MP pollution - State of knowledge

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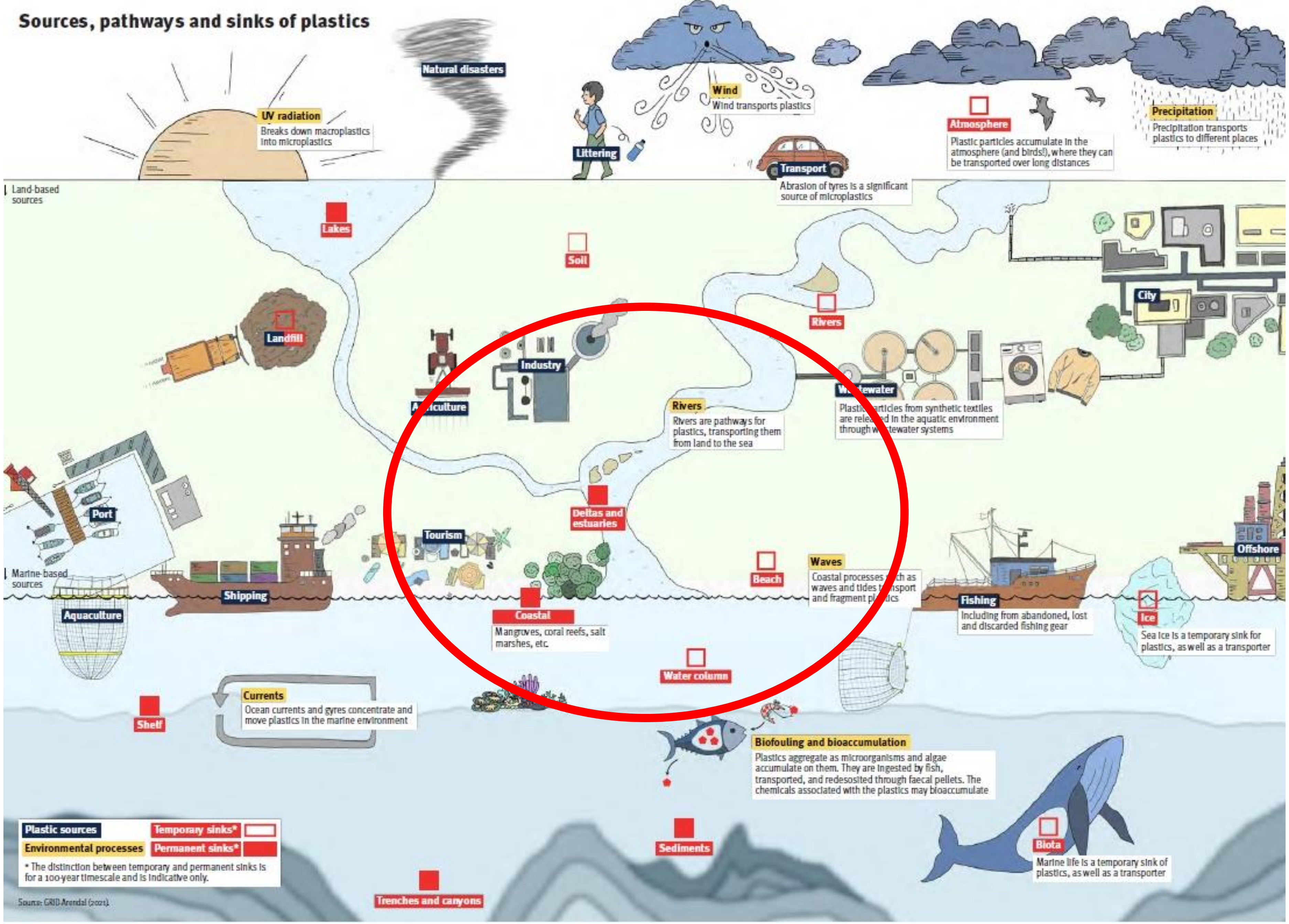
Interreg
North Sea Region
IMMERSE
European Regional Development Fund
EUROPEAN UNION

UNIVERSITY OF HULL | ENERGY AND ENVIRONMENT INSTITUTE

Content

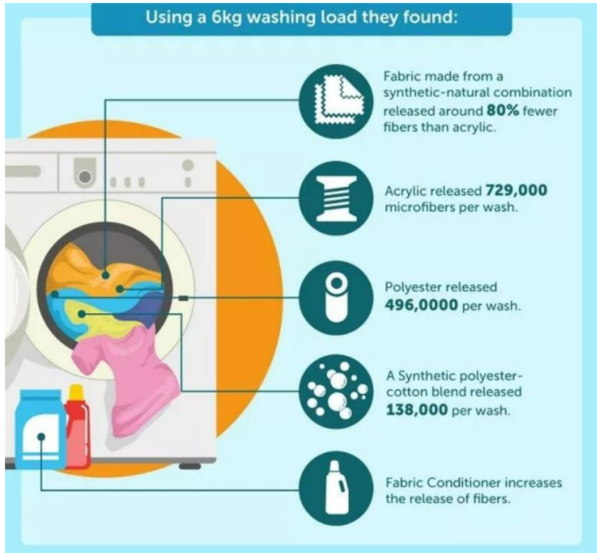
1. Key sources of MPs entering into estuarine environments
2. The physical, chemical and biological modifications that affect MPs
3. Spatial and temporal distributions
4. Issues with comparisons between studies
5. Global & NSR estuaries
6. Ecological risks
7. Overview



United Nations Environment Programme (2021). *Drowning in Plastics – Marine Litter and Plastic Waste Vital Graphics.* https://tinyurl.com/DrowninginPlastics

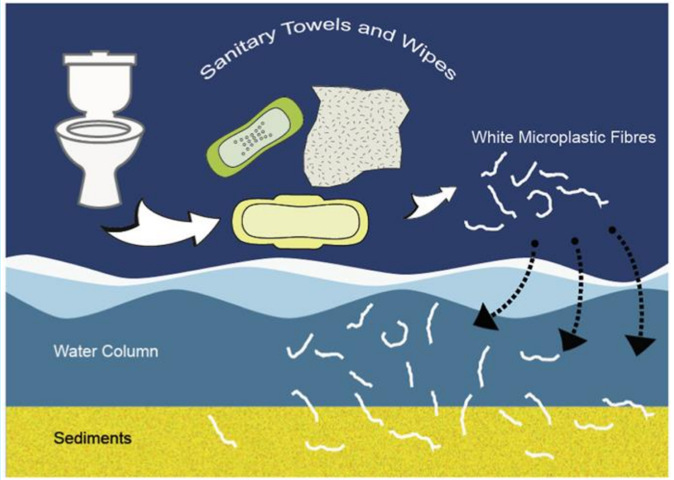
SOURCES

Wastewater



www.helpwithwashing.co.uk

O’Briain et al. 2020. *Wat. Res.* 182



www.helpwithwashing.co.uk

WWTPS can filter up to 99% of MPs.

1-2% escaping in effluent can result in the discharge of billions of MPs

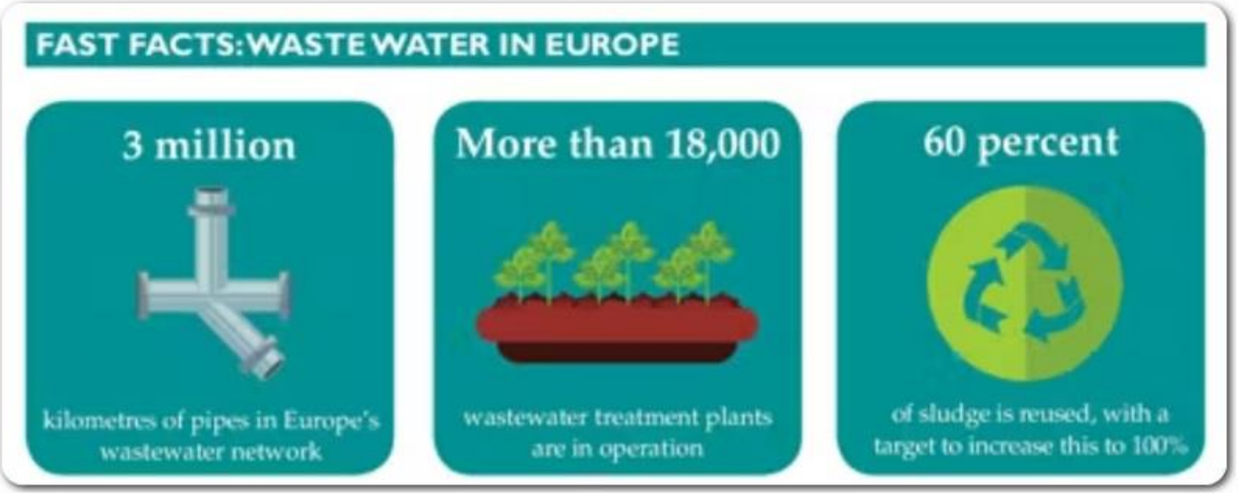
Effluents from 79 WWTPs in Germany suggests discharge rates up to **450,000 MPs m^3** (Schmidt et al. 2020)

Globally WWTPs discharge;

- 41 km^3 year^{-1} - treated & re-used
- **149 km^3 year^{-1} - treated & discharged**
- 170 km^3 year^{-1} - released untreated directly to the environment (Jones et al., 2021)

