MARINE LITTER AND MICROPLASTIC POLLUTION IN THE ANTARCTIC ENVIRONMENT: A GENERAL OVERVIEW

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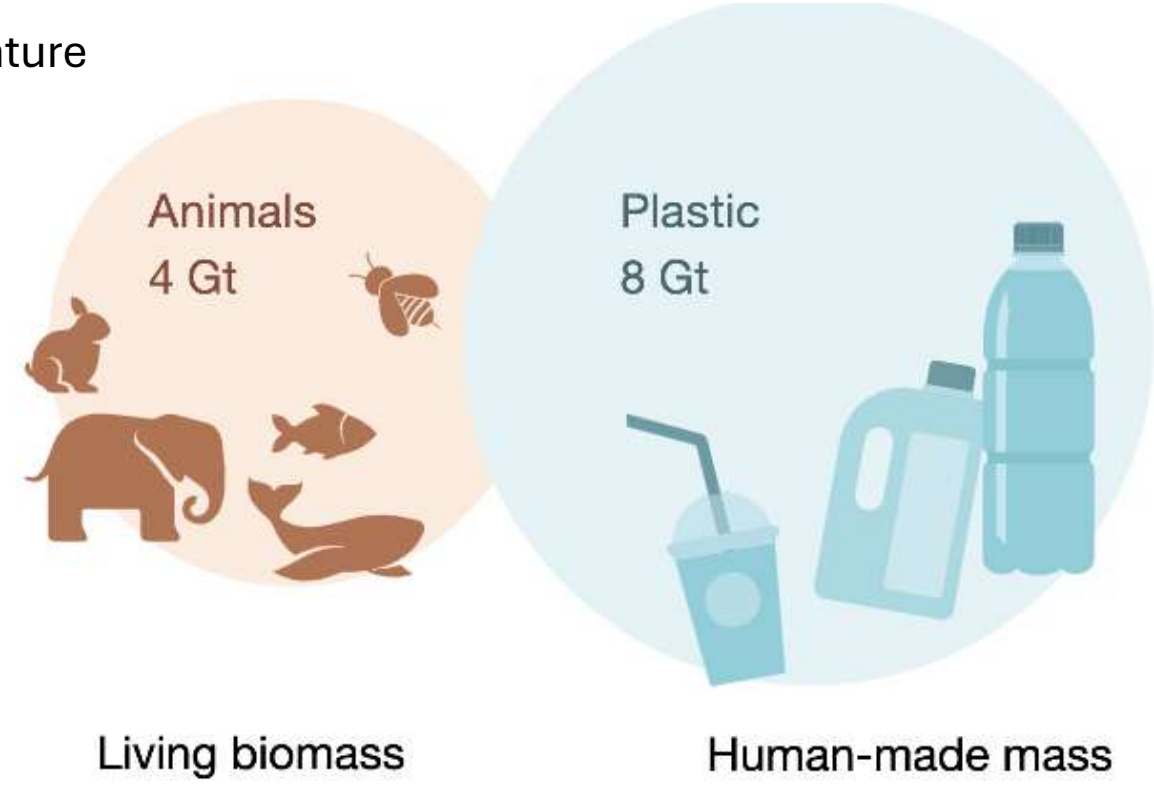
THE ELEPHANT IN THE ROOM

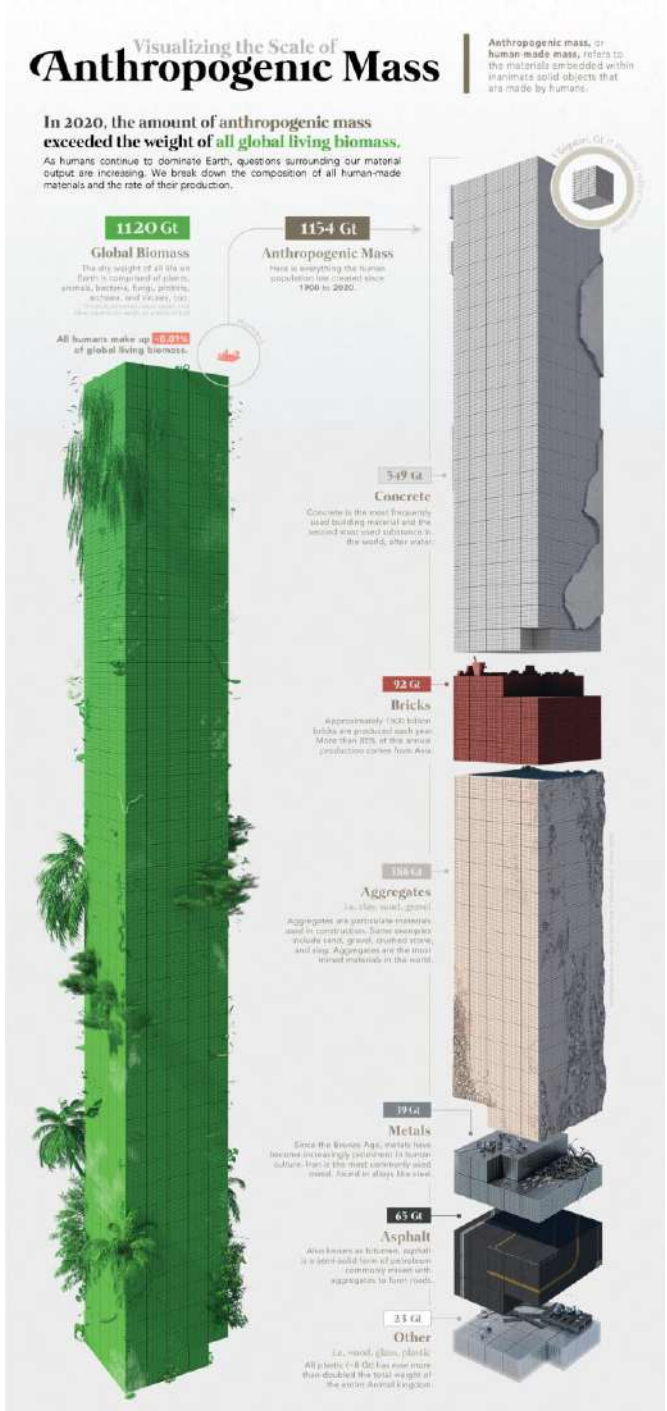
Article

Global human-made mass exceeds all living biomass

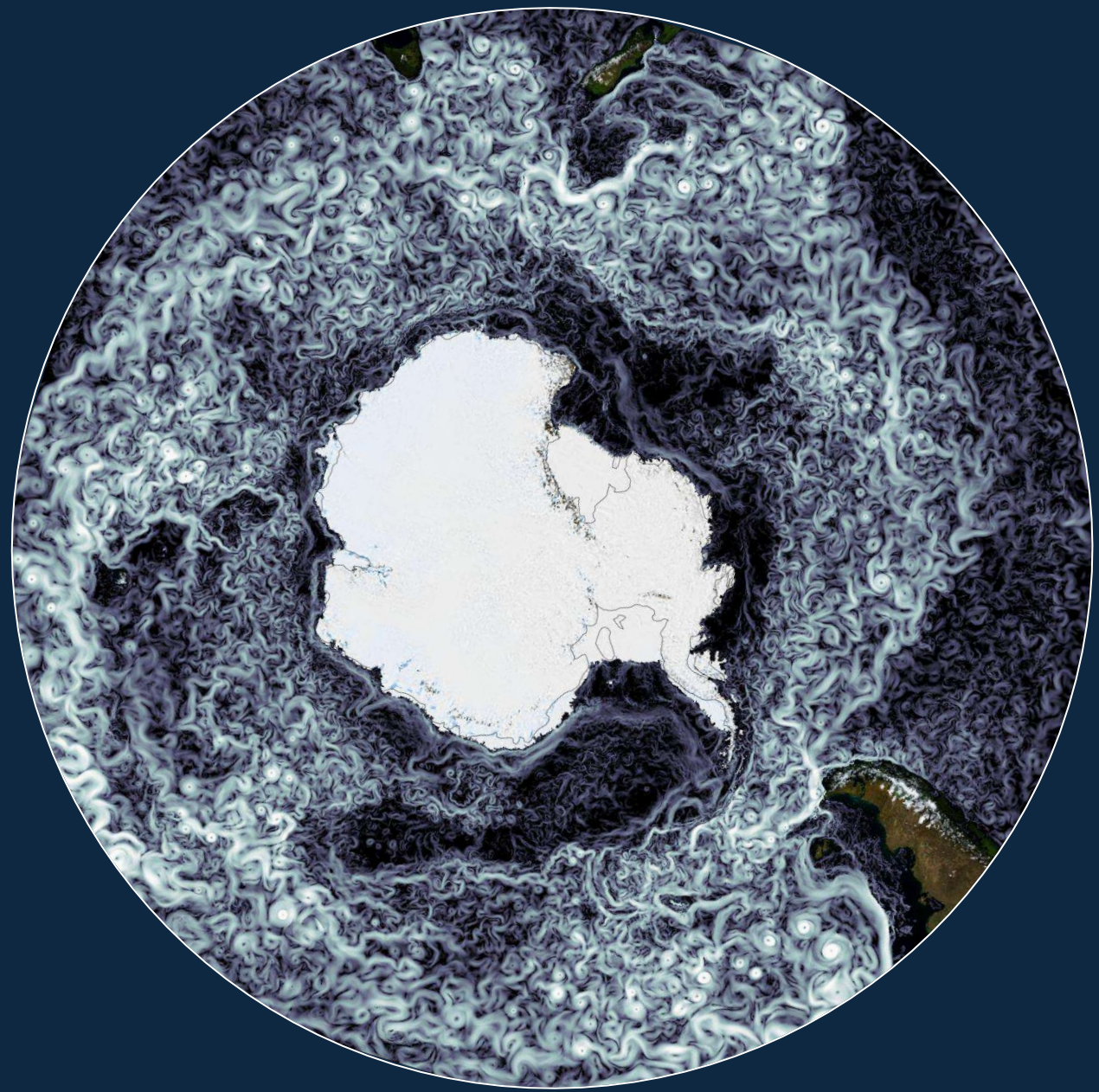
Elhacham et al. 2020 Nature



«The global mass of produced plastic is greater than the overall mass of all terrestrial and marine animals combined.»



Fraser et al. 2016



FESOM2 ocean model (https://fesom.de/)

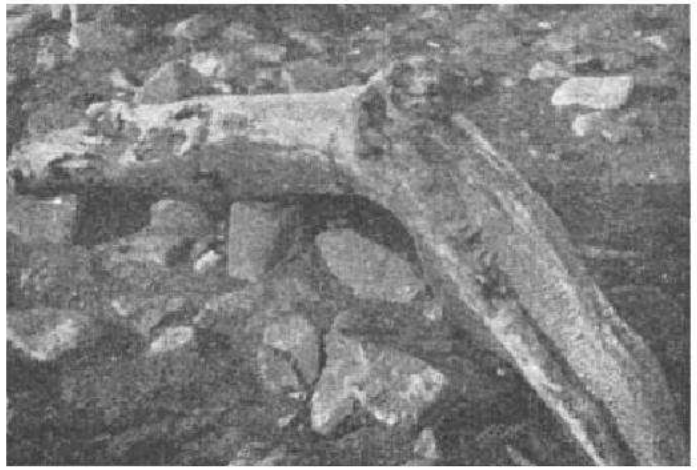
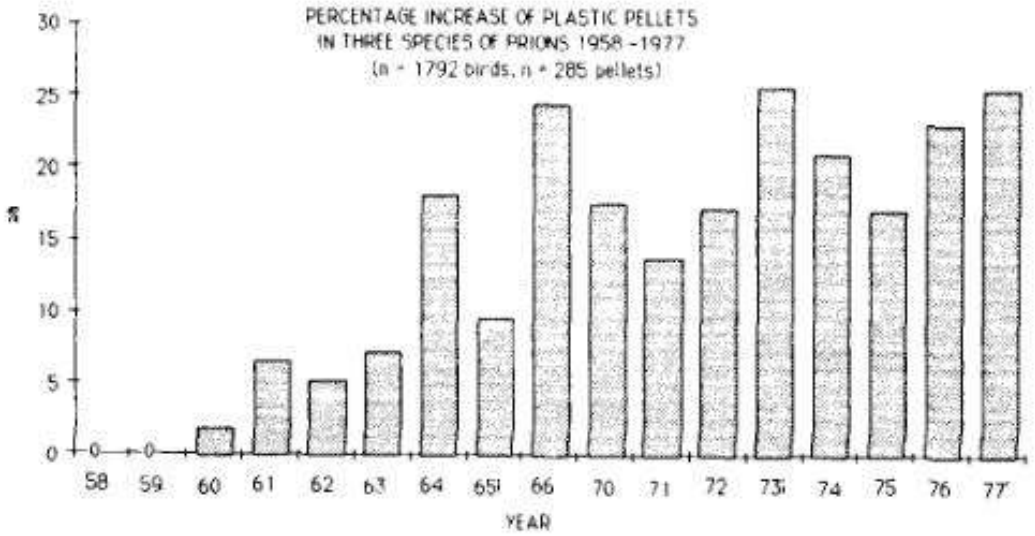
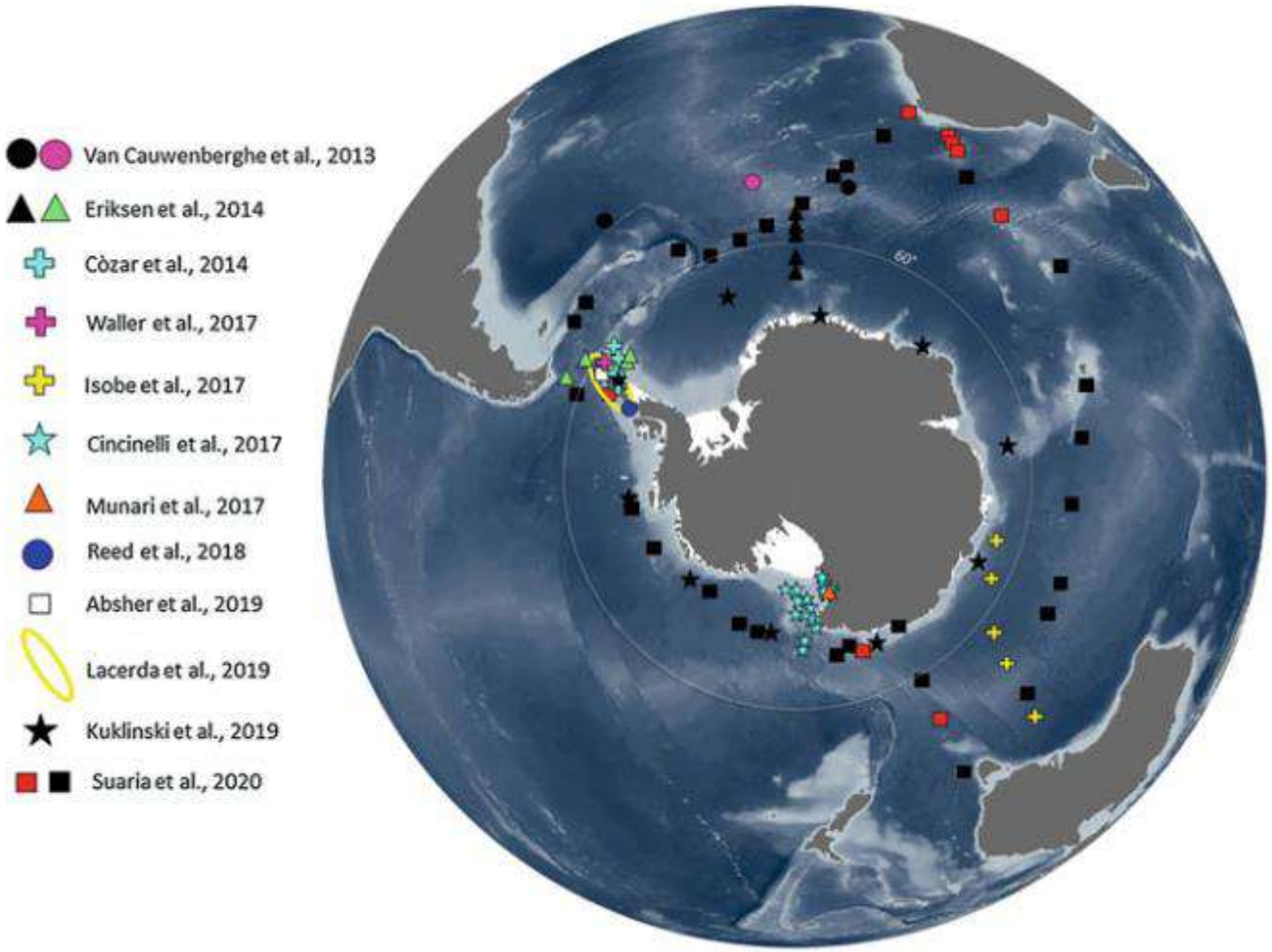


