Microplastic Transport between Land and Sea

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Overview

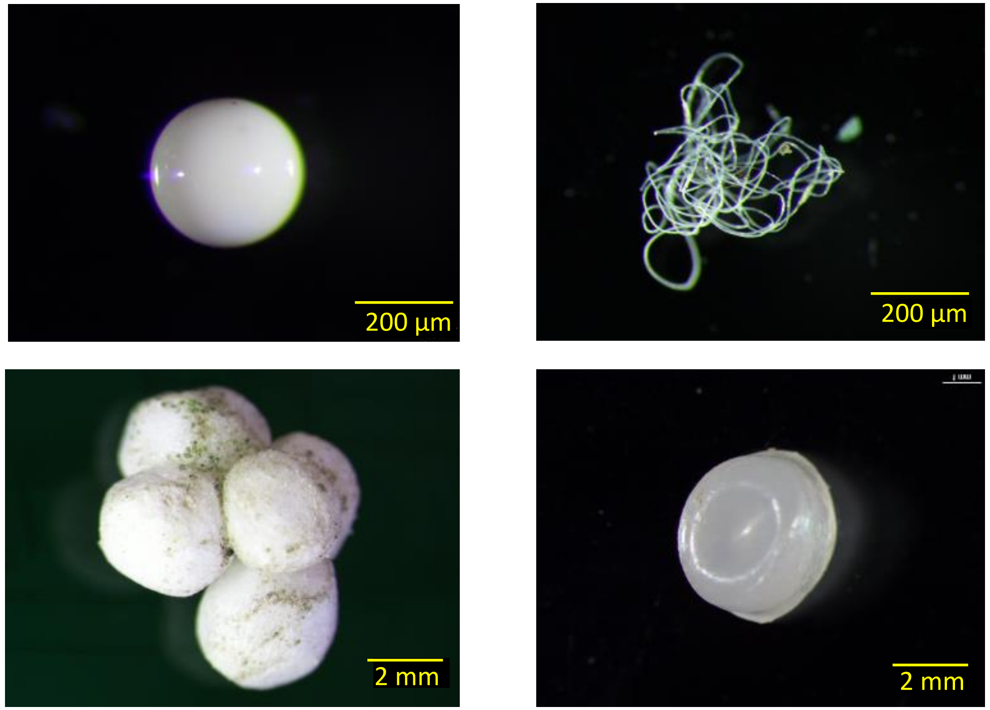
1. Introduction
2. Sources and Pollution on Land
3. Sources and Emissions to Rivers
4. Retention within Rivers
5. Estuaries: Sink or Source?
6. Lessons Learnt

1. Microplastic – Definition

Microplastic = synthetic polymer particles <5 mm

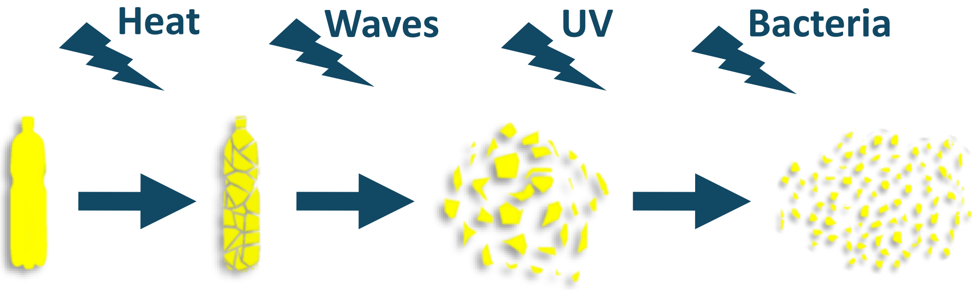
Primary microplastic

- Intentionally produced in this size class

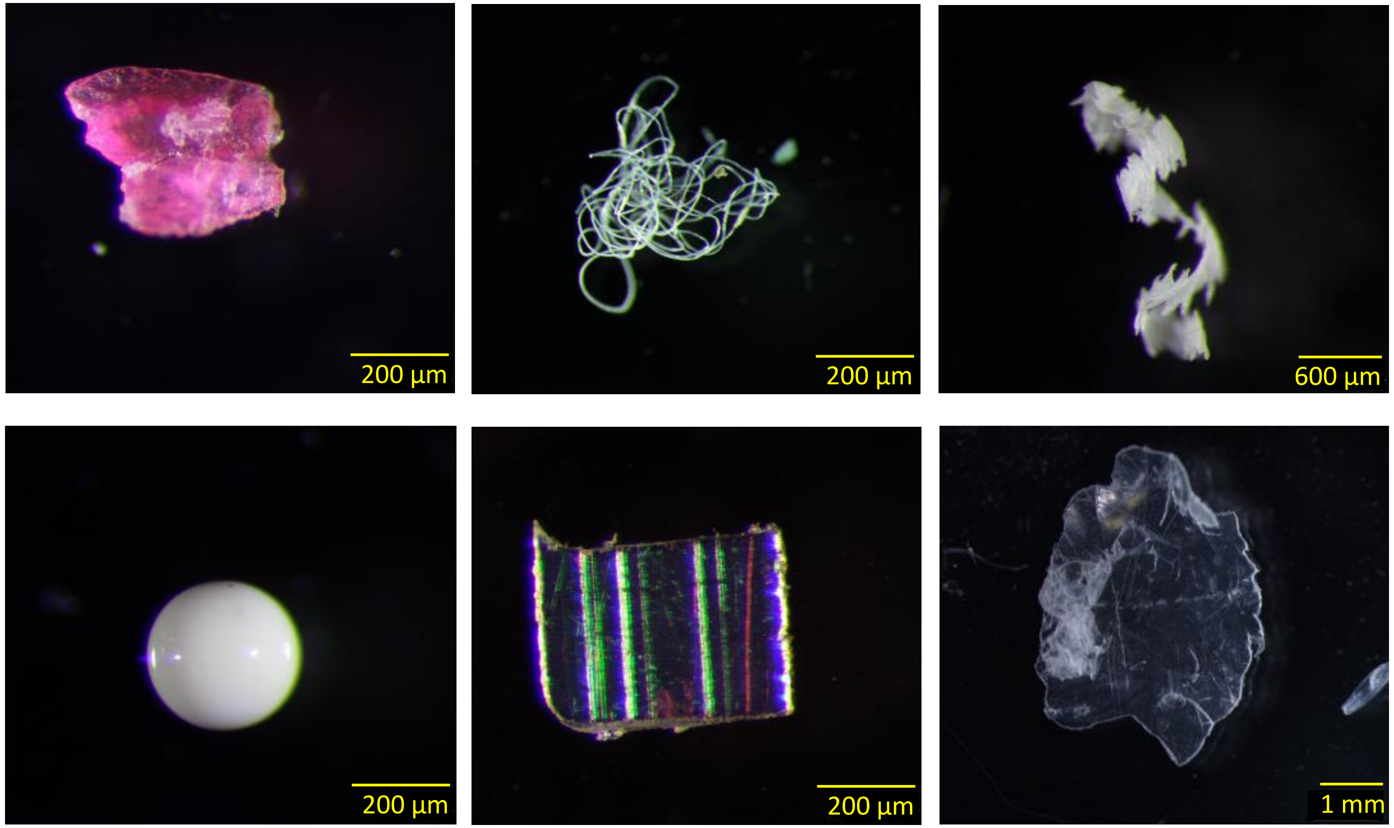


Secondary microplastic

- Fragmentation as origin of secondary microplastic



1. Microplastic – Properties



- ➢ Heterogeneous mix of various polymer types, sizes, densities, and shapes
- ➢ Various additives and material compositions
- ➢ High effort for sampling and analysis
- ➢ No standardized methods so far

