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REGIONAL WATER QUALITY CONTROL BOARDS

Research and Actions on Microplastics in Drinking Water by the California State Water Resources Control Board

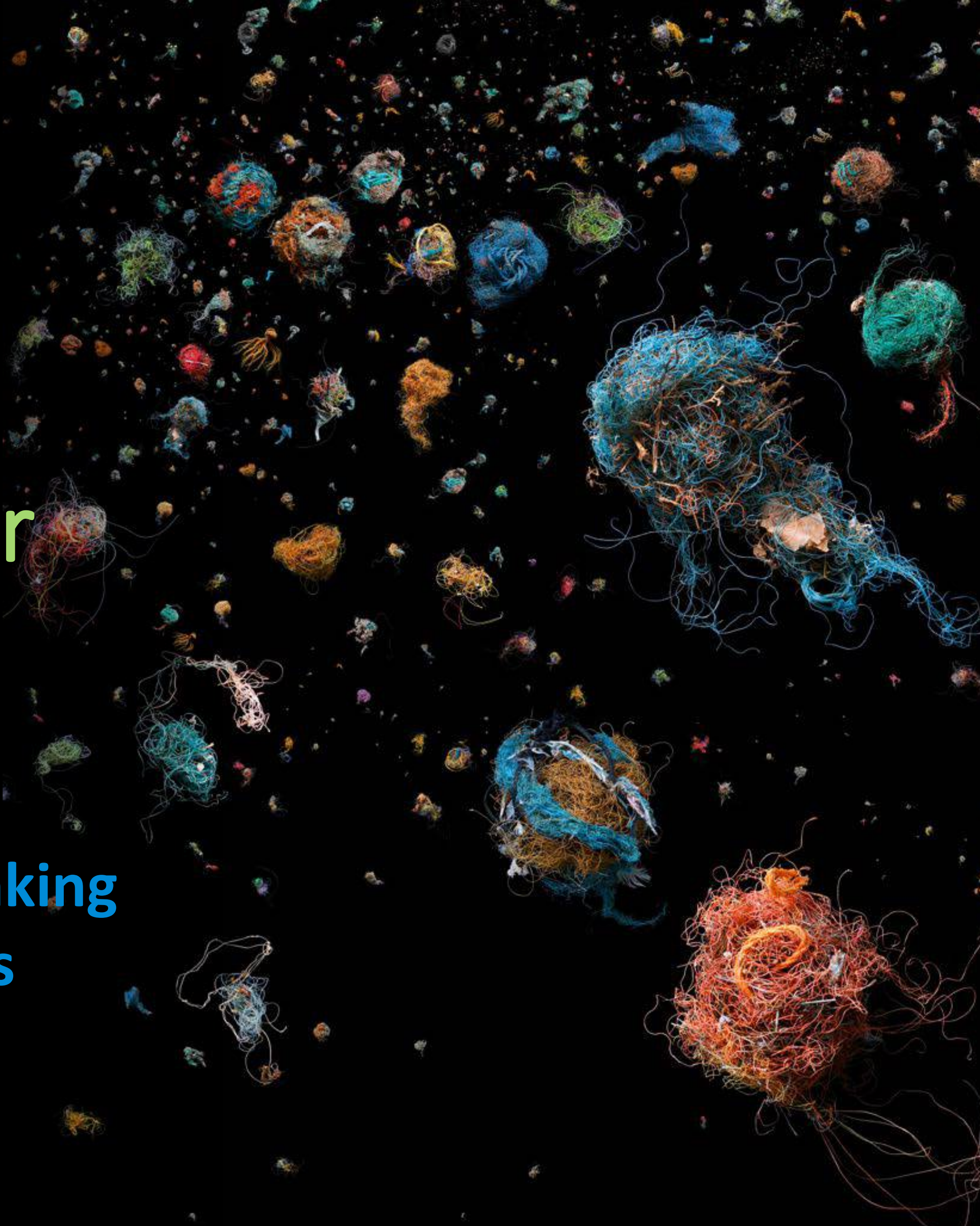


Photo: Mandy Barker

Microplastics in the Potomac River Basin: Drinking Water & Source Water Protection Perspectives