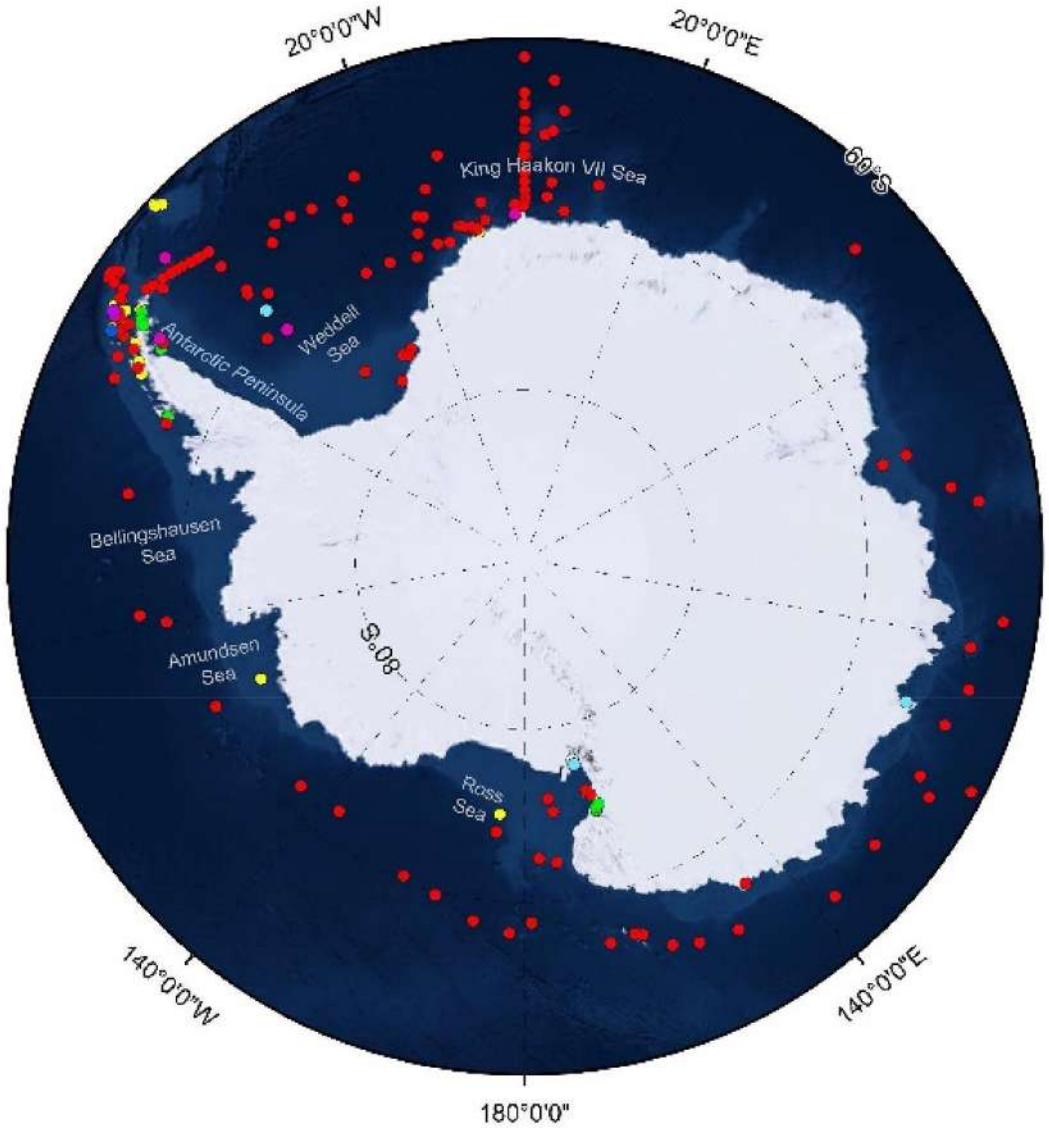
Fig. 1. Boomerang-shaped piece of driftwood from the west coast of Macquarie Island identified as *Nothofagus ? pumilio*; this appears to have been derived from a large limb. The piece was 4 ft. long, 6 in. tapering to 4 in. in diameter. (*Photo. by H. Black*)

Crossing of the Antarctic Polar Front (APF) by driftwood, pumice and fishing-related materials was reported in both directions since the early 1960s (Barber et al., 1959; Coombs and Landis, 1966)

The first records of microplastic ingestion by seabirds were from the Southern Ocean, when prions *Pachyptila* spp. were found to contain plastic in 1960 (Harper and Fowler, 1987)

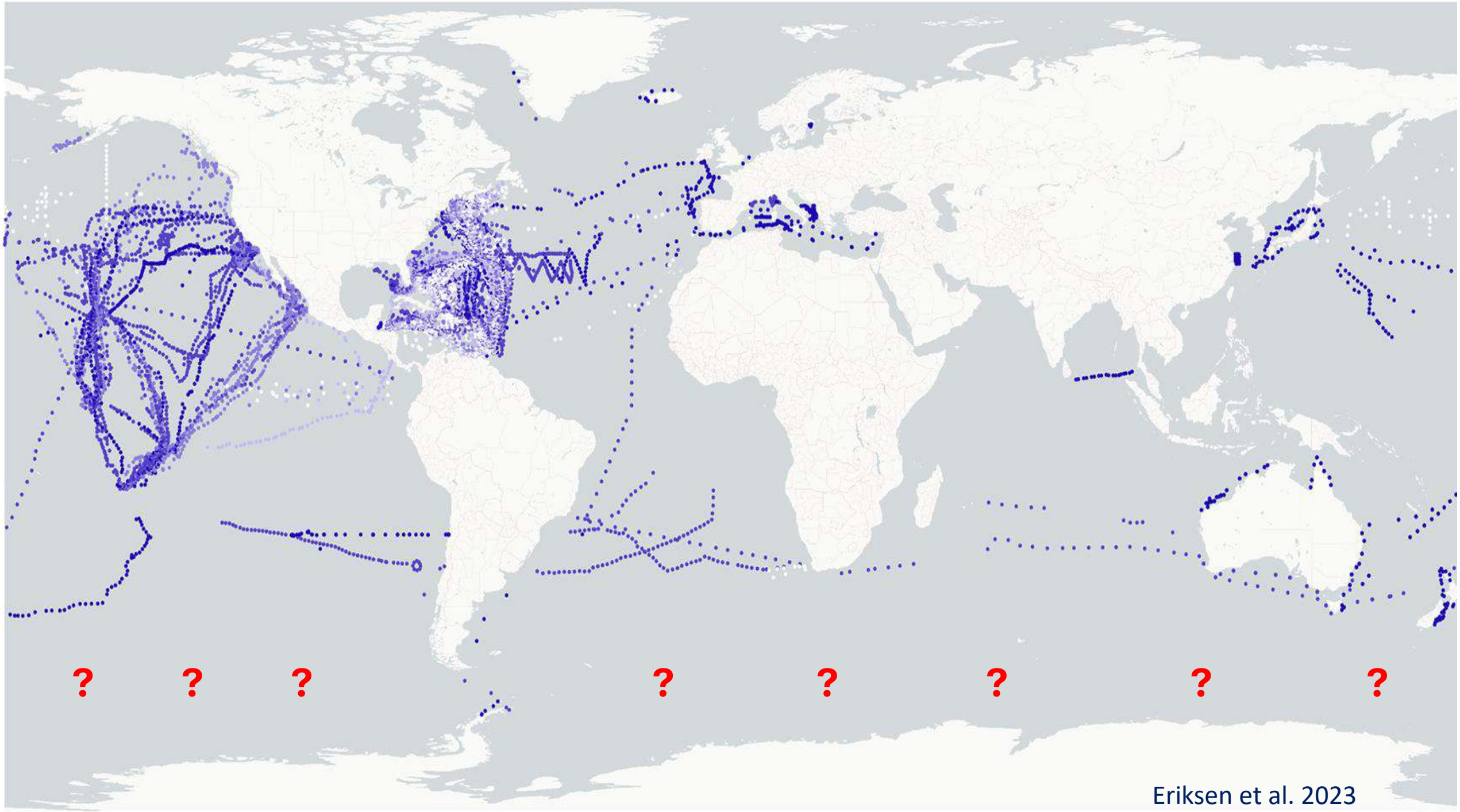






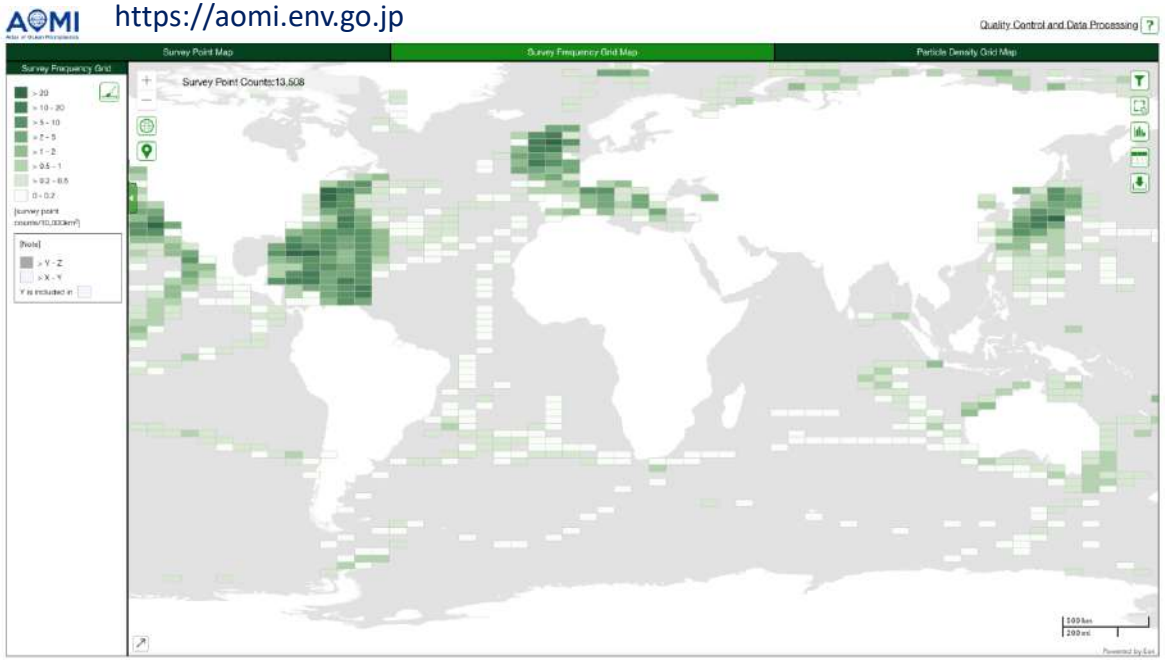
Tirelli V., Suaria G., Lusher A.L. (2022)