SOURCES

Sludge & Farm plastic



www.waterworld.com

FAO. 2021. Assessment of agricultural plastics and their sustainability

60% Sludge is applied to agricultural land

***Plans to increase to 100% to improve circular economy**

Regulated by heavy metal limits, nothing for MPs

Farming also uses a lot of plastic that ends up in the soil – e.g. plastic mulch

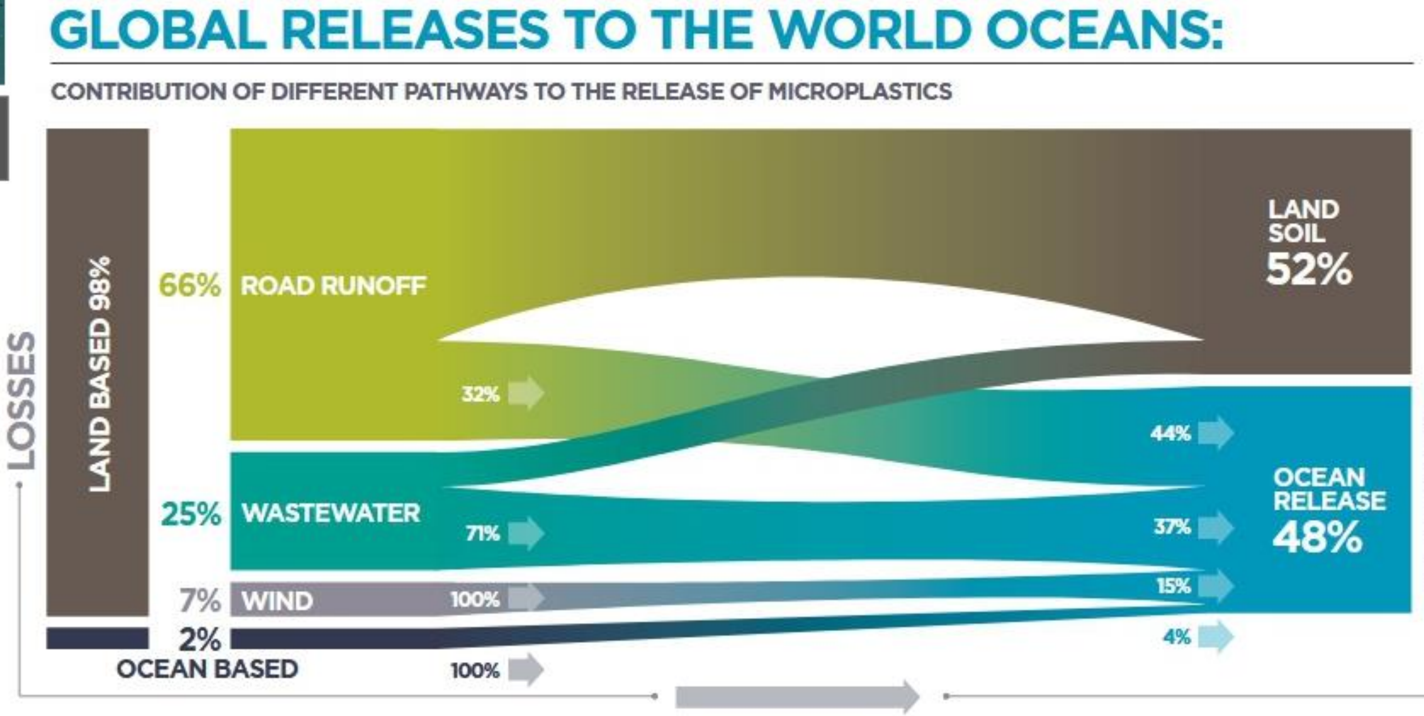
Soil erosion (& flooding) can mobilise these MPs into waterways