October 12th, 2021

Scott Coffin, Ph.D.
California State Water Resources Control Board

California Senate Bill 1263 (2018): Statewide Microplastics Strategy

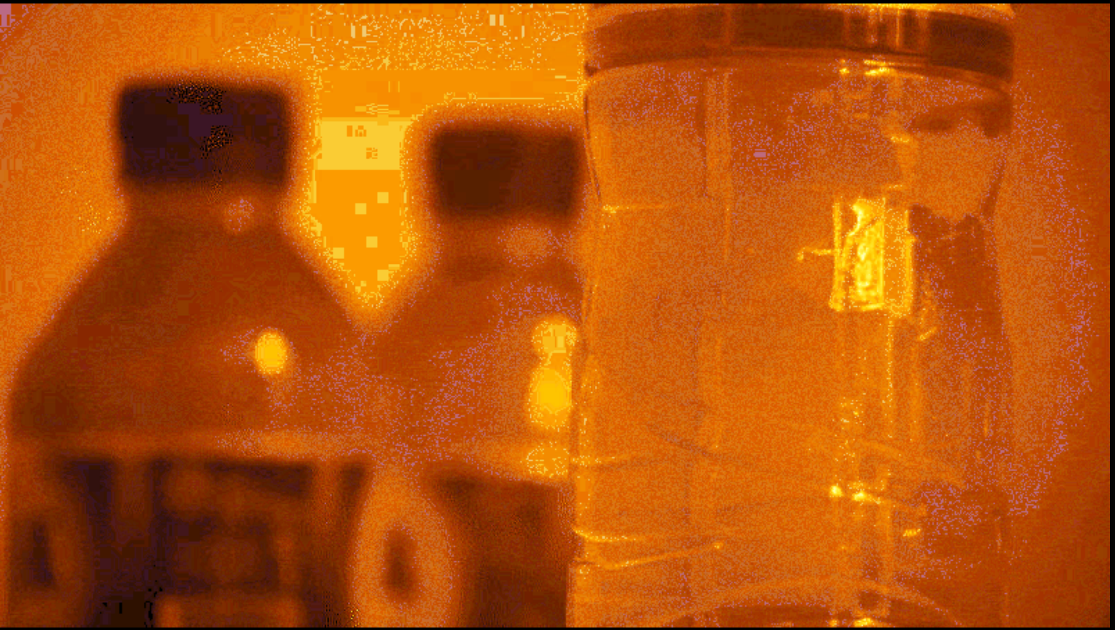
Deadlines

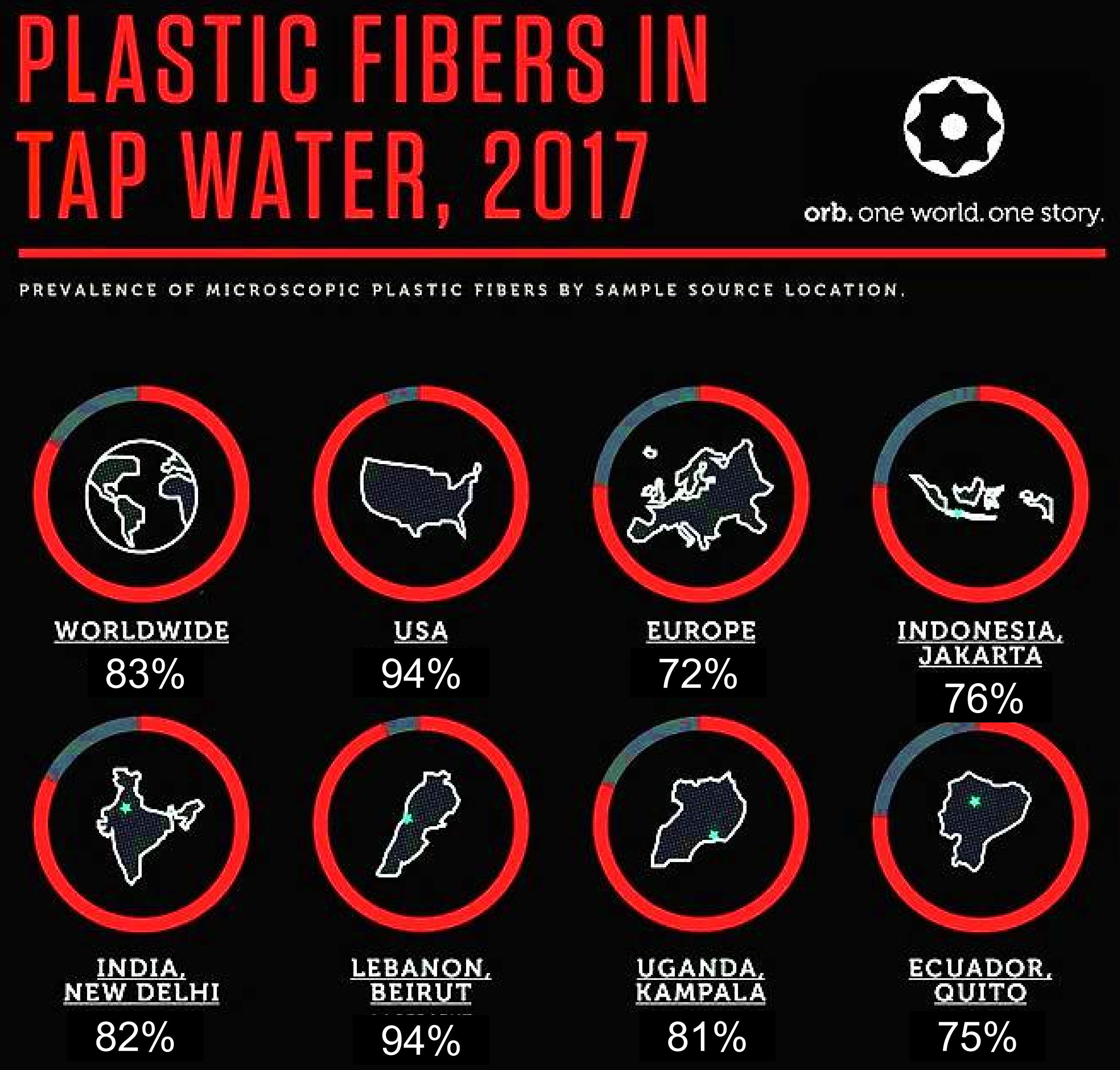
2022

- Initiate Statewide Microplastics Strategy

2026

- Develop **risk assessment** framework
- Develop standardized **methods**
- Establish baseline **occurrence** data
- Investigate **sources** and **pathways**
- Recommend **source reduction** strategies





Orbmedia.org

California Senate Bill 1422 (2018)

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Deadlines

July 1,2020

- Define ‘microplastics’

July 1,2021

- Standard method
- Four years of testing
- Health-based guidance level
- Accredit laboratories

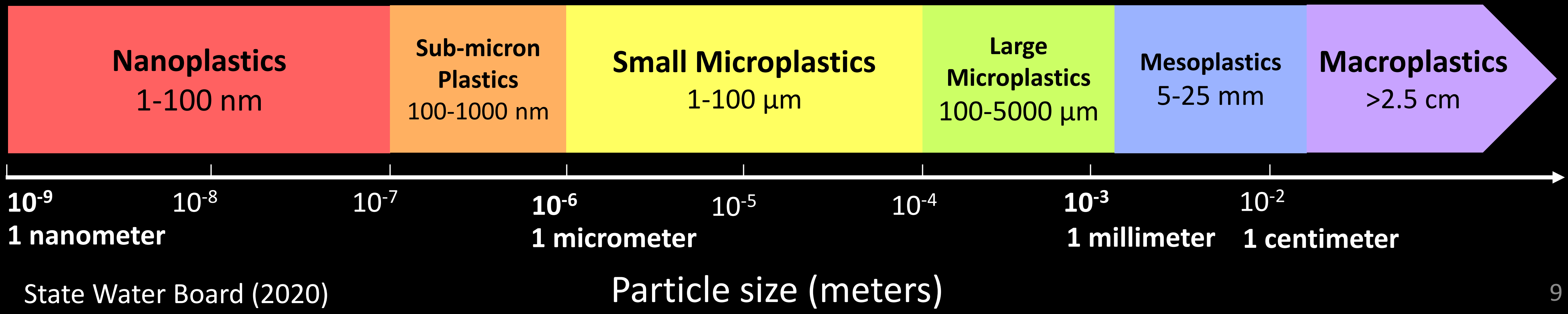
Photo: Mandy Barker

Official Definition: 'Microplastics in Drinking Water'

'solid polymeric materials to which chemical additives or other substances may have been added, which are particles which have at least three dimensions that are greater than 1 nanometer and less than 5,000 micrometers.

Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded.'

Size-Based Classification



State Water Board (2020)

Polymers included in Regulatory Definition

All "Traditional" Plastics…

State Water Board (2020)

Polymers included in Regulatory Definition

…and "Non-Traditional" Plastics

Synthetic rubber

Synthetic fibers

Silicones

Bio-based and biodegradable polymers

Cellulose acetate

State Water Board (2020)

California Senate Bill 1422 (2018)

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Method Development and Standardization