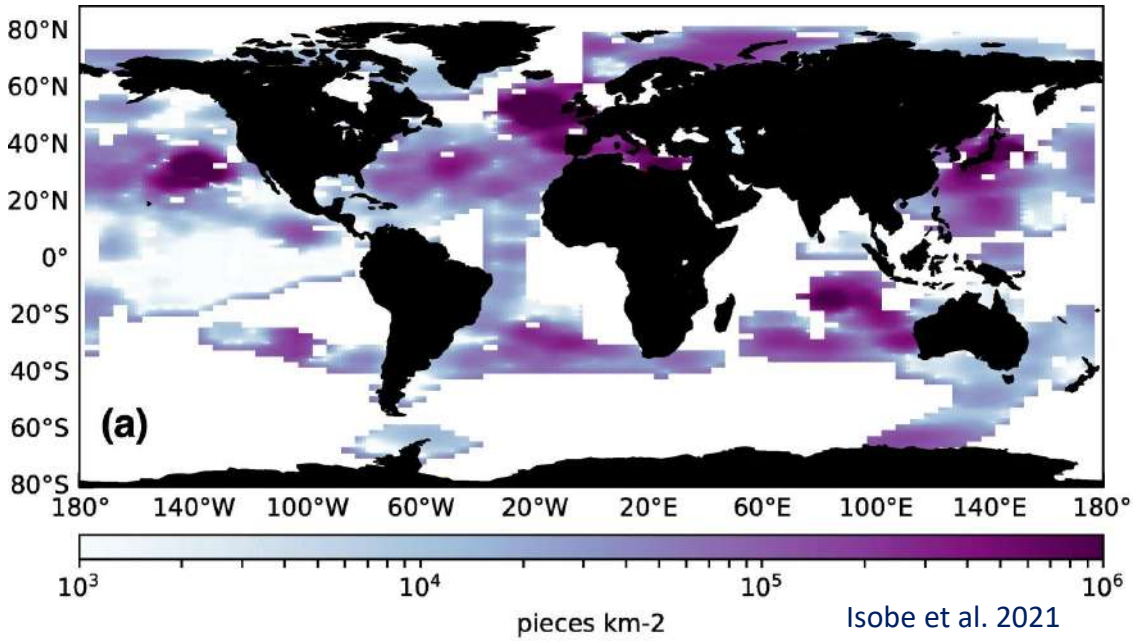
De-la-Torre et al. 2024



Eriksen et al. 2023

https://aomi.env.go.jp

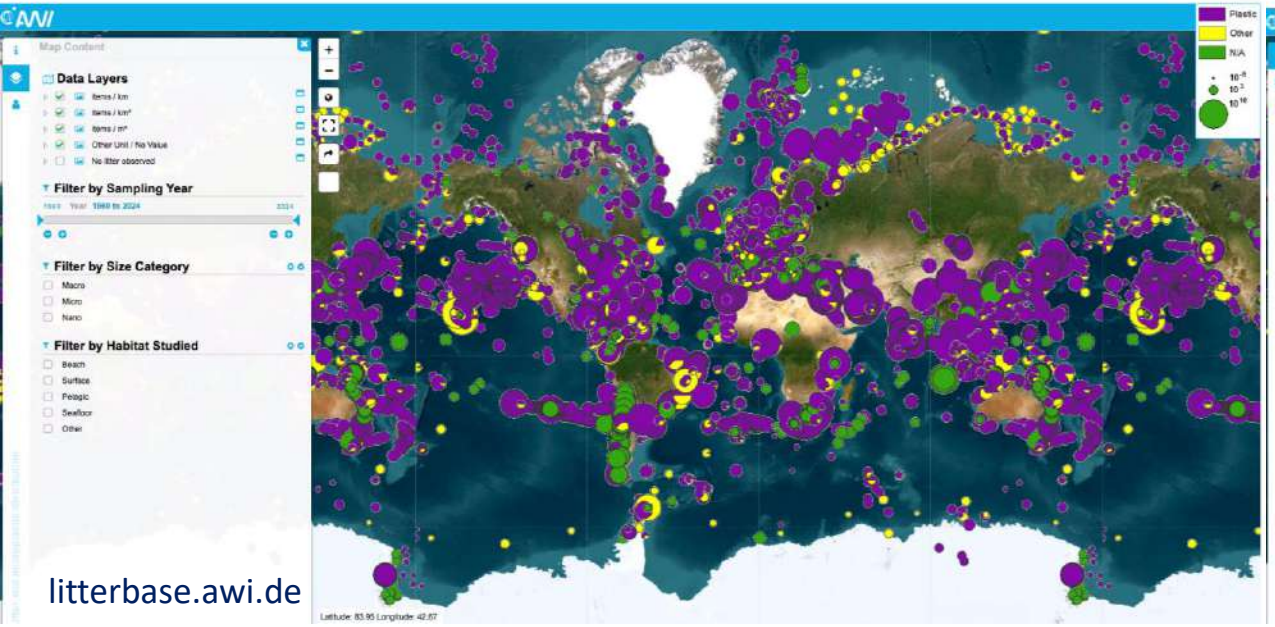




Isobe et al. 2021

LITTERBASE Litter Distribution Biological Impacts About us English

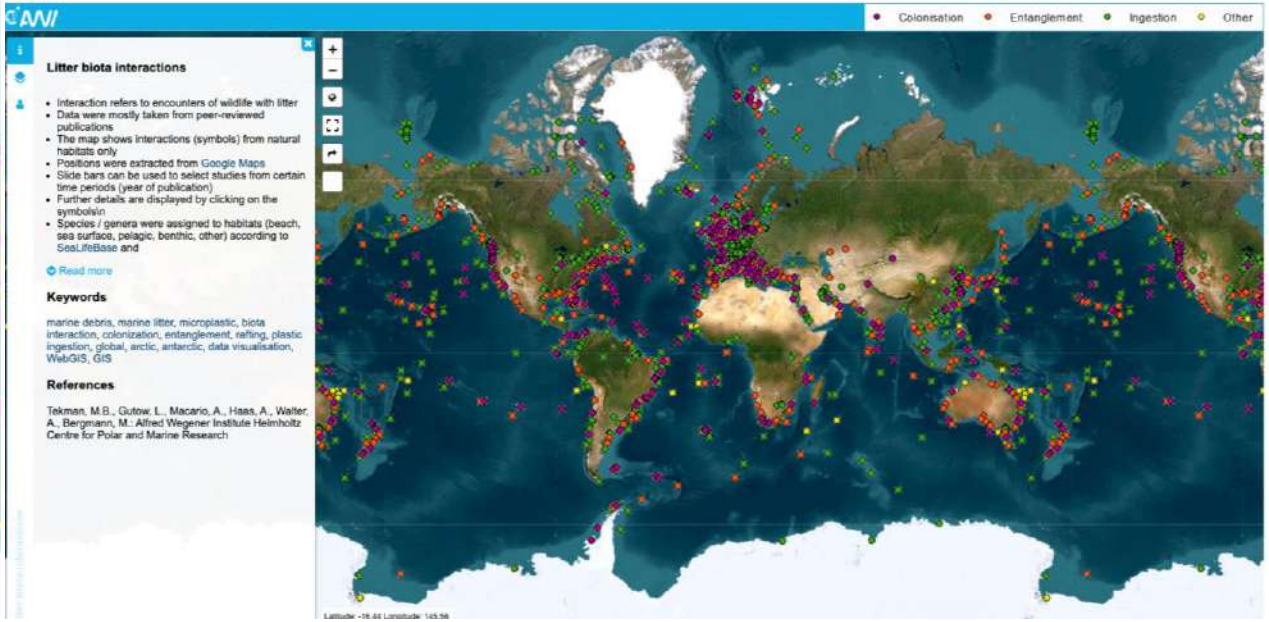
Distribution of litter types in different realms (1,426 publications)



litterbase.awi.de

LITTERBASE Litter Distribution Biological Impacts About us English

4,076 species are affected by litter (1,956 publications)



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ANTARCTIC CIRCUMNAVIGATION EXPEDITION

SWISS POLAR INSTITUTE

ACE

EPFL · WSL Swiss Federal Institute for Forest, Snow and Landscape Research WSL · ETH zürich · u b · Paulsen

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BEACH LITTER AND MICROPLASTICS

- Macroplastics counted and collected on all visited islands.
- **86 items** from 6 antarctic and sub-antarctic beaches.
- Evidence of rafting organisms attached to floating debris.
- 180 sand cores collected from 13 sites.
- Only few fibers retrieved from the sand samples.
- No large MPs were found on the sampled beaches.








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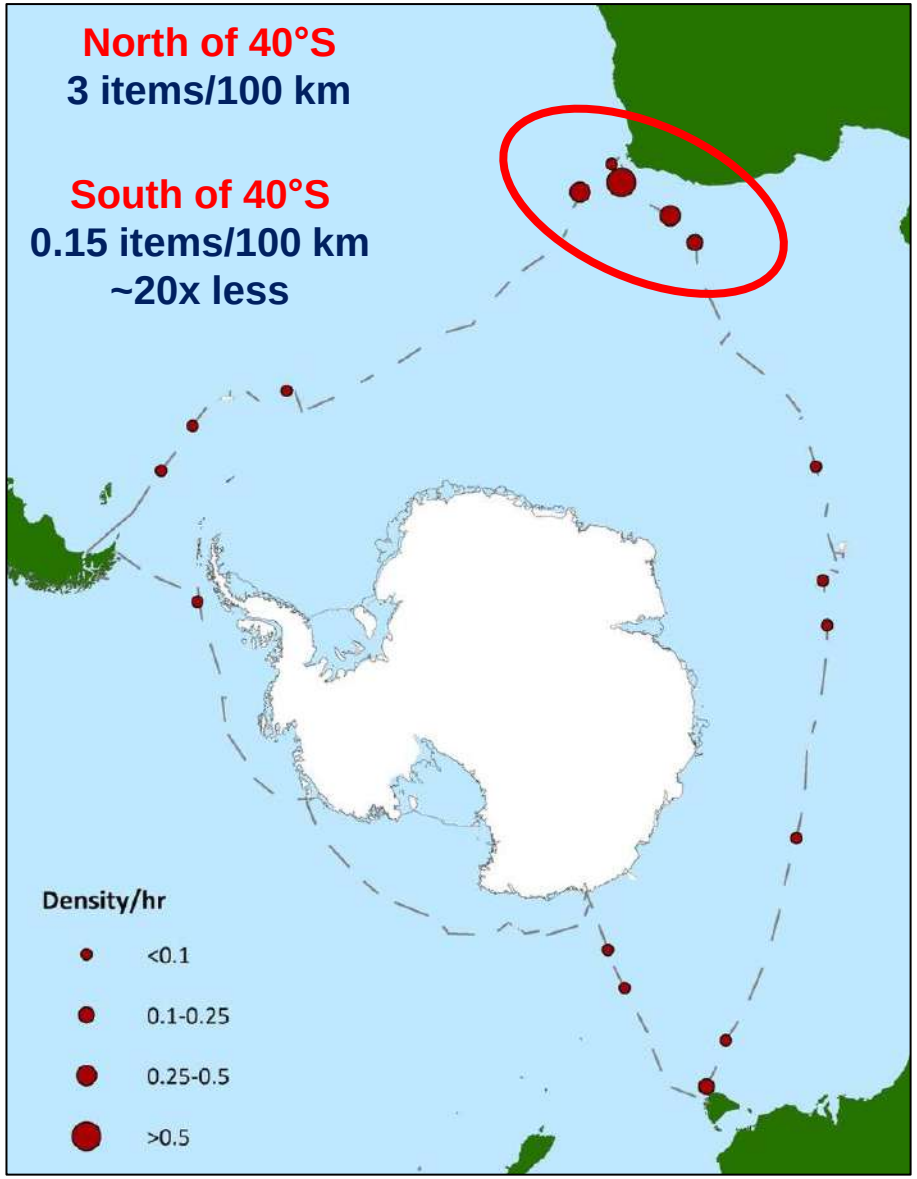
FLOATING MACROLITTER

- Only 54 litter items in 15,417 km of visual survey effort (626 hrs)
- FML density in temperate waters (0.28–0.51 items·km^{-2}) was an order of magnitude higher than in the SO (0.02–0.03 items·km^{-2}). Only 2 items > 60°S

Drifting kelp was 50x more abundant than plastic litter.



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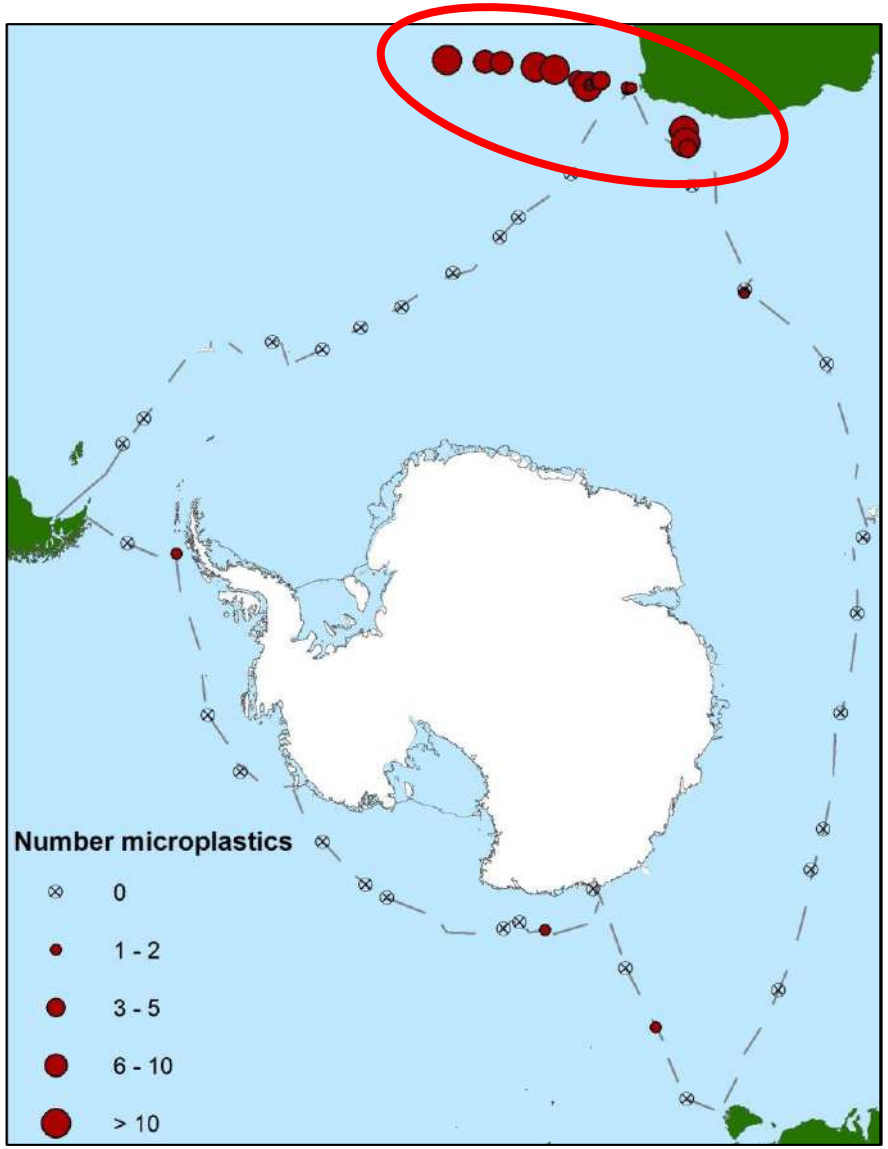
FLOATING MICROPLASTICS

- **33 samples** collected (mesh size 200 µm)
- **115 particles extracted** and characterized (µFTIR)
- **94%** of these particles were paint chips or other non-plastic materials (organic, quartz, $CaCO_3$)
- **Only 7 microplastics found in 5 samples**
- FTIR identification: **PS, PVC, PE, PP, PA.**
- Mean plastic concentration: **~290 items/km²**