SOURCES

Roychand et al. 2020. Jrl. Env. Chem. Eng. 8:1

Plastics from roads – tyres, road markings, dust particles, spillage of MPs

Enter through stormwater drains



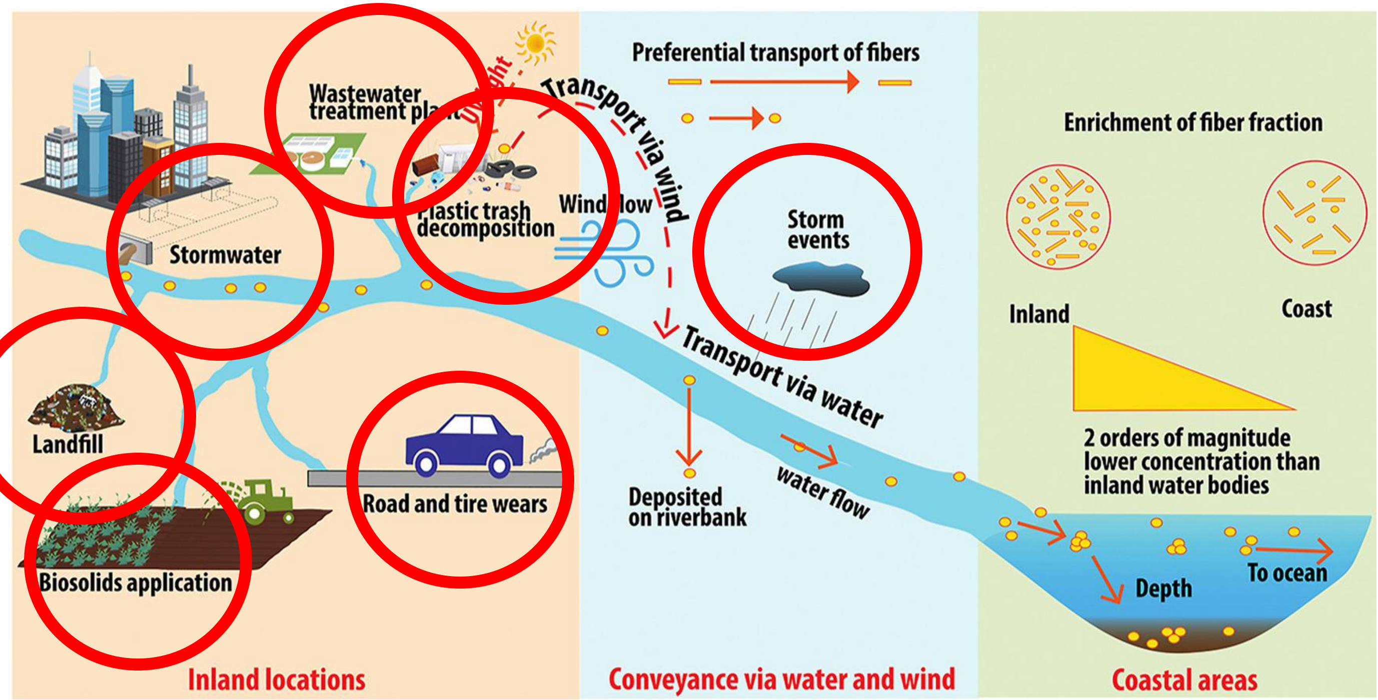
IUCN. 2017 report

IUCN report - estimated direct release of MPs during rain and storm events

44% of global release of MPs into oceans

SOURCES

Other sources



Koutnik et al. 2021. *Env. Poll.* 274

Landfill – MPs from managed waste streams, leachate and atmospheric

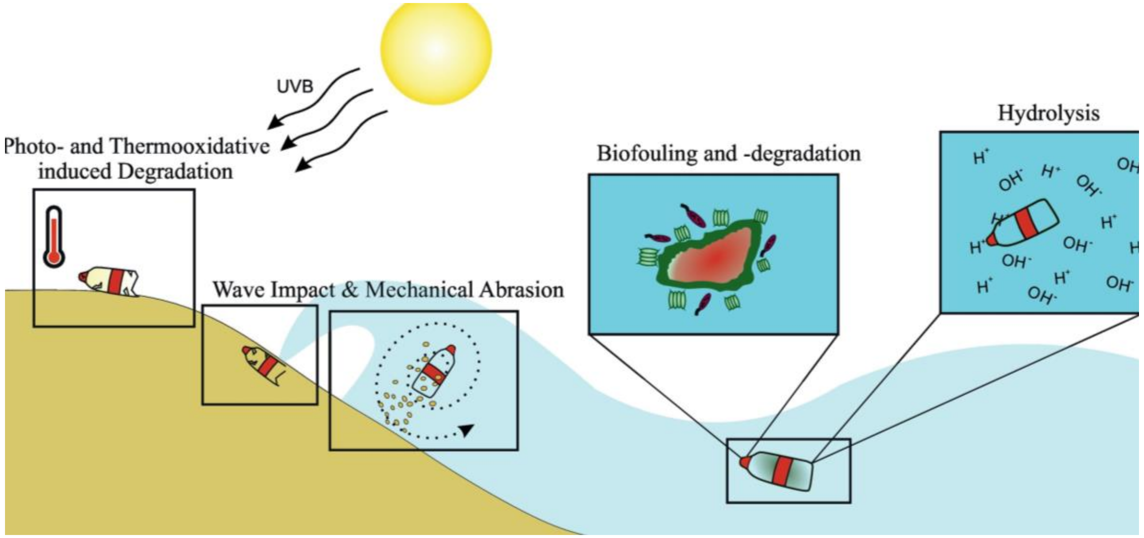
Litter – atmosphere, drains

Inadequate infrastructure – Combined stormwater overflow (CSO) systems

Storms & flooding – Erode soils, increase atmospheric transport

www.wikicommons.org

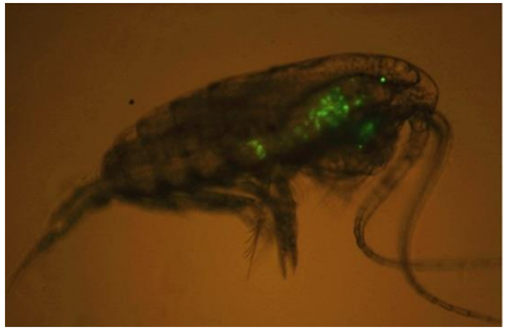
www.wikicommons.org



Born & Brull. 2022. *STE*. 811

Gerritse et al. 2022 *Sci. Rep. 10*

Cole et al.,2016. *ES&T*. 50:6



Physical — Mechanical abrasion

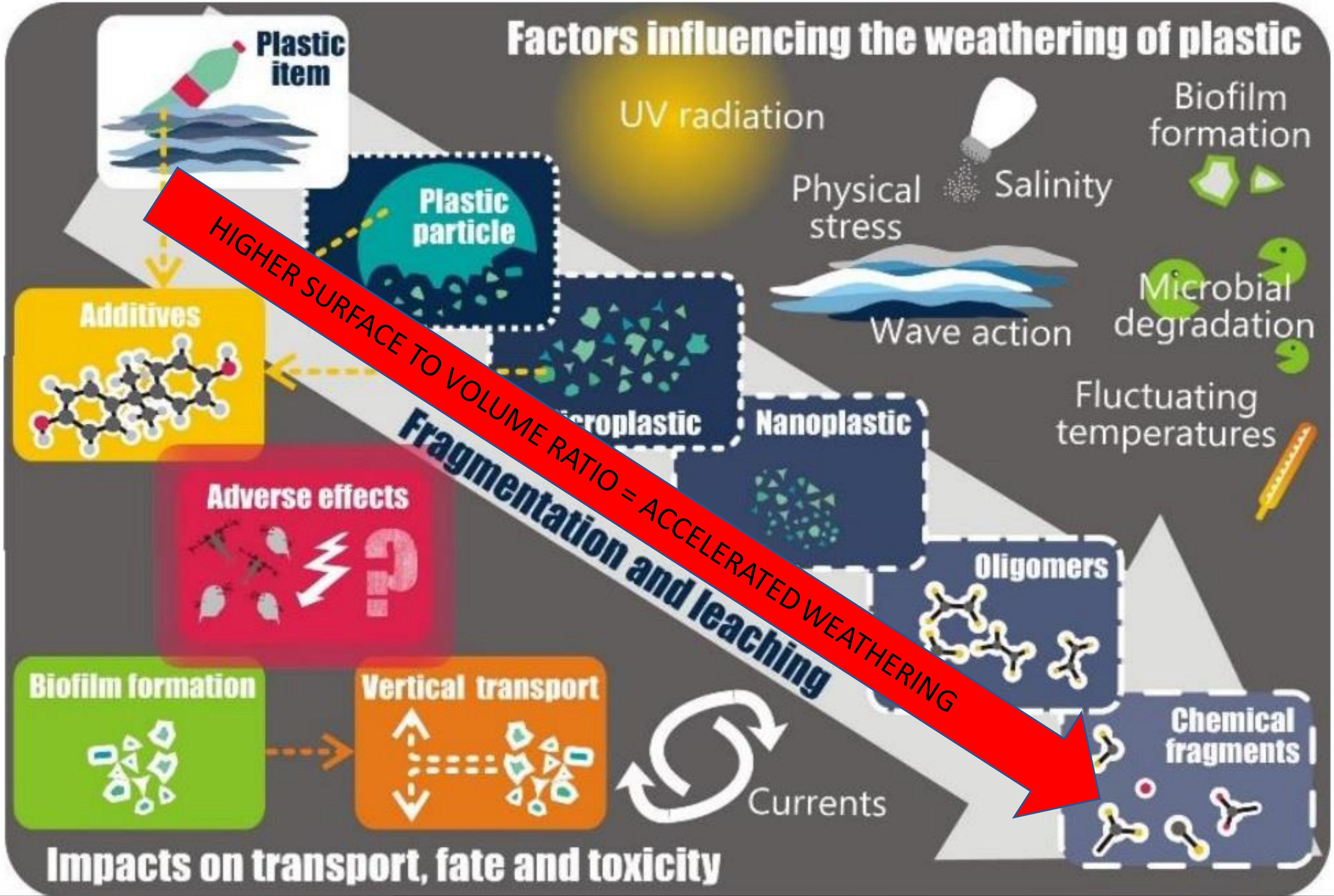
- Waves and currents can physical abrade plastics and MPs
- UV weathering

Chemical — Photo-oxidation & hydrolysis

- Alters mechanical and physico-chemical properties of the surface
- Formation of polar functional groups such as carbonyl groups

Biological — Microbial degradation

- Biofouling microbes can produce enzymes that can degrade certain polymers
- Ingestion of MPs subjects them to gut enzymes and can strip them of biofilm

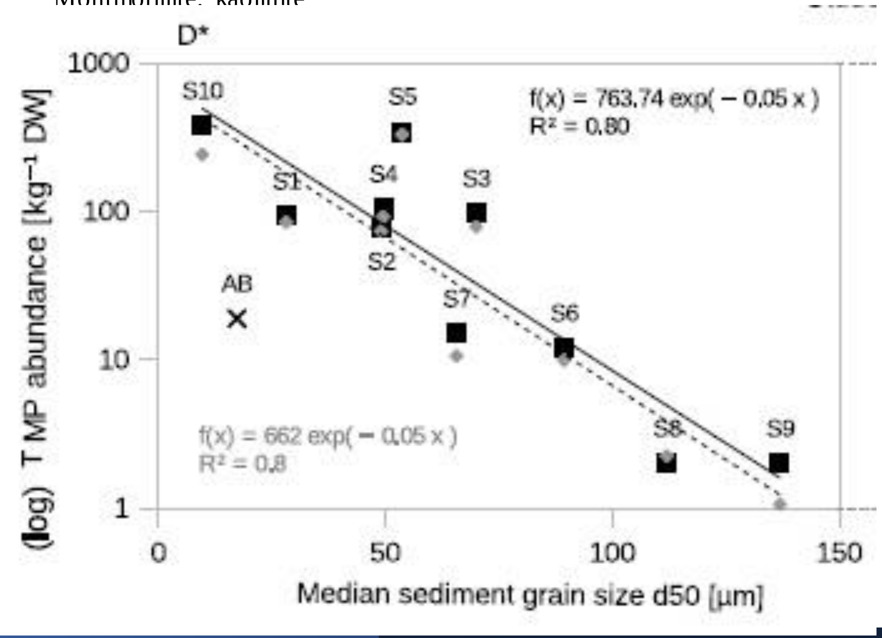


Jahnke et al. 2017. ES&T. 4:3

PHYSICAL, CHEMICAL & BIOLOGICAL MODIFICATIONS

Physico-chemical drivers of spatio-temporal distributions

Polymer type	Density (g/cm^3)	Common plastic names
Polypropylene (PP)	0.92	Rope, bottle caps,
Polyethylene (PE)	0.95	Plastic bags
Polystyrene (PS)	1.01-1.09	Floats, containers
Polyamide (PA)/Nylon	1.15	Fishing nets, clothing
Cellulose acetate	1.24	Cigarette filters
Polyvinyl chloride (PVC)	1.3	Plastic film
Polyester	1.35	Clothing
Polyethylene terephthalate (PET)	1.39	Clothing, carpets, bottles
Rayon (semi-synthetic)	1.5	Clothing
Natural particles		
Organic matter	0.9-1.3	Algae, plants, wood
Clays	1.7-2.68	Montmorillite, kaolinite
Quartz sand	2.65	
Calcite	2.71	
Aragonite	2.95	



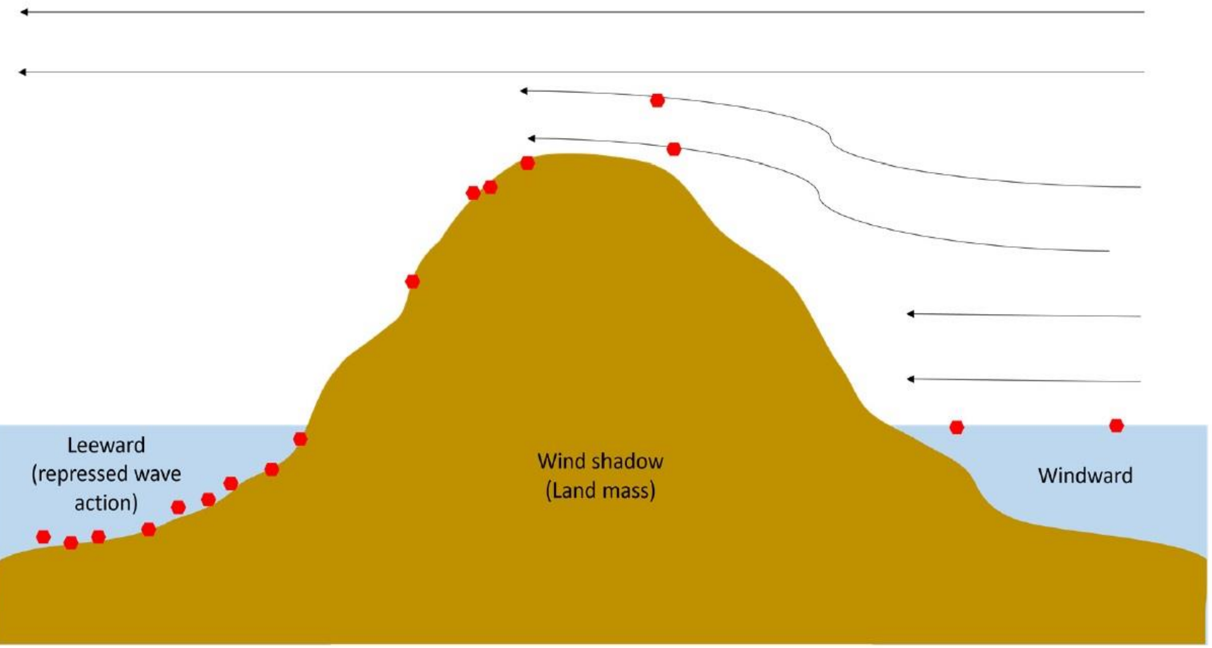
Enders et al. 2019. *Sci. Rep.* 9:1

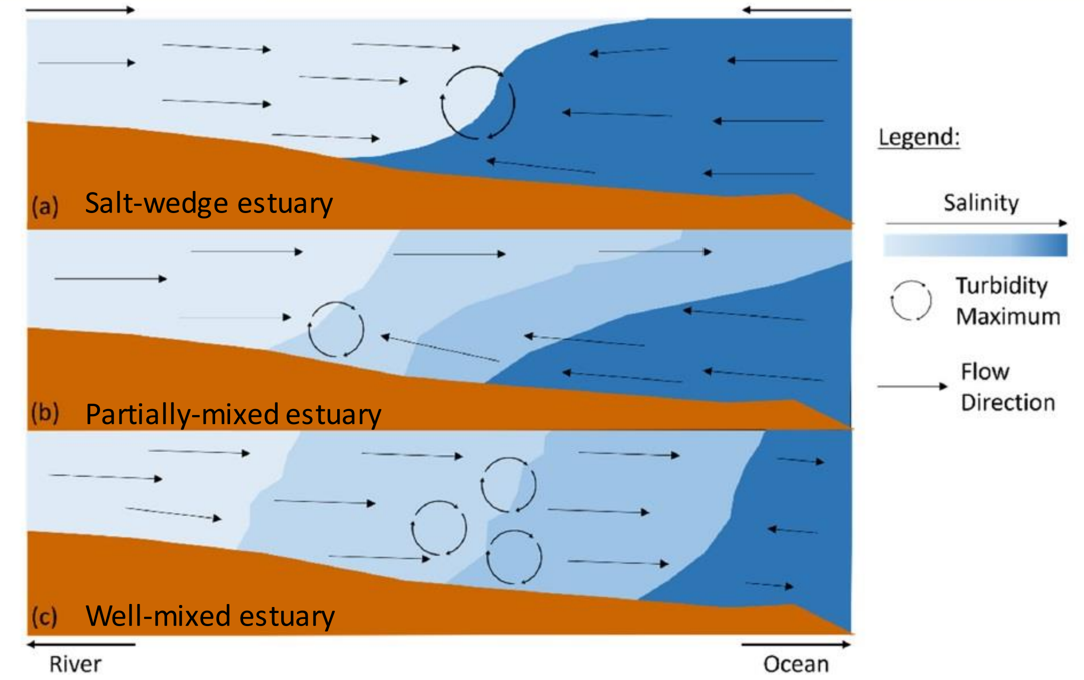
Plastics are light, somewhat similar densities to organic matter and clay particles.