The highly variable properties of microplastic

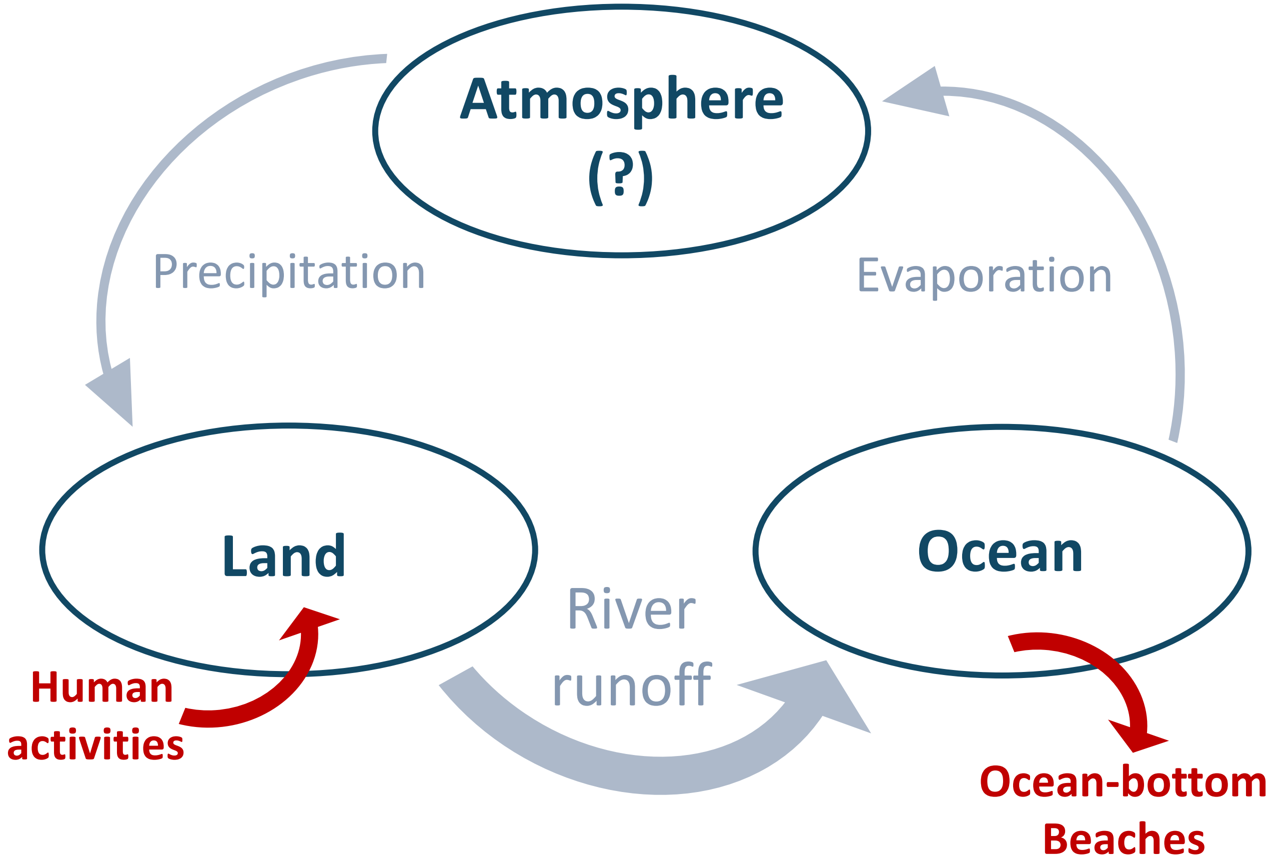
- ➢ **make sampling and analysis and therewith comparisons among studies difficult**
- ➢ **lead to a wide variety of distribution patterns and interactions with the environment**

1. Microplastic – General Overview

Political and social demand

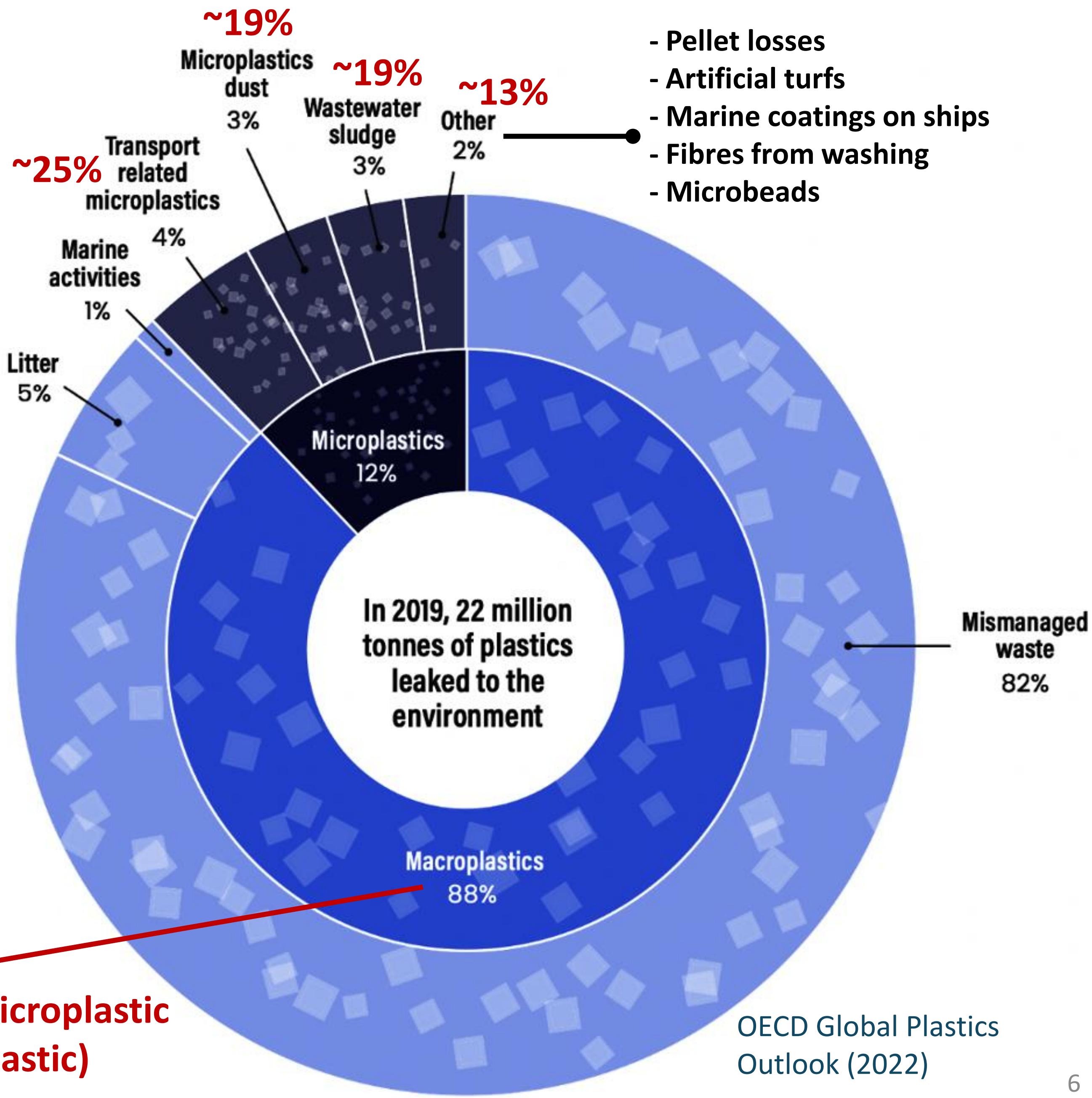
- ➢Effects controversially discussed
- ➢Potential risk for human health
- ➢Perceived as an environmental risk
- ➢Policy demand to identify sinks and sources and to develop mitigation measures

