WELCOME

United States Contributions to Global Ocean Plastic Waste Meeting 3

For Zoom participants, send questions in Q&A feature.

Committee Members

Margaret Spring, Chair
Mary Donohue
Michelle Gierach
Jenna Jambeck
Hauke Kite-Powell
Kara Lavender Law
Jay Lund
Ramani Narayan
Eben Schwartz
Rashid Sumaila

Committee Statement of Task

1.) Evaluate US contributions to global ocean plastic waste, including types, sources and geographic variations

2.) Assess the prevalence of marine debris and mismanaged plastic waste in saltwater and freshwater United States waterways

3.) Examine the import and export of plastic waste to and from the United States, including the destinations of the exported plastic and the waste management infrastructure and environmental conditions of these locations.

Committee Statement of Task

4.) Assess the potential value of a national marine debris tracking and monitoring system and how such a system might be designed and implemented.

5.) Develop recommendations on knowledge gaps that warrant further scientific inquiry.

6.) Recommend potential means to reduce United States contributions to global ocean plastic waste.

Microplastics in the Mississippi River

Katherine M. Martin, Jessica Myers Elizabeth A. Hasenmuller,
John R. White, Lisa G. Chambers and Jeremy L. Conkle

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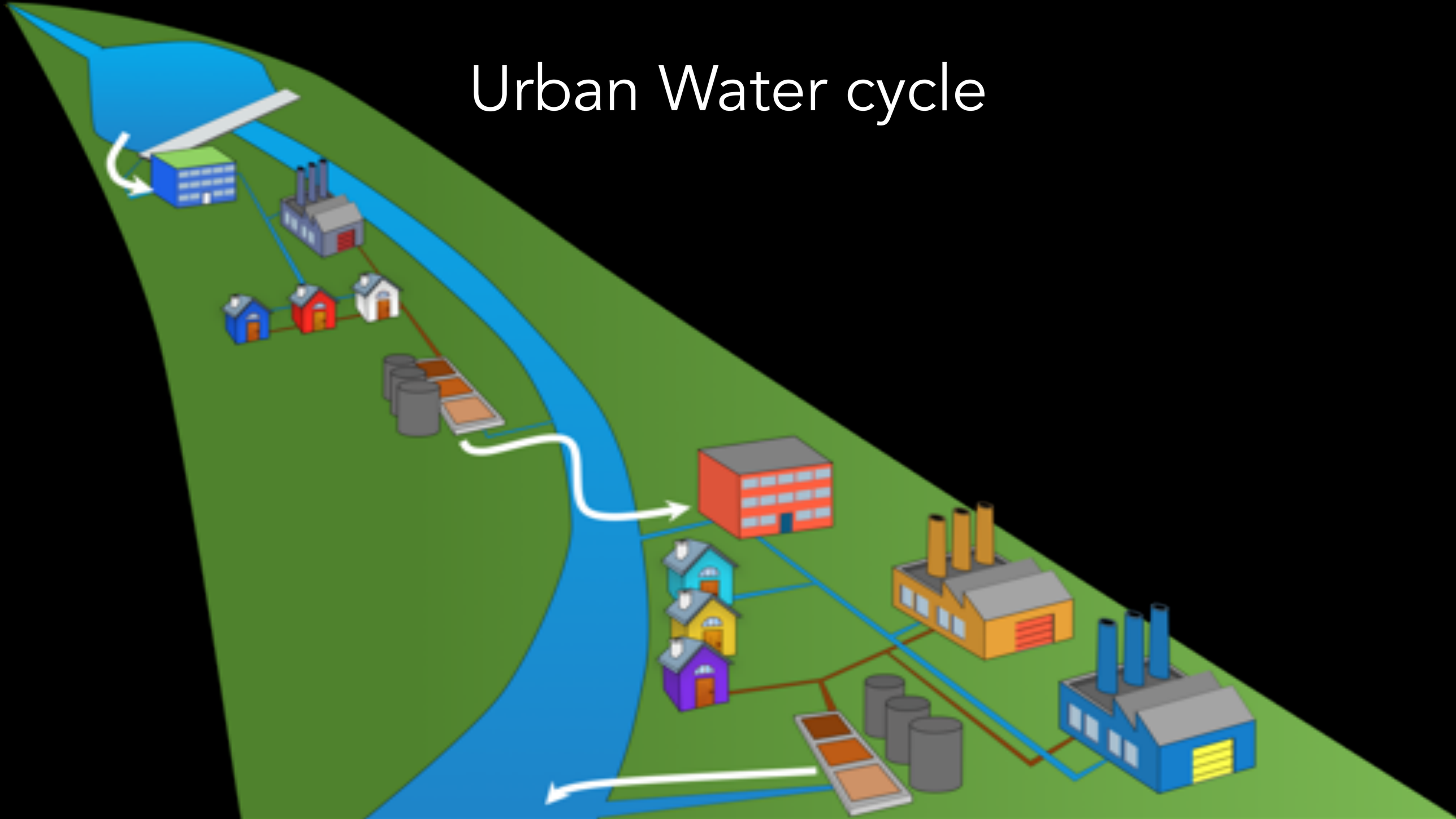
Urban Water cycle



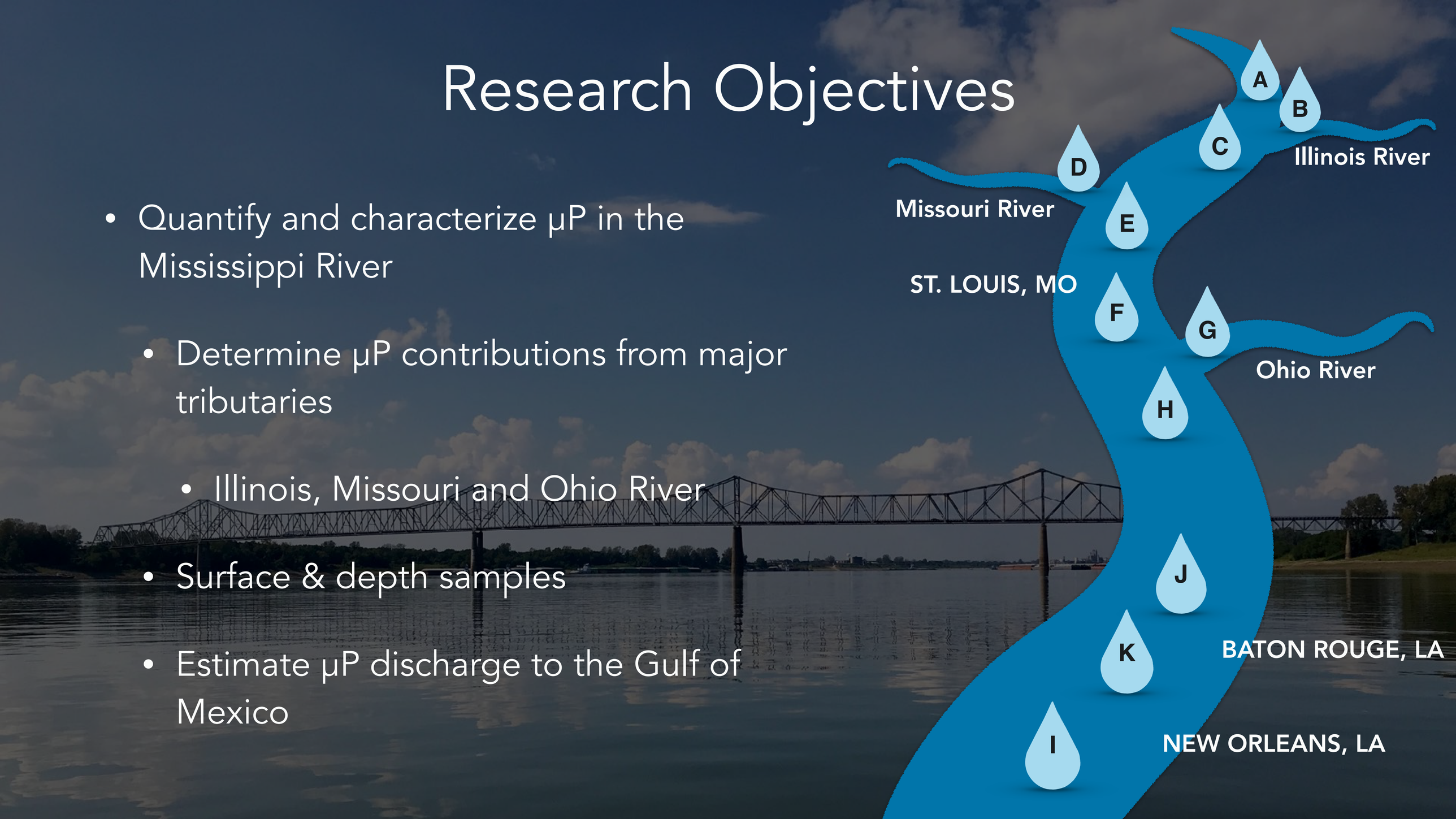
What's the problem?

- No greater receiving body in the U.S. than the Mississippi River!
- Covers over 40% of the U.S. and parts of Canada
- >90 million people
- >50 cities rely on the Mississippi for daily water supply
- >7,500 permitted wastewater discharges

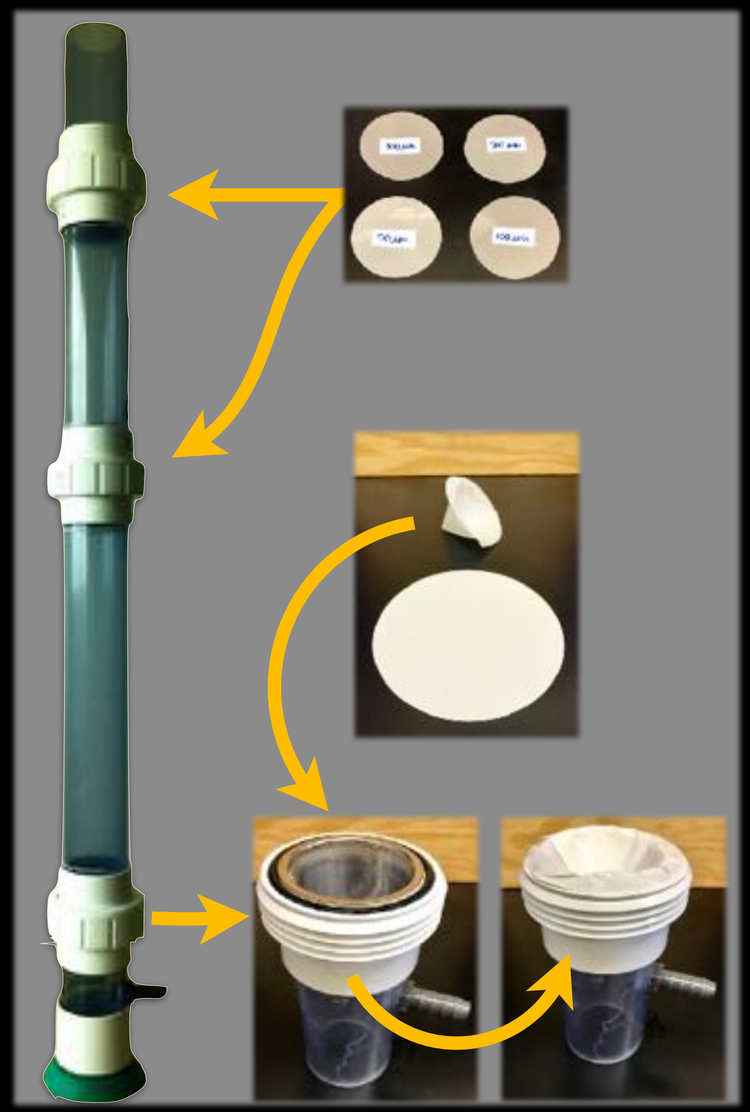
Image Courtesy of NOAA, Anthony Reisinger

Research Objectives

- Quantify and characterize µP in the Mississippi River
  - Determine µP contributions from major tributaries
    - Illinois, Missouri and Ohio River
  - Surface & depth samples
  - Estimate µP discharge to the Gulf of Mexico



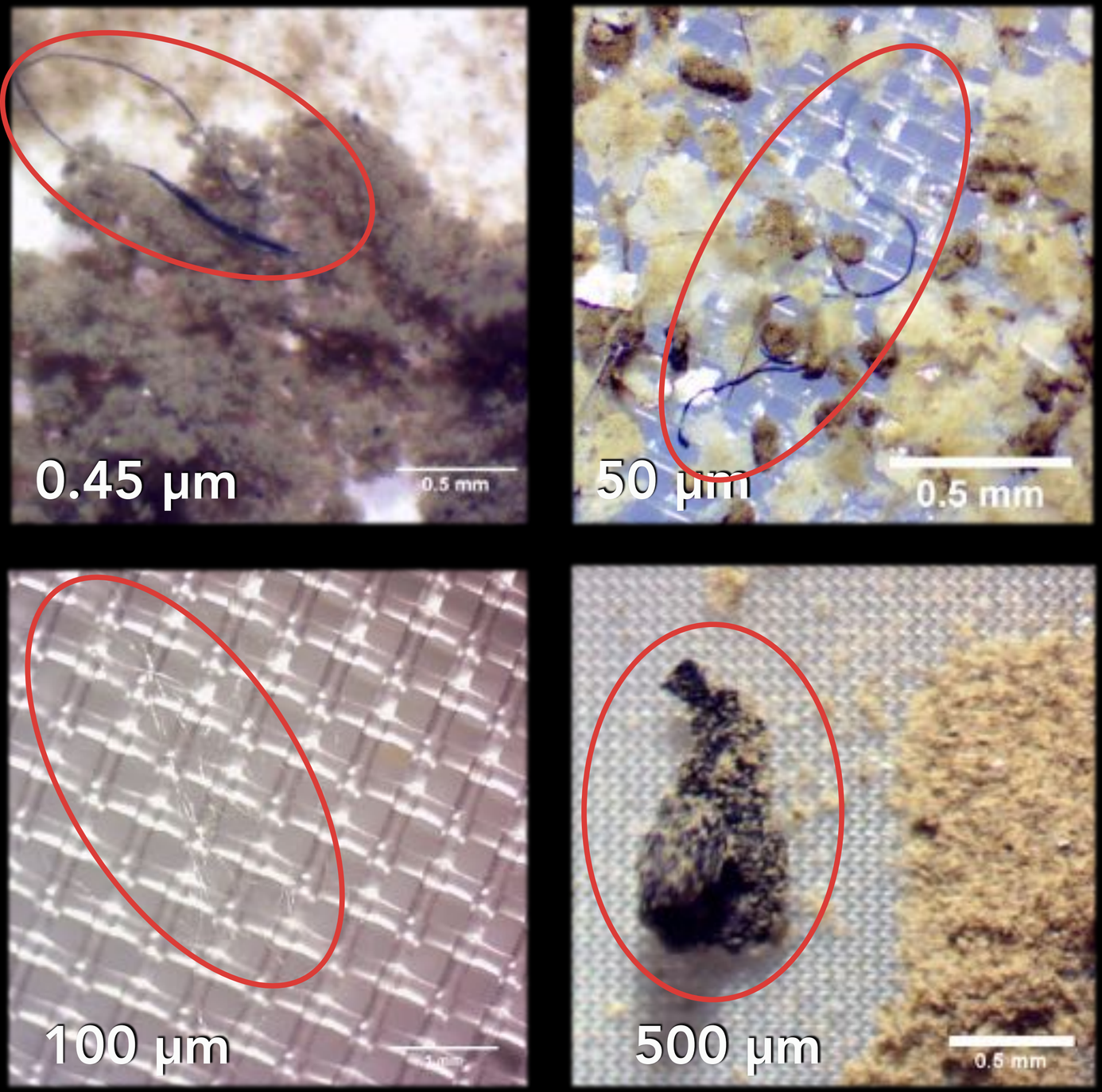
Mississippi River Methods



Martin, K. M., E. A. Hasenmueller, J. R. White, L. G. Chambers, and J. L. Conkle. 2018. Sampling, Sorting, and Characterizing Microplastics in Aquatic Environments with High Suspended Sediment Loads and Large Floating Debris. Jove-Journal of Visualized Experiments.