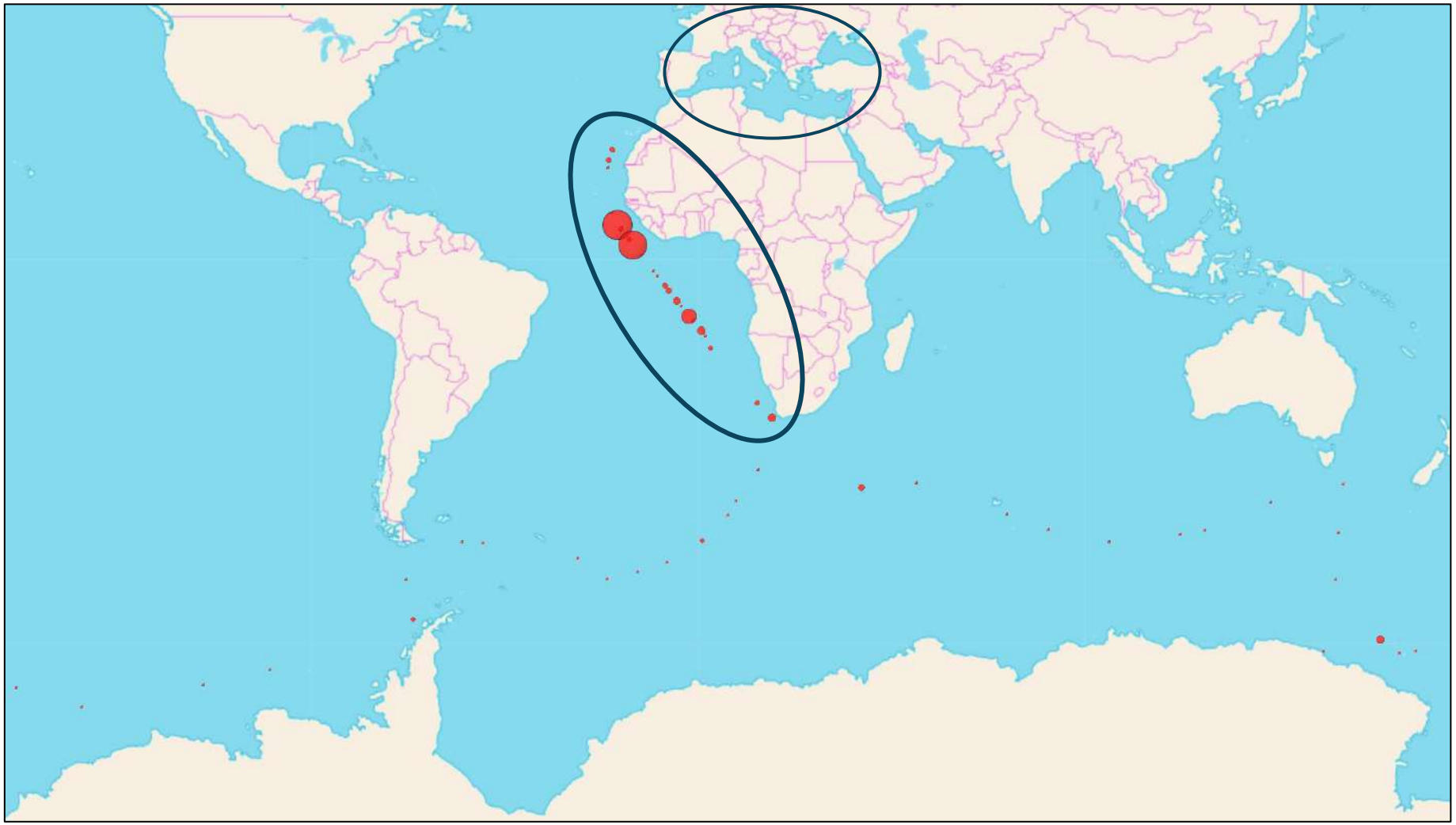
North of 40°S

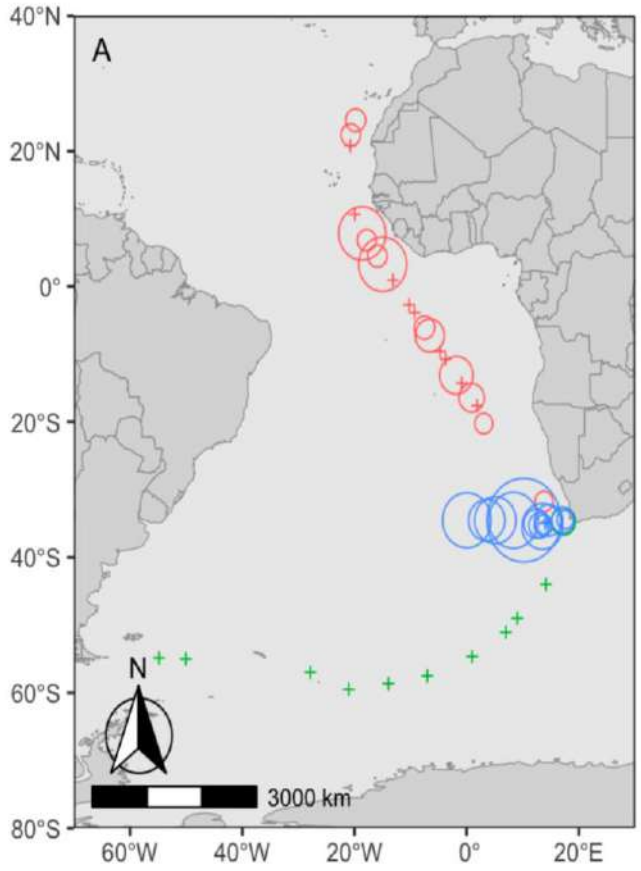
- 22 additional samples (May-Jul 2017)
- **Microplastics found in 90% of samples**
- **Average concentration: ~1350 items/km²**

(i.e. ~5x more than in the SO)

Atlantic Ocean (ACE Leg 0): **~2,500 microplastics/km²**

(~10x more than SO)





(Suaria et al., 2023)

Mediterranean Sea: 1,250,000 microplastics/km² (Suaria et al., 2016)

(~5000x more!)

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The world's cleanest ocean?

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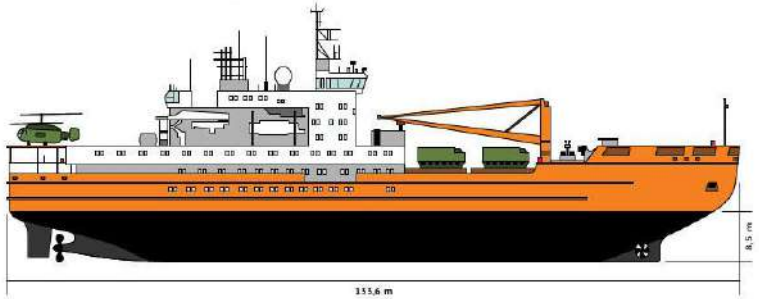
BACK TO BASICS

The Research Expedition Vessel
«Akademik Tryoshnikov»



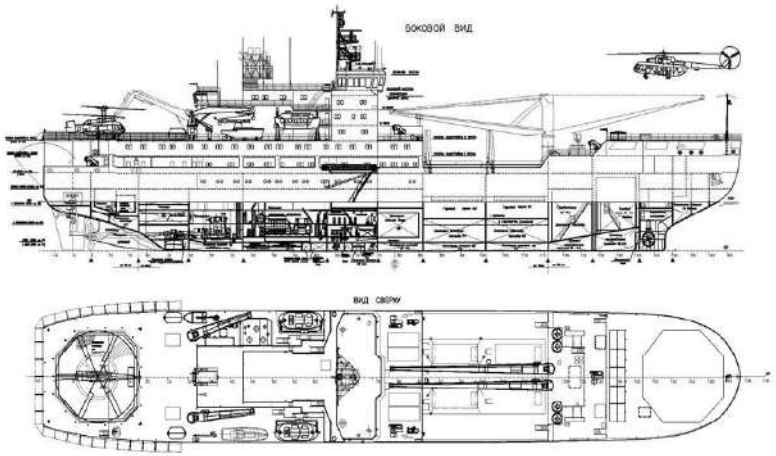
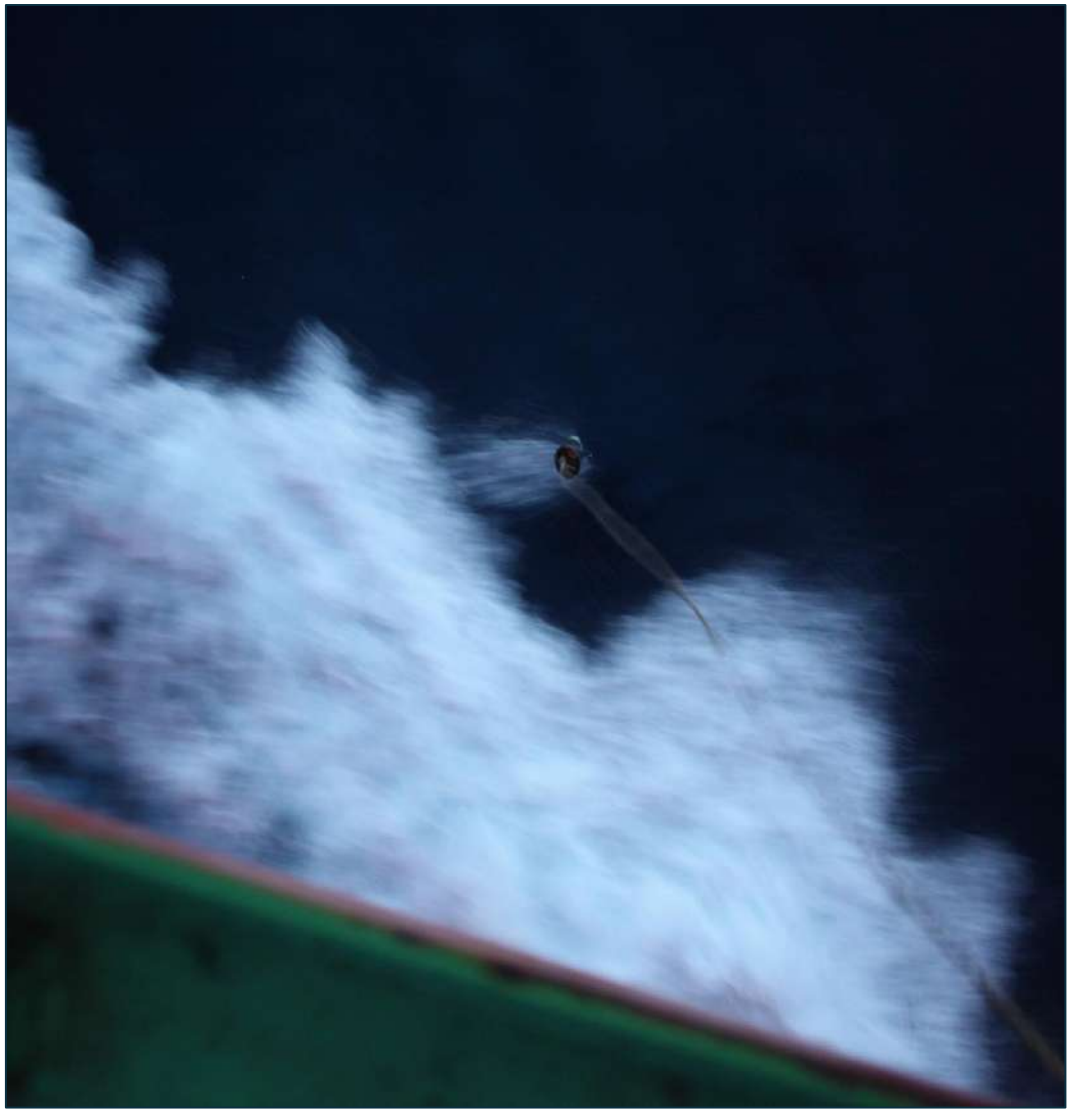


Рис. 1. ***Научно-экспедиционное судно (пр.22280)***



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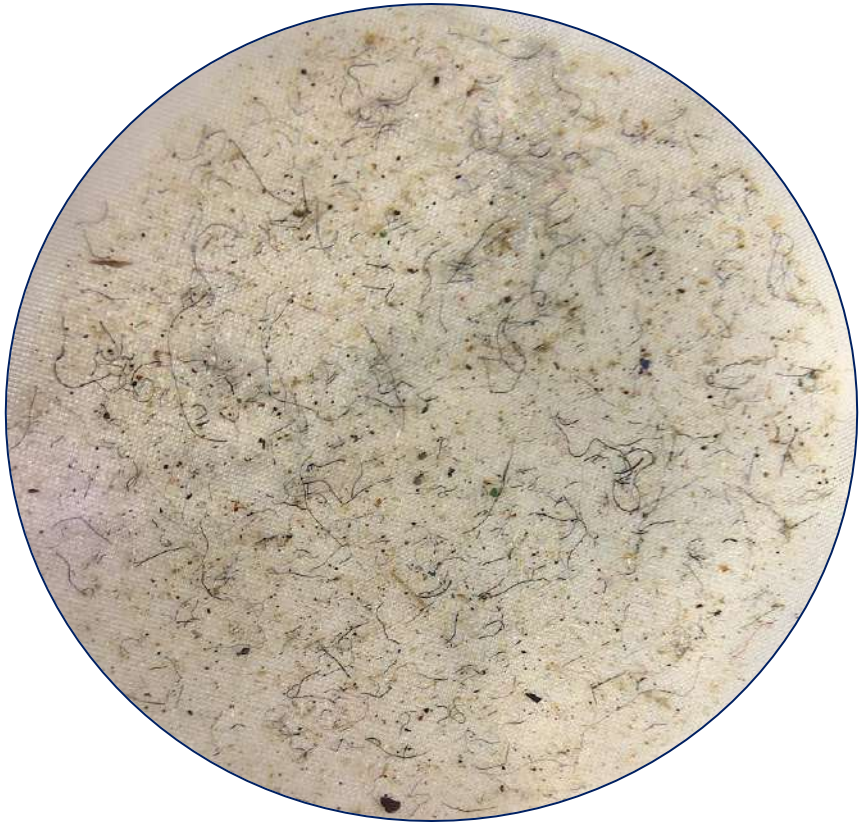
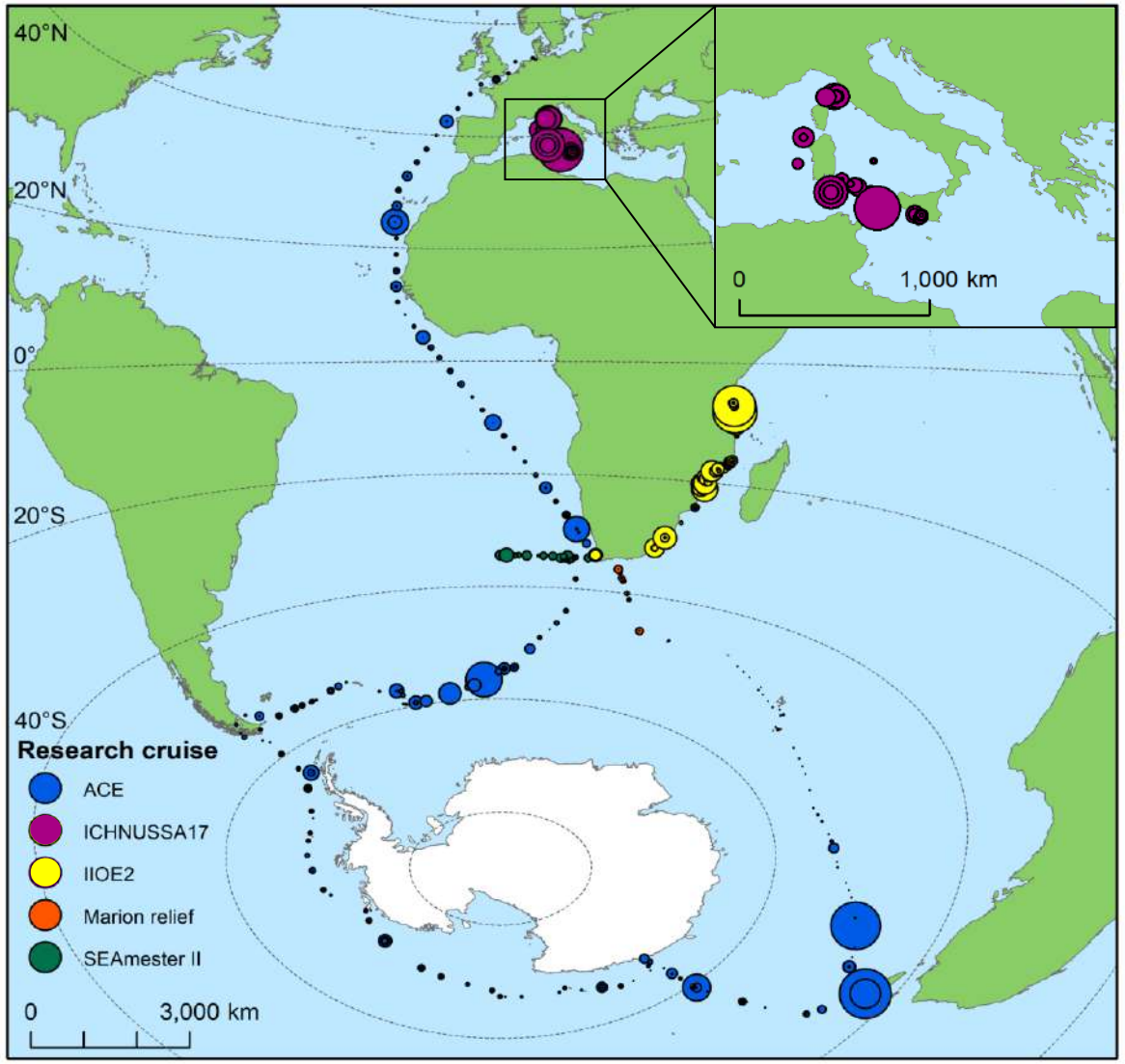
SEAWATER SAMPLING



- 5 research cruises between January and November 2017.
- **916 seawater samples** collected at 617 locations.
- 2/3 replicates per station were usually collected
- Water was poured into 10-liters pre-washed containers for on-board gravity or vacuum filtration through 0.7-63 µm mesh filters.