Conceptual model of microplastic flow in the water cycle



2. Major Sources on Land

- **Mismanaged waste**
- **(Un)intentional littering:** industrial spills, dumping, festivities…
- **Road transport**: tyre abrasion, eroded road markings…
- **City dust**: paint wear, textile dust, abrasion of shoe soles…
- **Microplastic-containing fertilizers:** wastewater sludge…



- Pellet losses
- Artificial turfs
- Marine coatings on ships
- Fibres from washing
- Microbeads

~4% fragmented to microplastic (~25% of microplastic)

OECD Global Plastics Outlook (2022)

Photo: A. Leibner

2. Major Sources – Agricultural Soils

Sewage sludge:

- >90% of particles in wastewater are retained in sewage sludge
- Used as fertilizer, this microplastic ends up on agricultural soils
- Amounts in soil increase with number of applications
- BUT: restrictions in use of sewage sludge as fertilizer will reduce microplastic inputs on farmland in Germany

Compost:

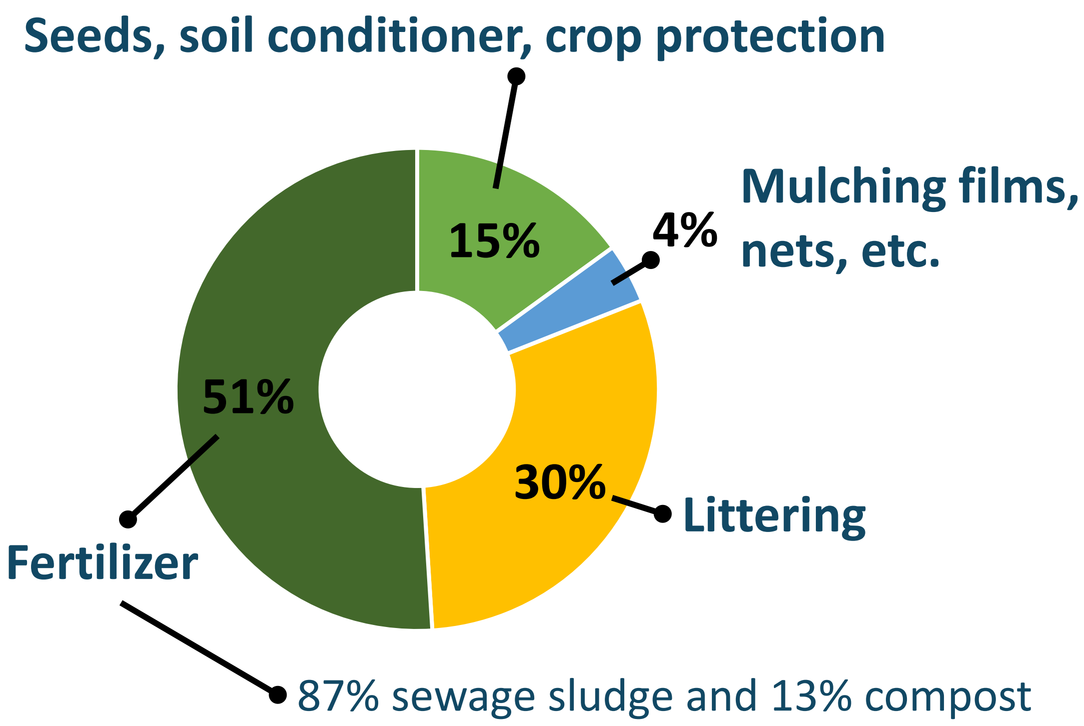
- Organic fertilizer from biowaste digestion and composting can be a significant source
- Polymer types found in compost from plants receiving the organic waste bin reflect packaging and consumer products
- **Plastic waste entering the organic waste bin can end up as microplastics on farmlands**

Organic waste sorting Photo: E. Robbe

Weithmann et al. (2018) Sci.Adv.; Büks & Kaupenjohann (2020) SOIL Vol.6; Bertling et al. (2021) Fraunhofer UMSICHT

2. Major Sources – Agricultural Soils

Share of plastic inputs to farmlands in Germany:



Adapted from: Bertling et al. (2021) Fraunhofer UMSICHT

Liu et al. (2014) Environ. Res. Lett. Vol. 9

- Agriculture often accounts for a large proportion of land area (about 50%), highlighting the importance of those sources

2. Pollution Patterns on Land

- **Farmland** is prone to microplastic contamination
- 10x higher concentrations in soils close to **urban areas** as compared to rural sites
- 10^2-10^4 times higher concentrations close to **industrial sites**