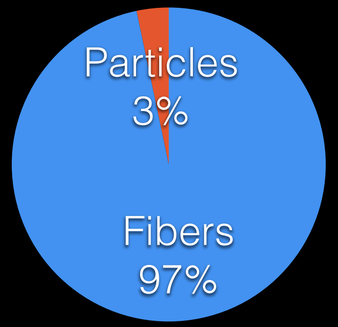
µ-FTIR Analysis

- Conservative approach: Recording/saving as much information as possible
- 116 ± 75 “suspected” µP per sample
- 10% = ~1,460 suspected µP for analysis
- 10 - 30 min per suspected µP (minimum of 250 hrs to analyze 1,400)
- QA/QC - how do you know the material you matched is the actual material?
  - Especially true for cellulose based materials


0.45 µm
0.5 mm
50 µm
0.5 mm
100 µm
500 µm
0.5 mm

Most of the Following Results are Preliminary

μ-FTIR Identification



FTIR Confirmed Materials

Fully Synthetic 10%

- Polyethylene
- Polyester
- Polyethylene Terephthalate
- Polystyrene
- Acrylic
- Nylon
- etc…

Semi-synthetic 65%

- Cellulose Origin
  - Cotton
  - Rayon
  - Linen
  - Cellophane
  - etc…

Other 25%

- Calcium Stearate
- Paint
- Hydrangea Root Powder
- Butternut Bark Powder
- Chitosan
- Coriander Seed Powder
- etc…

Material Categories - Blank Corrected

	Fully Synthetic	Semi-Synthetic	Total
	Fibers L^{-1}		
All Samples	6.3 ± 7.7	28.4 ± 36.5	34.0 ± 38.4
Summer 2017 (High River Stage)	3.5 ± 4.3	24.3 ± 28.5	26.5 ± 29.7
Fall 2017 (Low River Stage)	8.8 ± 9.1	31.7 ± 42.3	40.5 ± 44.2
All Surface Samples	7.9 ± 9.8	34.7 ± 45.1	42.6 ± 48.1
All Depth Samples	4.8 ± 4.8	22.1 ± 25.0	25.8 ± 24.8

Materials Found

- Fully Synthetic
  - 70% Polyester or Polyethylene Terephthalate (density: 1.38 g cm^{-3})
- Semi-synthetic
  - 76% Cellulosic materials
    - 46% Cotton (density: 1.54 g cm^{-3})
    - 16% Rayon (density: 1.5, 3.0 and 4.5 g cm^{-3})
    - 14% Other cellulosic

Gulf of Mexico Loading Estimates

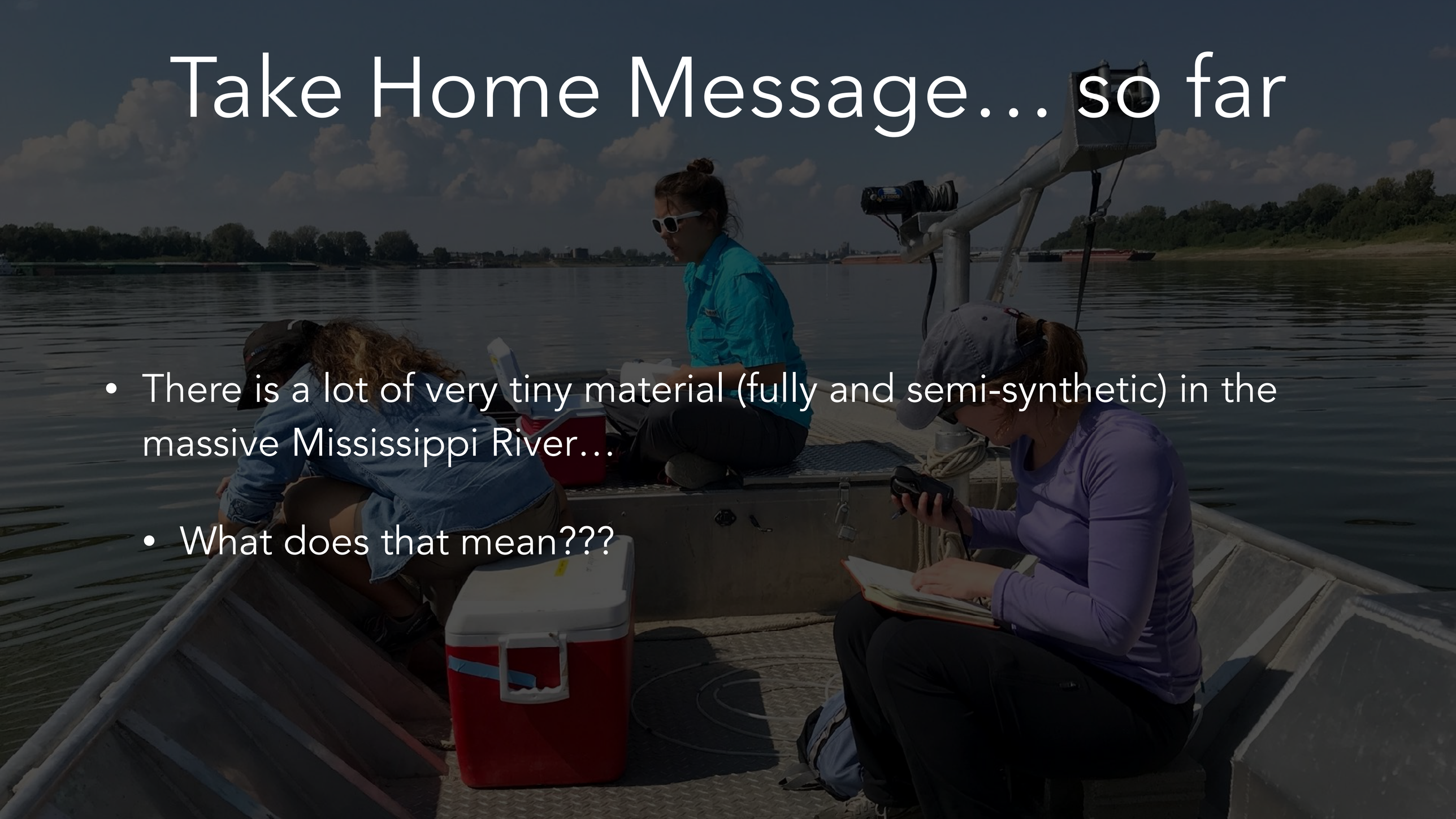
Date	River Discharge	Fully Synthetic	Semi-Synthetic	Total	Fully Synthetic	Semi-Synthetic	Total
	L day^{-1}	Fibers day^{-1}			Kg day^{-1}		
07/06/17	1,396,824,777,216	7,247,817,677,739	62,778,272,854,075	70,026,090,531,814	31.7	282.2	313.8
10/19/17	463,513,757,184	2,194,276,937,088	21,189,081,541,321	23,383,358,478,409	9.6	95.2	104.8
		Fibers yr^{-1}			Tonnes yr^{-1}		
07/06/17		2,645,453,452,374,740	22,914,069,591,737,400	25,559,523,044,112,100	11.6	103.0	114.5
10/19/17		800,911,082,037,120	7,734,014,762,582,170	8,534,925,844,619,290	3.5	34.7	38.3

- Rough Estimates of Annual discharge to the Gulf of Mexico
  - ~0.8 - 2.6 quadrillion fully synthetic µPs (3.5 - 11.5 Tonnes)
  - ~7.7 - 22.9 quadrillion semi-synthetic fibers (34.7 - 103.0 Tonnes)
  - ~8.5 - 25 quadrillion total (38.3 - 114.5 Tonnes)

What is Next…

- Currently working on QA/QC of μFTIR results
- Need to conduct blank corrections by individual material types
- Then we will:
  - Compare high to low river stages
  - Compare surface to depth
  - Examine spatial trends and land-use where possible
- Currently conducting a similar study in Texas

Take Home Message… so far



- There is a lot of very tiny material (fully and semi-synthetic) in the massive Mississippi River…
  - What does that mean???

Thanks & Questions

Research funded by the NOAA Marine Debris Program

Undergraduate Researchers

- Claire Berger
- Elise Rother
- Katelyn Tubbs
- Nicholas Dominguez
- Rachel Stefancik
- Rachel Stefancik
- Jennifer Aredondo
- Felipe Martinez
- Rebecca Wagner
- Josiah Wray

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- Jessica Myers - 2nd Project Lead
- Kieu Tran
- Elijah Waddell
- Camille Valenta

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Additional Thanks

- Chelsea Rochman (University of Toronto)
- National Great Rivers Research and Education Center (NGRREC)
  - Miles Corcoran

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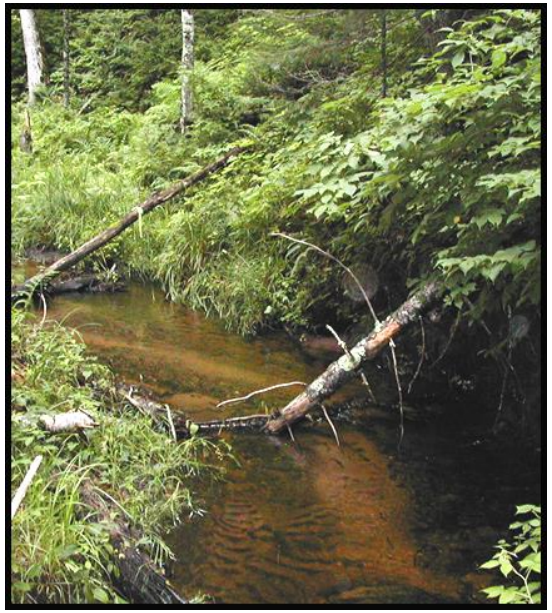
Plastic in Rivers and Litter on Great Lakes Beaches

Timothy Hoellein, PhD

Associate Professor
Dept. Biology, Loyola University Chicago

National Academy of Sciences Engineering and Medicine
US Contributions to Global Ocean Plastic Waste

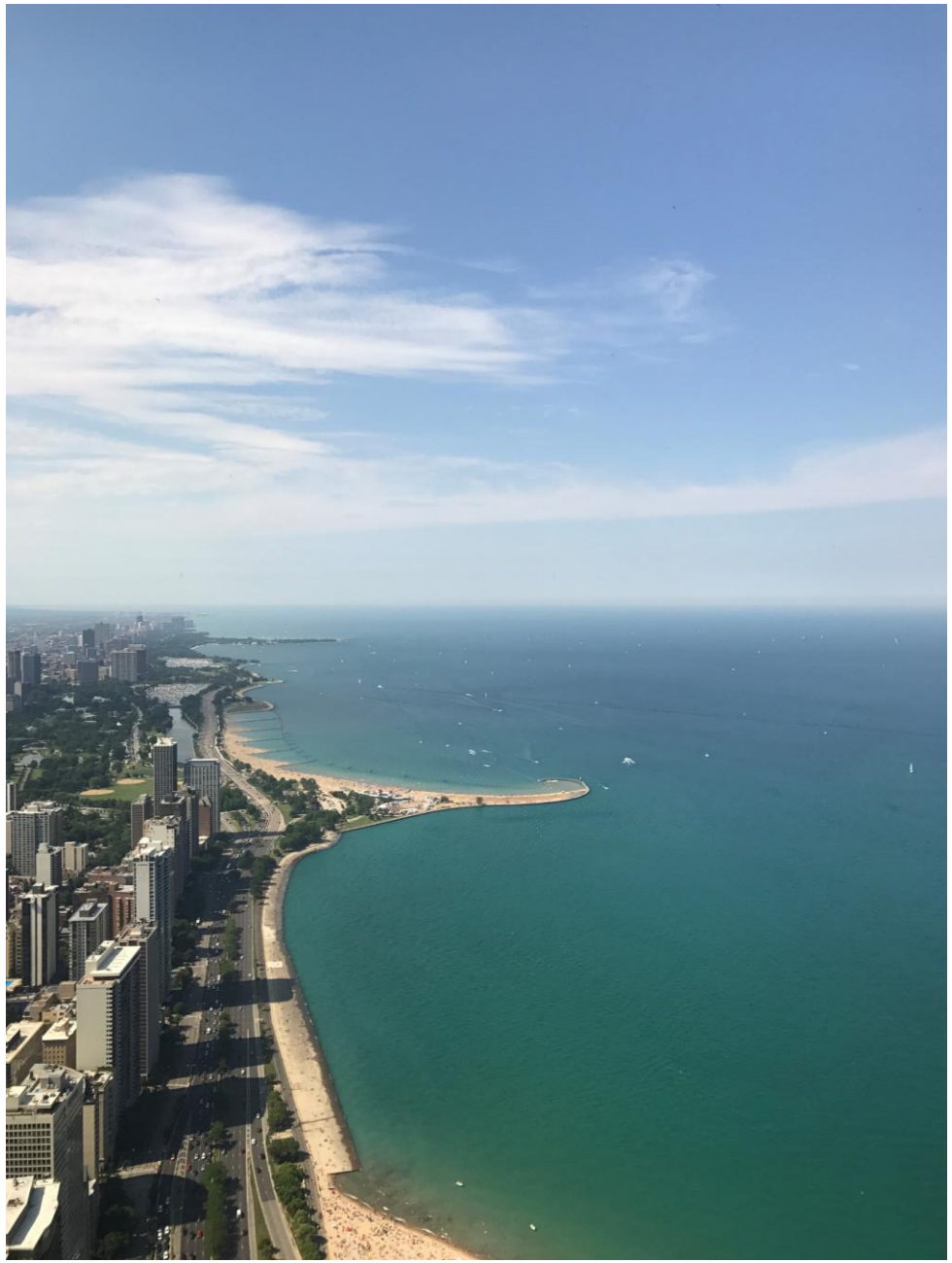
January 2021



What are the

- Sources
- Fate
- Biological interactions

of anthropogenic litter (AL) in freshwaters?



Goal: Highlight research results, conclusions.

AL and microplastic on Great Lakes beaches and streams

1. Spatial distribution
    - Small scale: Habitat
    - Large scale: Watershed

2. Temporal variation
    - Short term: 1 year
    - Longer term: Decades

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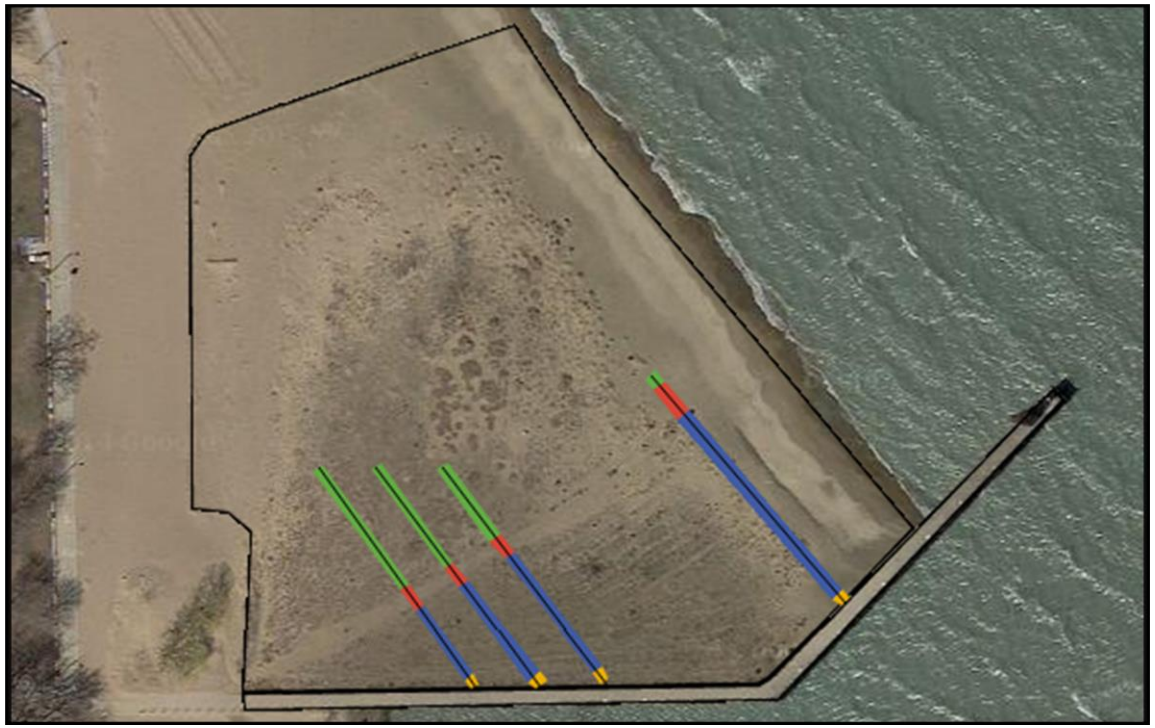
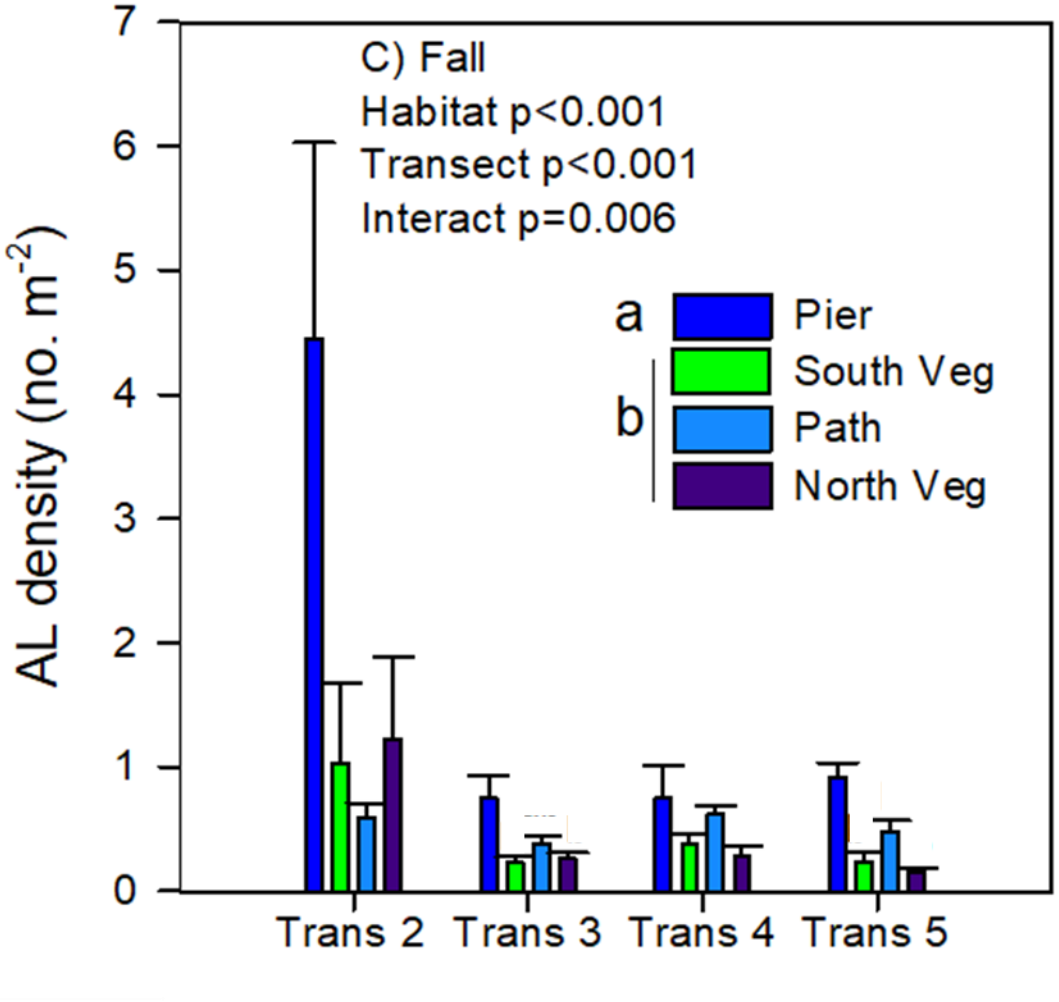
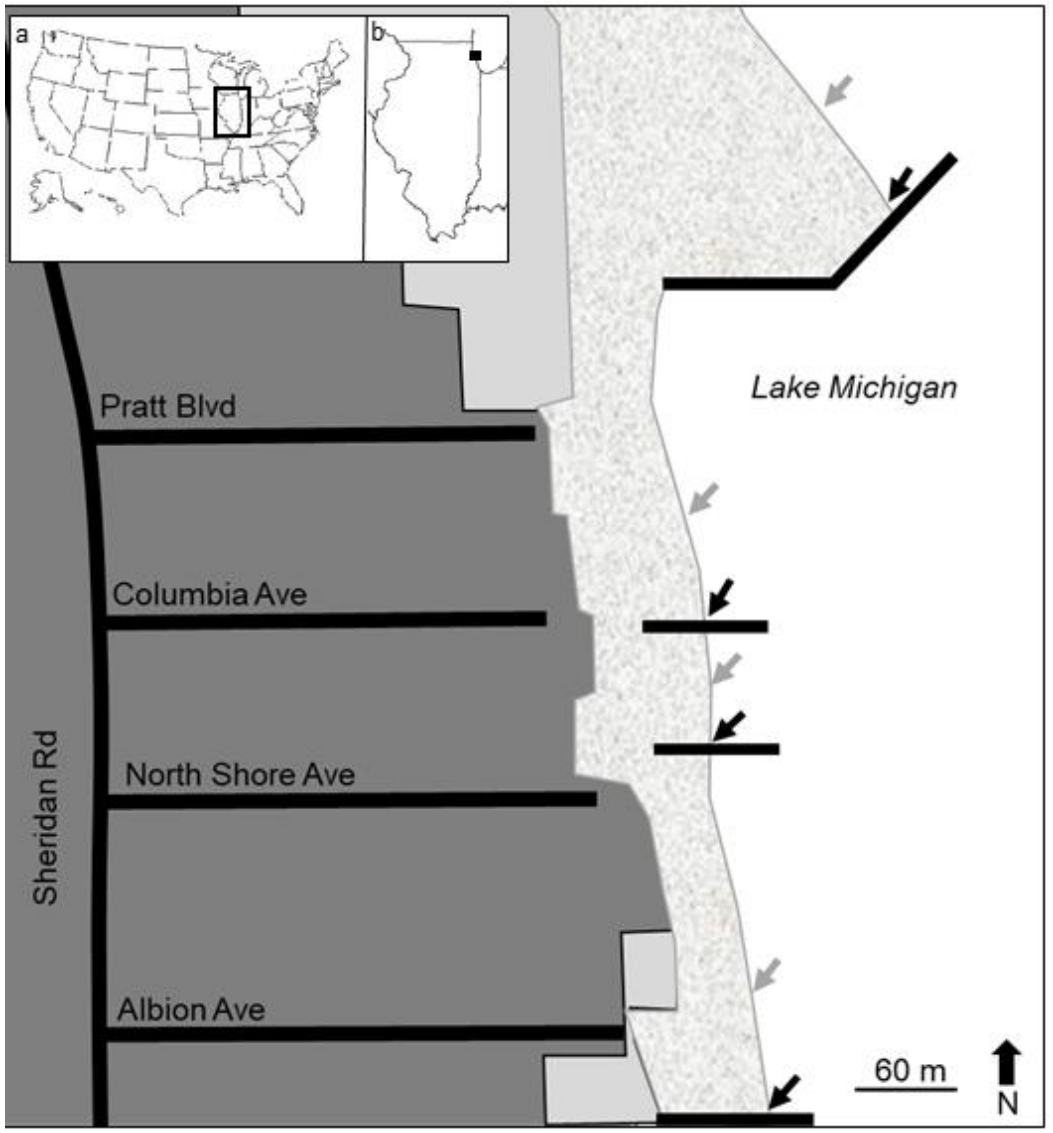
Patchy distribution of AL on Great Lakes beaches