Drinking Water

Ocean Water

Fish Tissue

Sediment

40 Labs from 6 Countries

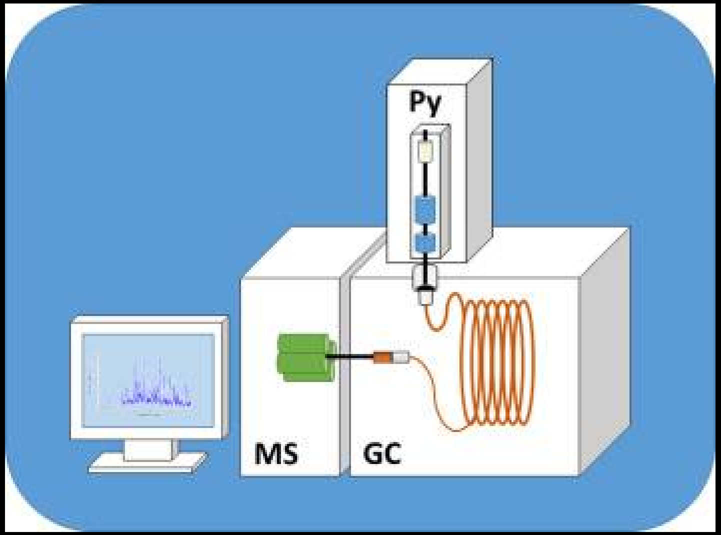
AWI
RJ Lee Group
DELIVERING SCIENTIFIC RESOLUTION
The Metropolitan Water District of Southern California
Oregon State University
UMD
University of Minnesota Duluth
Barnett Technical Services
CDPH
California Department Of PublicHealth
The Pennsylvania State University 1855
LeverPhotonics
California State University Channel Islands 2002
eurofins
Ontario
Ministry of the Environment and Climate Change
California State University Bakersfield 1965
Excellence Partnerships Community
EASTMAN
MOORE INSTITUTE
for Plastic Pollution Research
NIVA
Norwegian Institute for Water Research
NatureWorks
SiMPore Inc.
Precision Membrane Technologies
Ocean Protection Council
California Water Boards
State Water Resources Control Board
Regional Water Quality Control Boards
University of California
SCCWRP
Established 1969
ThermoFisher Scientific
United States Environmental Protection Agency
HORIBA
National Oceanic and Atmospheric Administration
NOAA
U.S. Department of Commerce
BASF
We create chemistry
University of Toronto
Orange County Sanitation District
Protecting the Environment

Five methods used

Visual microscopy
(+ - nile red)