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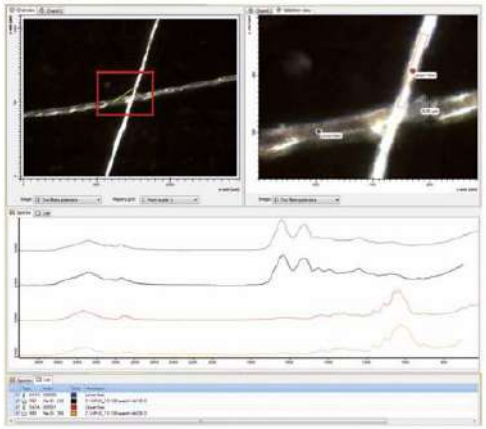
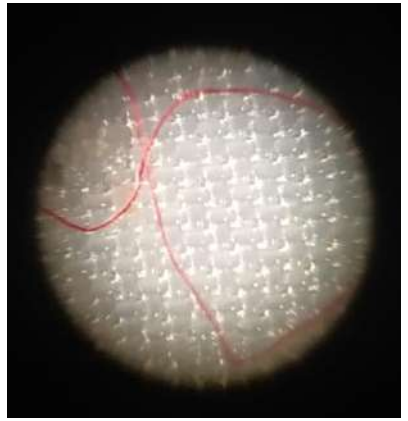
LABORATORY ANALYSIS

- Counting and sorting at the stereomicroscope according to standard criteria.
- Raw fiber concentrations computed for all samples and expressed as fibres·l^{-1}
- A random subset of **2134 fibres** (i.e. ~10 fibres/sample) extracted for µFTIR analysis (Bruker LUMOS in ATR-mode).
- Fiber length and diameter measured to the nearest 1 µm from the digital images collected by the instrument.
- Fibres classified as: **Synthetic** (polyester, acrylic, polyamides, etc.), **Animal** (wool, silk) or **Cellulosics** both natural (cotton, linen, jute, kenaf, hemp, flax, sisal) and man-made (rayon/viscose, acetate).

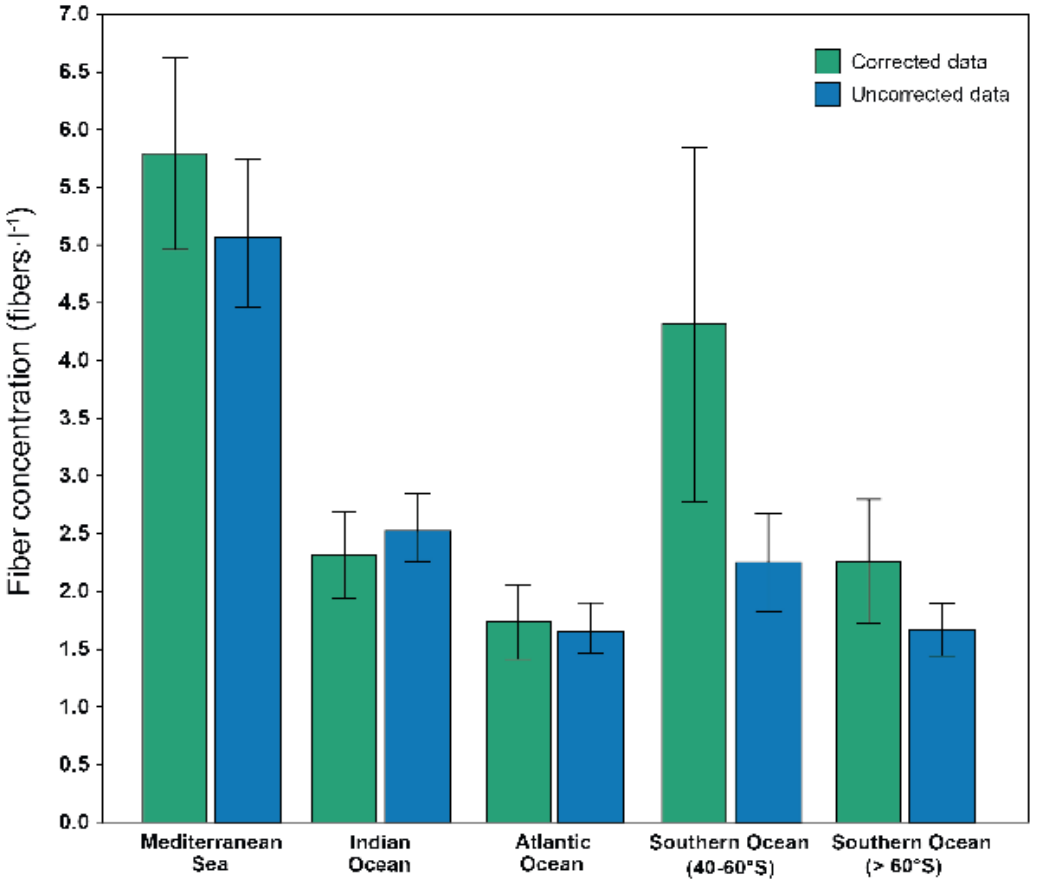
- **23,593 fibres counted**
- Fibres found in 99.7% of samples
- Range: 0.02-25.8 fibres·l^{-1}
- Median 18 fibres/sample
- Q_1-Q_3 : 10-31
- Median concentration: **1.7 fibres·l^{-1}**

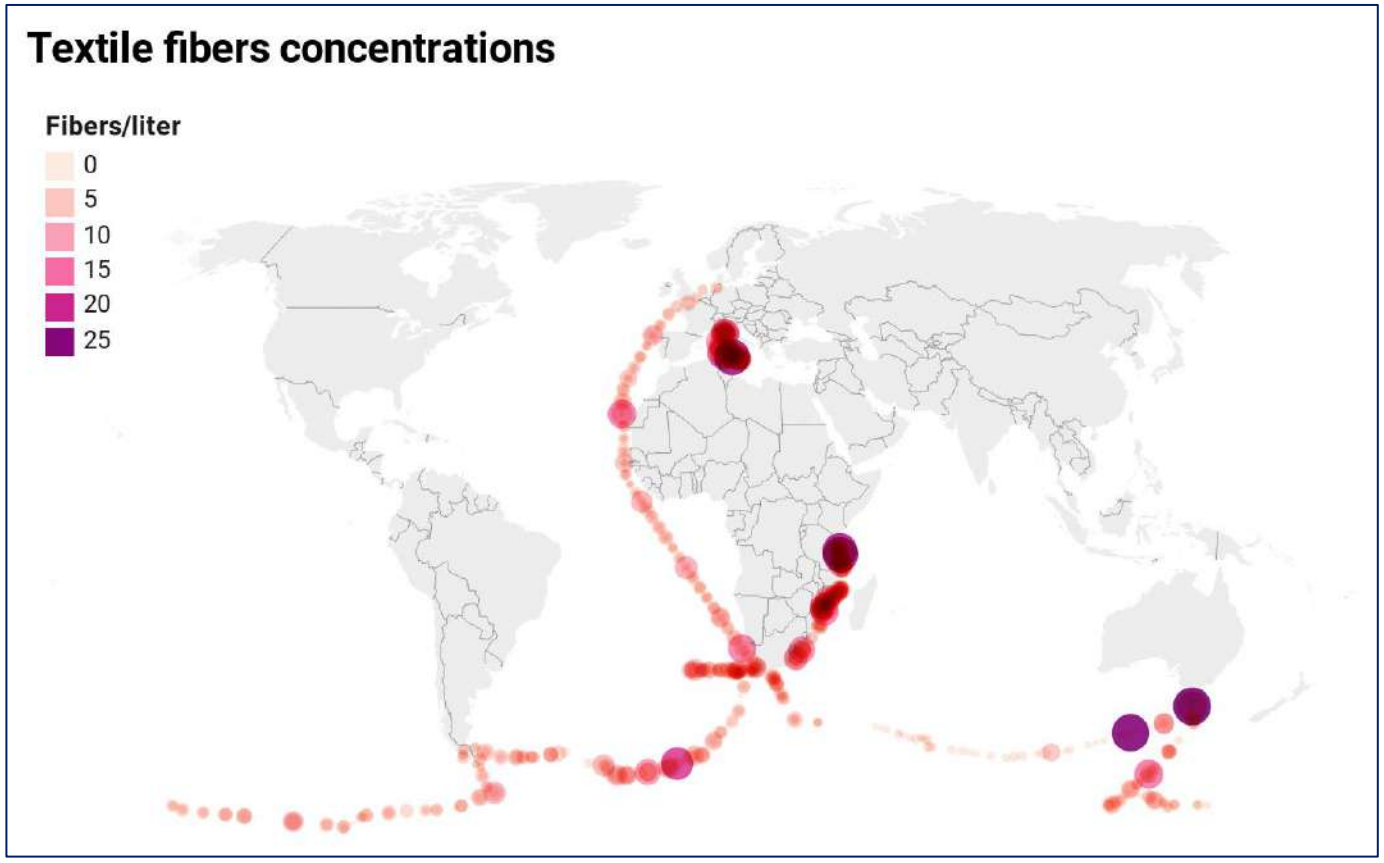




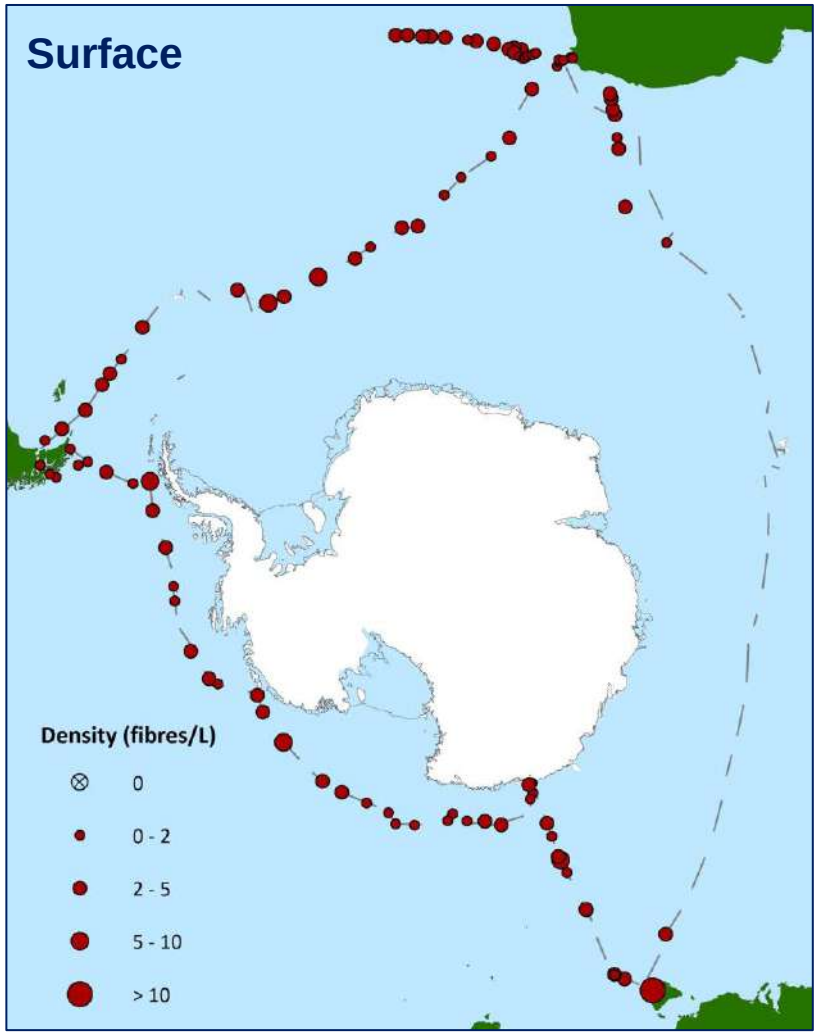
ABUNDANCE AND DISTRIBUTION

- **Fiber concentration was not homogenous across ocean basins.**
- High concentrations were found in the Mediterranean Sea and in the SO
- No clear trend in relation to distance with land, but fibers concentration tended to increase from north to south (negative correlation with latitude).