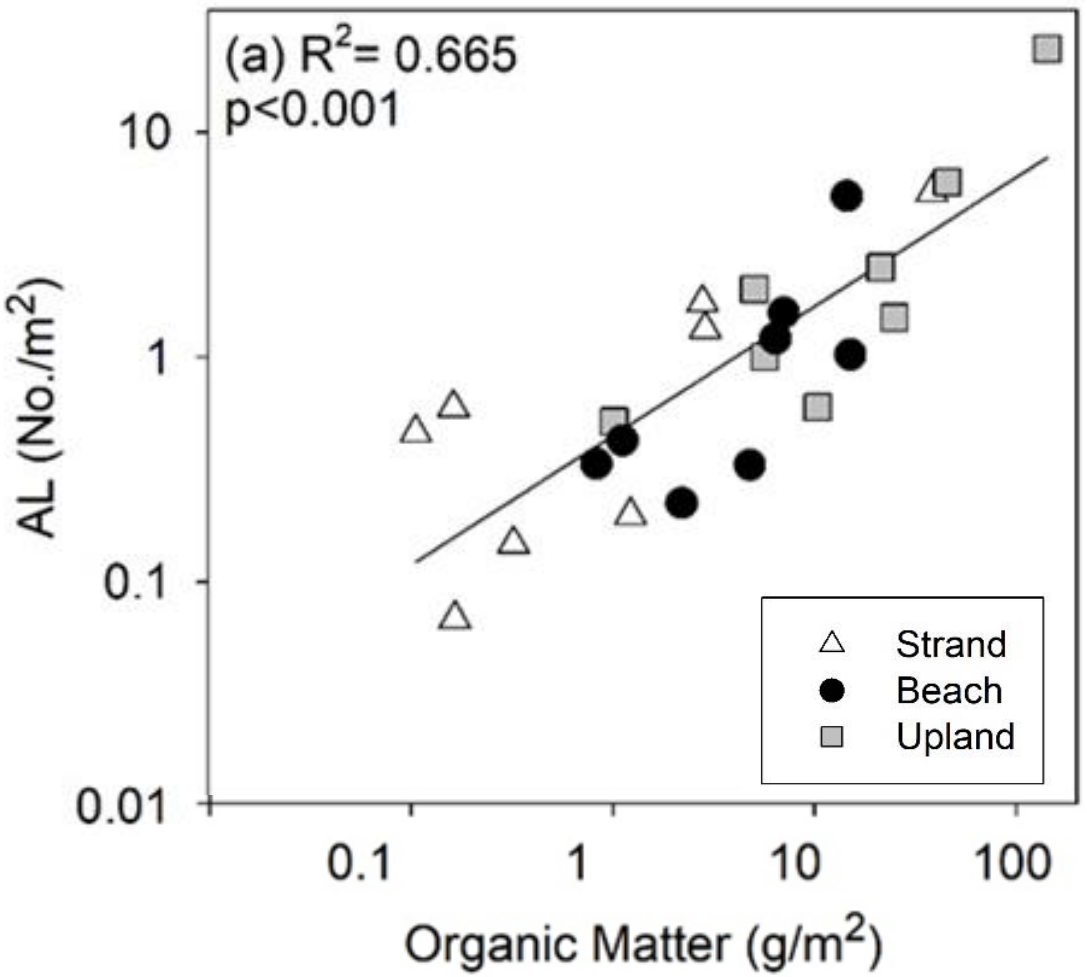




Vincent and Hoellein (2017)

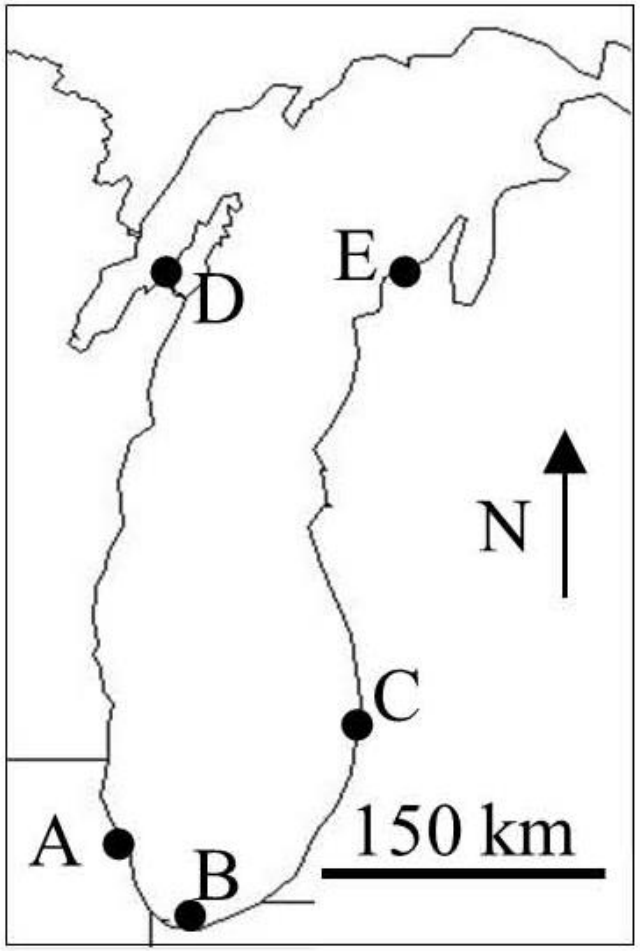
Patchy distribution of AL on Great Lakes beaches

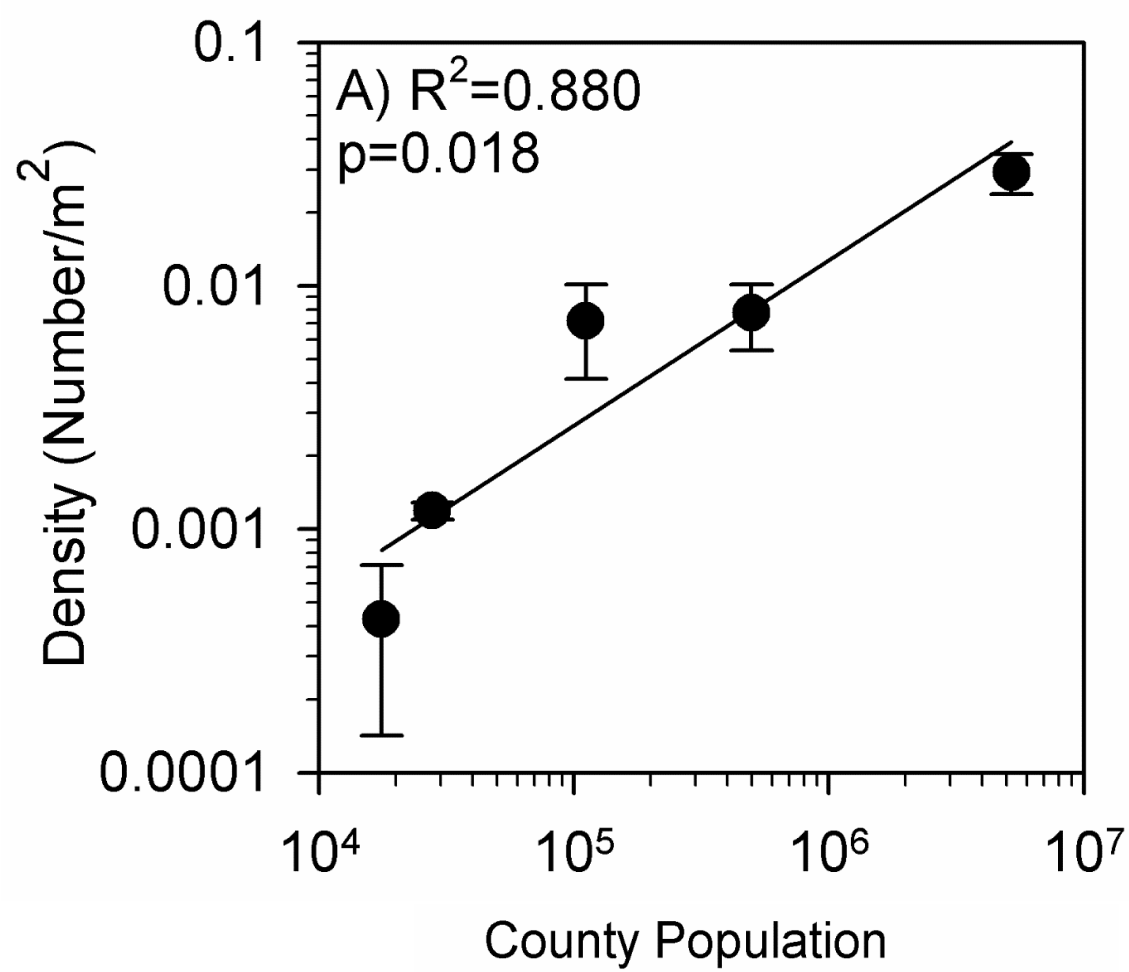




Lazcano et al. (2020)