Our knowledge of sediment transport dynamics can be used

Low density particles tend to settle out in low flow depositional areas (with fine sediments)

However MP modifications and interactions alter MP behaviour





Malli et al. 2022. MPB. 177

Physico-chemical drivers of spatio-temporal distributions

Wind, waves, currents – Direction, magnitude of flow

Tidal effects – asymmetry (flood/Ebb dominated), spring/neap cycles

Circulation patterns & TMZ – high MP concentrations in the water column, many MPs deposit

Salinity gradient – differences between estuaries

Constant et al., 2021. *ES&T.* 55:9

Influence of management activities on spatio-temporal distributions

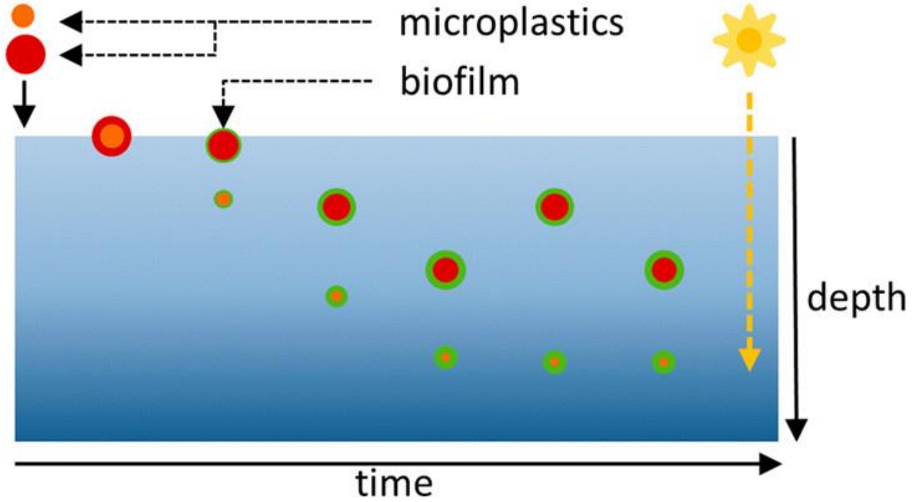
Dredging – removal of sediment to dumping sites on land or at sea

0.98-2800 MPs kg^{-1} sed (Aa River, France)

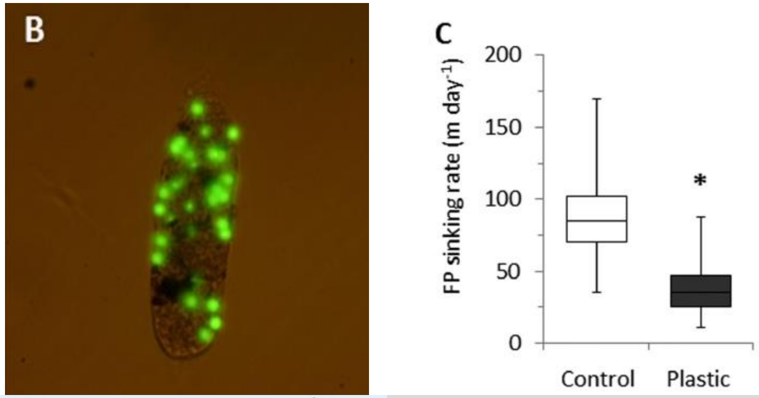
Estimated up to 9 tons of plastic dumped at a single site

MP resuspension – dredging causes resuspension of fines & other contaminants

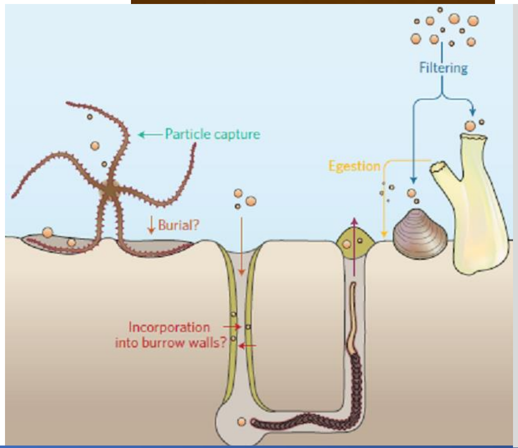
Biological drivers of spatio-temporal distributions



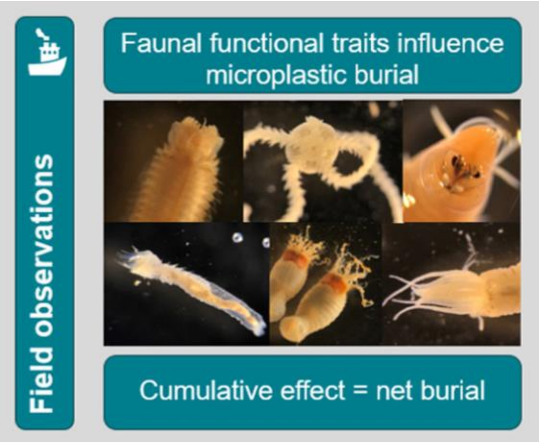
Kooi et al. 2017. *ES&T.* 51:14



Cole et al., 2016. *ES&T.* 50:6



Galloway et al. 2017



Coppock et al. 2021. *Jrl. Haz. Mat.* 415

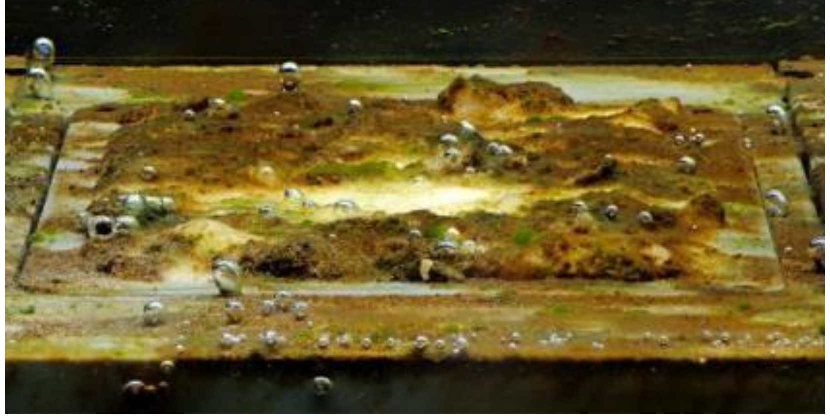
Biofouling – the formation of biofilms will alter settling rates as MPs are transported through estuaries

Ingestion & fecal pellets – Significant changes in the sinking rates

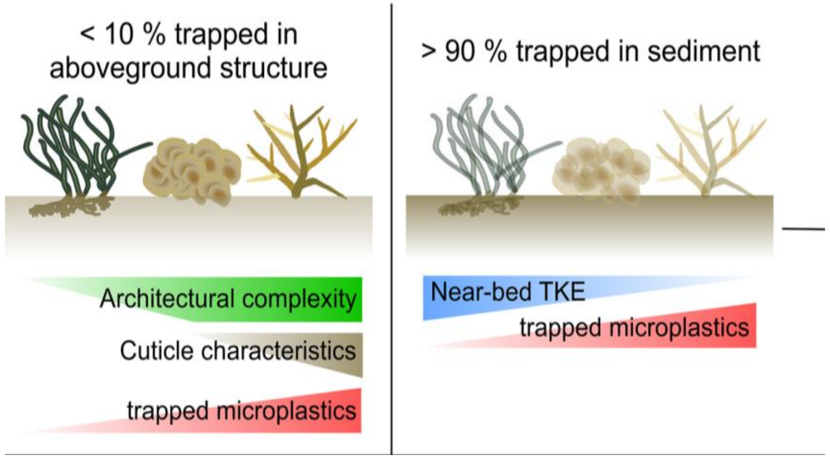
Filter feeding – Suspension feeders can capture MPs from the water column

Bioturbation – benthic invertebrates in the bed can bury MPs to deeper layers

Biological influence spatio-temporal distributions



Gerbersdorf



De Smit et al. 2021. *STE.* 772

www.rspb.org (Whimbel eating shellfish

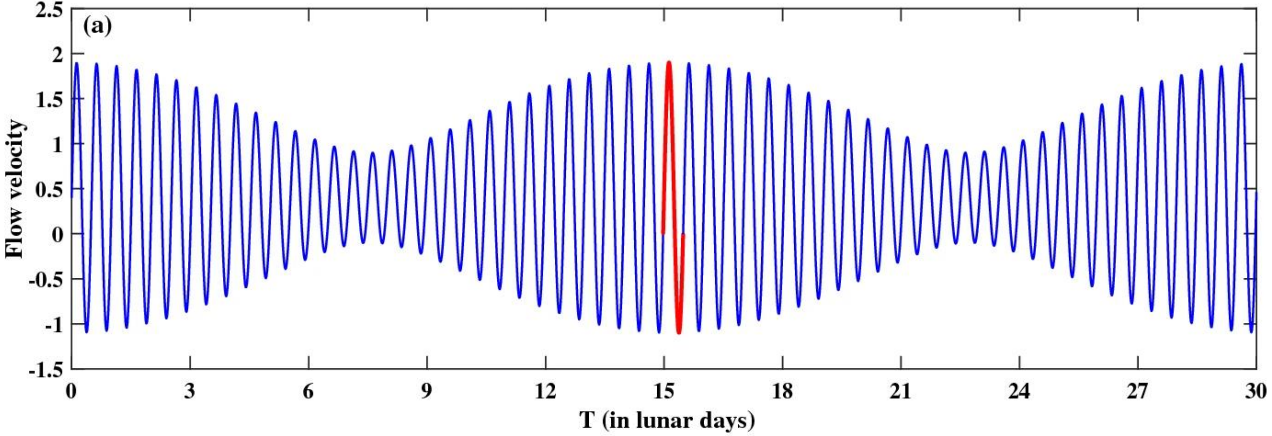
Benthic biofilms – MPs can stick on surface biofilms that mediate MP resuspension *(More in session 4)*

Vegetation & reefs (Biogenic habitats) – saltmarsh, seagrass, mussel & oyster beds, corals can all trap MPs (up to 90% in the underlying sediment)