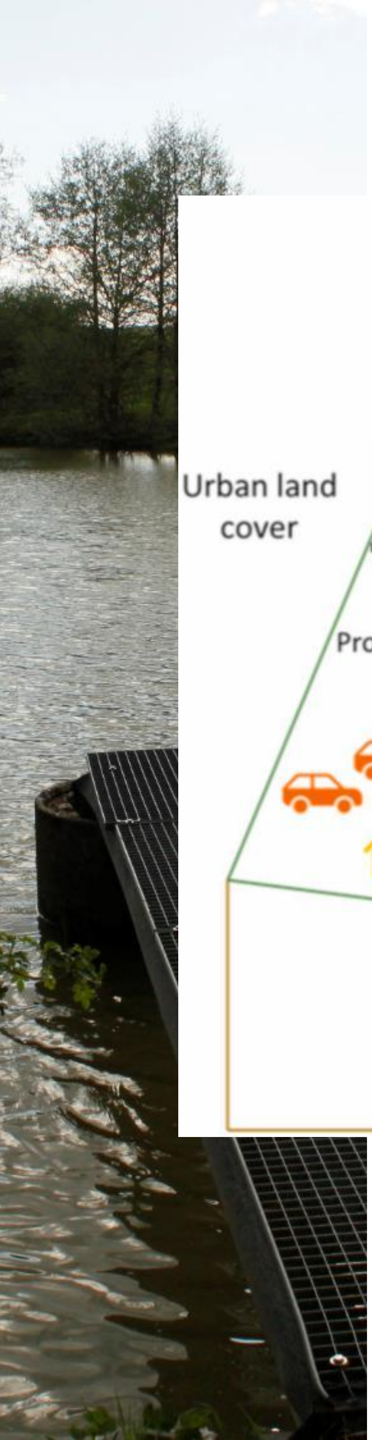
Photo: G. Schernewski

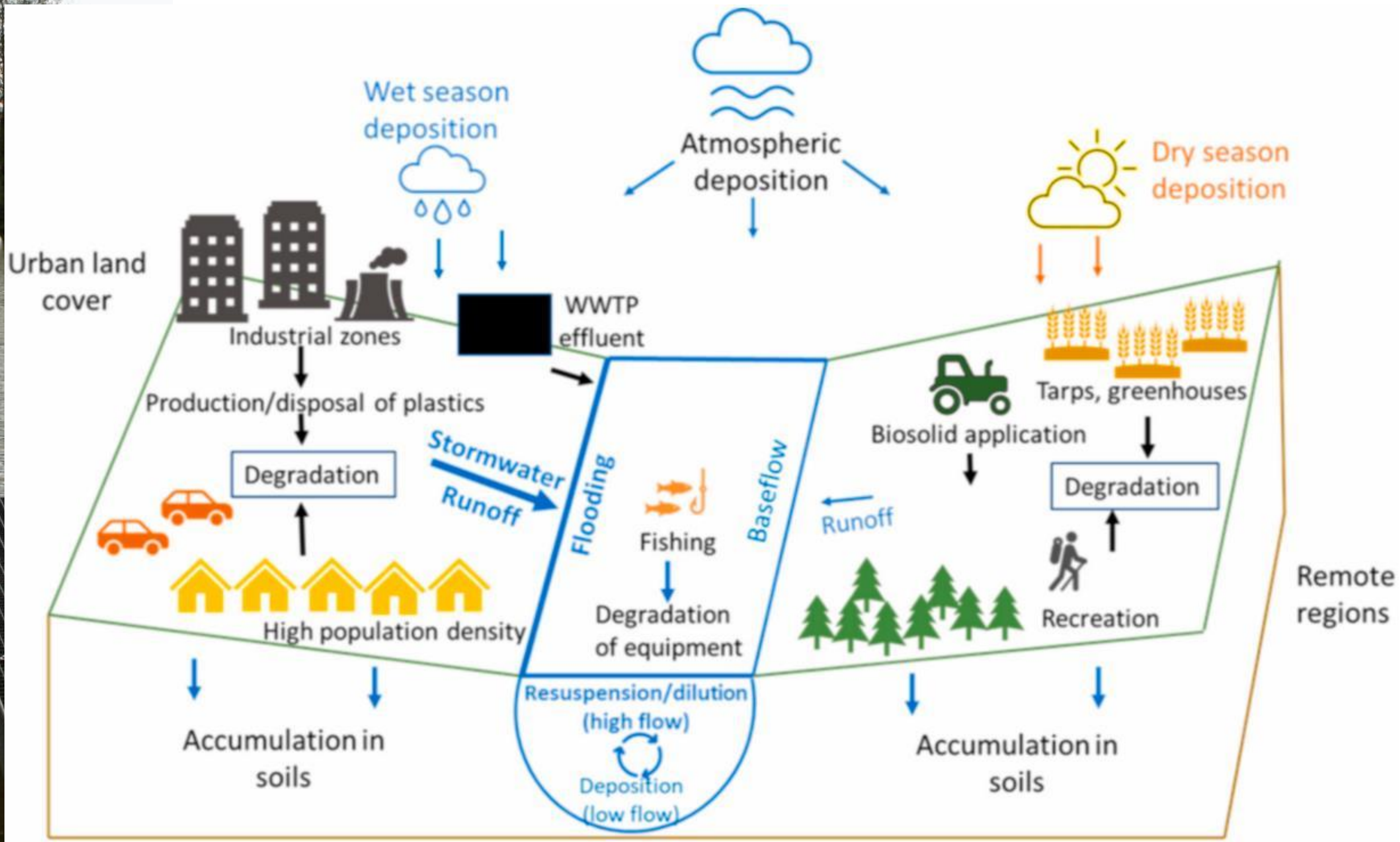
➡ **Positive relation between population density and microplastic concentration**

➡ **Land-use (e.g. urban, agriculture, grassland, forest) influences the level of microplastic pollution on land**

Büks & Kaupenjohann (2020) SOIL Vol. 6; Tagg et al. (2022) Sci. Total Envirn. Vol. 806

3. Emissions to Rivers





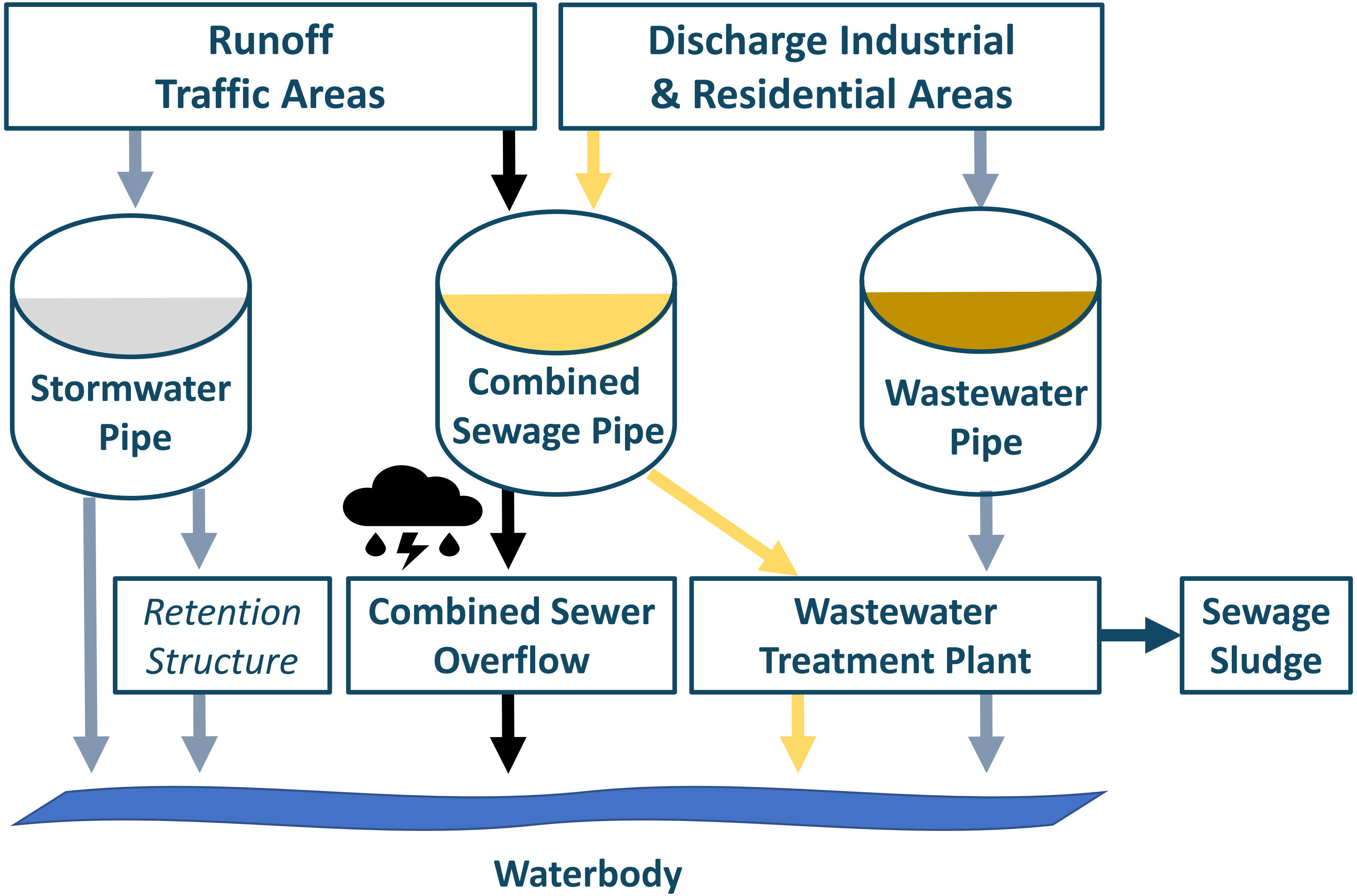
Talbot & Chang (2021) Env. Poll. Vol. 292