Bulk water samples

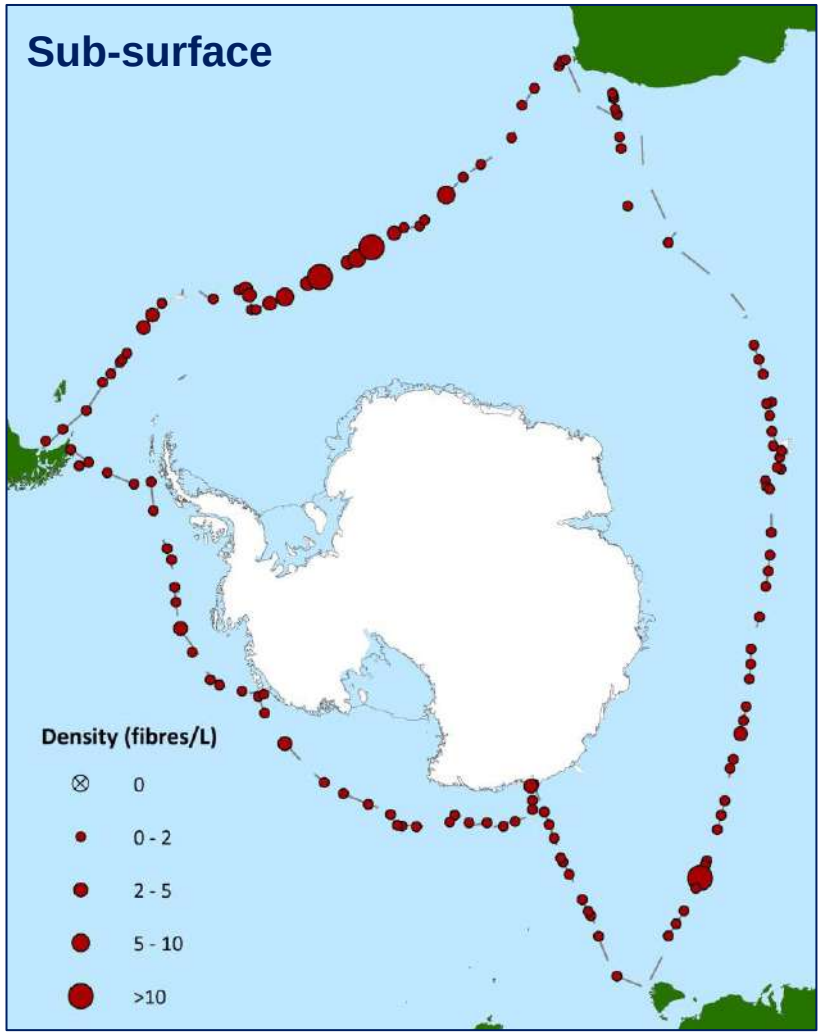


North of 40°S: 2.0 fibres/litre

South of 40°S: 2.7 fibres/litre

~1/3x more

Underway samples



North of 40°S: 0.3 fibres/litre

South of 40°S: 1.3 fibres/litre

~5x more

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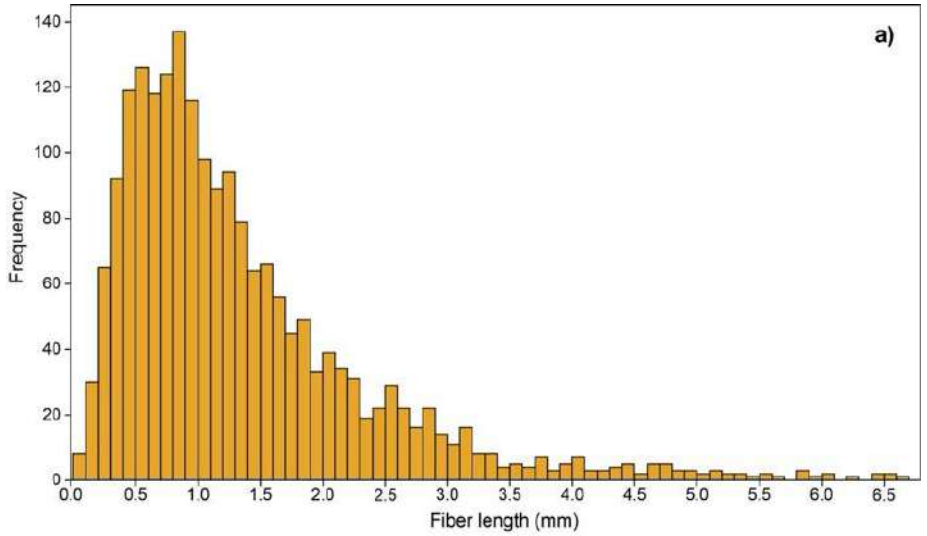
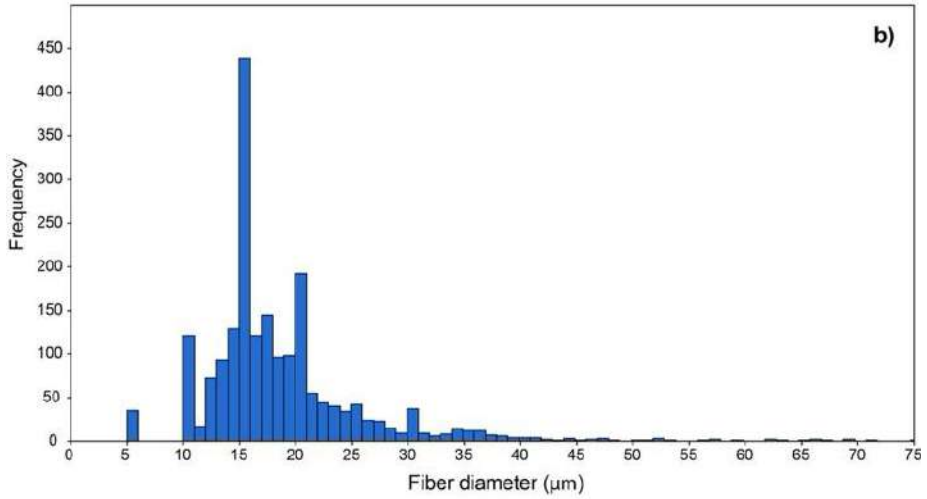
LENGTH AND DIAMETER





Length

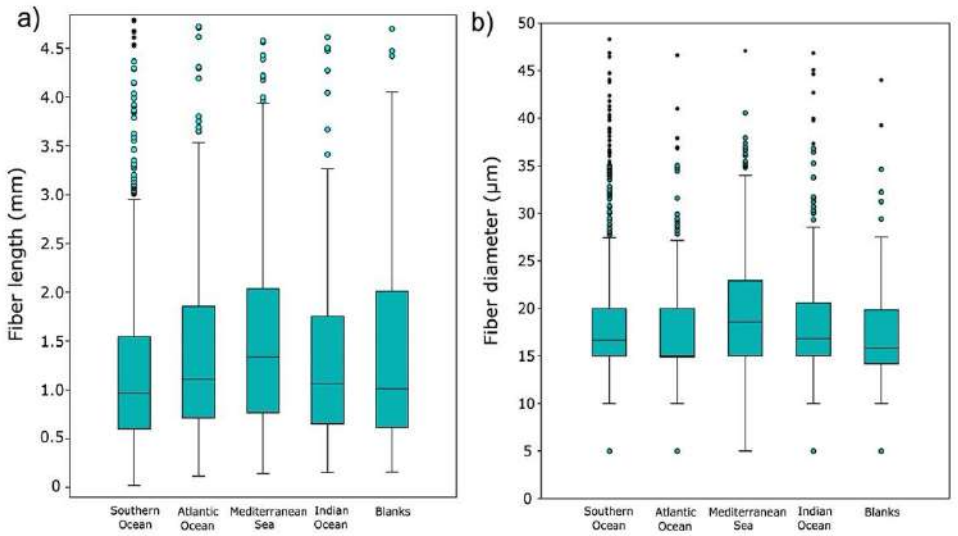
- median 1.07 mm
- Q_1-Q_3: 0.65 to 1.74 mm
- range: 0.09–27.06 mm
- only 10 fibers > 10 mm
- only 3 fibers > 15 mm

Diameter

- median 16.7 µm
- Q1-Q3: 15.0-20.4 µm
- range: 5-239 µm

Colors

- dark/black (57.1%)
- light/grey (24.2%)
- blue (10.1%)
- red/orange (5.2%)
- yellow/amber (2.9%)
- green (0.4%)

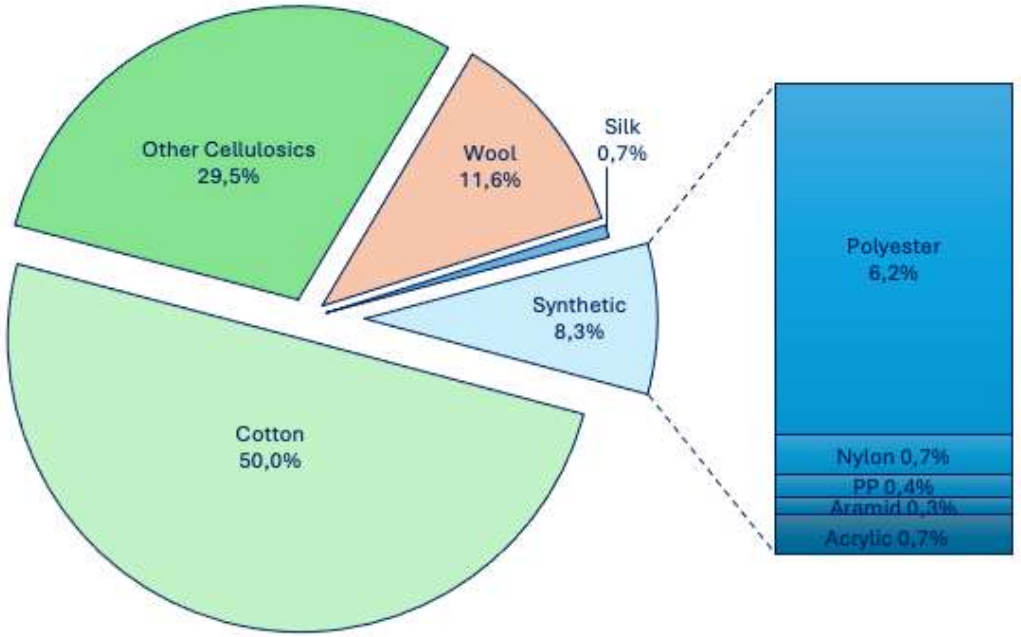


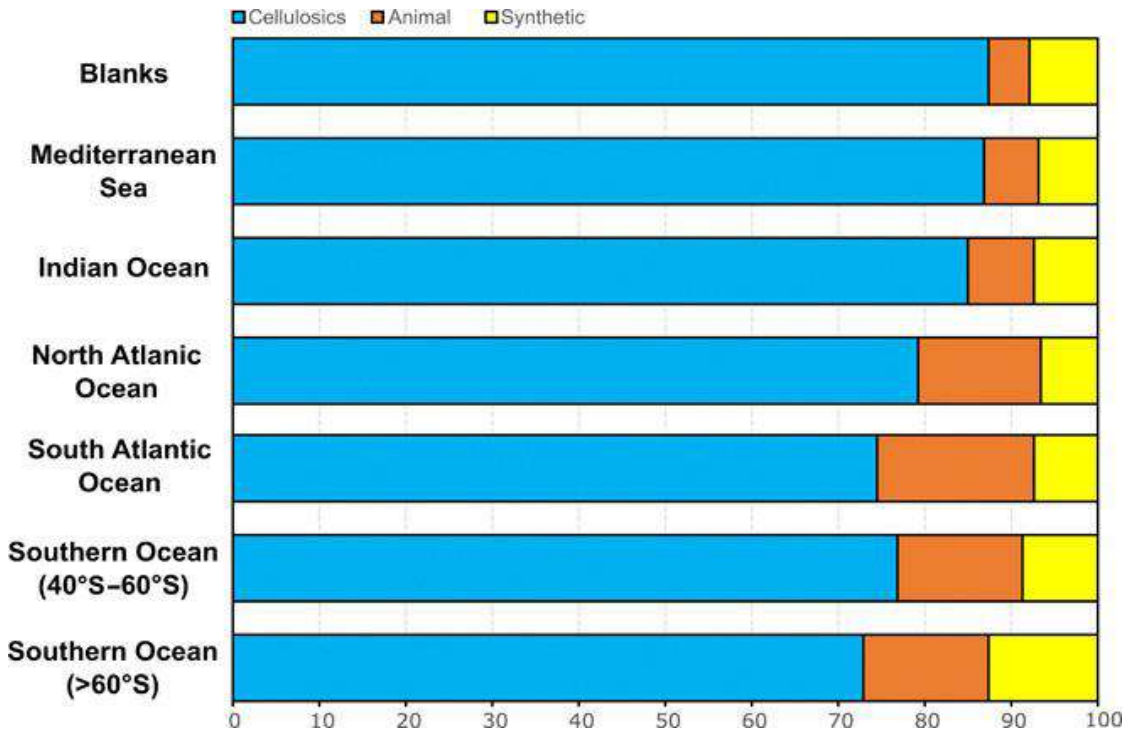
Fibers from the Mediterranean were significantly longer and thicker than those found in other basins.

Fibers from the Southern Ocean were significantly shorter than all other basins.

µFTIR ANALYSIS

- **91.8% of all analyzed fibres (n=1984) were natural fibres of animal or plant origin.**
- Most fibres are non-synthetic: cotton 50%, wool 11.6% or other cellulosics 29.5%.
- **Only 8.3% synthetic**, with polyester the most abundant (6.2%), followed by nylon (0.7%), acrylic (0.7%), polypropylene (0.4%) and aramid fibers (0.3%).





- The composition of fibers was not homogenous across ocean basins, but the general trend remains constant (cellulosics >70-80% in all oceanic basins).
- **The proportion of synthetic fibers increased at higher latitudes** from 6.8% in the Med to 12.6% in Antarctic waters south of 60°S (similar pattern for wool fibres).

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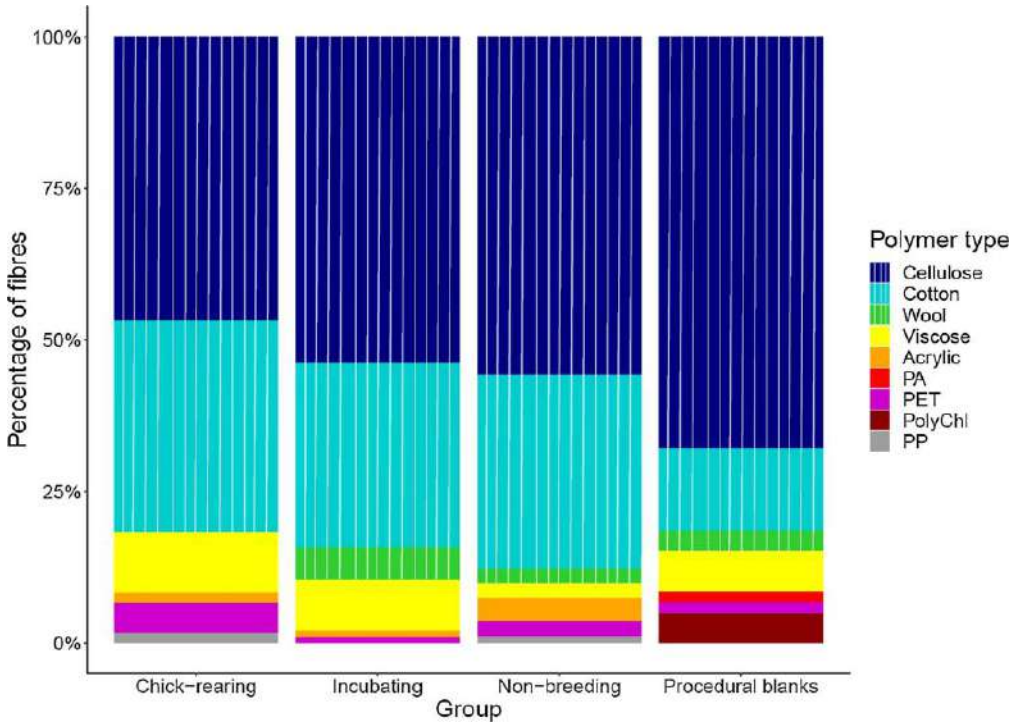
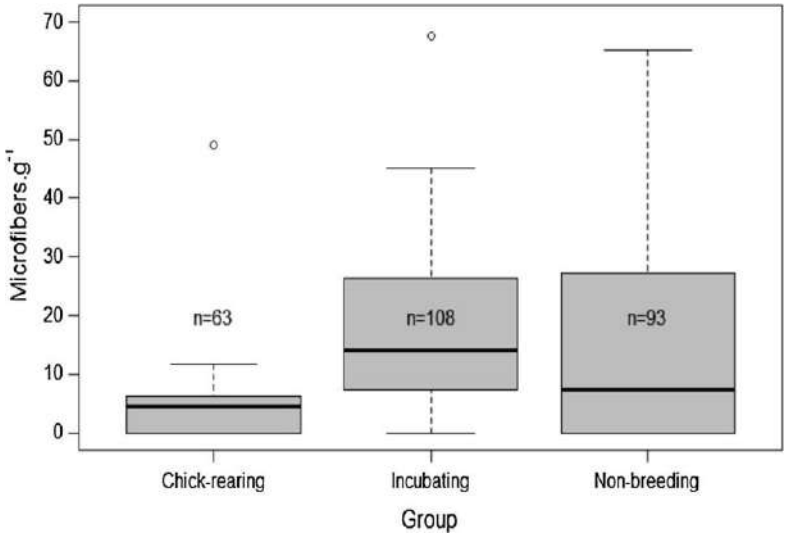
KING PENGUINS

NATURAL AND SYNTHETIC FIBRES IN THE DIET OF KING PENGUINS (*APTENODYTES PATAGONICUS*) FORAGING FROM SOUTH GEORGIA

- Microfibres were found in 77% of the King Penguin faecal samples collected at South Georgia.
- Most microfibres (88%) were of natural origin (e.g. cellulose, cotton, wool).
- Faeces of incubating penguins were twice as contaminated as samples from chick-rearing birds.