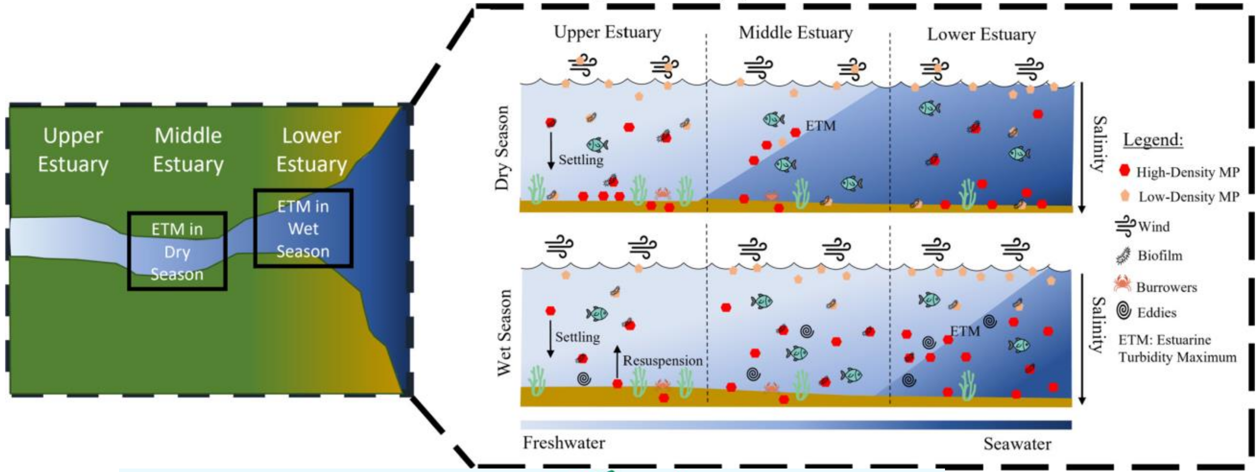
Fauna – Ingestion, migration, trophic interactions

Temporal dynamics

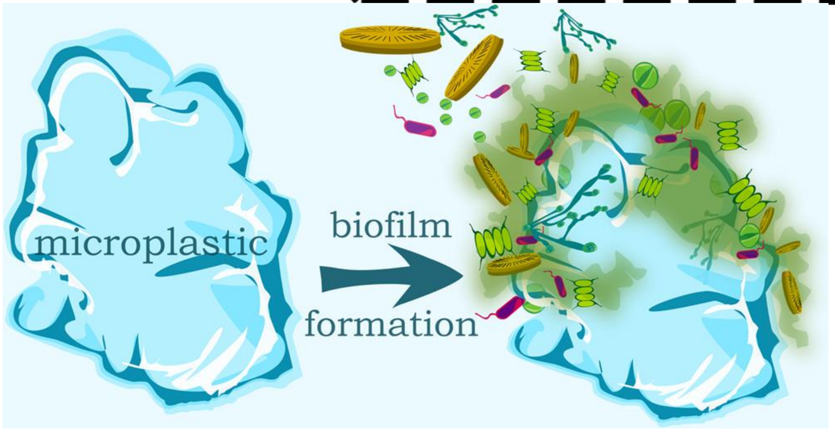
Al-Kasbi. 2022. Env. Fl. Dyn. 22:!



Malli et al. 2022. *MPB.* 177



Rummel et al. 2017. *ES&T.* Let. 4:7



Tidal trapping - Variability in MP distributions over tidal cycles and phases (springs/neaps, flood/ebb)

Seasonal effects – Changes in TMZ, but also biofilm formation (WC & bed)

Interannual variation –

Firth of Forth: 30 & 440 MPs Kg^{-1} Sed in 2016 & 2017 (Blumenröder et al., 2017)

Tokyo Bay: 5385 & 243 MP kg^{-1} Sed in 2012 & 2014 (Uddin et al., 2020)

Contents lists available at ScienceDirect
Marine Pollution Bulletin
journal homepage: www.elsevier.com/locate/marpolbul

Comparison of microplastic isolation and extraction procedures from marine sediments[☆,☆☆]

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Contents lists available at ScienceDirect
Environment International
journal homepage: www.elsevier.com/locate/envint

Moving forward in microplastic research: A Norwegian perspective

Amy L. Lusher[a,b,*], Rachel Hurley[a], Hans Peter H. Arp[c,d], Andy M. Booth[e], Inger Lise N. Bråte[a], Geir W. Gabrielsen[f], Alessio Gomiero[g], Tânia Gomes[a], Bjørn Einar Grøsvik[h], Norman Green[a], Marte Haave[g,i], Ingeborg G. Hallanger[f], Claudia Halsband[j], Dorte Herzke[k,l], Erik J. Joner[m], Tanja Kögel[b,h], Kirsten Rakkestad[n], Sissel B. Ranneklev[a], Martin Wagner[o], Marianne Olsen[a]

Chapter 8
Methodology Used for the Detection and Identification of Microplastics—A Critical Appraisal

Martin G.J. Löder and Gunnar Gerdts

M. Bergmann et al. (eds.), *Marine Anthropogenic Litter*,
DOI 10.1007/978-3-319-16510-3_8

Comparisons between studies

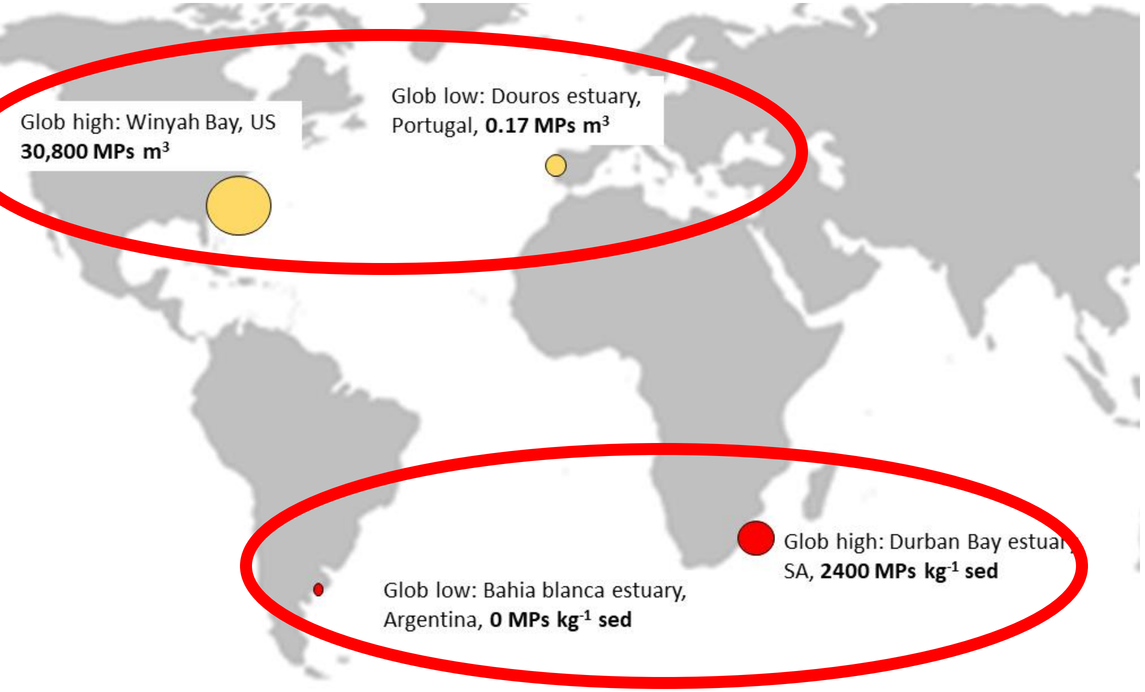
Several studies use different units (sediment)
– mass (g MPs) Vs counts (items MPs)
– areal (m^2, m^3) Vs weight (kg^{-1} Sed)

Different collection, extraction and identification methods

Conversions difficult

Here I only present studies that presented their data as;
- Counts (MPs) kg^{-1} DW sediment.
- Counts (MPs) m^3 water
- Counts (MPs) ind^{-1} organism

Global & NSR estuaries



Global estuarine waters

0.17 MPs m^3, Douros estuary, Portugal
– 30,800 MPs m^3 Winyah Bay, US

Global estuarine sediments

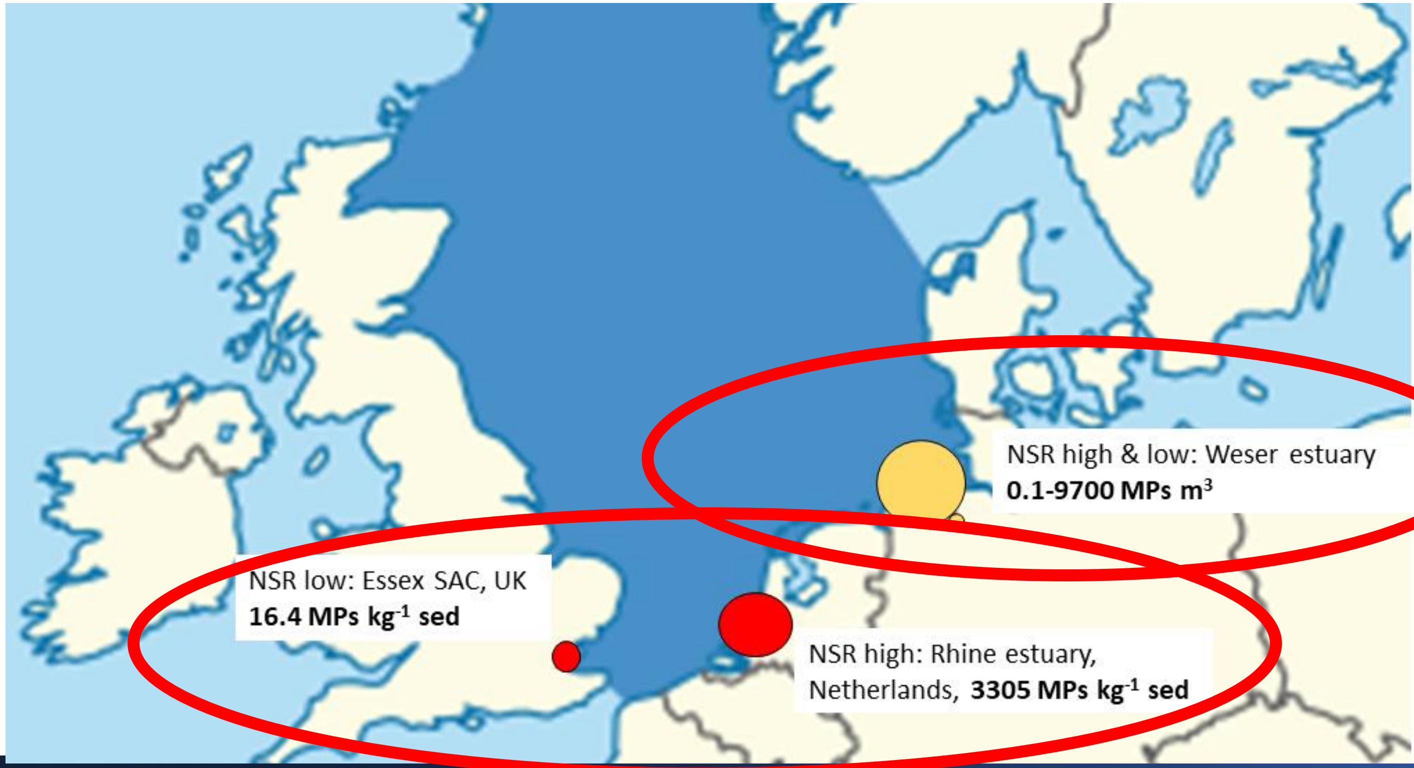
0 MPs kg^{-1} Sed, Bahia Blanca estuary, Argentina
– 2400 MPs kg^{-1} Sed, Durban Bay estuary, SA