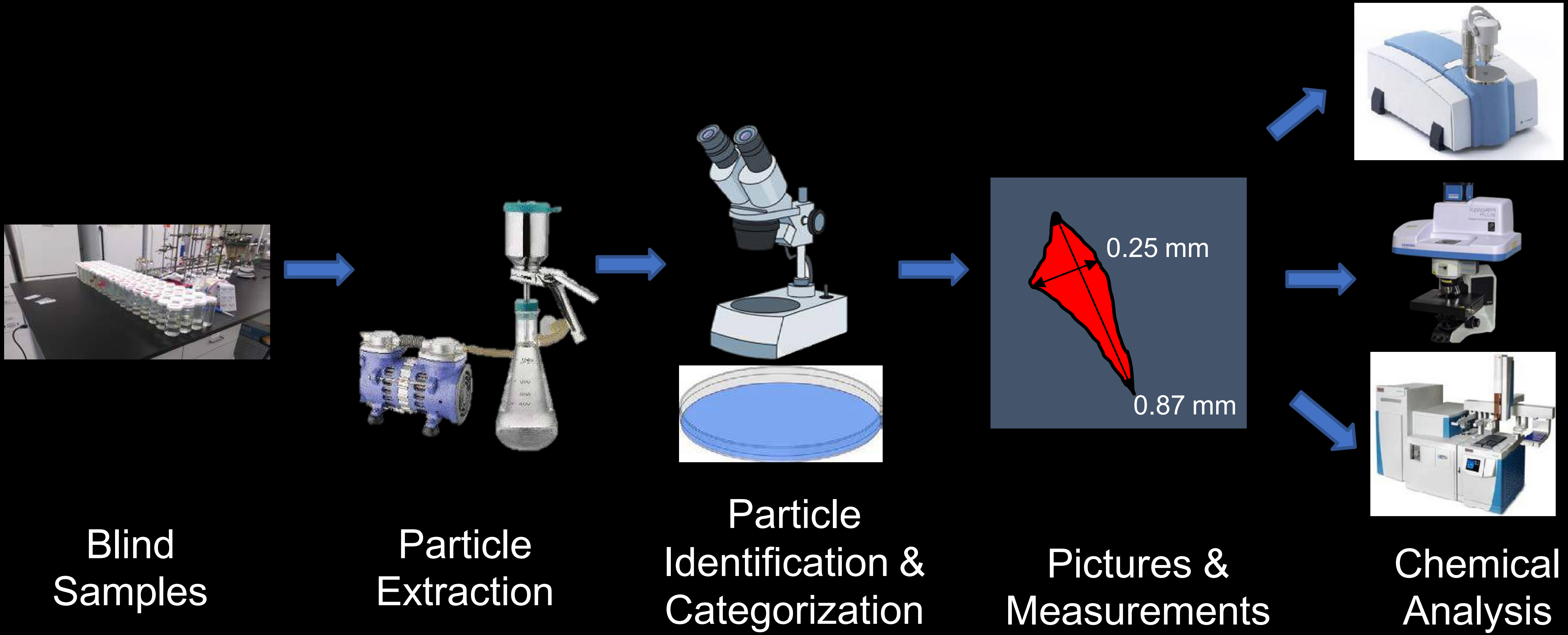
FTIR
Spectroscopy

Raman
Spectroscopy



Pyrolysis- GC/MS

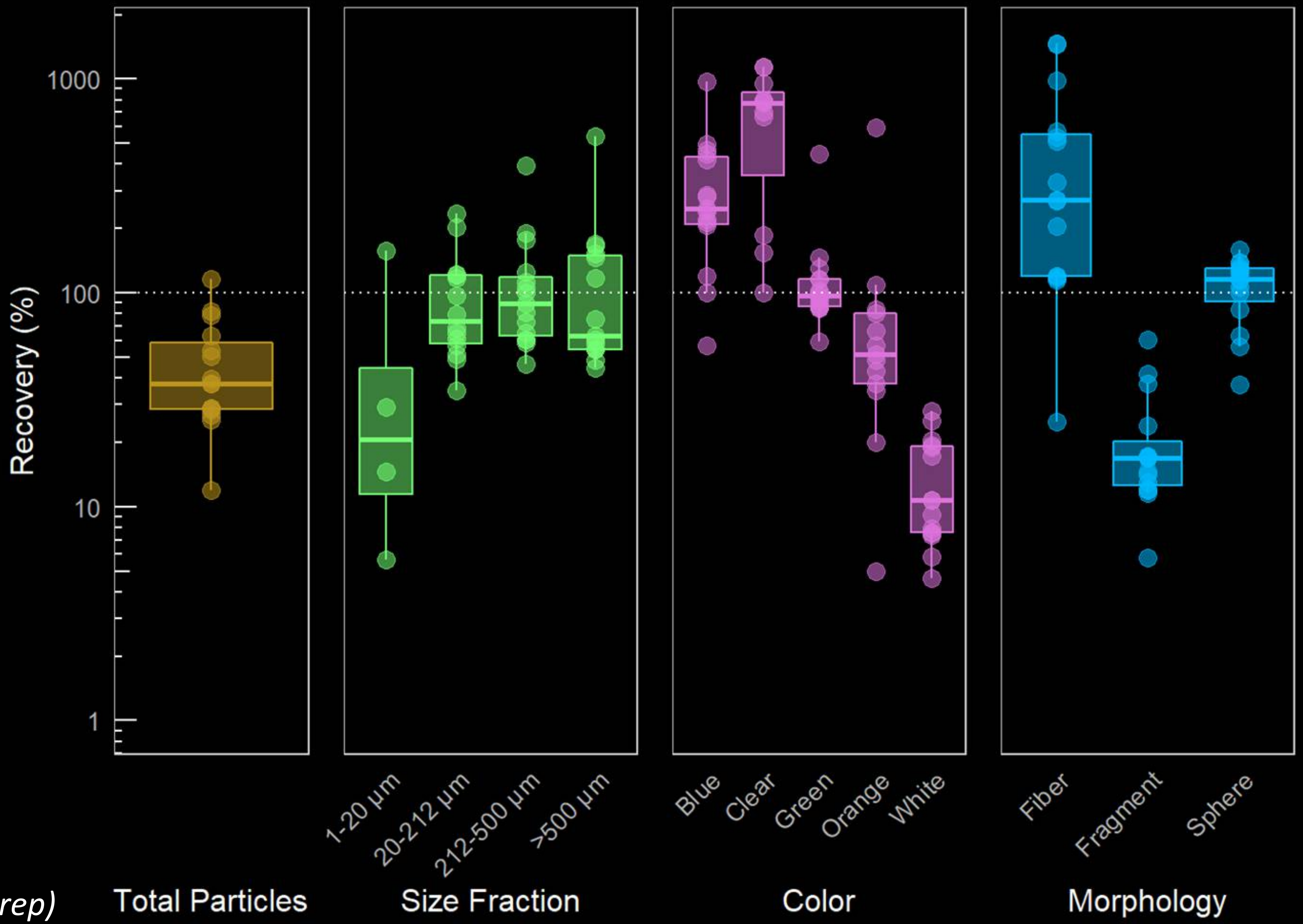
General Laboratory Process



Blind samples

- **Four Polymers**
  - Polystyrene, polyethylene, PVC, PET
- **Four size fractions**
  - 1-1000 um
  - 1-20 um, 20-212 um, 212-500 um, >500 um
- **Four shapes**
  - Pellets, fragments, spheres, fibers
- **False positives**
  - E.g., sand, shell fragments, cotton, cellulose, bunny fur

Method Performance at a glance



De Frond et al (*in prep*)