Population related to AL density on beaches

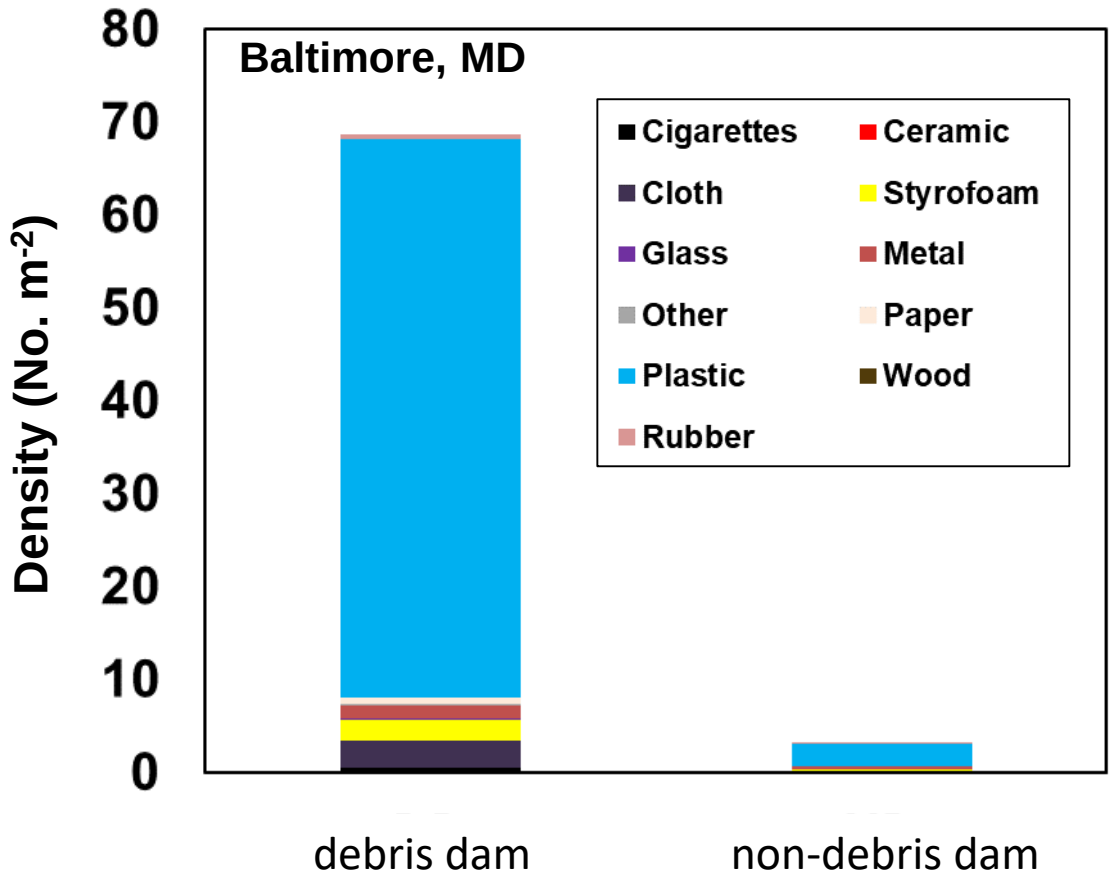


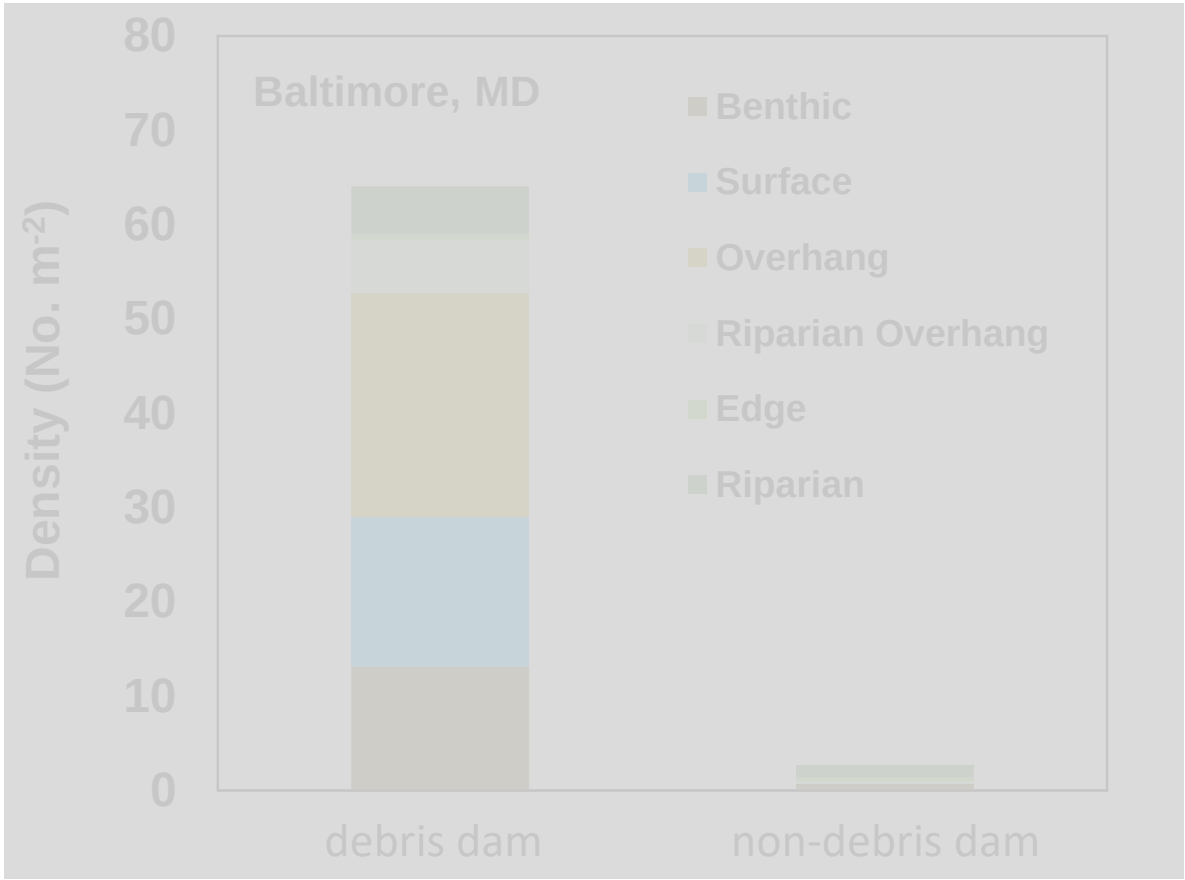


Hoellein et al. (2015)

Patchy distribution of AL in streams – Habitat

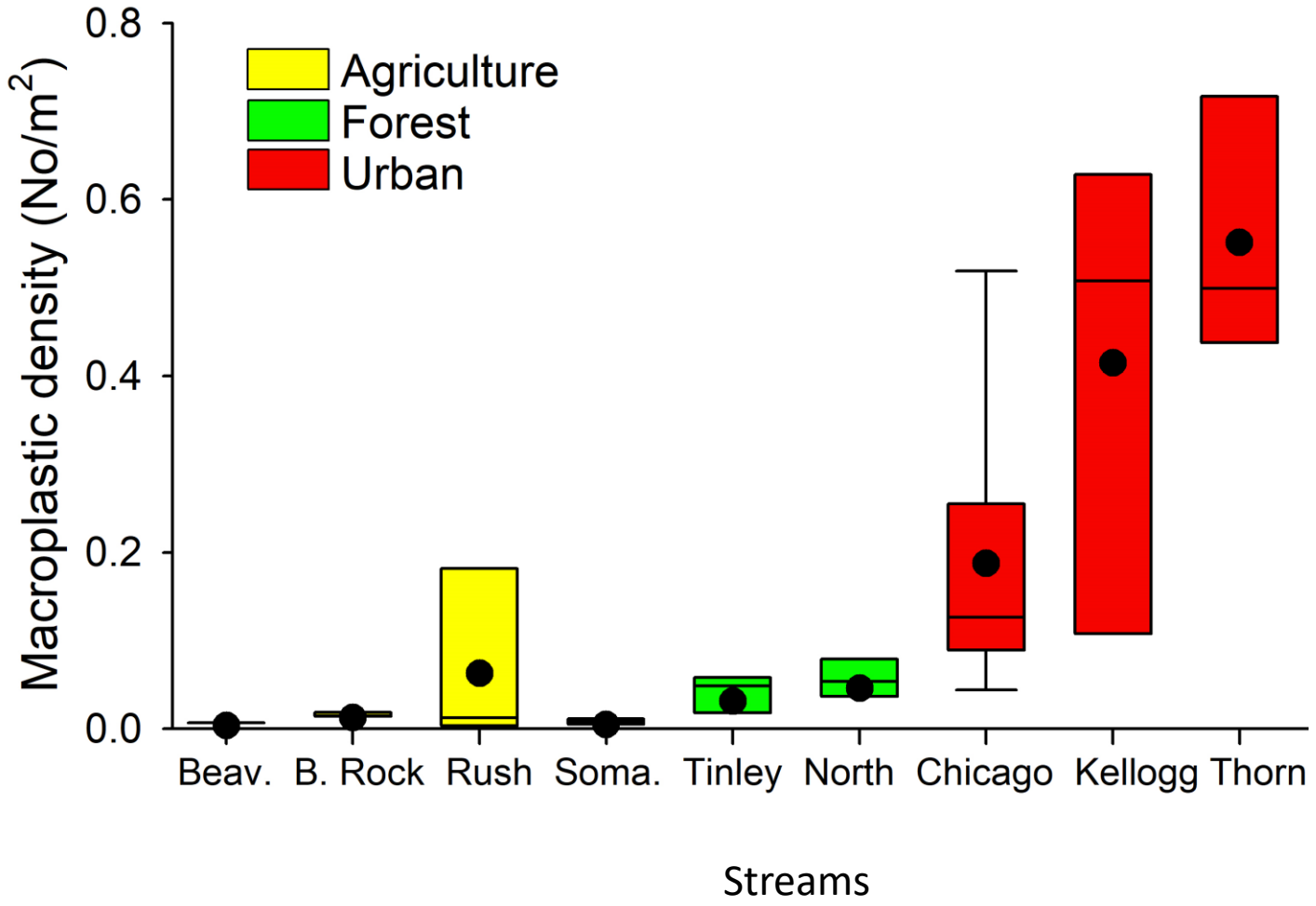
Patchy distribution of AL in streams – Habitat





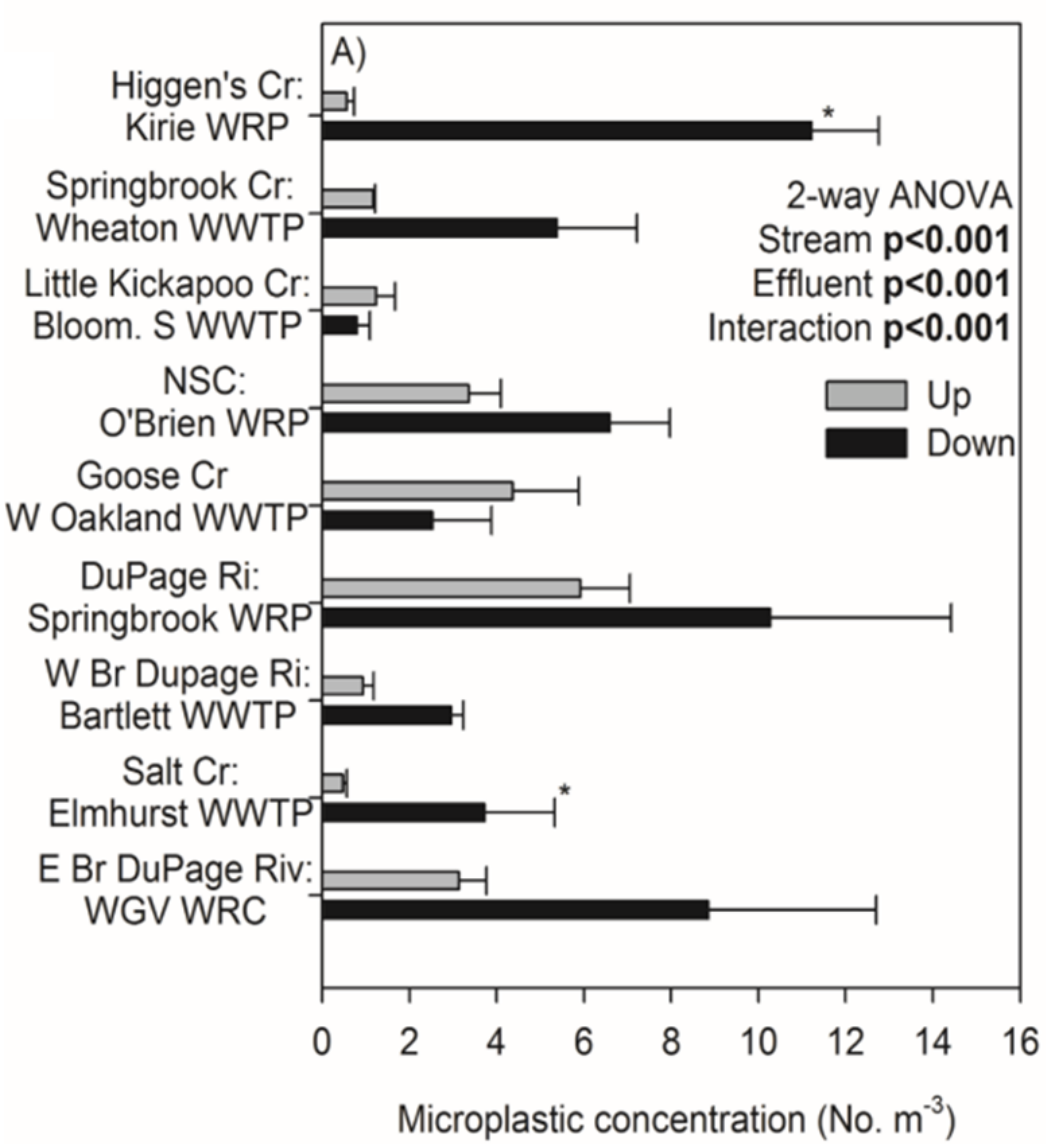
Kim and Hoellein (unpublished)

Land-use related to distribution of AL in streams



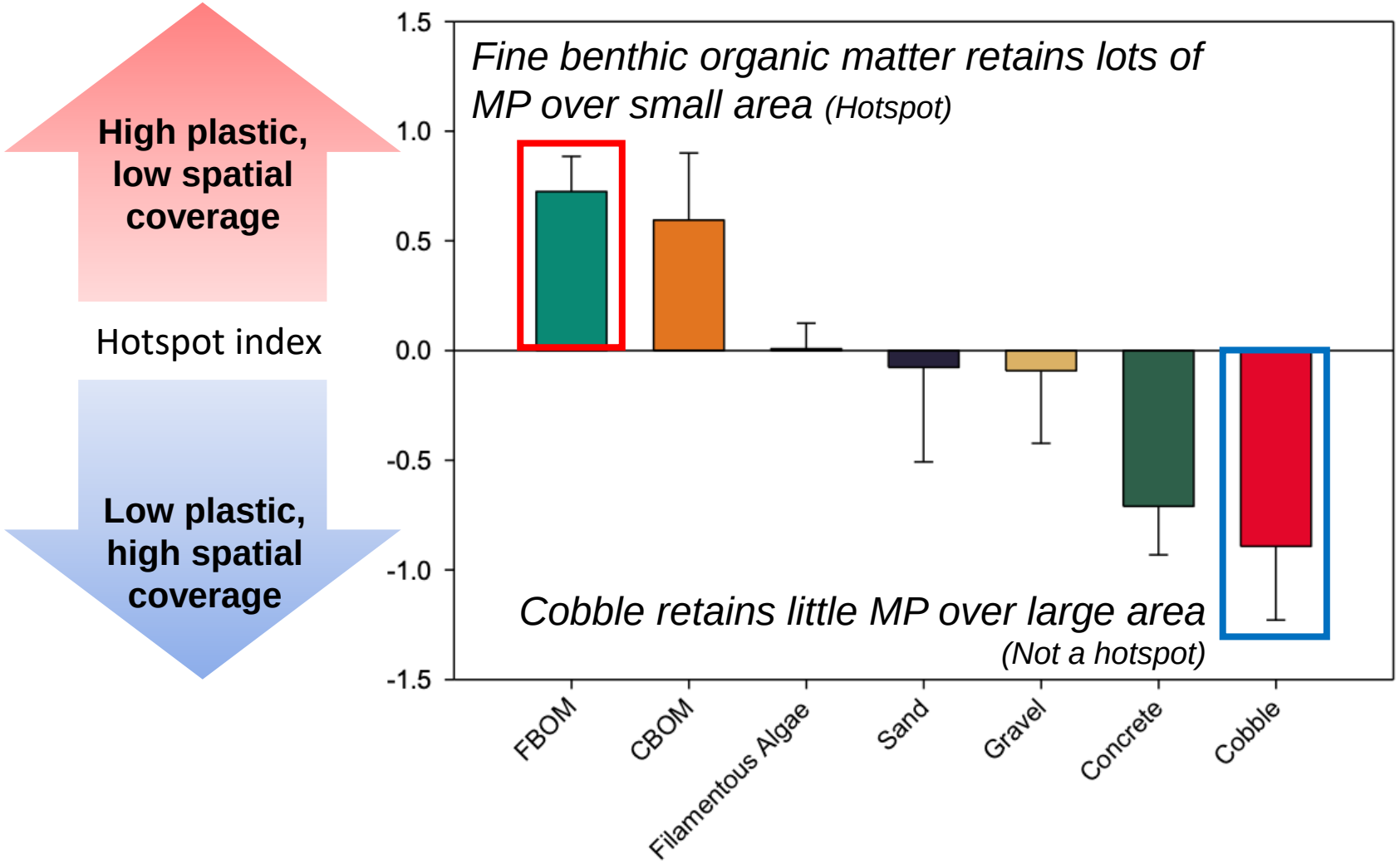
Wisbrock et al. (unpublished)

Patchy distribution of microplastics in streams: WWTP



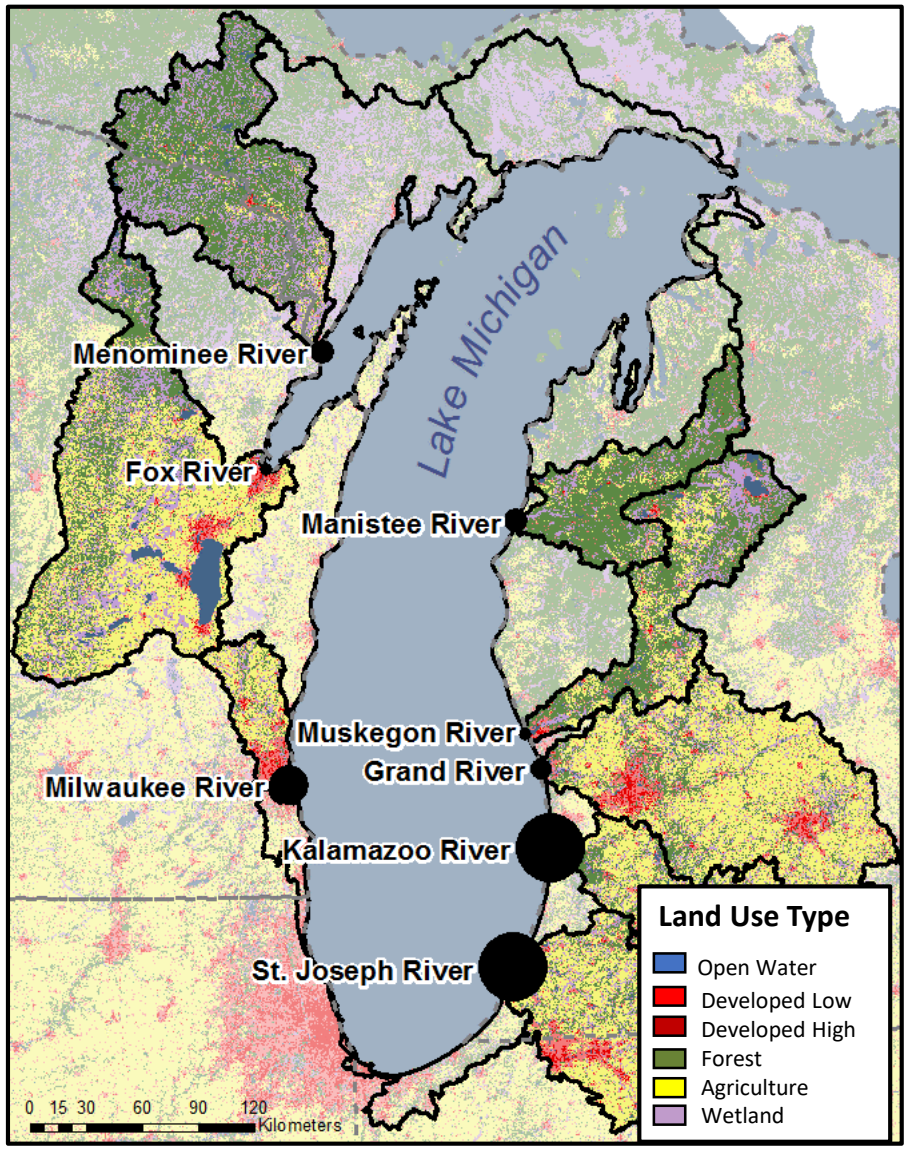
McCormick et al. 2016 *Ecosphere*

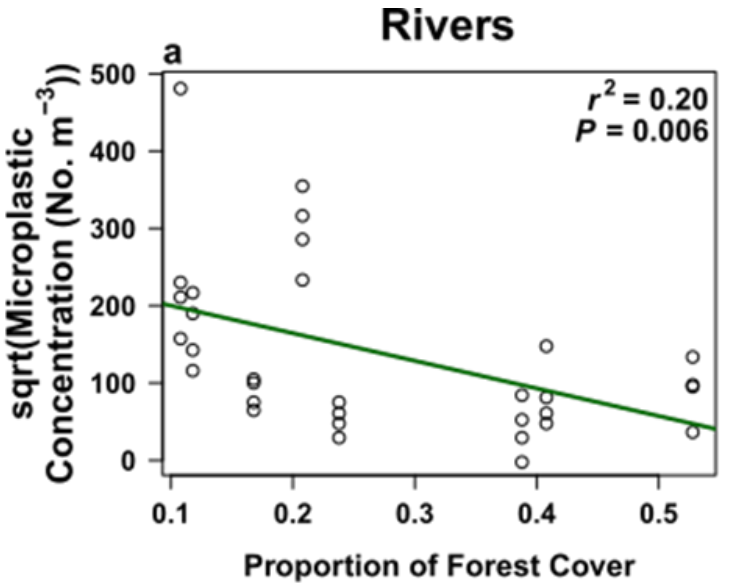
Patchy distribution of microplastics in stream substrates