NSR estuarine waters

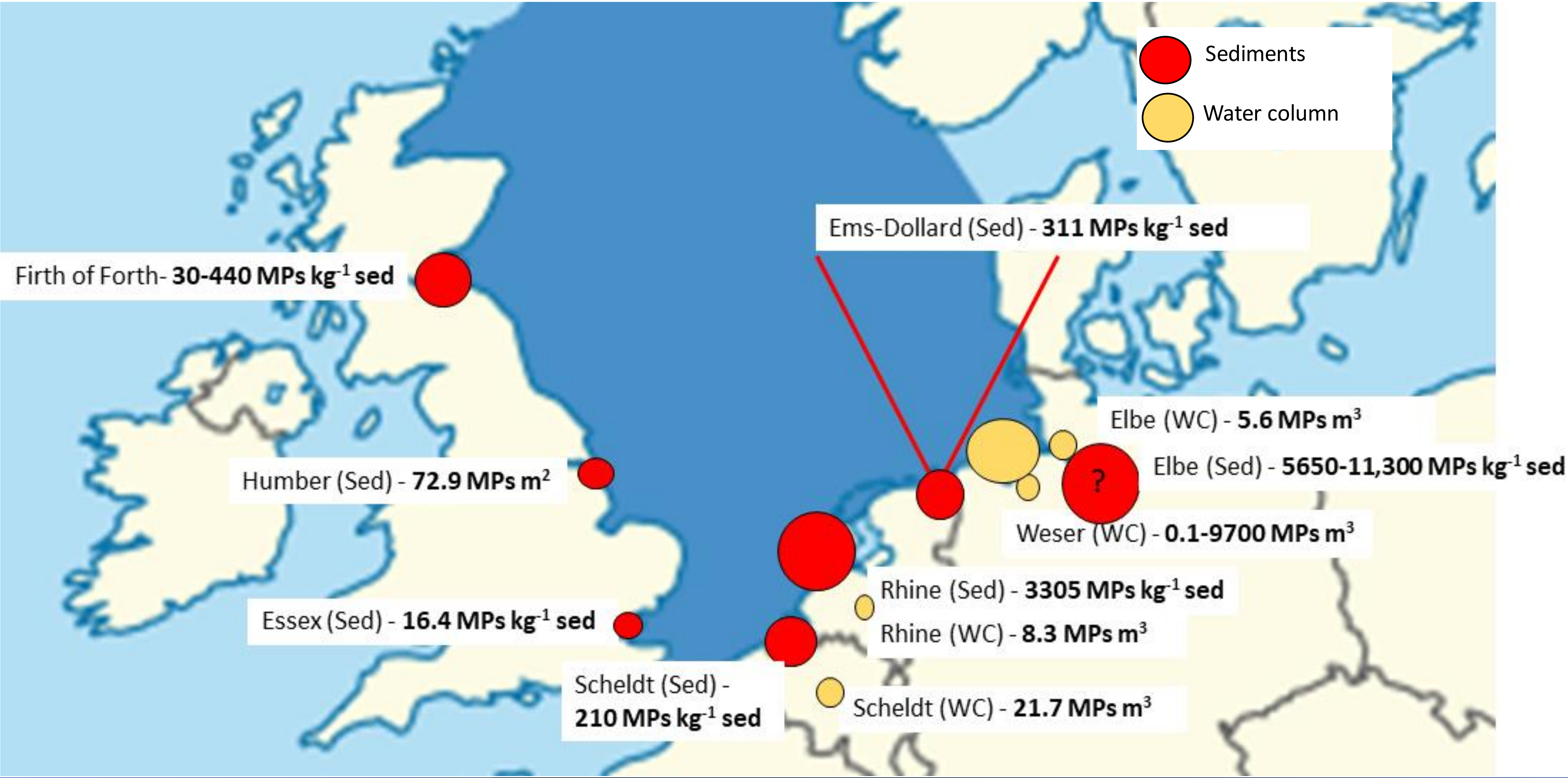
0.01 – 9700 MPs m^3, Weser estuary to North Sea

