10.15 a.m. on Monday, 25 November 2024.

4. Opening statements were delivered by Mr. Vayas Valdivieso, Chair of the intergovernmental negotiating committee; Inger Andersen, Executive Director of UNEP; Yoon Suk Yeol, President of the Republic of Korea, via video message; Cho Tae-yul, Minister for Foreign Affairs, Republic of Korea,

K2502045[E] 250225

Negotiations since 2022 have mostly focused on reducing **plastic pollution**

Solutions to specifically address **microplastic pollution** at the international level is the elephant in the room

UNEP (2023); UNEP (2025).

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A global plastics treaty must cap production

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HOME > SCIENCE > VOL. 376, NO. 6592 > A GLOBAL PLASTIC TREATY MUST CAP PRODUCTION

LETTER

A global plastic treaty must cap production

MELANIE BERGMANN , BETHANIE CARNEY ALMROTH, SUSANNE M. BRANDER, TRIDIBESH DEY, DANNIELLE S. GREEN, SEDAT GUNDOGDU, ANJA KRIEGER, MARTIN WAGNER, AND TONY R. WALKER Authors Info & Affiliations

SCIENCE • 28 Apr 2022 • Vol 376, Issue 6592 • pp. 469-470 • DOI: 10.1126/science.abq0082

Bergmann, M. et al. (2022). A global plastic treaty must cap production. *Science*, *376*(6592), 469-470.

Strategies to reduce (micro)plastic pollution

- **Policies, legislation and regulations**
  - **UNEA5.2 Global Plastic Treaty - legally binding international agreement (Walker, 2022)**
  - Basel Convention Plastic Waste Amendments
  - Extended Producer Responsibility (EPR)
  - EU Plastics Strategy – packaging recyclable by 2030
  - G7 Canada adopting zero plastic waste by reducing & recycling single-use plastics (Walker & Xanthos, 2018)
- **Market-based instruments**
  - Plastic bag levies, bottle deposits

Walker, T.R. (2022). Calling for a decision to launch negotiations on a new global agreement on plastic pollution at UNEA5.2. *Marine Pollution Bulletin*, 176, 113447.
Walker, T.R. & Xanthos, D. (2018). A call for Canada to move toward zero plastic waste by reducing and recycling single-use plastics. *Resources, Conservation & Recycling* 133, 99-100

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Regulating microplastics and microbeads

CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

CANADA

CONSOLIDATION | CODIFICATION

Microbeads in Toiletries Regulations | Règlement sur les microbilles dans les produits de toilette

SOR/2017-111 | DORS/2017-111

PUBLIC LAW 114–114—DEC. 28, 2015 129 STAT. 3129

Public Law 114–114
114th Congress

An Act

To amend the Federal Food, Drug, and Cosmetic Act to prohibit the manufacture and introduction or delivery for introduction into interstate commerce of rinse-off cosmetics containing intentionally-added plastic microbeads.

Dec. 28, 2015
[H.R. 1321]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

Microbead-Free Waters Act of 2015.
21 USC 301 note.

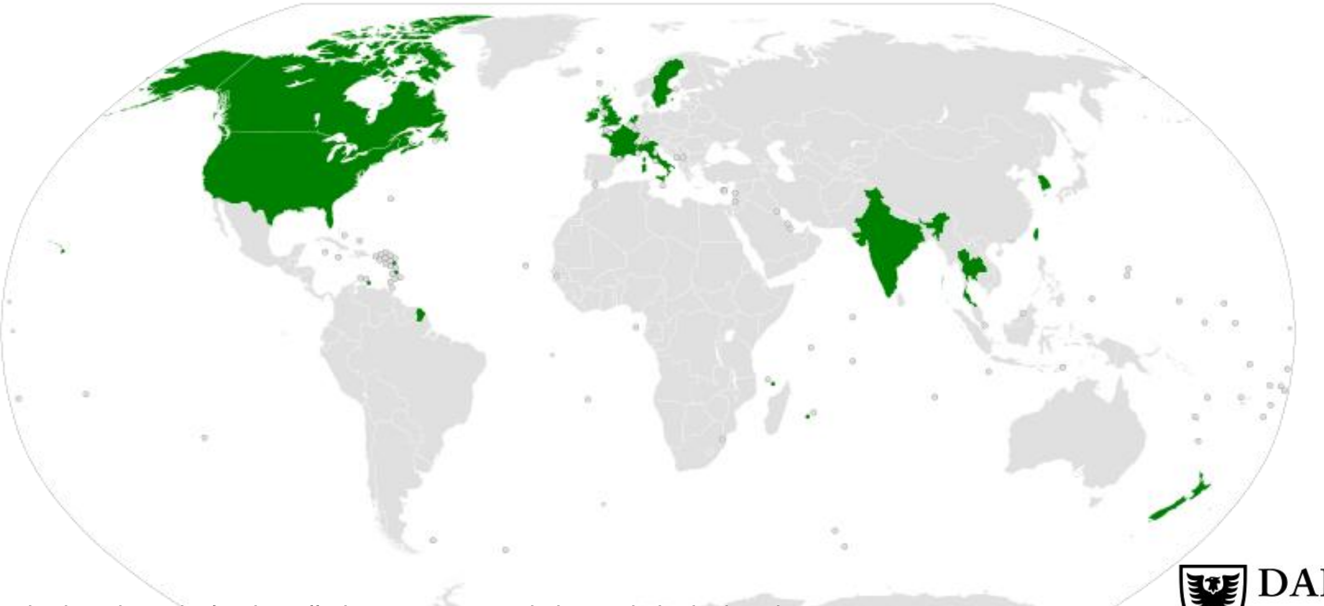
This Act may be cited as the "Microbead-Free Waters Act of 2015".

SEC. 2. PROHIBITION AGAINST SALE OR DISTRIBUTION OF RINSE-OFF COSMETICS CONTAINING PLASTIC MICROBEADS.

POLICY HANDBOOK ESTABLISHING A STANDARD METHOD OF TESTING AND REPORTING OF MICROPLASTICS IN DRINKING WATER

August 9, 2022

Prepared by:
THE DIVISION OF DRINKING WATER
STATE WATER RESOURCES CONTROL BOARD
STATE OF CALIFORNIA



Walker, T. R., & Fequet, L. (2023). Current trends of unsustainable plastic production and micro (nano) plastic pollution. *TrAC Trends in Analytical Chemistry*, *160*, 116984.
Xanthos, D. & Walker, T.R. (2017). *Marine Pollution Bulletin*, *118*(1-2), 17-26. https://doi.org/10.1016/j.marpolbul.2017.02.048

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Thank you

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