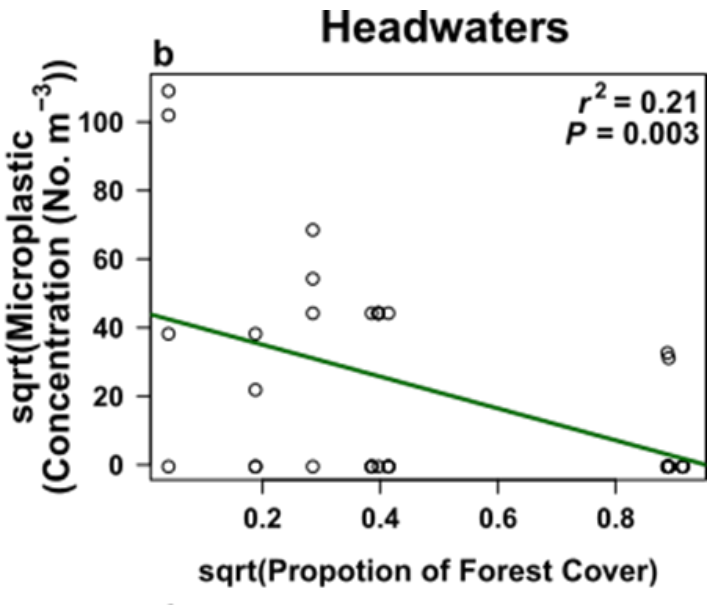


Vincent and Hoellein (in review)

Patchy distribution of microplastics at watershed scale







McNeish et al. (unpublished)

Plastic litter: Patchy distribution in the environment

<u>Small spatial scale</u>

- Habitat
- Next to piers
- Debris dams
- Point sources (WWTP)
- Different stream substrates (fine particles, cobble)

1) *Spatial distribution of AL is uneven*
2) *Litter and microplastics follows pattern for natural materials (leaves, sediment)*

<u>Large spatial scale</u>

- Land use patterns
- Population

1) *Watershed attributes land use offers some explanatory power*
2) *Much variation still unexplained, temporal dynamics also critical.*

Goal: Highlight research results, conclusions.

AL and microplastic on Great Lakes beaches and streams

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    - Short term: 1 year
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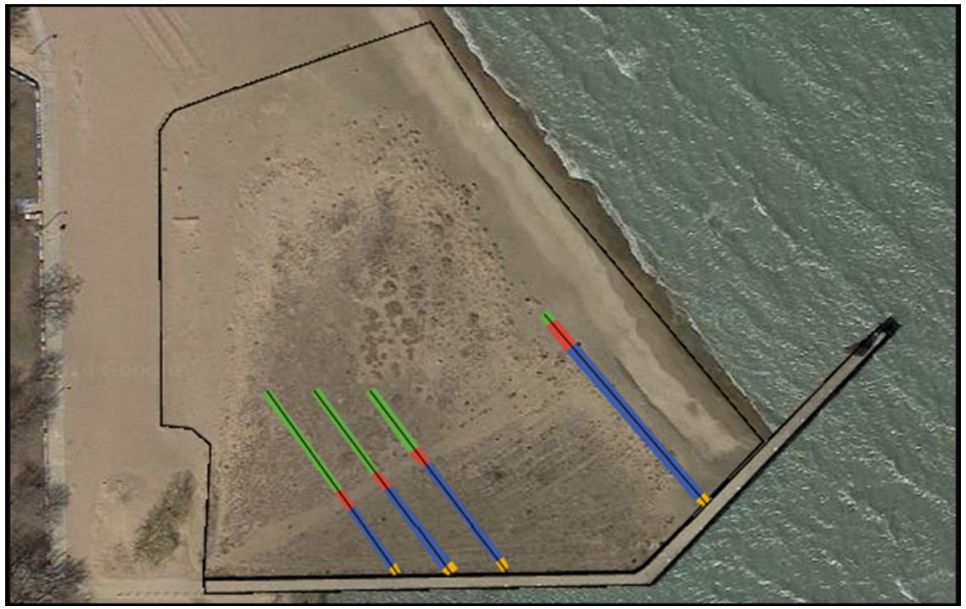
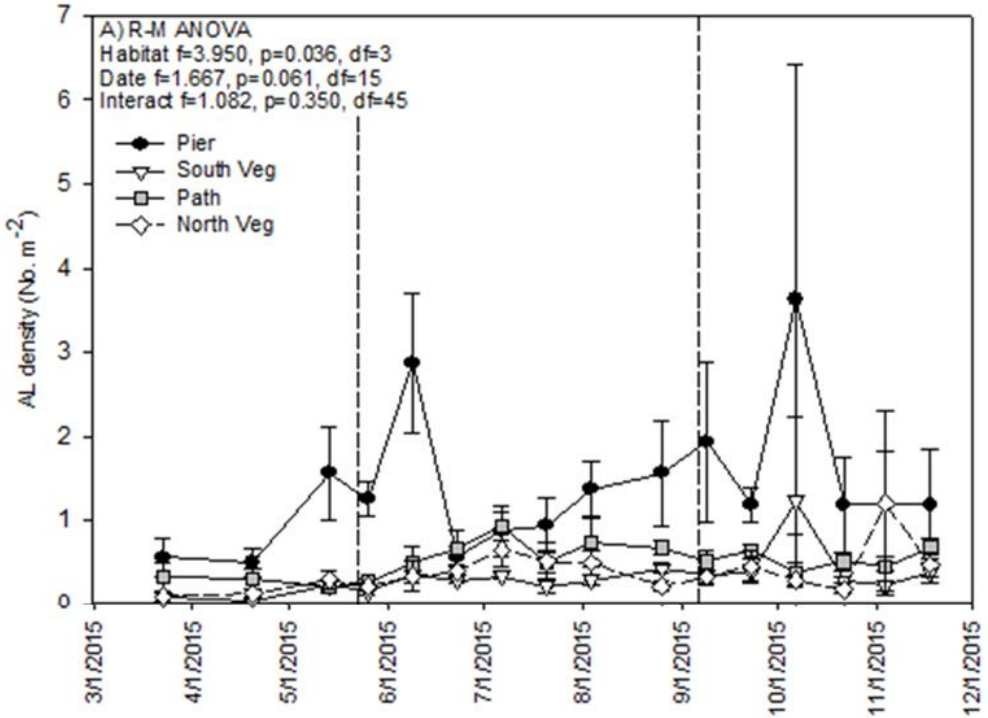
AL is moving around on beaches





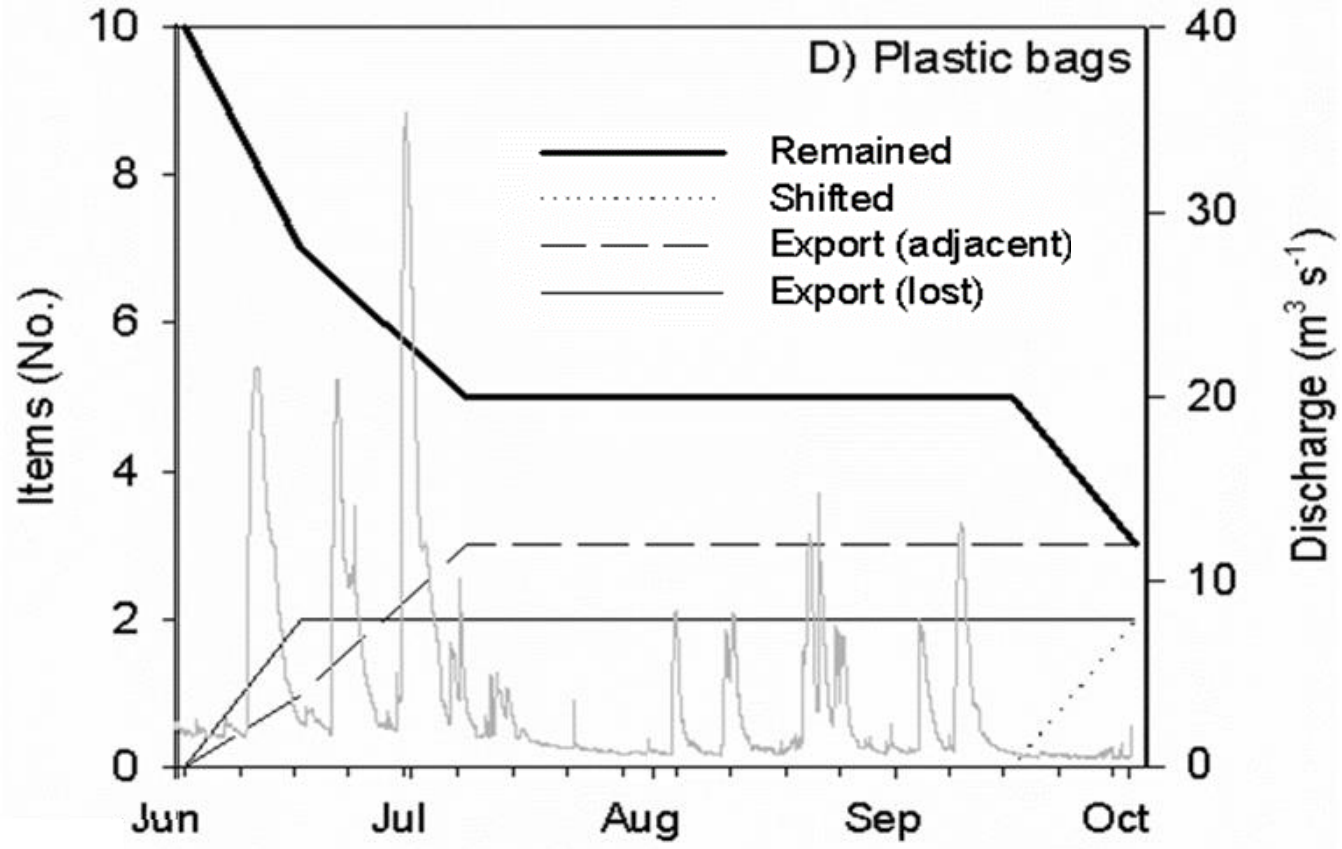
Permanent transects
Clear and collect new AL input every 2 weeks for 1 year (ice and snow free)

1 year: 79,915 items arrived on transects
Total area = 11,366 m^2

	Area (m^2)	Total No. (All Items)
Transect 2	3,605	40,144
Transect 3	3,478	20,628
Transect 4	1,384	6,004
Transect 5	2,899	13,140
Pier	374	7,562
South Veg	2,945	17,537
Path	556	4,606
North Veg	7,490	50,209

Vincent and Hoellein (2017)

AL is moving around in streams



In our 40 m^2 study area

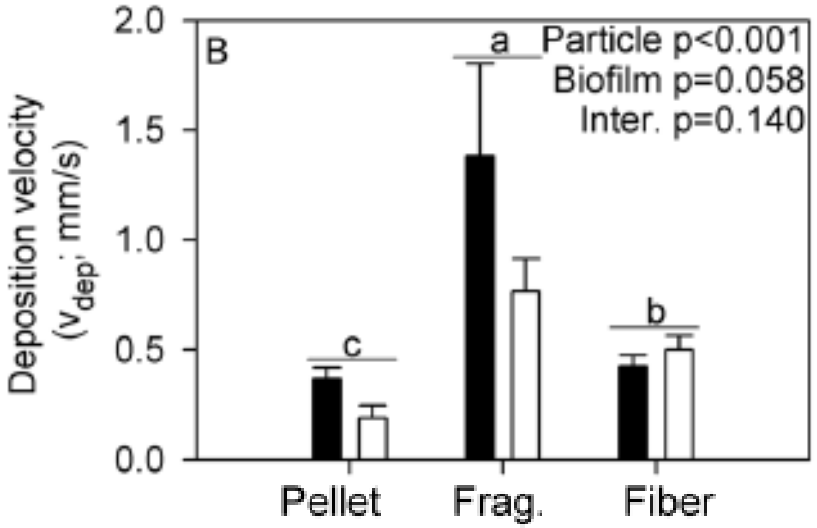
407 retained
954 gross input

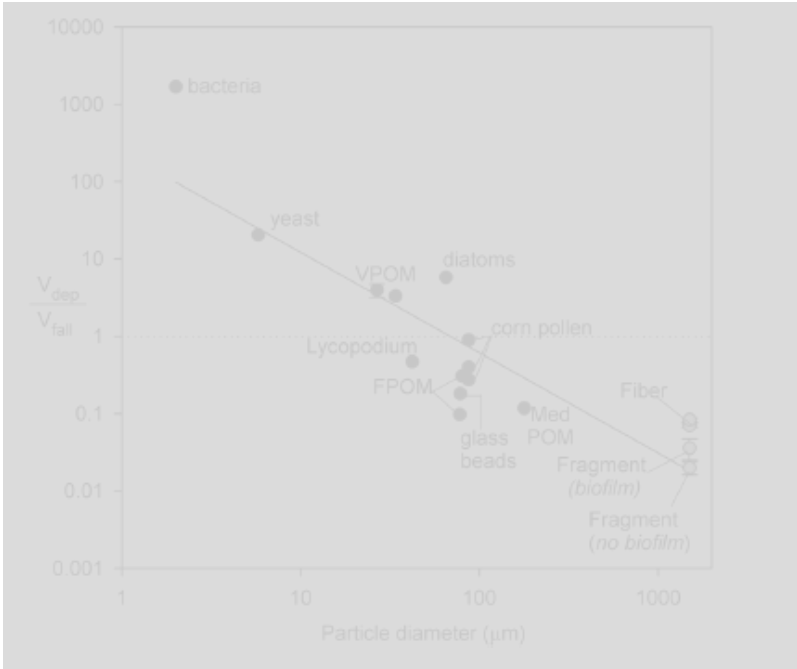
43% retention in 1 yr.