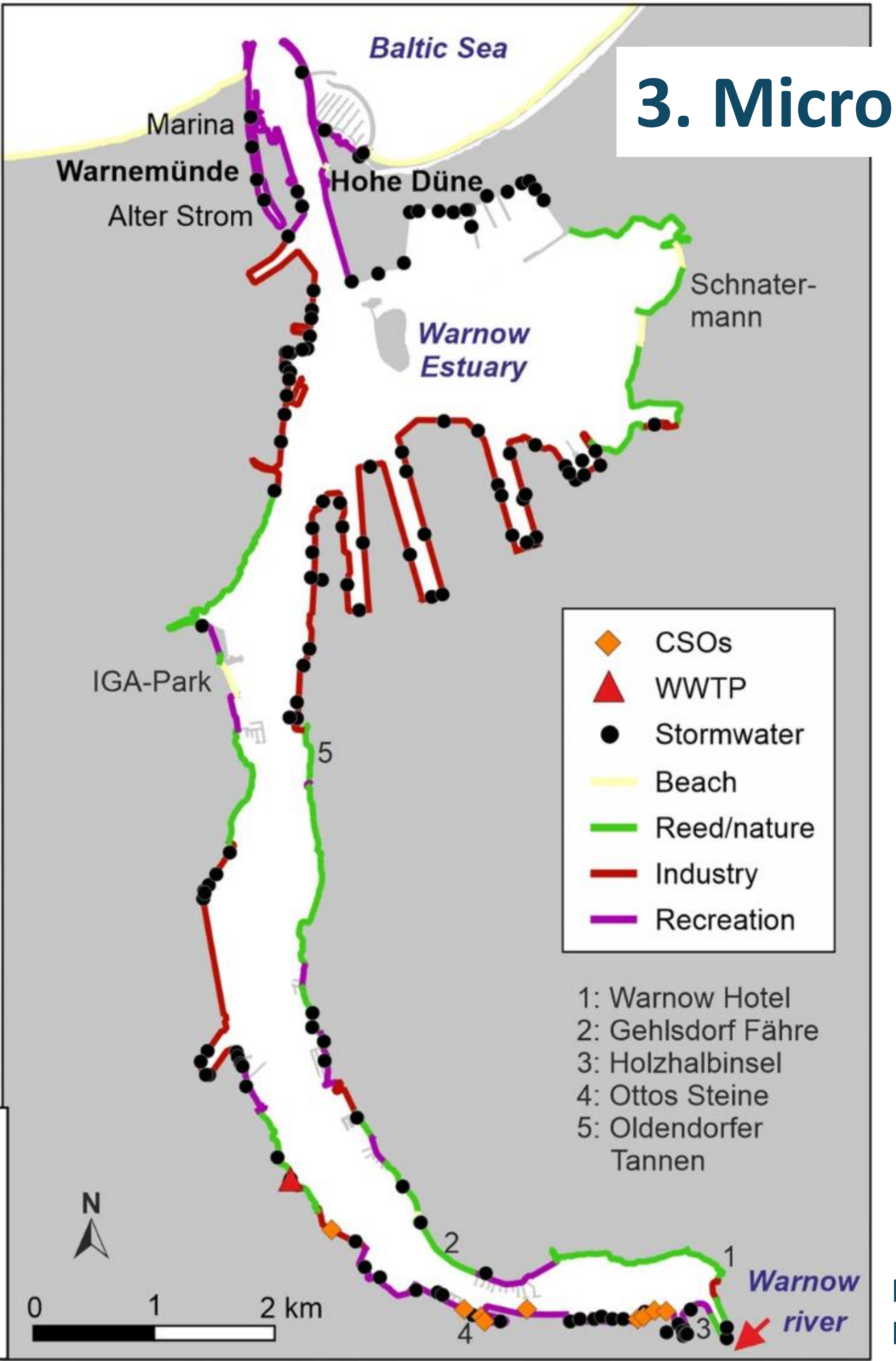
- ➢Atmospheric deposition
- ➢Groundwater emissions
- ➢Soil erosion
- ➢Surface runoff

- ➢**City sewer system emissions**

Waterborne emissions from urban areas are the most important source for microplastics in rivers

3. City Sewer System Emissions





3. Microplastic Emissions Within an Urbanized Estuary

Estimated share among investigated sources:

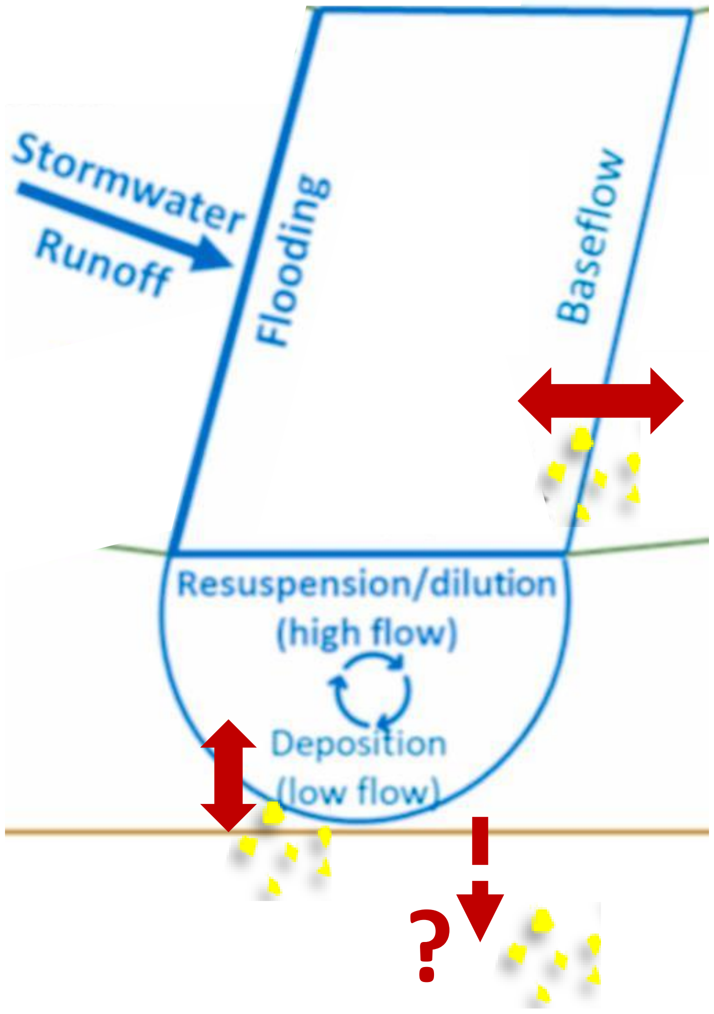
Stormwater:	~43.1%
Combined Sewer overflow(CSO):	~6.1%
Wastewater treatment plant (WWTP):	~1.4%
Total Rostock city:	**~50.6%**
Catchment:	**~49.4%**