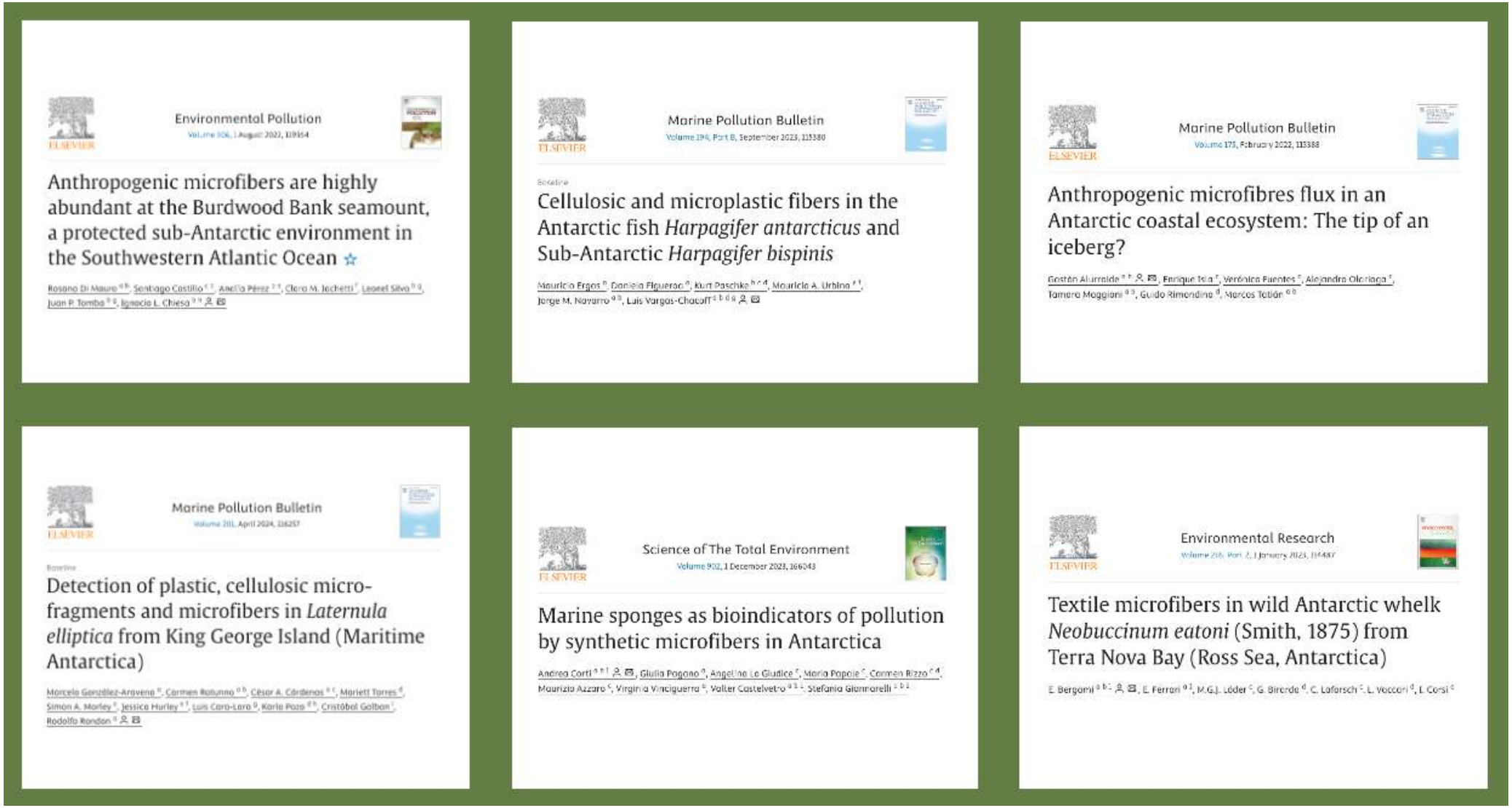




Le Guen et al. 2020 https://doi.org/10.1016/j.envint.2019.105303

TEXTILE FIBERS

Fibers are the most prevalent type of anthropogenic particle found by microplastic pollution surveys around the world, including Antarctica, consistently accounting for **80-90% of 'microplastics' counts** in all compartments surveyed.



ARE POLAR REGIONS SINK AREAS FOR TEXTILE MICROFIBERS?

A.P.W. Barrows et al. / Environmental Pollution 237 (2018) 275–284

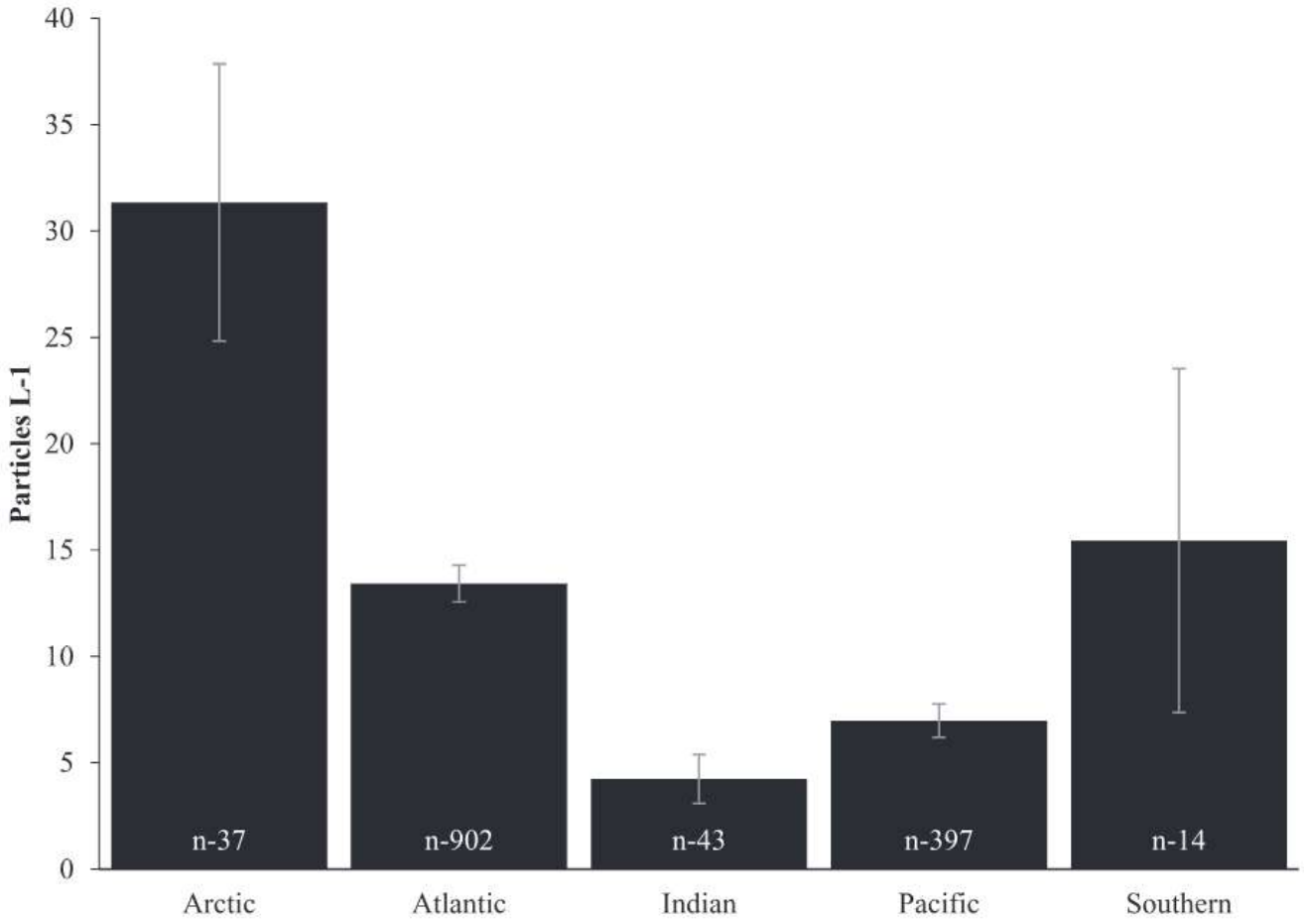


Fig. 1. Average particles L^{-1} of surface water for each major ocean basin. Number of samples shown at bar base. Error bars show standard error.

Sources?
Sinks?
Impacts?
Degradation times?

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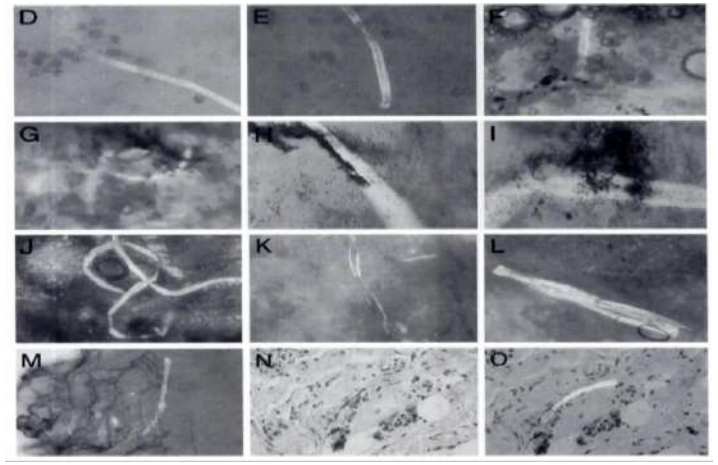
Not only clothes and not only washing machines….

- The main uses of natural and synthetic fibers are clothing and apparel, followed by household and furnishings, automotive and other industrial applications, e.g. construction, filtration, and personal care.
- Large numbers of fibers are discharged into wastewater from washing clothes (10^{7-9} fibers per wash).
- But it is very likely that washing machines are not the largest source of fibers…

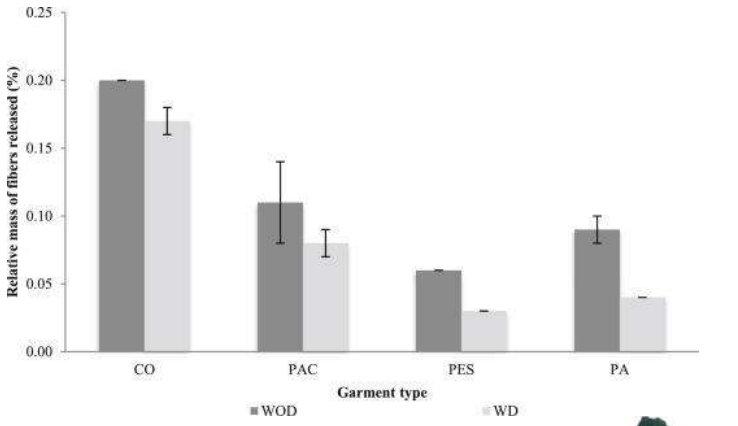


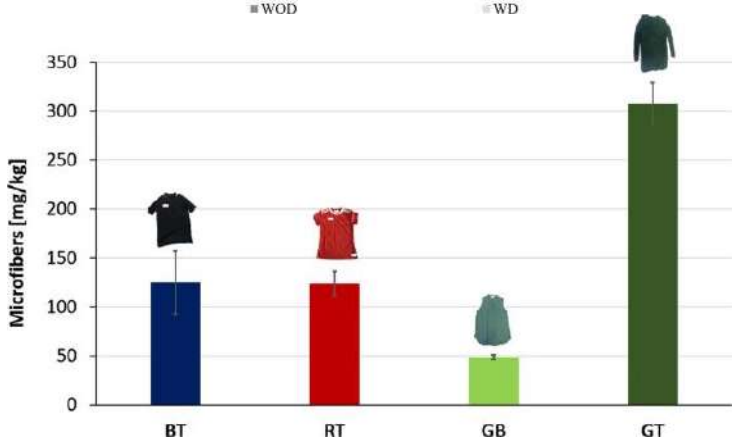
Pauly, John L., et al. "Inhaled cellulosic and plastic fibers found in human lung tissue." Cancer Epidemiology and Prevention Biomarkers 7.5 (**1998**): 419-428.

87% of the studied lungs (n = 114) contained fibers
97% of malignant lung specimens contained fibers

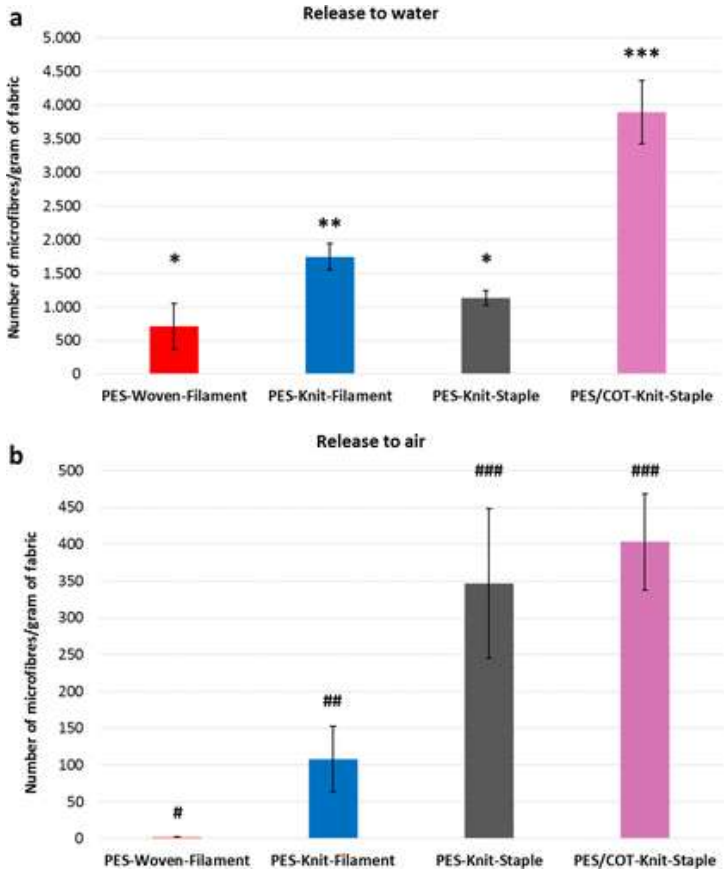
Not only clothes and not only washing machines….

Release from washing (Zambrano et al. 2019; Cesa et al. 2019; De Falco et al. 2019)





Release to air by wearing clothes (De Falco et al. 2020)



Science of the Total Environment 857 (2023) 159317

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Examining the release of synthetic microfibres to the environment via two major pathways: Atmospheric deposition and treated wastewater effluent

I.E. Napper [a,1], F.N.F. Parker-Jurd [a,*,1], S.L. Wright [b], R.C. Thompson [a]

[a] International Marine Litter Research Unit, School of Biological and Marine Sciences, University of Plymouth, Drake's Circus, Plymouth PL4 8AA, UK
[b] MRC Centre for Environment and Health, Imperial College London, White City Campus, 80-92 Wood Lane, London W12 0BZ, UK

«When the two pathways were compared, atmospheric deposition of synthetic microfibres appeared the dominant pathway, releasing fibres at a rate several orders of magnitude greater than via treated wastewater effluent.»