McCormick and Hoellein 2016

Microplastic is retained AND exported from streams

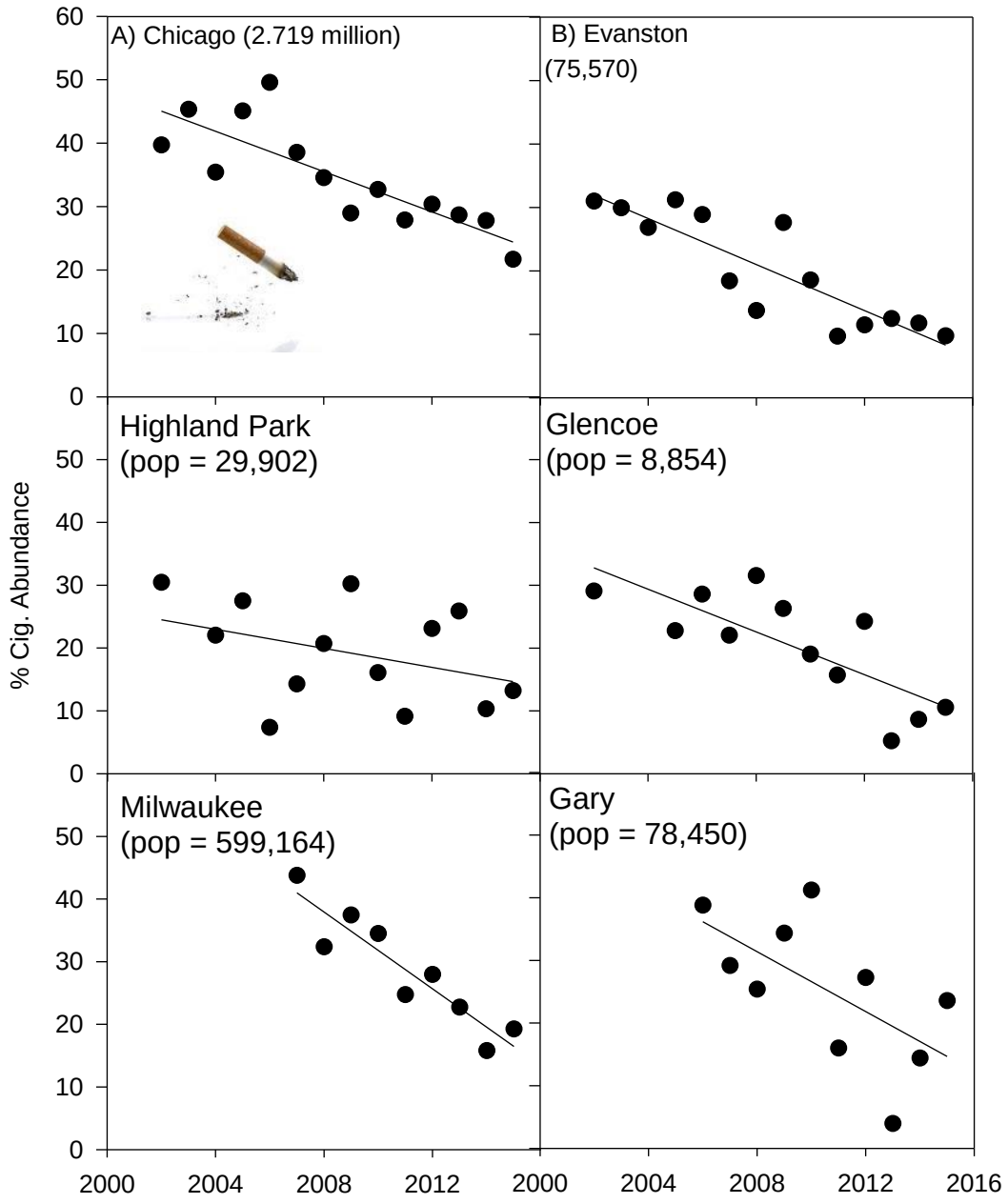
Acrylic fibers (1-2 mm)





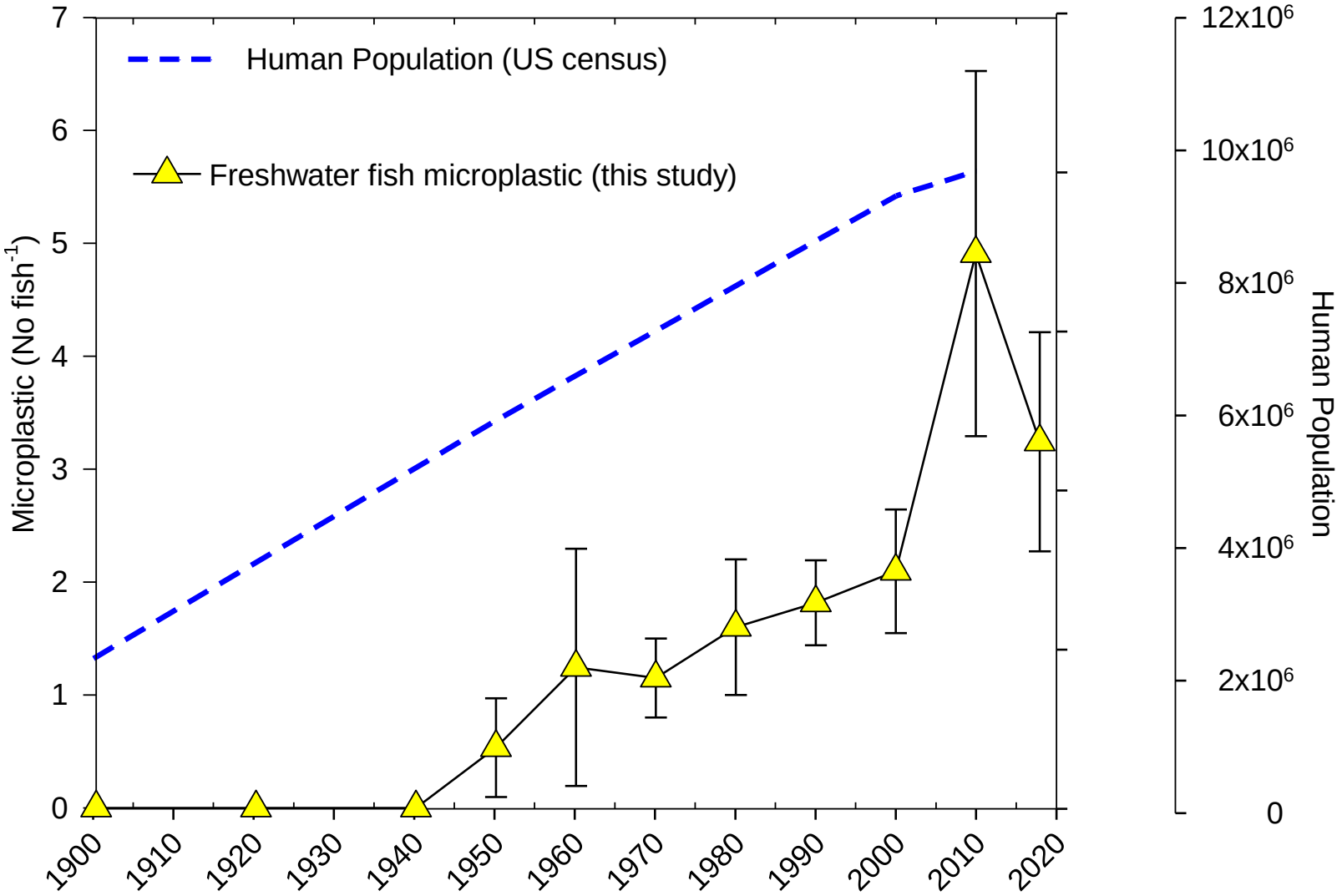
Hoellein et al 2019

Some AL is decreasing over long time scales



Hoellein et al (unpublished)

Microplastic is increasing over long time scales



Hou et al. In press

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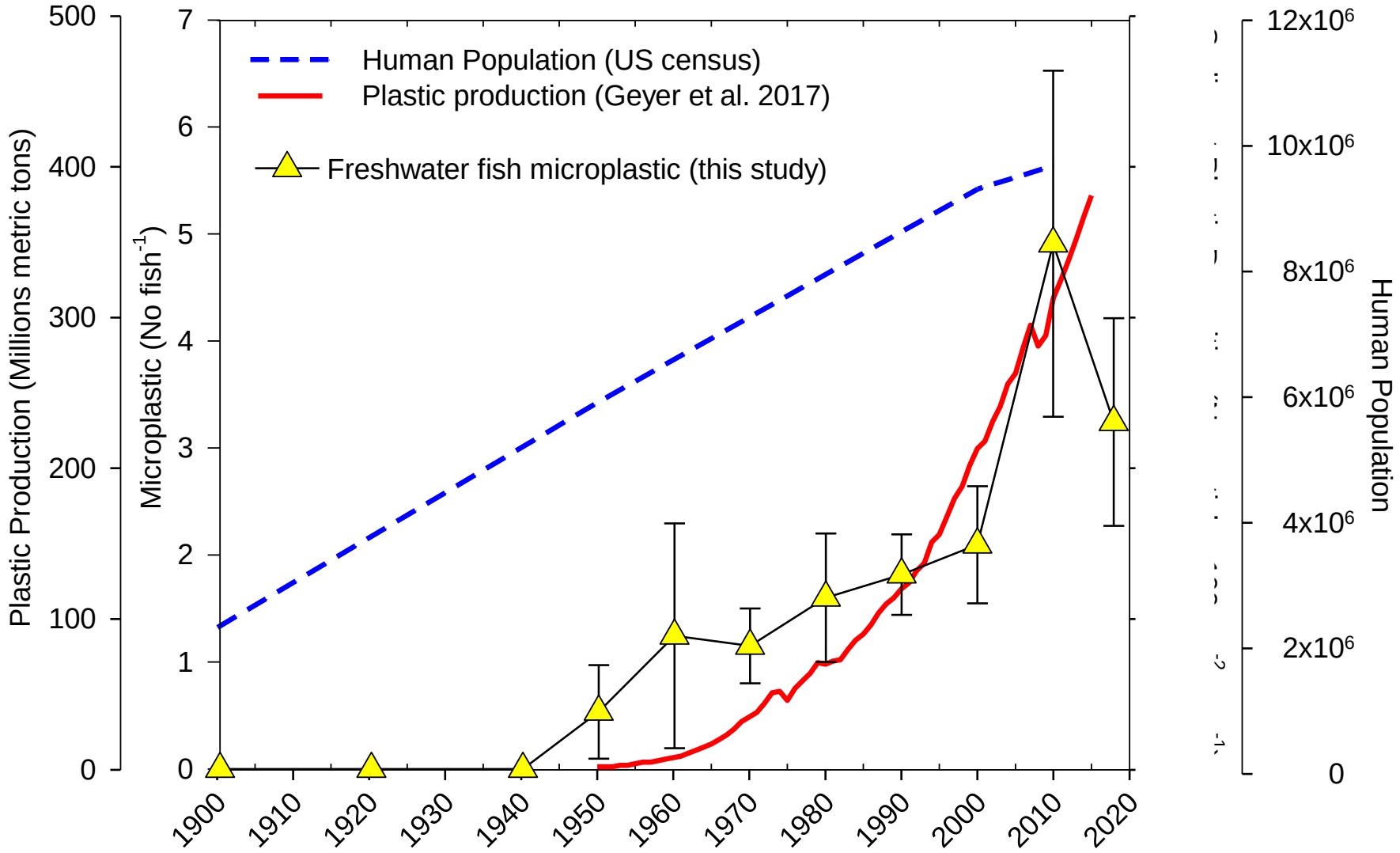

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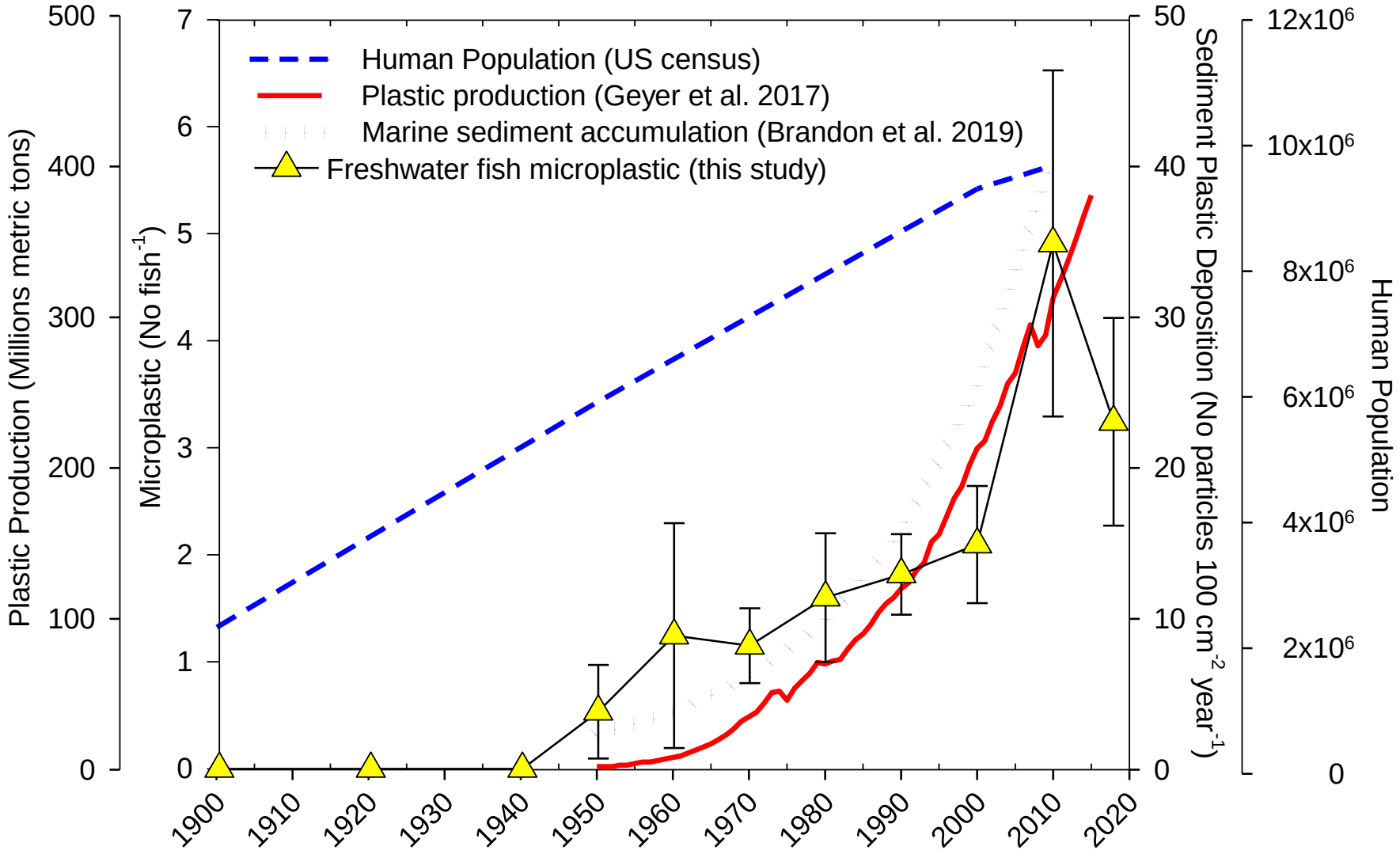

Hou et al. In press

Plastic litter: Variation in time

Short time scale

1) *Dynamic: AL and microplastic are mobile*
2) *Both retained and moving*
3) *Patterns similar to natural particles*

Long time scale

1) *Change in litter reflect broad policy and behavior shifts (smoking litter)*
2) *Microplastic in freshwater fish increasing – follows expected global trends*