- **Treated wastewater emissions exhibit lowest share**
- **Stormwater and combined sewer outlets are emission hotspots**

Piehl et al. (2021) Front. Environ. Sci.
Figure: Schernewski et al. (2021) Environ. Manag. Vol. 68

4. Retention within Rivers

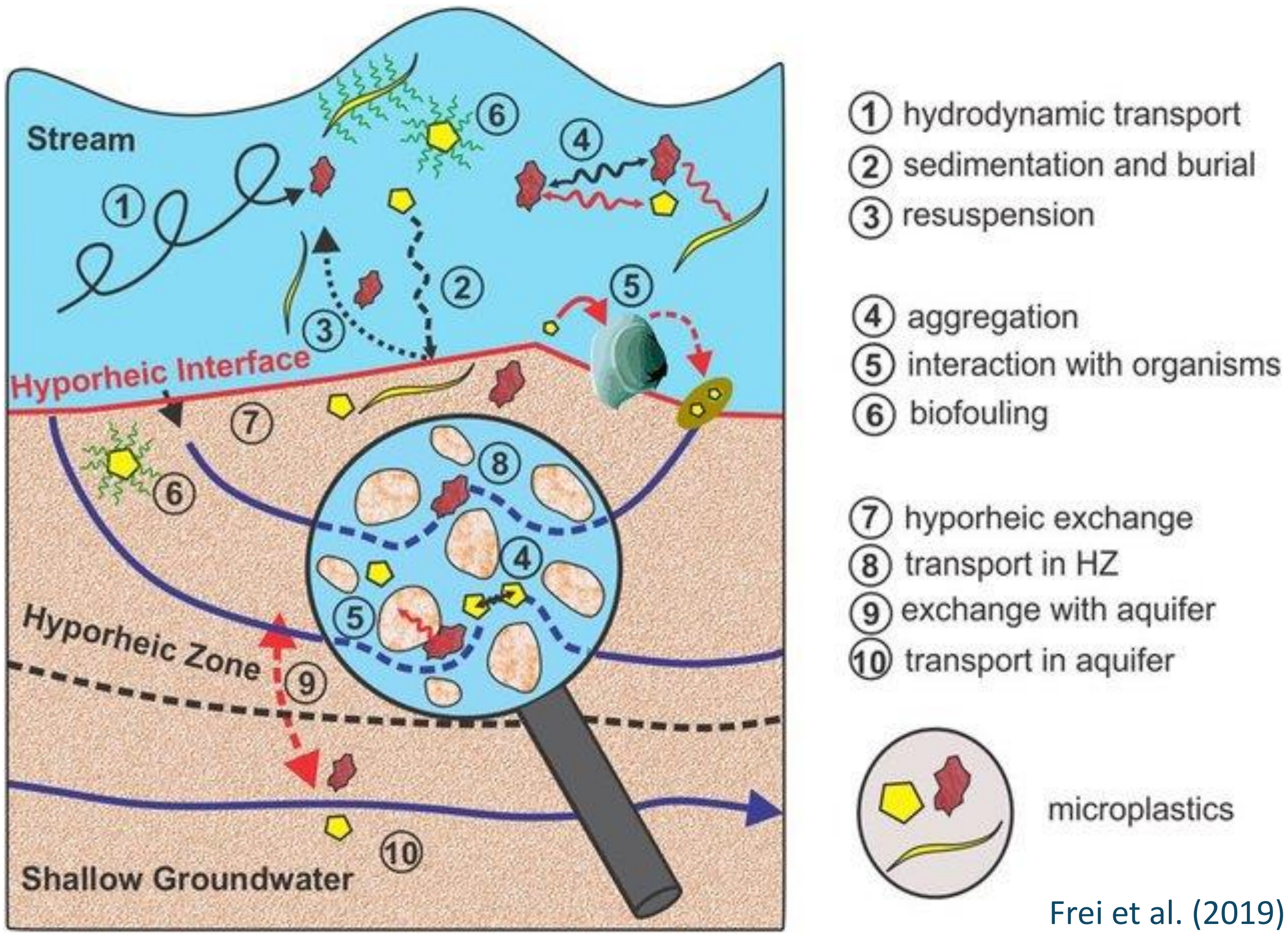
- Flow conditions determine the deposition/ resuspension on riverbanks and in river sediments
- Time between floods determines how much is remobilized and how much can accumulate
- Hydrometerological, river morphology and artificial factors influence retention
- Long-term retention
  → in sediments of river lakes and damns as well as silted shore areas
  → if transferred to deeper river sediment layers



➡ Retention varies strongly between rivers

Figure adapted from: Talbot & Chang (2021) Env. Poll. Vol. 292

4. Retention within Rivers



Frei et al. (2019)

Hyporheic zone

= riverbed area that is equally influenced by surface and groundwater flow dynamics

- Transfer of small particles across the streambed interface due to hyporheic exchange

Factors influencing retention in rivers include flow conditions, particle properties and interactions (biofouling, aggregation), and river morphology

Frei et al. (2019) Sci. Rep.; Drummond et al. (2022) Sci. Adv.

5. Estuaries: Sink or Source?

The Warnow Estuary, Germany

- Bi-directional freshwater-seawater flow results in complex hydrodynamics
- Accumulation of coastal sediments in the estuary
- Approach based on assumptions considering
  - → density of particles
  - → retention capacity for suspended particulate matter

Source	Mean [MPs*10^6/a]	Mean [%]
Catchment	143,965	49.4
Stormwater	125,500	43.1
Sewer overflows	17,725	6.1
Treated wastewater	4,064	1.4
Σ	291,254	100