	Optical Microscopy	FTIR	Raman
Accuracy (Overall)	44 ± 27%	93%	83%
Measurement time/sample	26 ±54 hours	10 ±9 hours	15 ±16 hours
Instrument cost	$26,500 ($500 - $110,000)	$95,000 ($550 -$300,000)	$165,000 ($10,000 - $337,000)
Consumables cost	$1,100 ($84-$5000)	$900 ($10 -$5000)	$2,500 ($10-$12000)
Chemical identification	No	Yes	Yes
Lower size limit (approximate)	> 20 µm	> 10 µm	> 2 µm

De Frond et al (*in prep*)

Standardized methods **available** on State Water Board webpage

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State Water Resources Control Board

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Standardized Analytical Method for Microplastics in Drinking Water

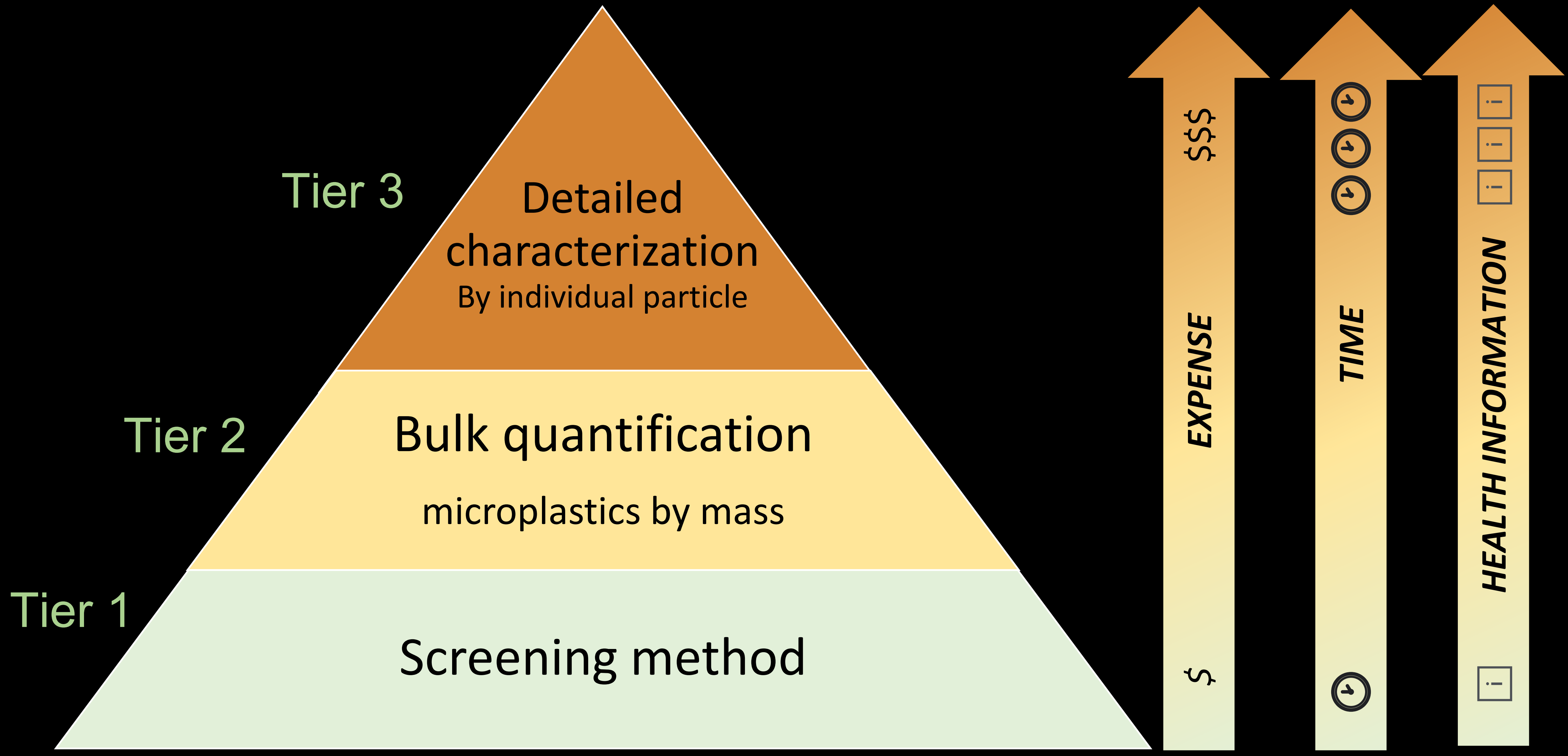
Health and Safety Code section 116376(1) requires the State Water Board to adopt a standardized methodology for monitoring microplastics in drinking water. Due to a lack of available standardized methods, the State Water Board, in collaboration with the Southern California Coastal Water Research Project (SCCWRP), developed and evaluated analytical methods. Methodology for sampling, extraction, and analysis of microplastics were developed at a workshop facilitated by SCCWRP in 2019.