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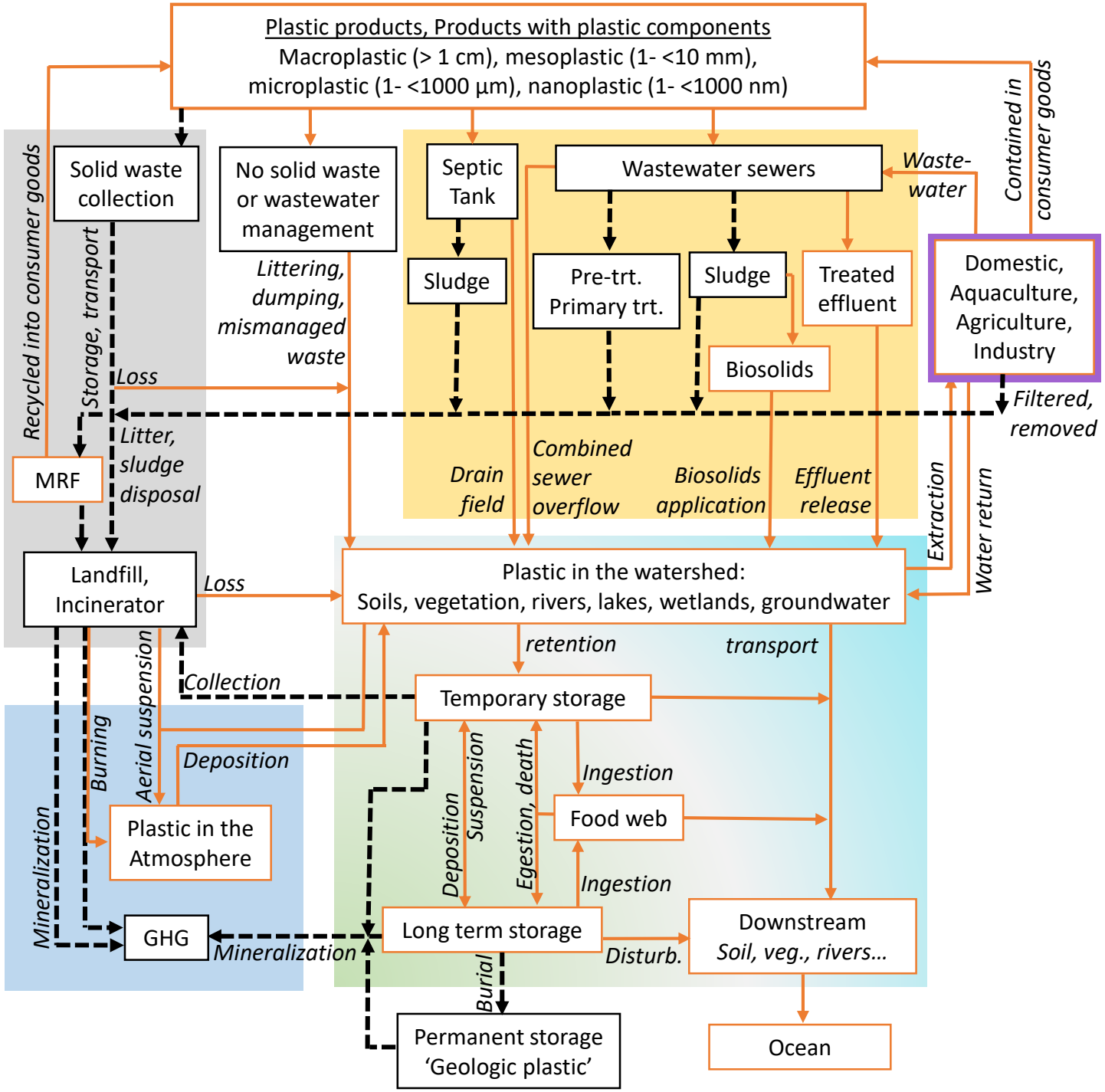
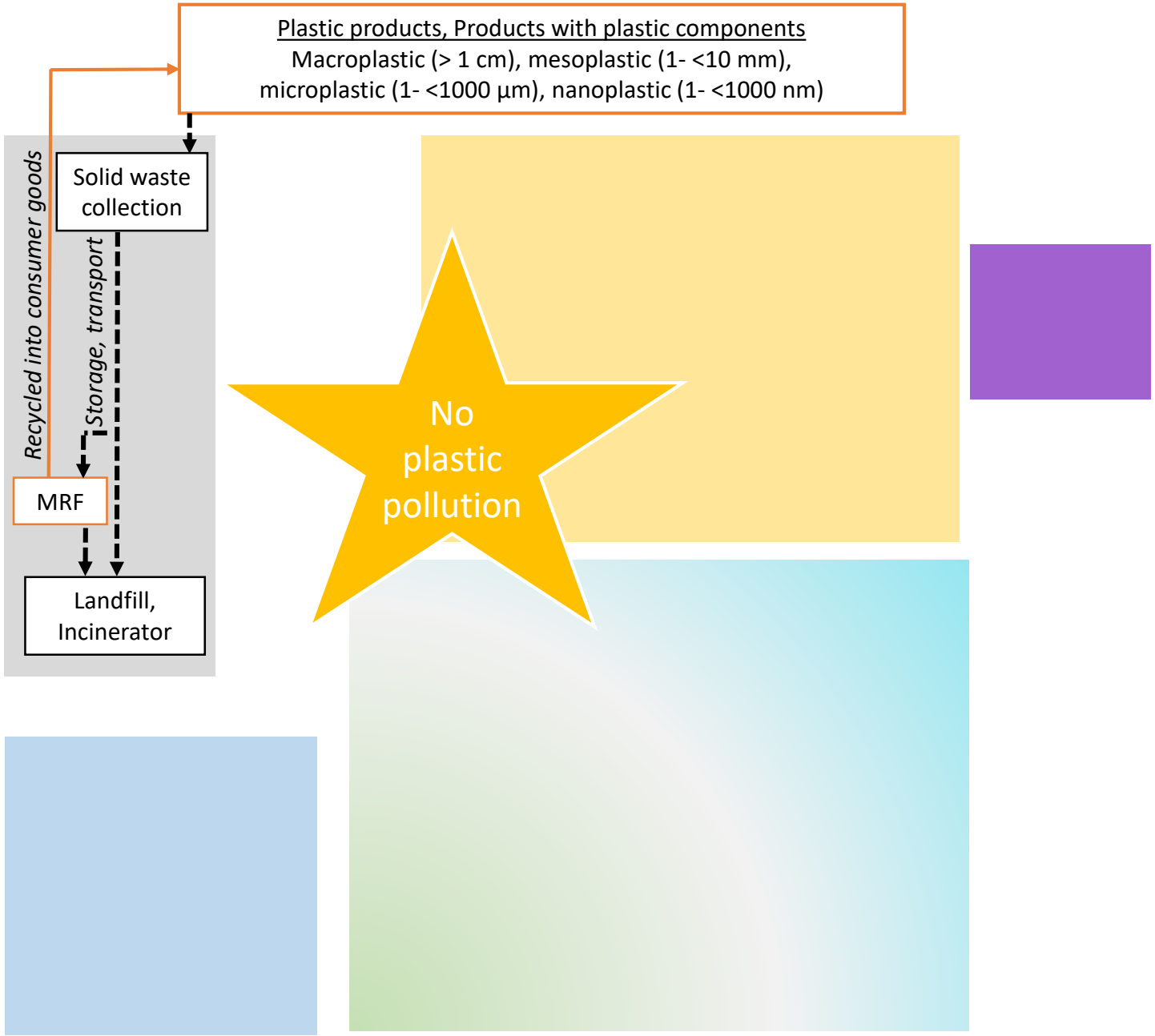
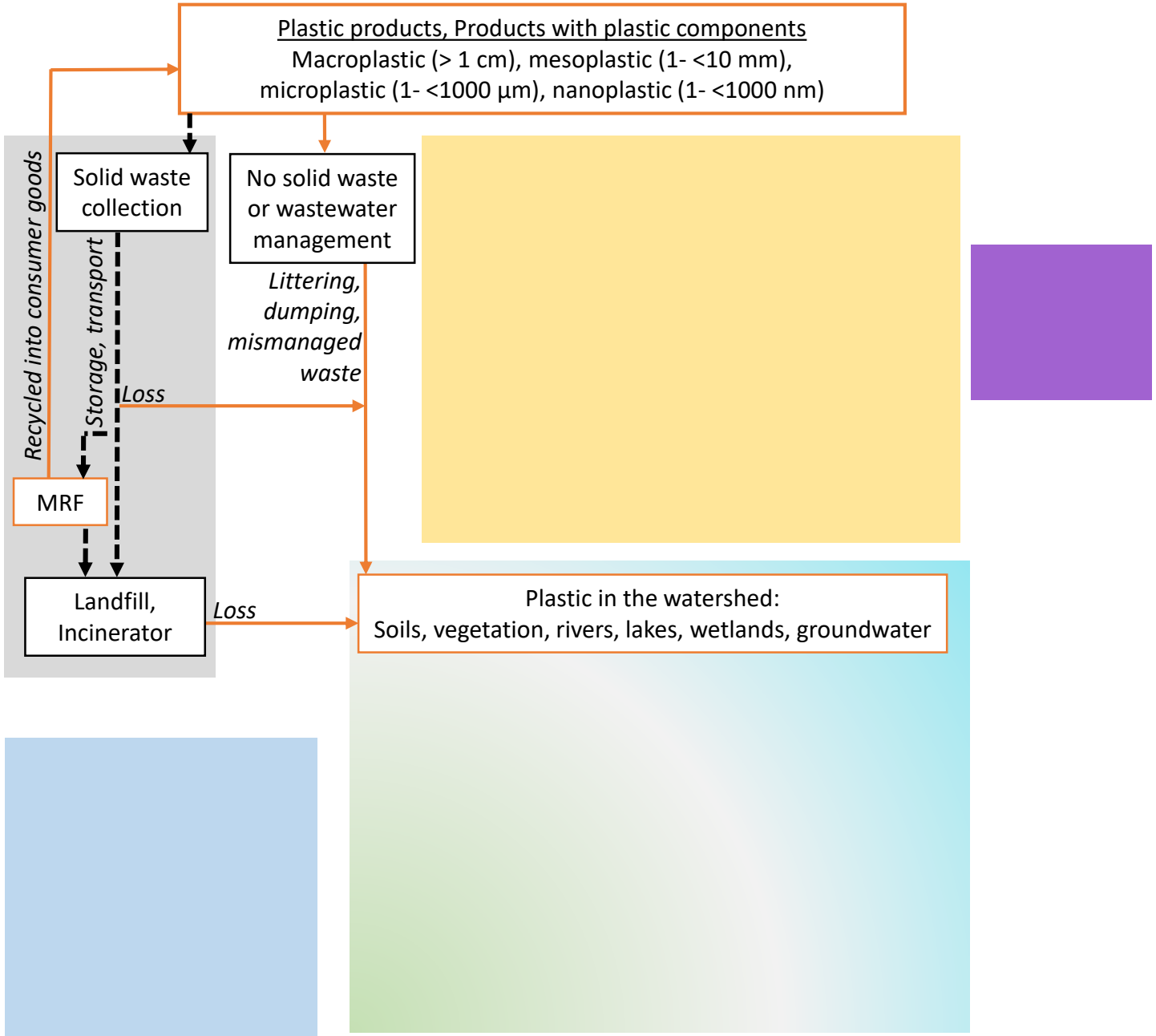


Hoellein and Rochman 2021


Plastic products, Products with plastic components
Macroplastic (> 1 cm), mesoplastic (1- <10 mm),
microplastic (1- <1000 µm), nanoplastic (1- <1000 nm)
Solid waste collection
Storage, transport
Recycled into consumer goods
MRF
Landfill, Incinerator
No plastic pollution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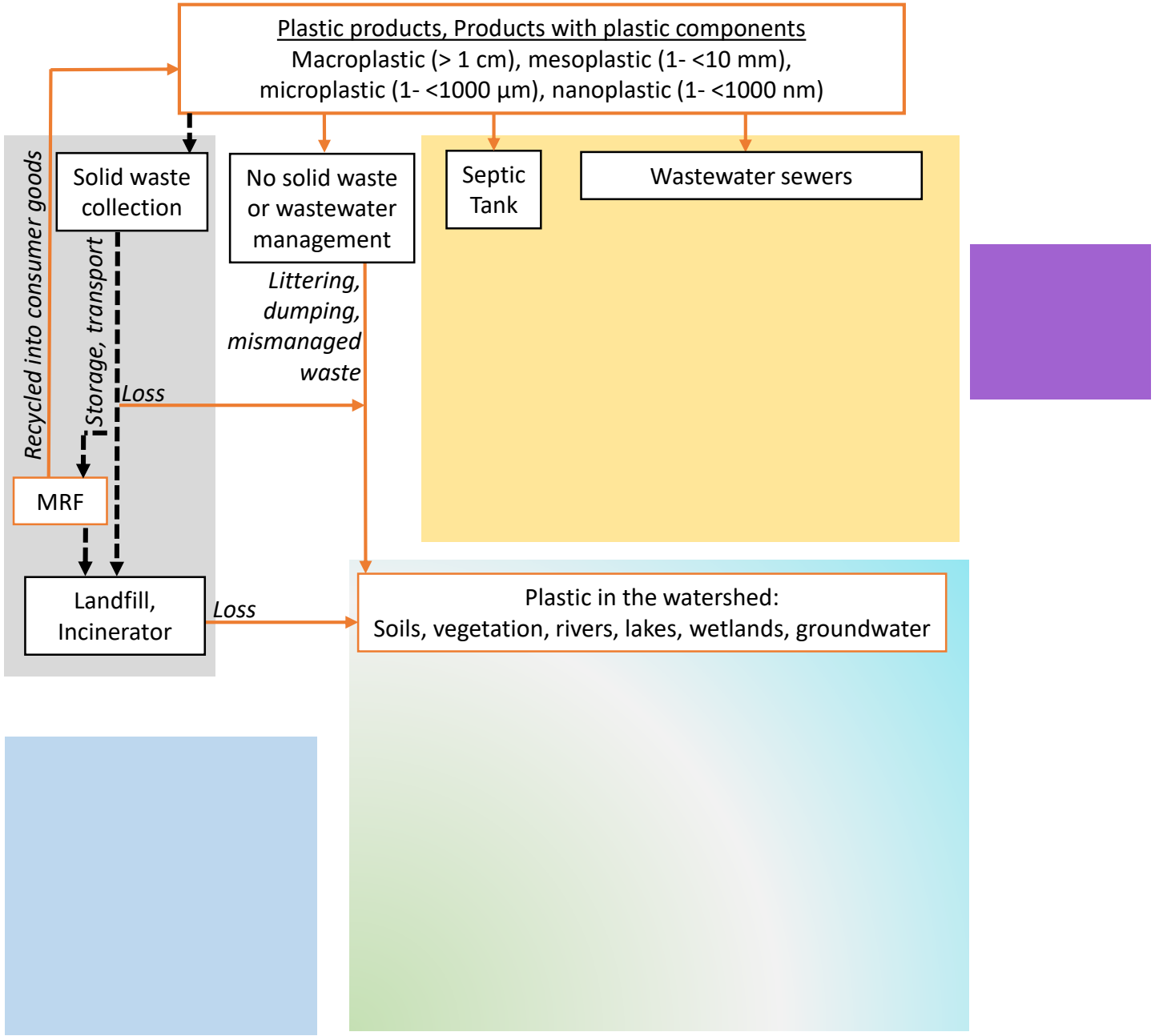
Solid waste collection
No solid waste or wastewater management
Recycled into consumer goods
Storage, transport
Loss
Littering, dumping, mismanaged waste
MRF
Landfill, Incinerator
Loss
Plastic in the watershed:
Soils, vegetation, rivers, lakes, wetlands, groundwater