OPEN

Microplastics generated when opening plastic packaging

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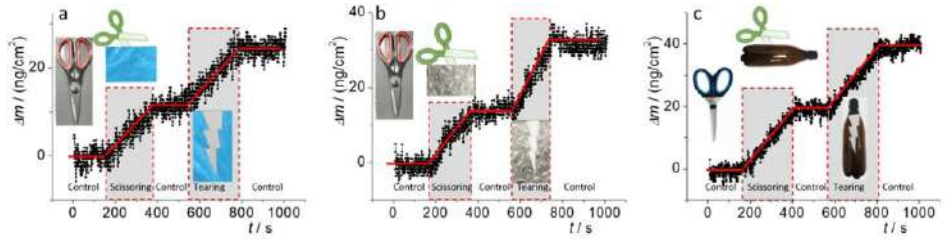
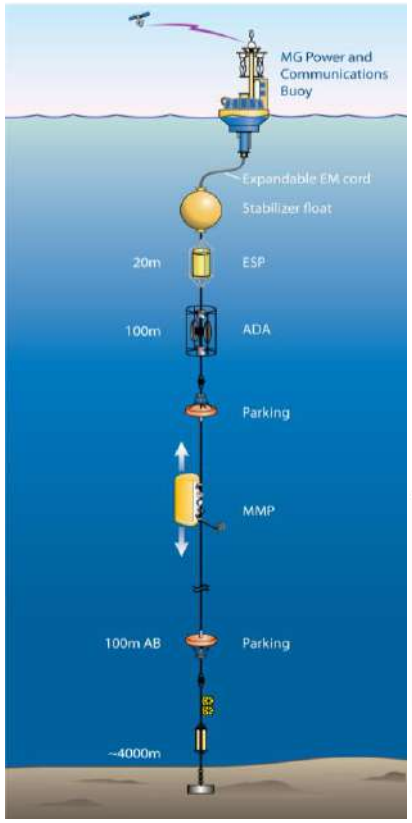
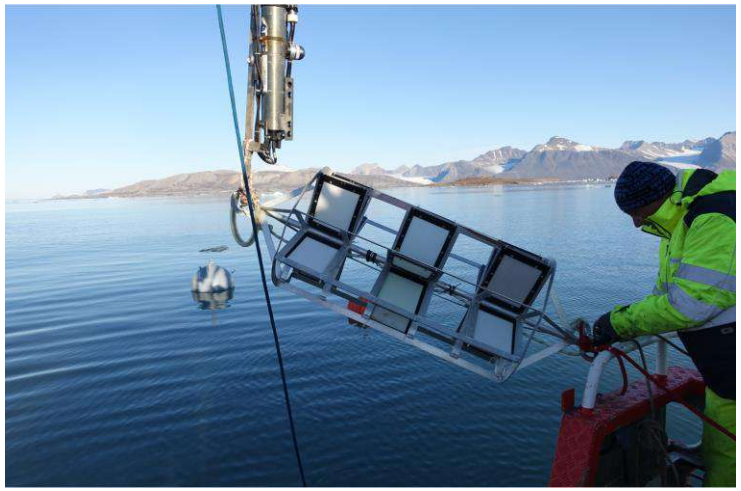
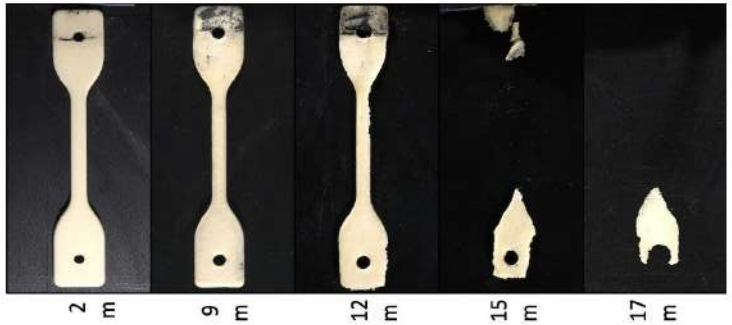


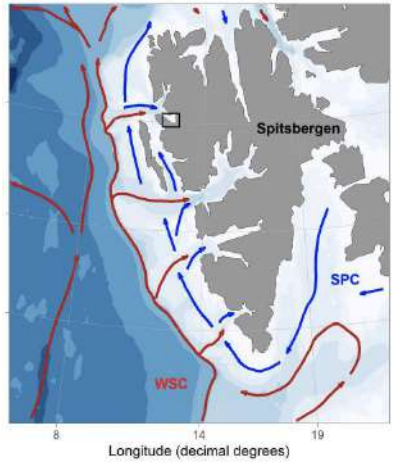
The Endurance sank in 1915 and was found in 2022 in the Weddell Sea at 3008 metres depth after 107 years underwater....

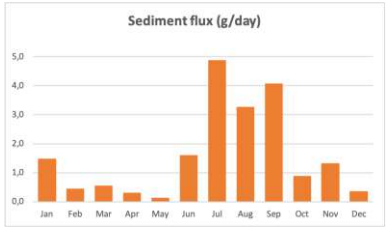
FROM NORTH TO SOUTH...

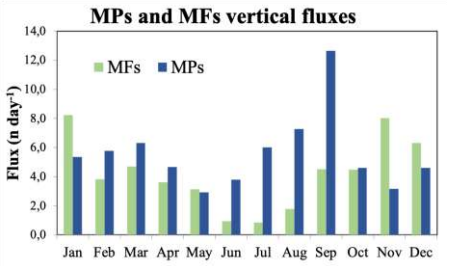


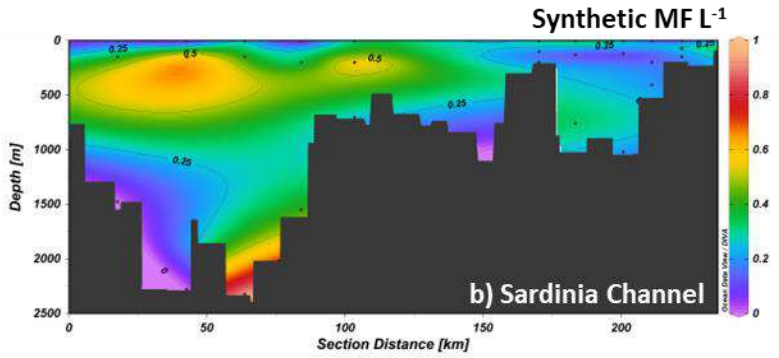


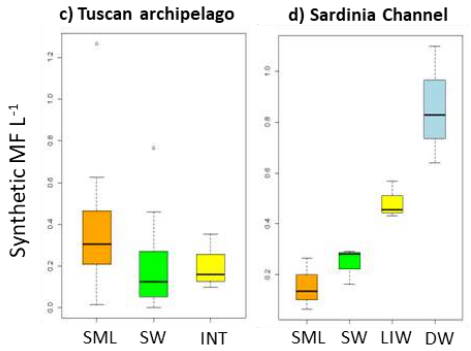


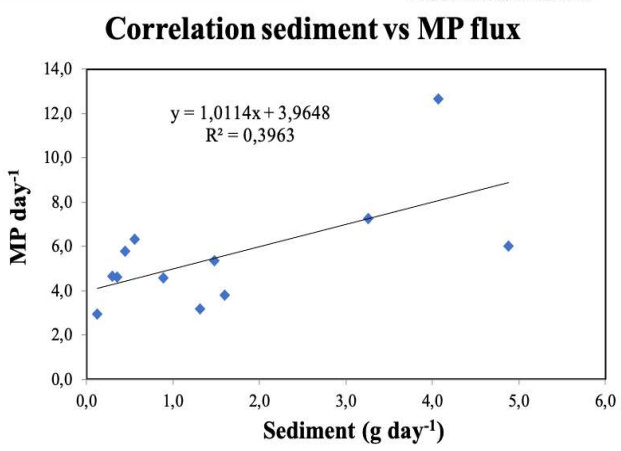


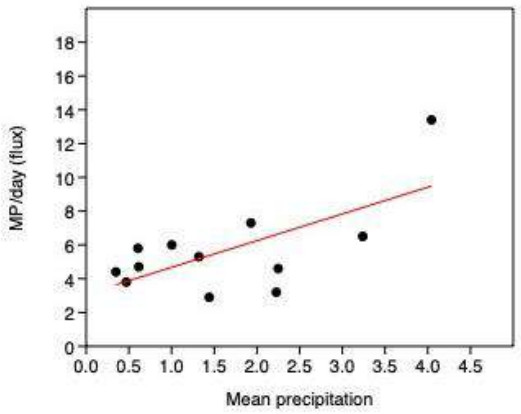












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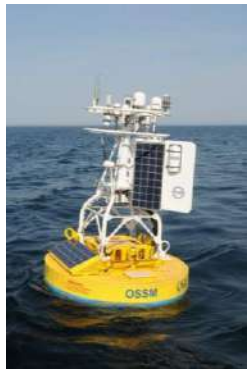
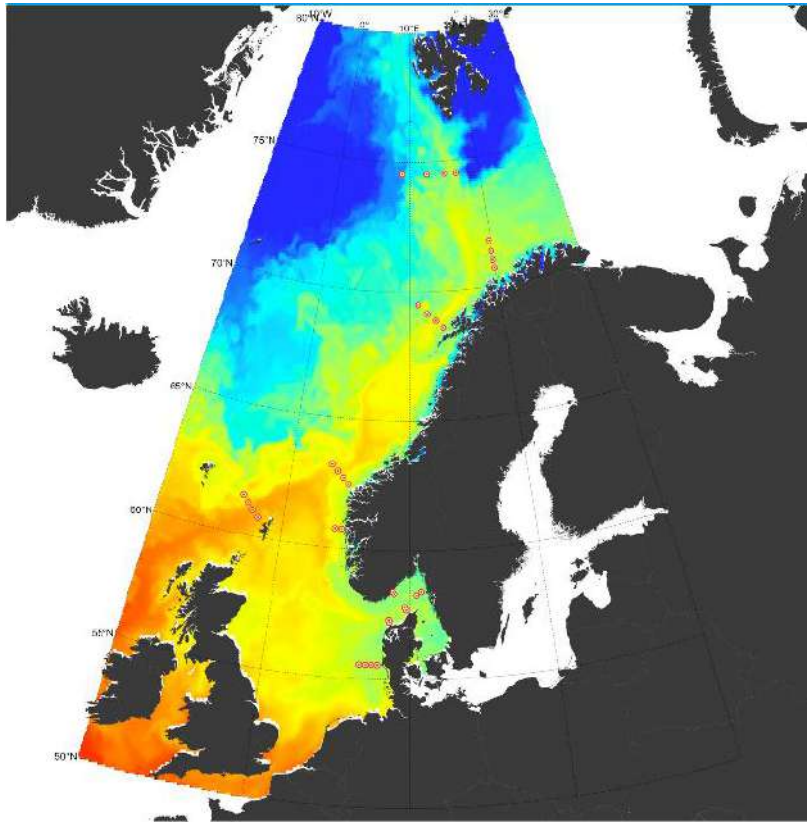
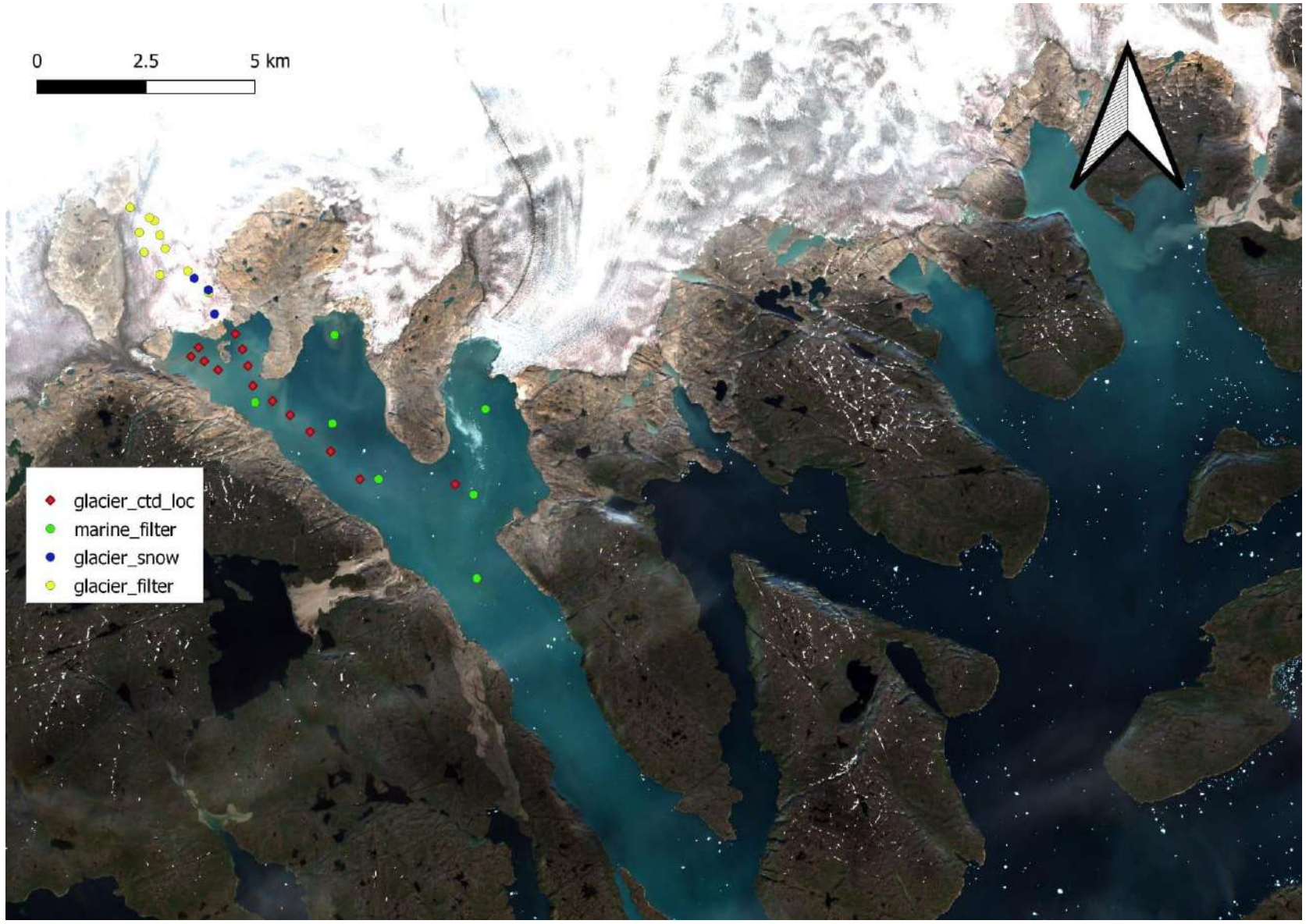
FROM NORTH TO SOUTH...







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SUMMARY

- Most macro-litter found in Antarctica is locally produced (i.e. fisheries and research activities)
- The long-range transport of FML and large secondary microplastics is probably limited in the SO.
- On the contrary, small MPs and textile fibers are most easily transported in the atmosphere from lower latitudes and are contaminating the Antarctic Environment.

- The main knowledge gaps are related to deposition rates, local generation mechanisms, environmental impacts, exposure levels for biota, degradation times and sinking mechanisms.
- Harmonization and standardization of sampling and analytical protocol is critical to ensure intercomparability of the results and a proper assessment of MP pollution levels in Antarctica.

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