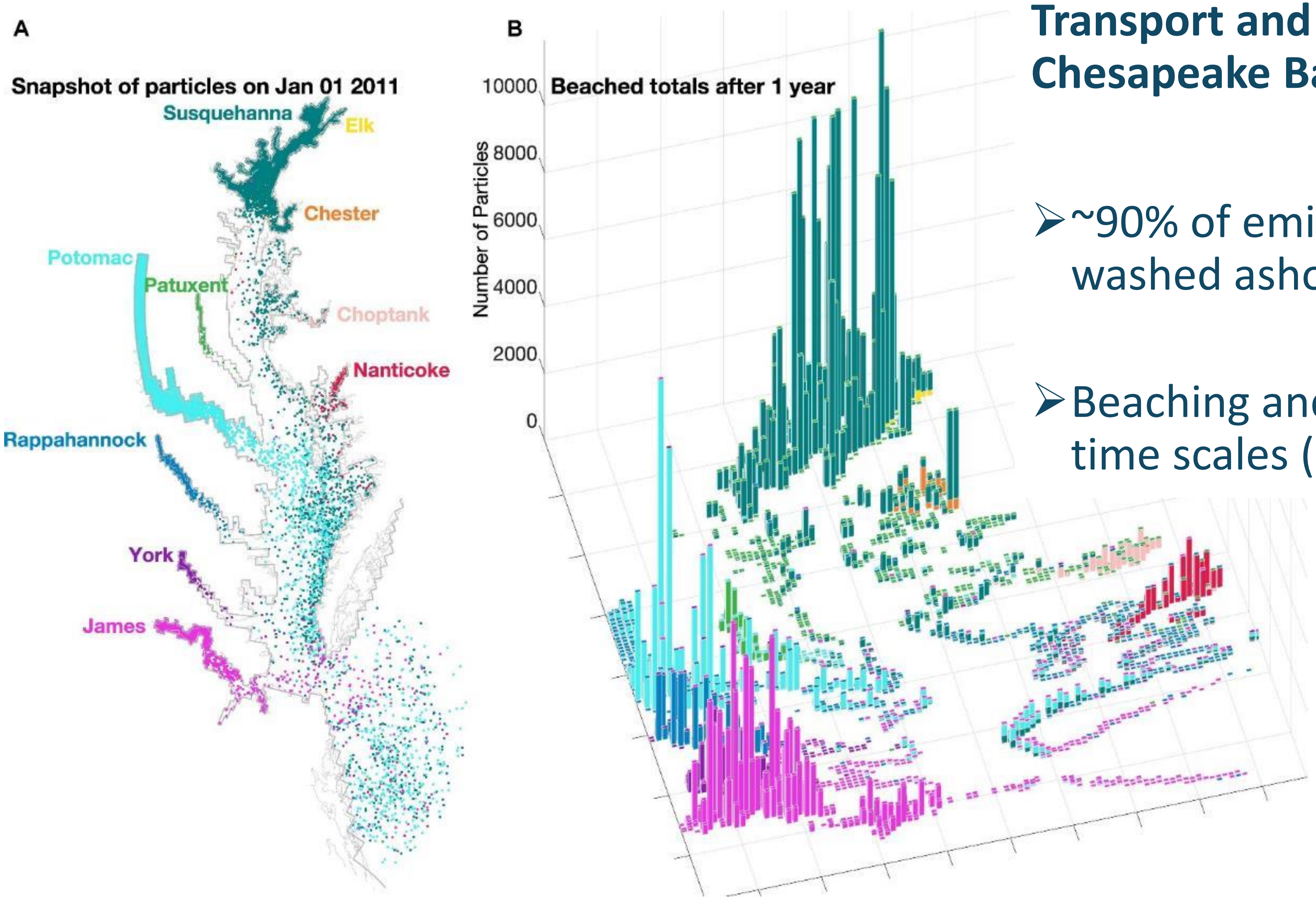
Sinking microplastics (>1.0 g/cm³) → 100% retained

Floating microplastics (<1.0 g/cm³) → 31% retained

(Separation into density classes for each source)

Piehl et al. (2021) Front. Environ. Sci.

5. Estuaries: Sink or Source?



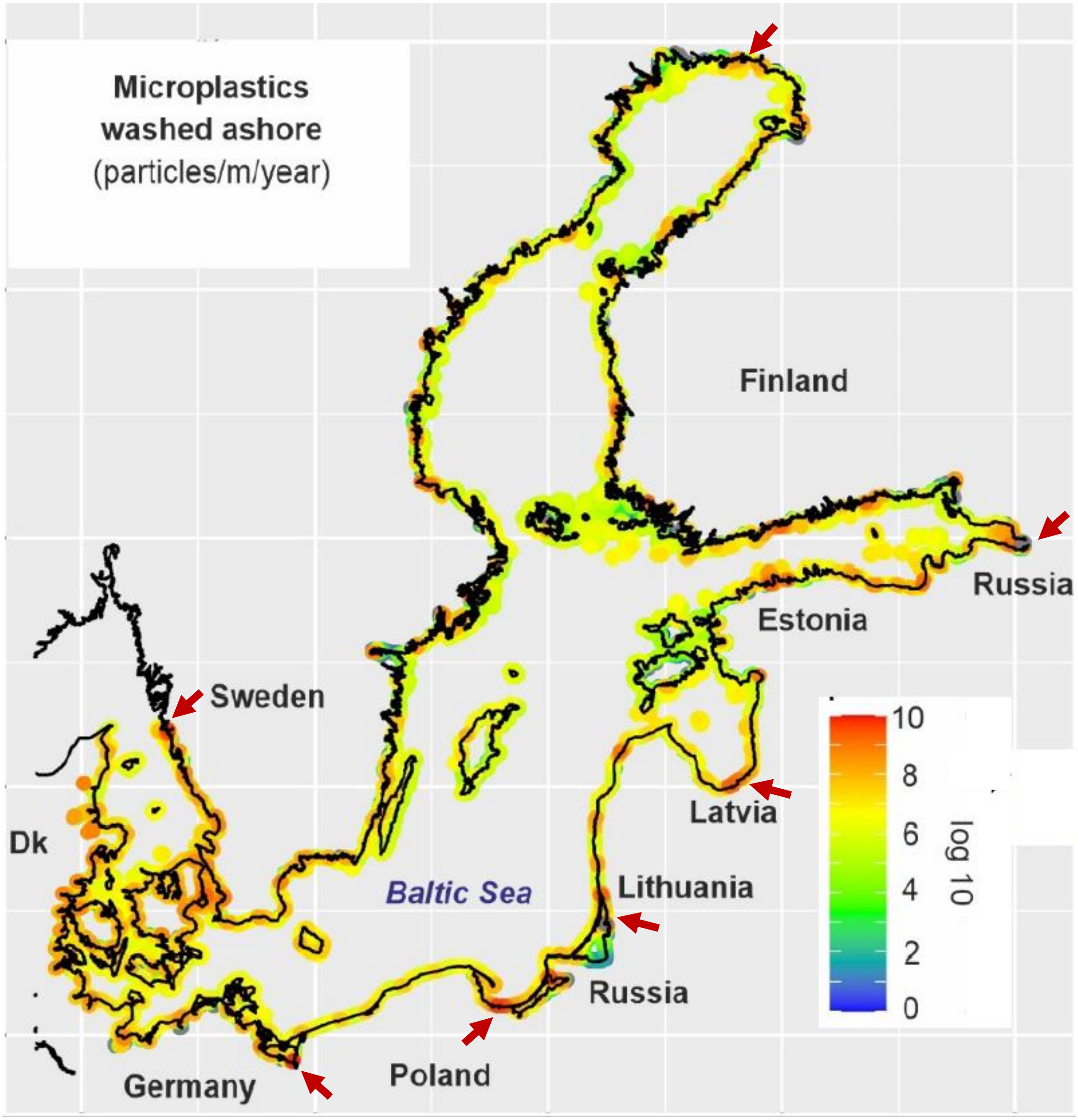
Transport and distribution in the Chesapeake Bay, USA

- ~90% of emitted microplastic is washed ashore within the estuary
- Beaching and export have short time scales (weeks)
- Particle density influences distribution
- Particle size has no influence

López et al. (2021) Front. Mar. Sci.

5. Estuaries: Sink or Source?

Photo: NASA Earth Observatory



Schernewski et al. (2021) Front. Environ. Sci.