NSR estuarine sediments

16.4 MPs kg^{-1} Sed, Essex SAC (subtidal)
– 3305 MPs kg^{-1} sed, Rhine estuary, Netherlands



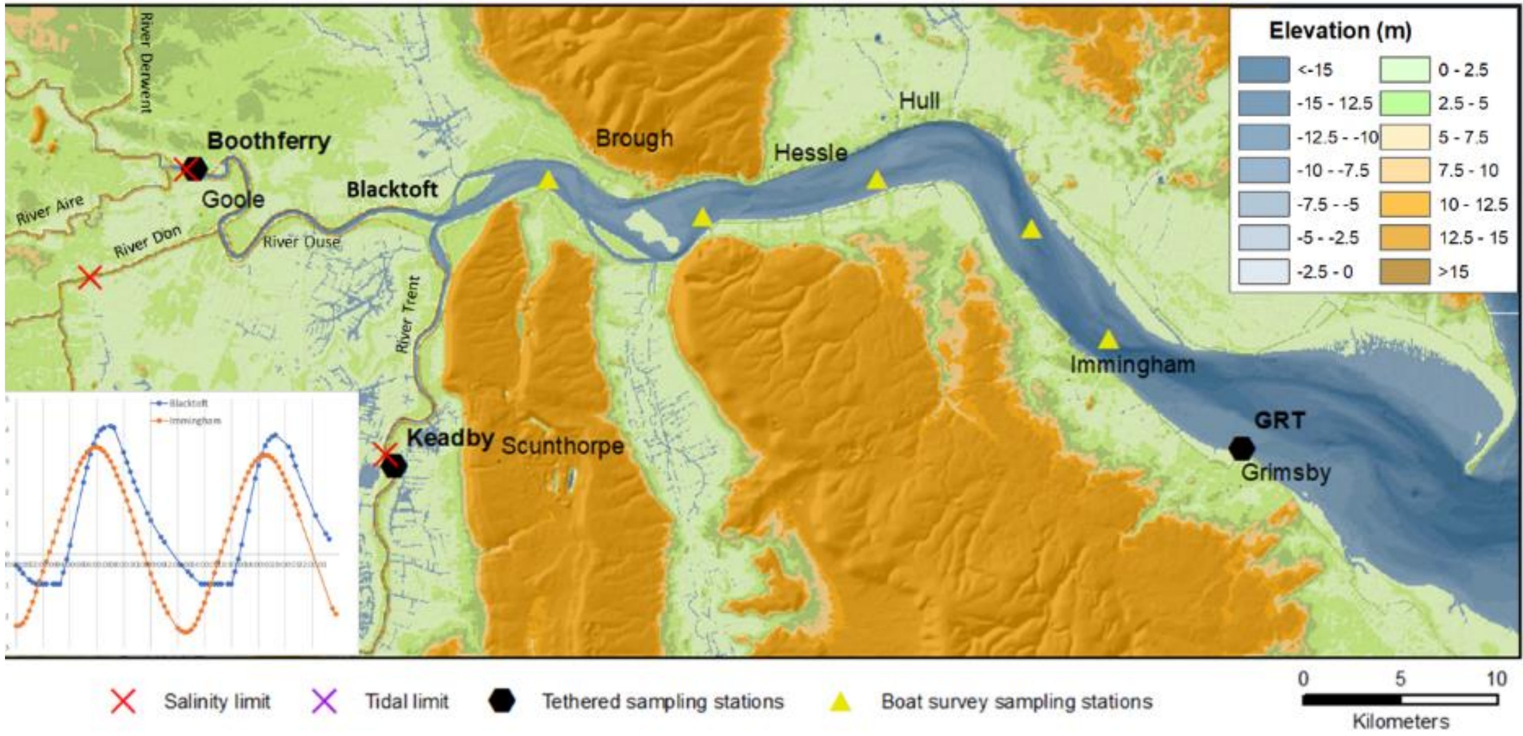
NSR estuary sediments & water samples



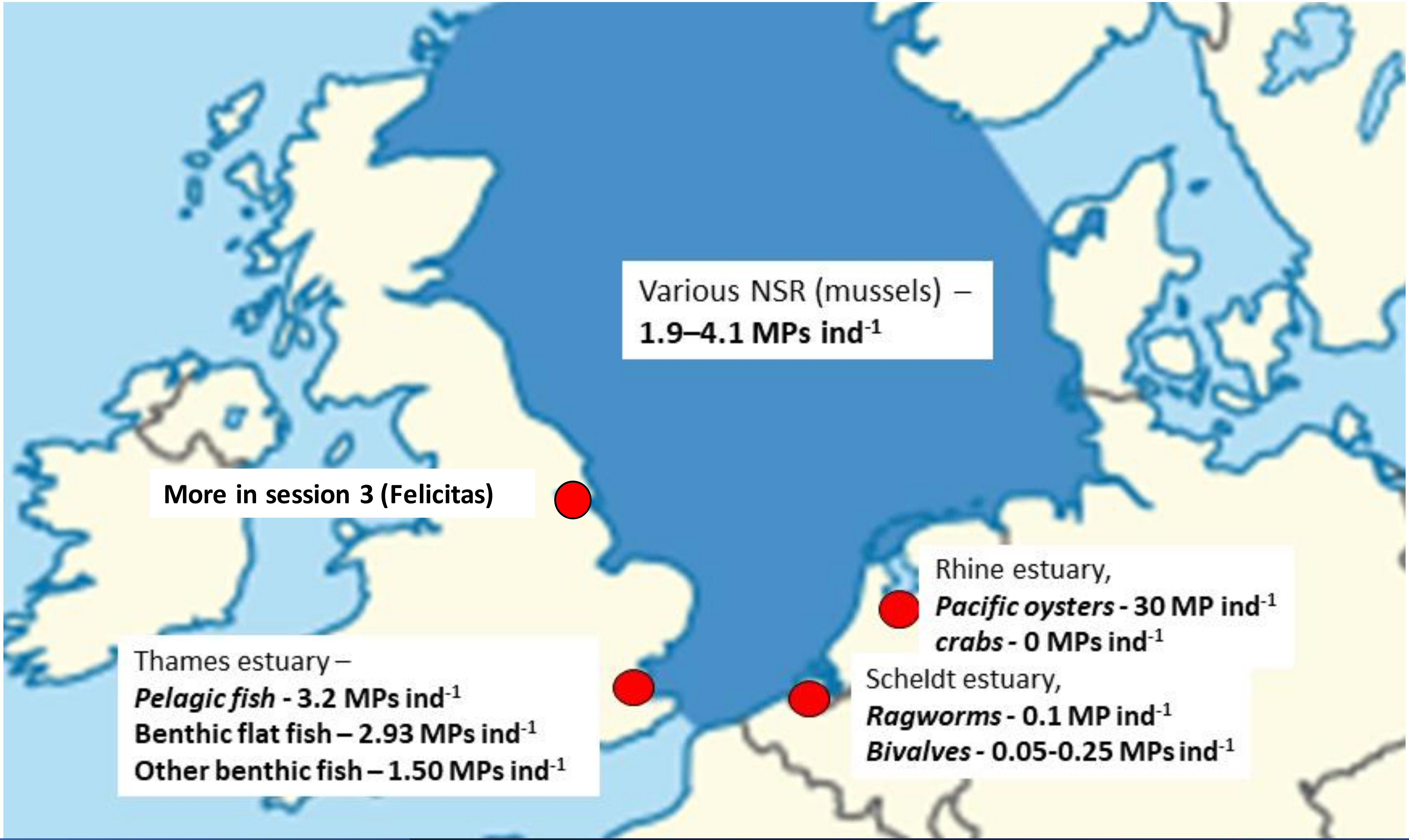
Spatio-temporal trends of MPs in the Humber

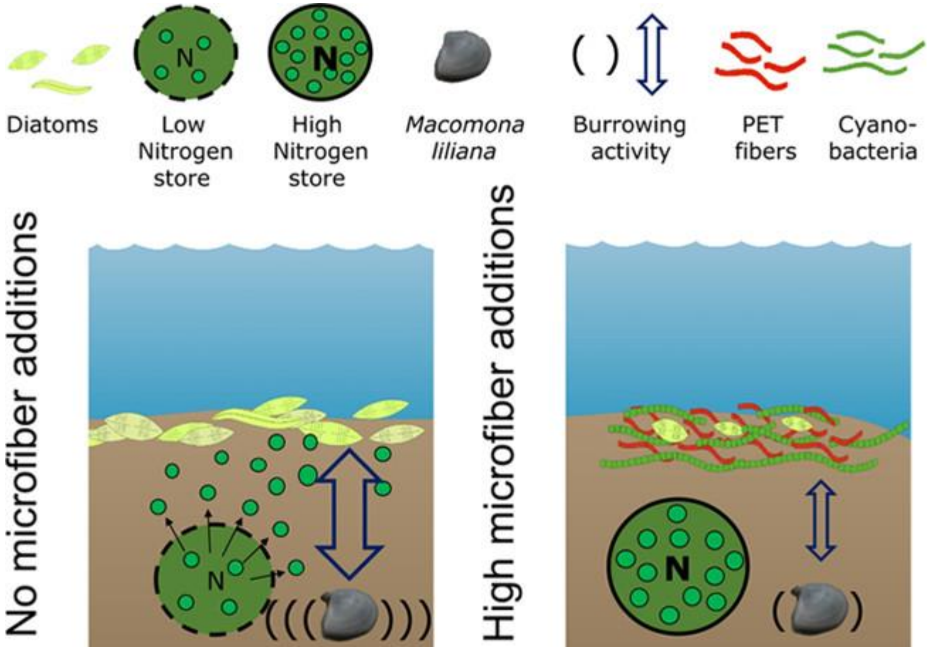
Samples for suspended sediment concentration and water quality (IMMERSE)

- Quantify MP concentrations and identify polymers
- Relate to water quality parameters

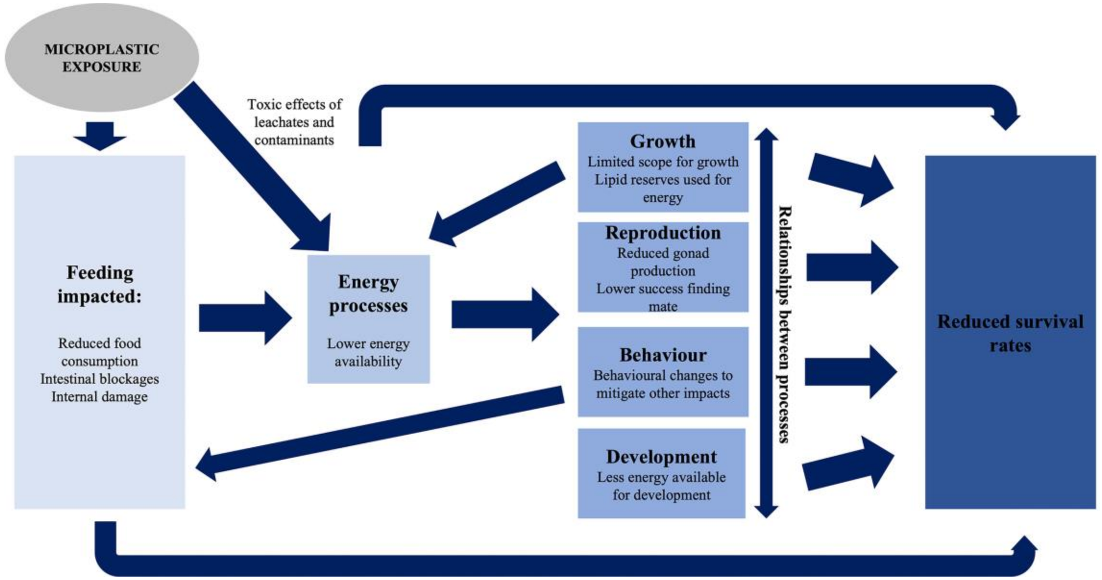


NSR estuarine biota





Hope et al. 2020. *ES&T.* 54:13



Mason et al. 2022. *STE.* 845

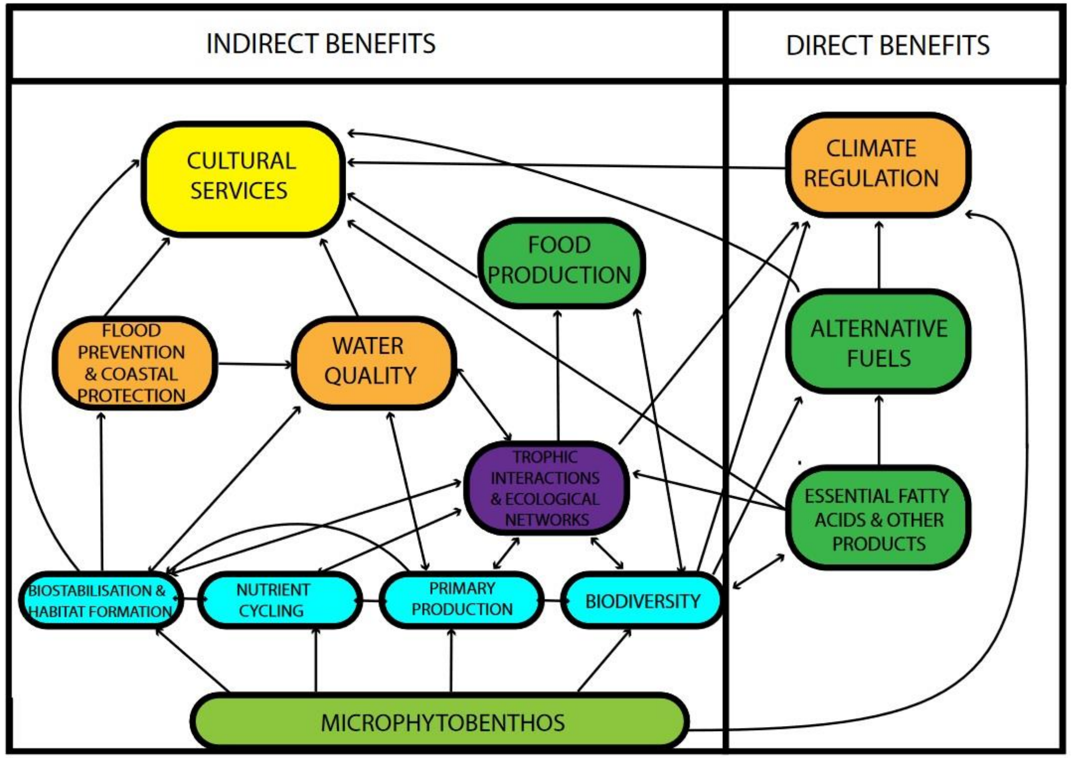
Are MPs a threat to NSR estuaries?