Method precision, repeatability, cost and other issues were assessed through an inter-laboratory comparison study between 2020 and 2021, in which twenty-two laboratories from six countries participated. Methods for sampling extraction via filtering/sieving, optical microscopy, infrared spectroscopy, and Raman spectroscopy were evaluated. Each laboratory received three spiked samples of simulated clean water and a laboratory blank. Spiked samples contained known amounts of microplastics in four size fractions (1-20 µm, 20-212 µm, 212-500 µm, >500 µm), four polymer types (PE, PS, PVC, and PET), and six colors (clear, white, green, blue, red and orange). Spiked samples also included false positives (natural hair, fibers and shells) that may be mistaken for microplastics. Overall, participants demonstrated excellent average recovery and chemical identification for particles greater than 20 µm and 50 µm in size using Raman spectroscopy and infrared spectroscopy, respectively, with opportunity for increased accuracy and precision through training and further method refinement. Details regarding the method interlaboratory comparison study will be published in a peer-reviewed journal (anticipated Winter 2022).

Standardized methods for extraction and analysis of microplastics in drinking water were made available on September 28, 2021 for Raman spectroscopy and infrared spectroscopy. Please address questions and comments regarding the method to scott.coffin@waterboards.ca.gov, and cc' charlesw@sccwrp.org.

waterboards.ca.gov/drinking_water/certlic/drinkingwater/microplastics

Wanted: Tiered Monitoring Framework



California Senate Bill 1422 (2018)

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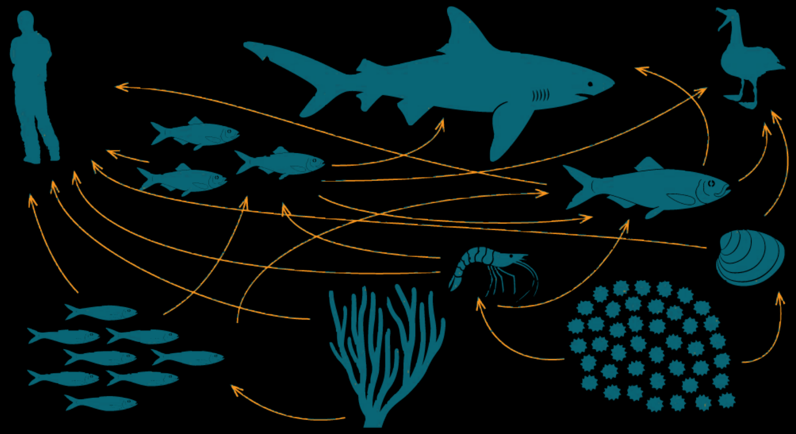
Microplastics Health Effects Workshop

2020-2021

Drinking Water



Ecosystem

Not Possible to Derive Regulatory Levels Yet

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Highest Concern
Water advisory notice
(e.g. public notice for limited use)

Advisory Level
Site/situation specific

Elevated Concern
Mitigation strategies recommended

Response Level
≥1x10^{-4} Cancer Risk
≥10x Notification Level

Moderate Concern
Monitoring of potential sources, public notification may be issued

Notification Level
≥1x10^{-6} Cancer Risk
≥Health-Protective Concentration

Low Concern
Monitoring to assess aqueous levels and sources of contamination

Investigatory Level

No Concern
No action required

Non-regulatory Screening level

Possible Concern
Targeted, investigatory monitoring
No responses required

Identify necessary toxicity studies

Re-evaluate thresholds

Three classes of problems

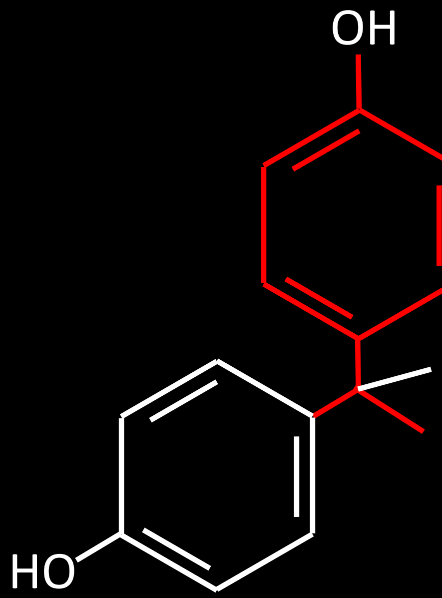
1. Effects database inadequate
    - generally poor particle characterization
    - limited polymers, shapes, sizes tested
    - few endpoints tested
2. Effect Mechanisms Unknown
    - necessary for extrapolation to diverse particle types
3. Incomplete exposure data
    - limited information on food