Plastic products, Products with plastic components
Macroplastic (> 1 cm), mesoplastic (1- <10 mm),
microplastic (1- <1000 µm), nanoplastic (1- <1000 nm)
Solid waste collection
No solid waste or wastewater management
Septic Tank
Wastewater sewers
Recycled into consumer goods
Storage, transport
Loss
Littering, dumping, mismanaged waste
MRF
Landfill, Incinerator
Loss
Plastic in the watershed:
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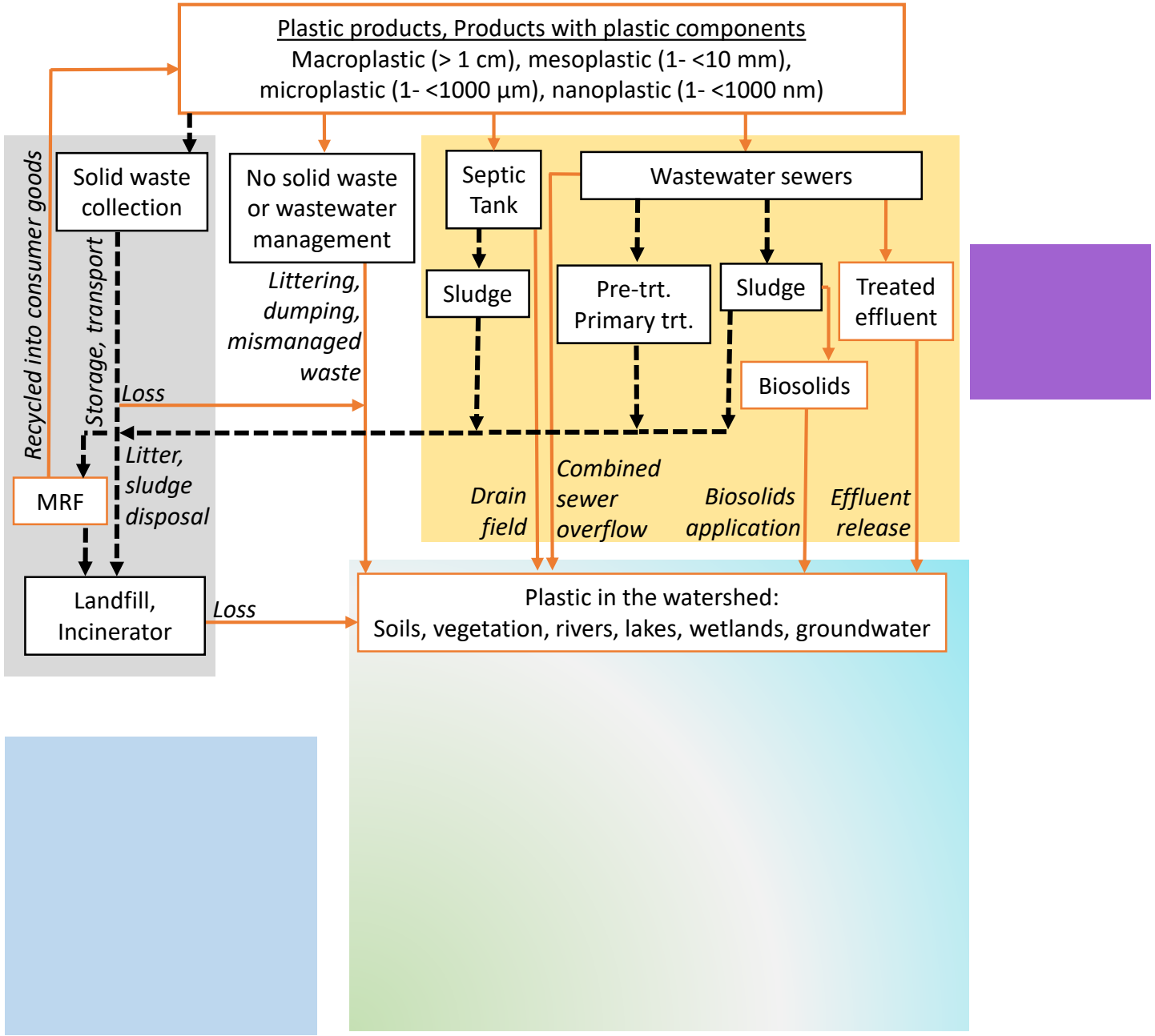
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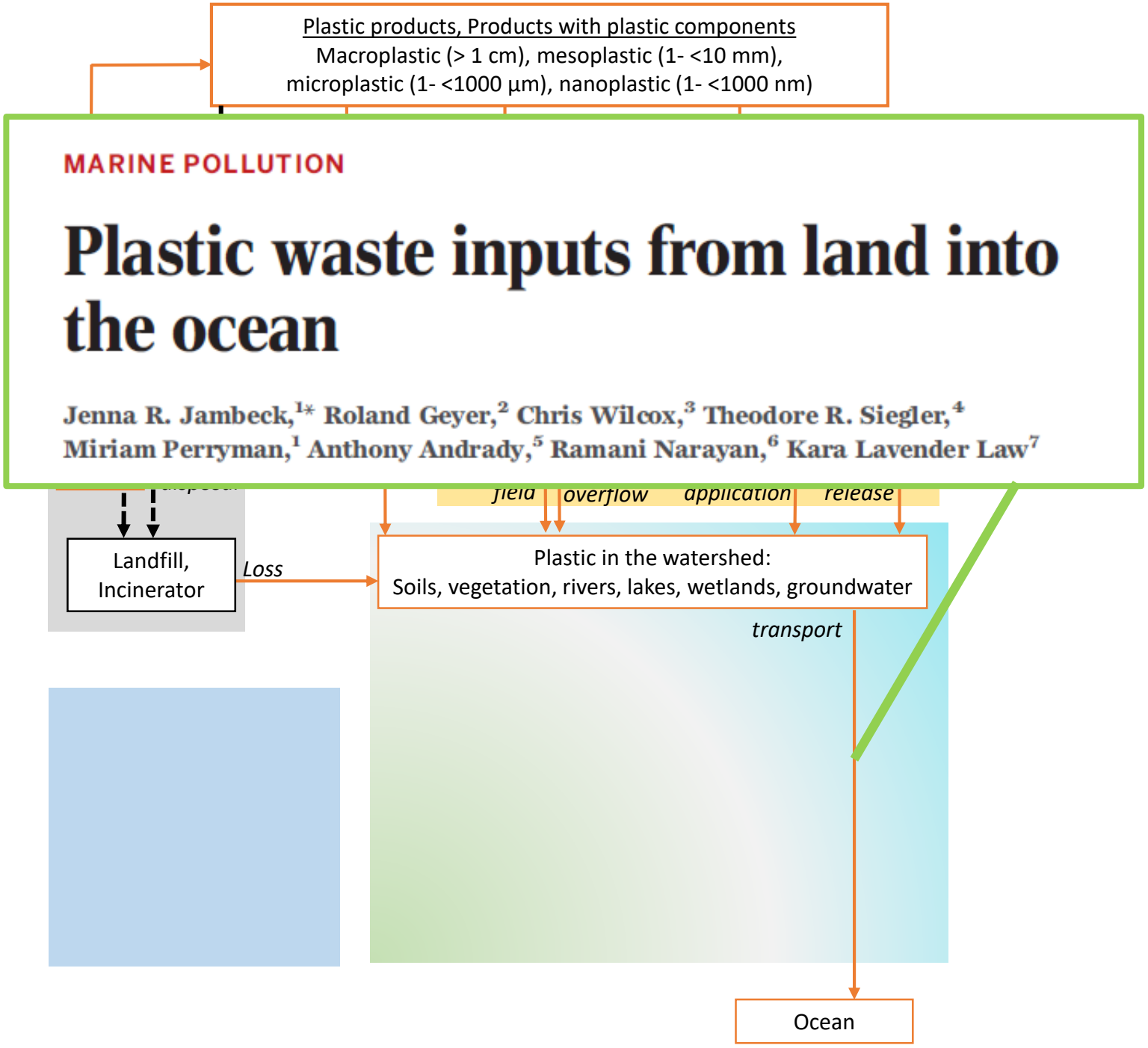
Littering, dumping, mismanaged waste
Sludge
Pre-trt. Primary trt.
Sludge
Treated effluent
Biosolids
Loss
Litter, sludge disposal
MRF
Drain field
Combined sewer overflow
Biosolids application
Effluent release
Landfill, Incinerator
Loss
Plastic in the watershed:
Soils, vegetation, rivers, lakes, wetlands, groundwater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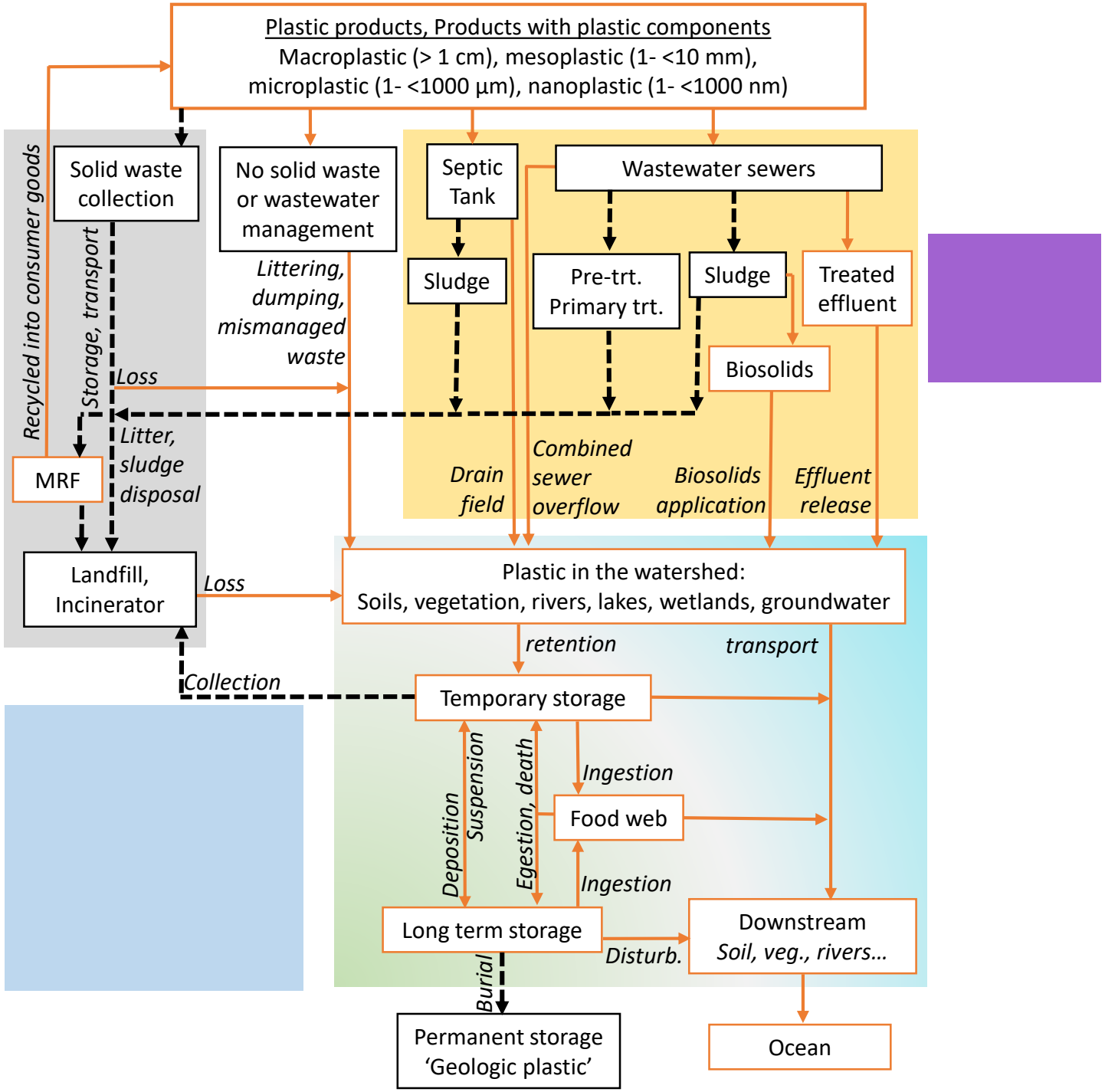
MARINE POLLUTION
Plastic waste inputs from land into the ocean
Jenna R. Jambeck,[1]* Roland Geyer,[2] Chris Wilcox,[3] Theodore R. Siegler,[4]
Miriam Perryman,[1] Anthony Andrady,[5] Ramani Narayan,[6] Kara Lavender Law[7]
field
overflow
application
release
Landfill,
Incinerator
Loss
Plastic in the watershed:
Soils, vegetation, rivers, lakes, wetlands, groundwater
transport
Ocean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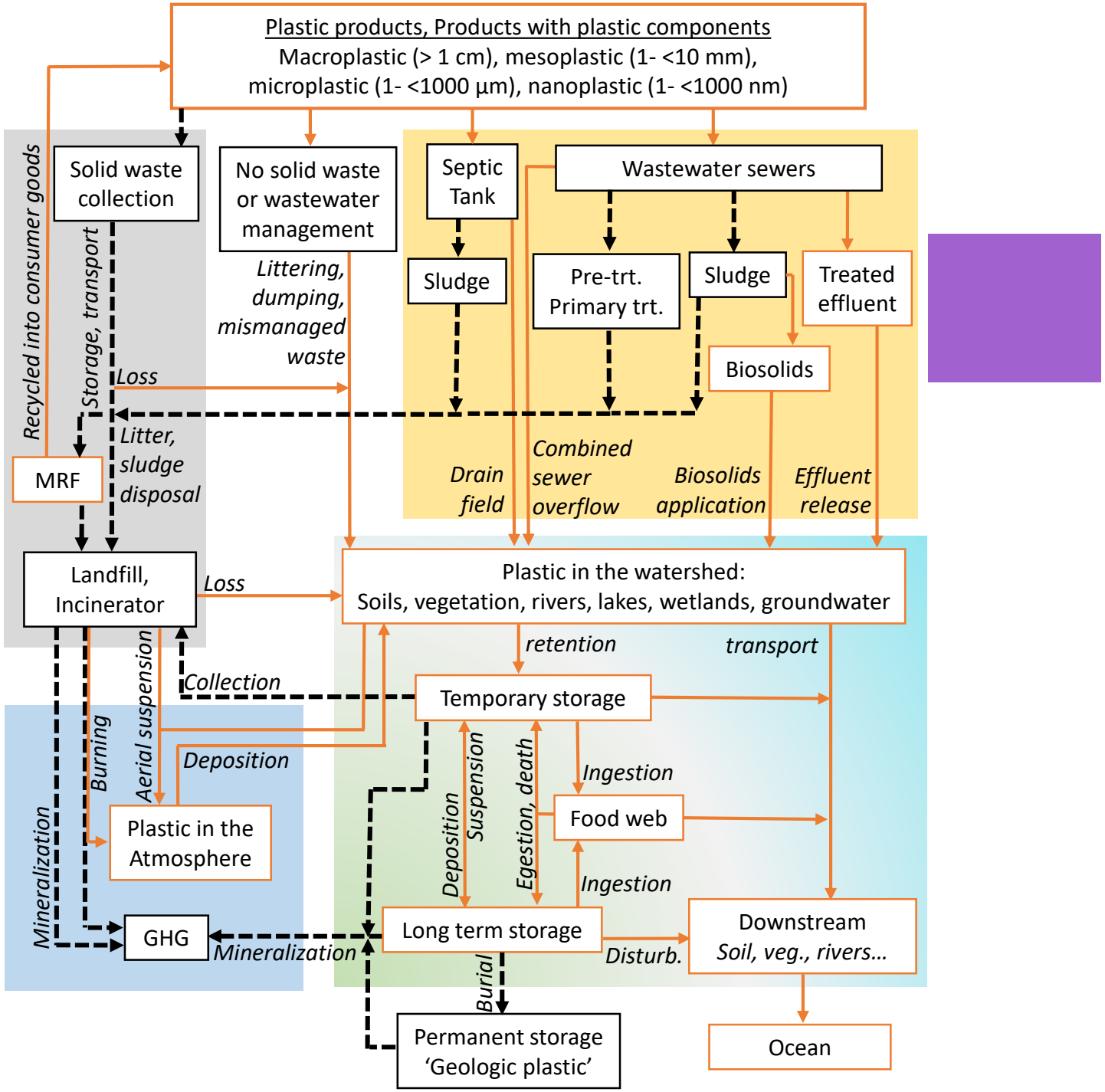
Biosolids
Loss
Litter, sludge disposal
MRF
Drain field
Combined sewer overflow
Biosolids application
Effluent release
Landfill, Incinerator
Loss
Plastic in the watershed:
Soils, vegetation, rivers, lakes, wetlands, groundwater
retention
transport
Collection
Temporary storage
Deposition
Suspension
Egestion, death
Ingestion
Food web
Ingestion
Long term storage
Disturb.
Downstream
Soil, veg., rivers…
Burial
Permanent storage
'Geologic plastic'
Ocean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Recycled into consumer goods
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Sludge
Pre-trt. Primary trt.
Sludge
Treated effluent
Biosolids
Loss
Litter, sludge disposal
MRF
Drain field
Combined sewer overflow
Biosolids application
Effluent release
Landfill, Incinerator
Loss
Plastic in the watershed:
Soils, vegetation, rivers, lakes, wetlands, groundwater
retention
transport
Collection
Temporary storage
Burning
Aerial suspension
Deposition
Ingestion
Deposition
Suspension
Egestion, death
Food web
Plastic in the Atmosphere
Mineralization
Ingestion
GHG
Mineralization
Long term storage
Disturb.
Downstream
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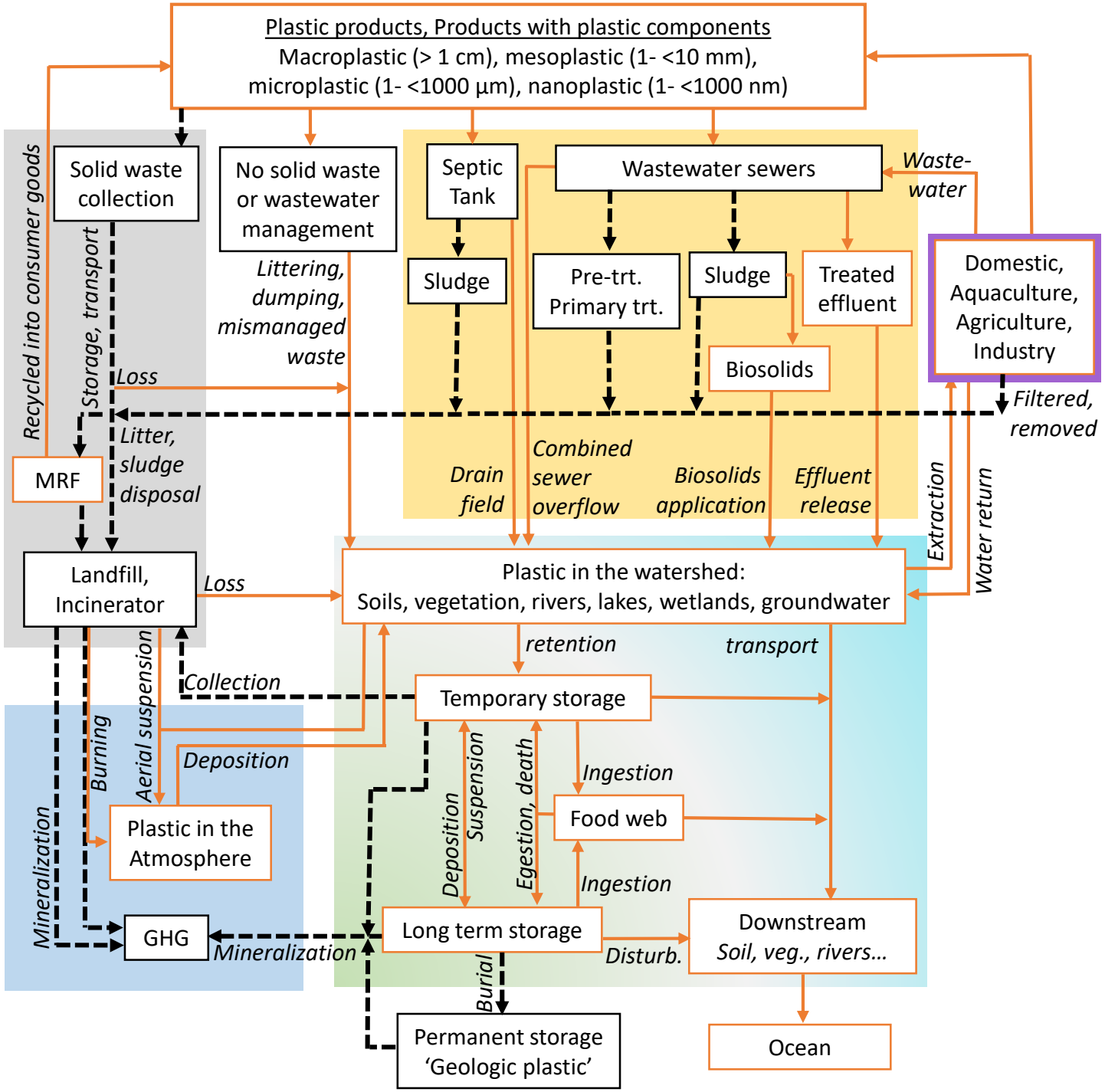
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Septic Tank
Wastewater sewers
Waste-water
Domestic, Aquaculture, Agriculture, Industry
Recycled into consumer goods
Storage, transport
Littering, dumping, mismanaged waste
Sludge
Pre-trt. Primary trt.
Sludge
Treated effluent
Biosolids
Loss
Filtered, removed
Litter, sludge disposal
MRF
Drain field
Combined sewer overflow
Biosolids application
Effluent release
Extraction
Water return
Landfill, Incinerator
Loss
Plastic in the watershed:
Soils, vegetation, rivers, lakes, wetlands, groundwater
retention
transport
Collection
Temporary storage
Burning
Aerial suspension
Deposition
Ingestion
Deposition
Suspension
Egestion, death
Food web
Plastic in the Atmosphere
Mineralization
Ingestion
GHG
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Long term storage
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Soil, veg., rivers…
Burial
Permanent storage
'Geologic plastic'
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Final take home points

1) Plastic litter: Spatial and temporal variation

- Patchy distribution across spatial scales
- Variable in time: Sources, retention, transformation, movement

2) Freshwaters are **dynamic** ecosystems

- Biologically and chemically reactive
- Provide key ecosystem services
- Critical sites for intervention, clean-up, prevention
- *Not pipes!* ☺

Plastic litter research needs freshwater science

- Freshwater ecosystems are less well studied for than oceans
- Hydrology, biology, chemistry, engineering, social science
- Attempts to craft global (or USA-based) assessments of plastic litter must include measurements of plastic litter dynamics within watersheds
- If focusing only on exports to coastlines, the assessment is incomplete.

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Goal: Highlight research results, conclusions.

AL and microplastic on Great Lakes beaches and streams

1. Spatial distribution
    - Small scale: Habitat
    - Large scale: Watershed

2. Temporal variation
    - Short term: 1 year
    - Longer term: Decades

3. Conceptual model update

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THANK YOU

United States Contributions to Global Ocean Plastic Waste Meeting 3

Recording will be available on our website in a few weeks.

The paper referred to by Dr. Timothy Hoellein in his presentation about the model is available here, with open access. https://esajournals.onlinelibrary.wiley.com/doi/10.1002/fee.2294