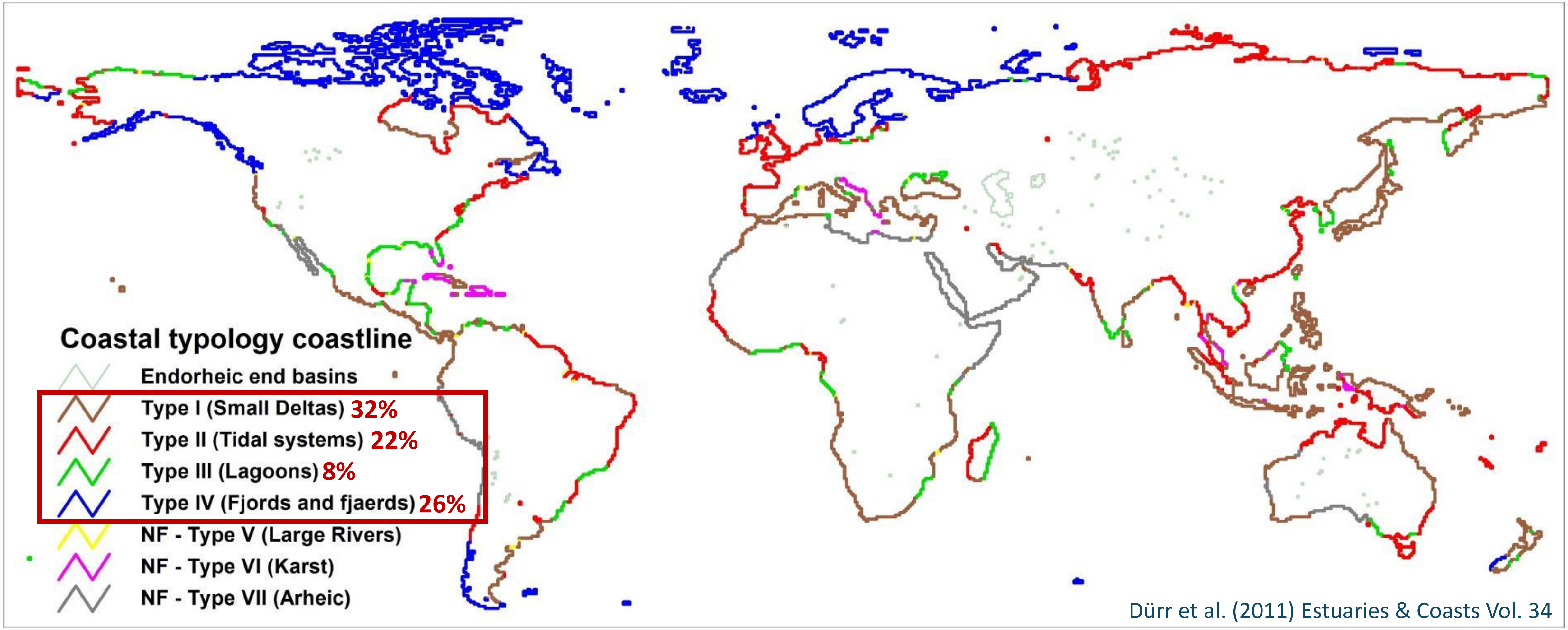
Transport and distribution in the Baltic Sea

- Coasts are major accumulation areas
- Majority of particles are washed ashore close to their emission point
- Only small influence of particle shape and size

Estuaries may act as filter for riverine microplastic

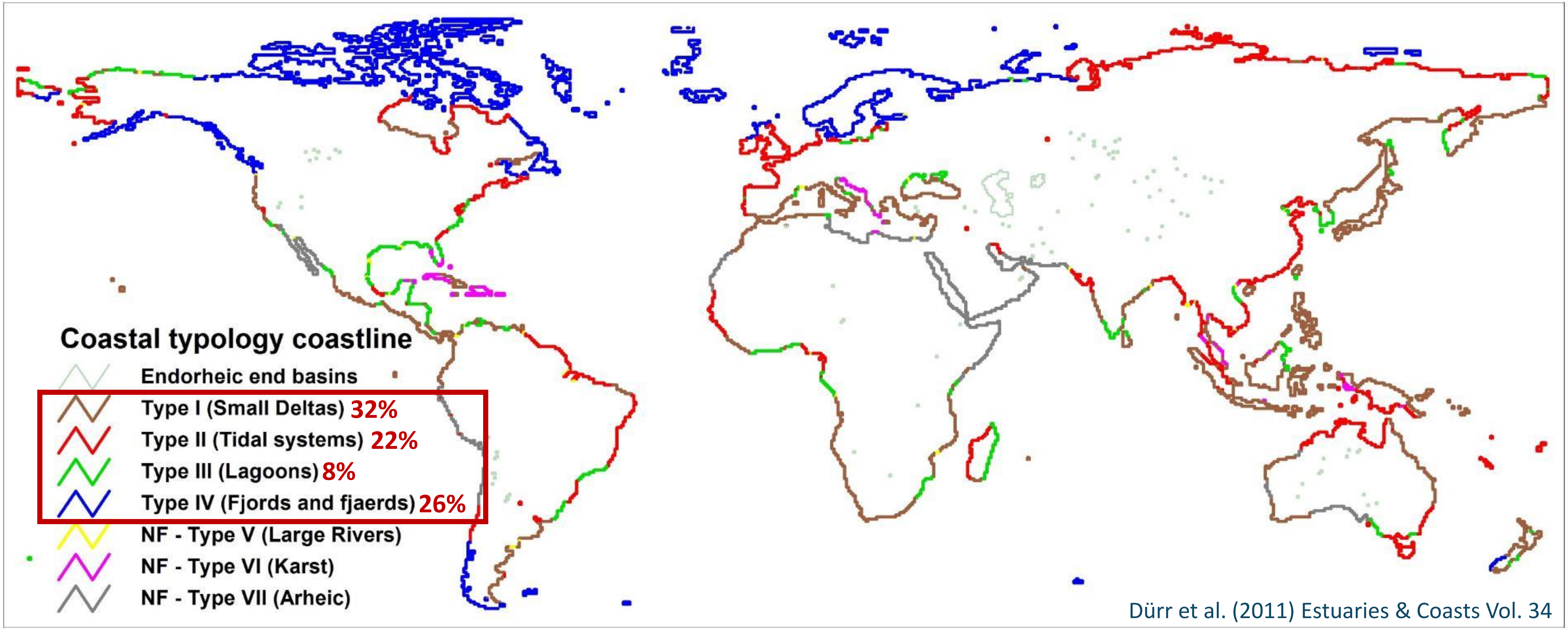
Hydrodynamic modeling to gain process understanding

5. Estuaries: Sink or Source?



- Estuarine filters account for ~88% of the global coastline
- ~57% of river water and ~71% of the sediment discharge to the oceans pass through estuarine filters

5. Estuaries: Sink or Source?



Retention capacity of rivers and estuaries as explanation for mismatch of global river emission estimates and ocean budgets?

Schmidt et al. (2017) Environ. Sci. Technol. Vol. 51; van Sebille et al. (2015) Environ. Res. Lett. Vol. 10

7. Lessons Learnt

- Microplastic pollution is linked to population density and land use
- Especially industrial sites, urban areas and farmlands have a high microplastic load
- For soils, littering and agricultural practices are a major source for microplastics
- For rivers, waterborne emissions from urban areas are the most important source
- City sewer systems are the most important emission pathway to rivers, with combined sewer overflows and stormwater emissions being the most significant (treated wastewater plays a minor role)

7. Lessons Learnt

- Rivers play a key role in the transportation of microplastics to the marine environment but…
- …influence of retention cannot be estimated at present and varies strongly between rivers (possibly from 0% to 100%)
- Estuarine filters account for ~88% of the global coastline and their role as a filter for riverine microplastics into the oceans needs to be clarified
- Oceans are considered the final sink of microplastic fluxes from hydrological catchments, whereas coastal areas are major accumulation areas

Thank you for your attention!

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IOW

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Statue from beach plastic litter, Italy 2016

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