We don't know true extent of the risks - inconsistent findings & methods

Changes to benthic primary producers – community structure changing, interactions with fauna, function

Key fauna negatively affected – Changes to activity levels, behaviour, growth, reproduction, productivity, survival

Need more information on whole *in situ* communities



Hope et al., 2019. *Jrl. Ecol.*

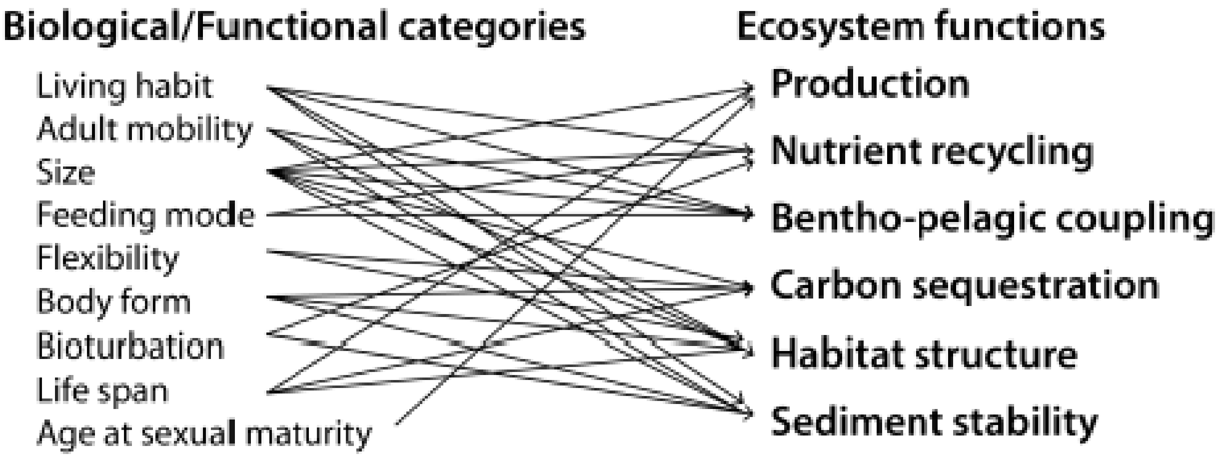
Ecosystem processes & function

Benthic microorganisms and fauna underpin various ecosystem functions

Changes to their activity, behaviour, growth, reproduction, productivity

May influence how estuaries function

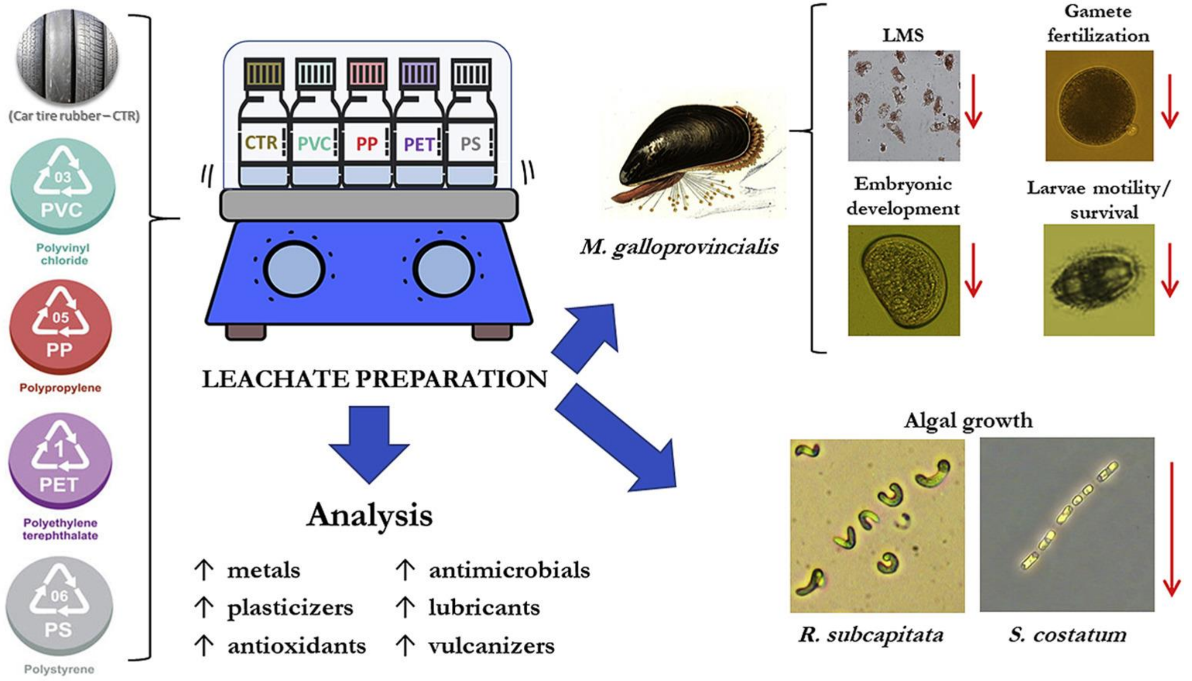
May affect how estuaries cope with other stressors



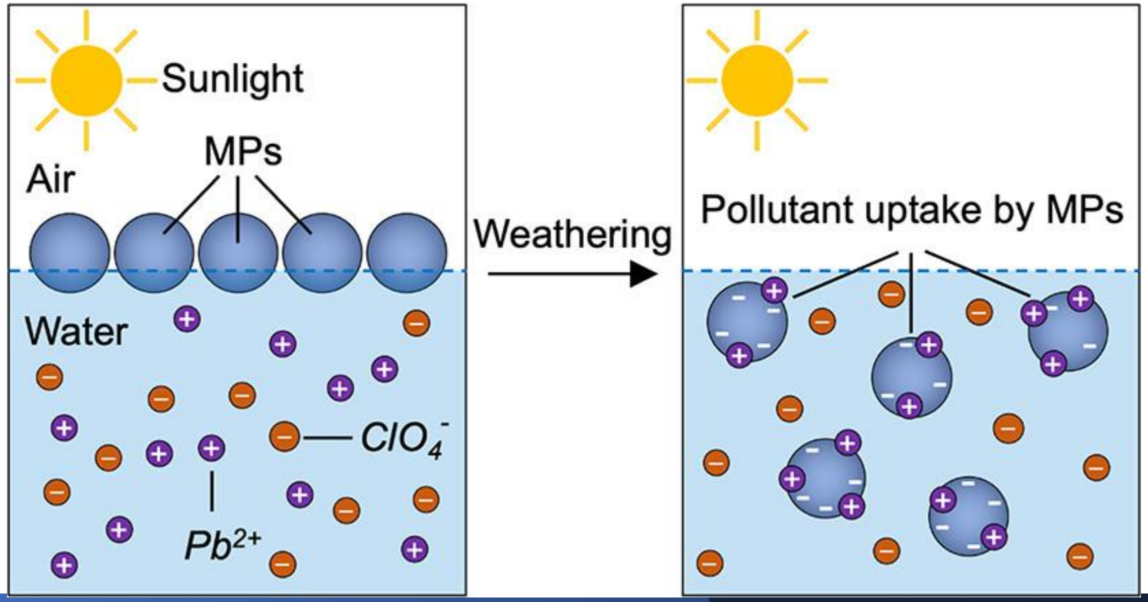
Hewitt et al. 2014. DOC report. NIWA. Report No: HAM2014-001.

Interaction with other contaminants

Capolupo et al. 2020. *Wat. Res.* 169



Al Harraq et al. 2022. ACS. Env. Au. 2:6



Leach additives and chemicals - differences between polymers

Negative effects on algae and fauna

High affinity for contaminants - increases with ageing and decreasing size

Transport and bioavailability of PAHS, POPs, Heavy Metals, Pathogens

Summary

MPs enter from a variety of sources

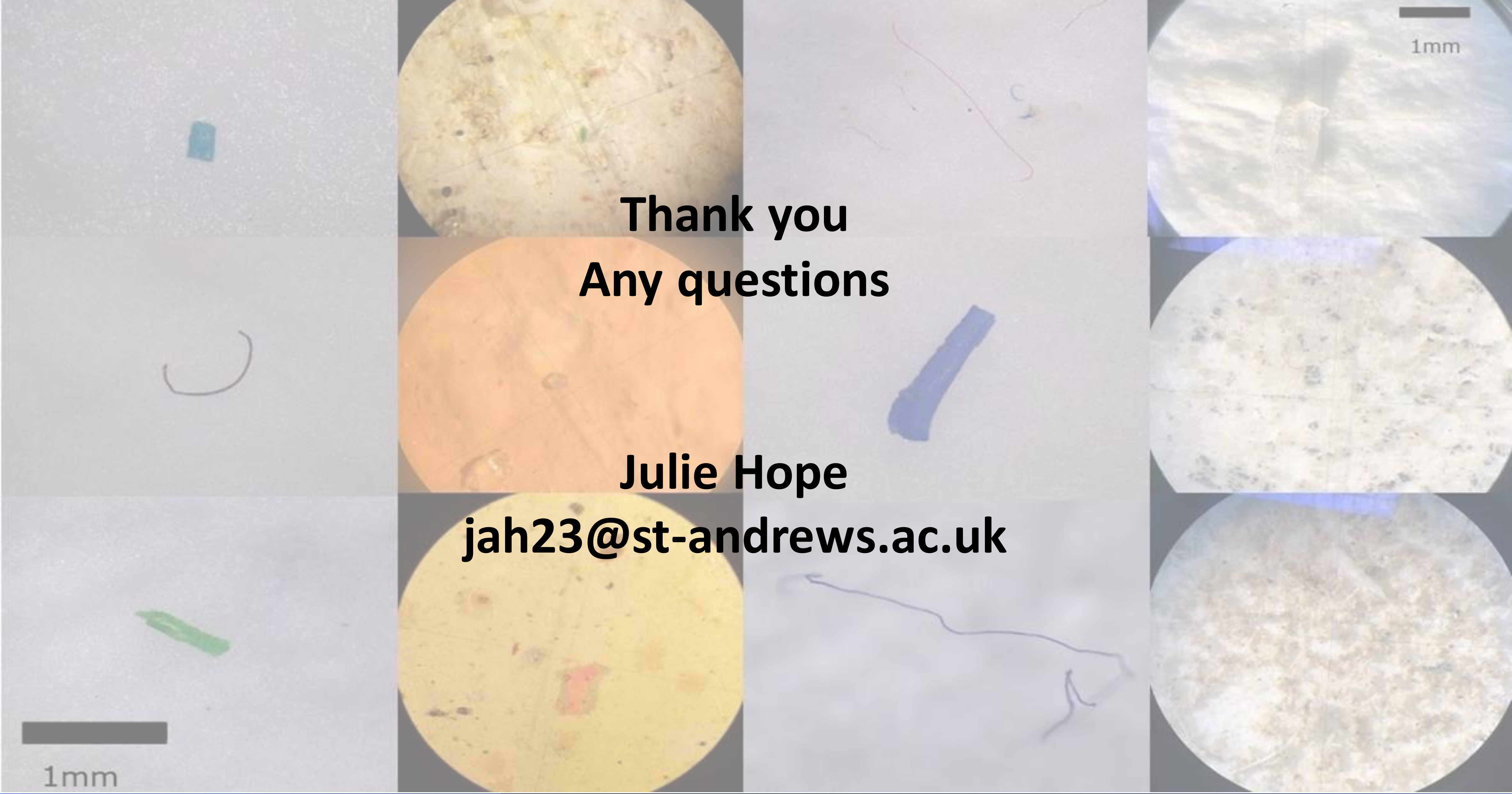
Various physical, chemical and biological modifications

These modifications act to alter the behaviour of MPs, their transport and fate in estuaries

NSR estuaries are comparable to other systems - MP concentrations in estuarine waters, sediment, biota

MP effects on key estuarine biota may lead to ecosystem scale effects, but we need more field evidence

Need to understand how MP pollution interacts with other stressors



Thank you
Any questions

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