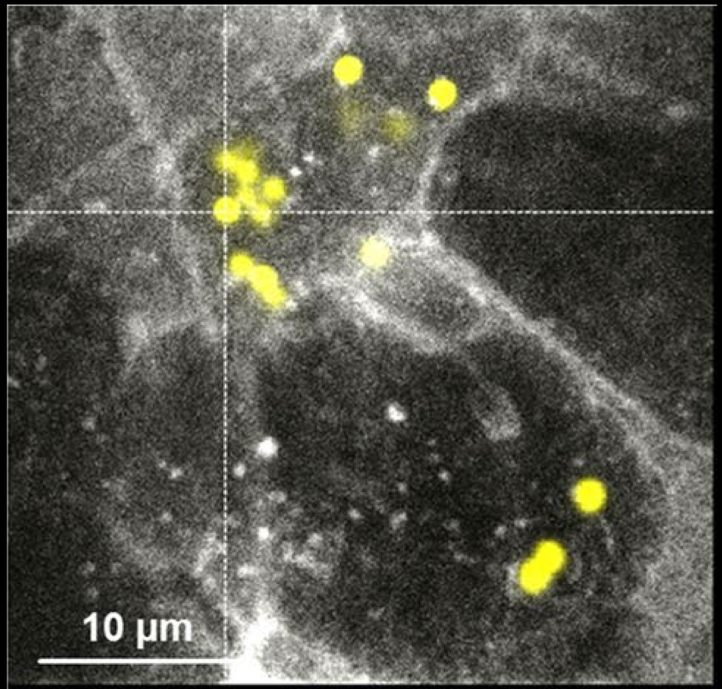
Values we DID Derive

1. Recommended concentrations for toxicity studies
    - experiments done at very high concentrations
    - sensitive lower concentrations identified

2. Water volume for monitoring
    - Vital for exposure characterization in drinking water
    - Too much = expensive
    - Too little = miss critical concentrations

Chemical and Particle Hazards





Stock et al. (2019). *Archives of Toxicology*

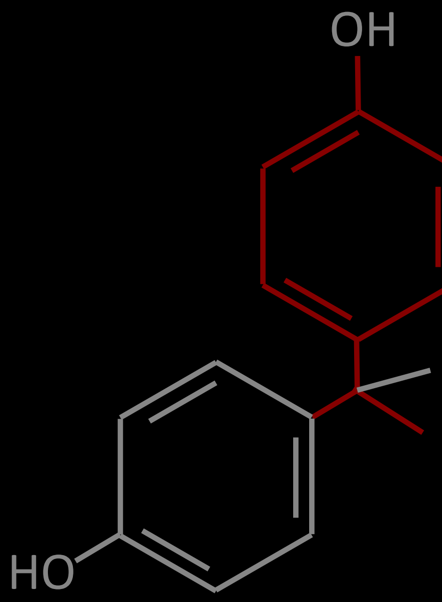
Plastic Contains Un-regulated **Hazardous Chemicals**

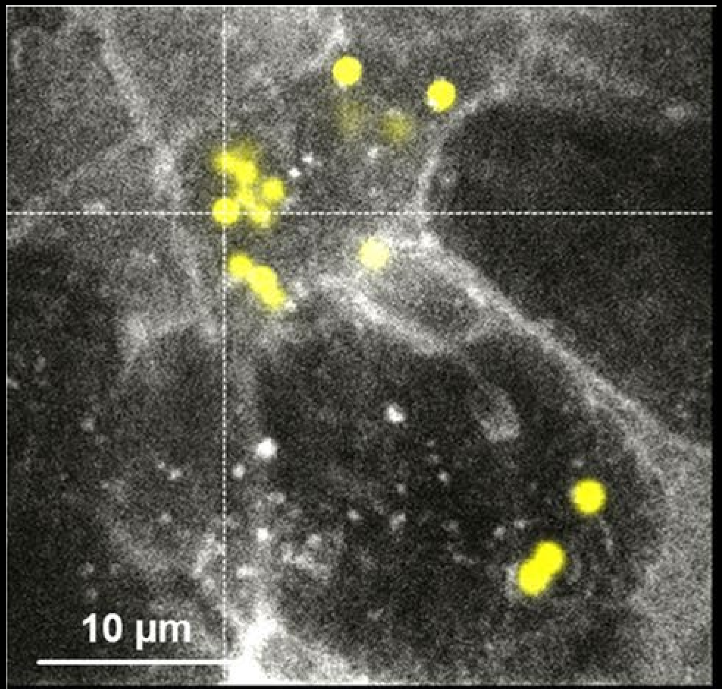
- >10,000 known additives
- **> 2,400 substances of concern**
- 53% toxic substances **un-regulated**
- 11% of toxic substances without

  scientific references

Weisinger *et al* (2021). *Environmental Science & Technology*

Chemical and Particle Hazards

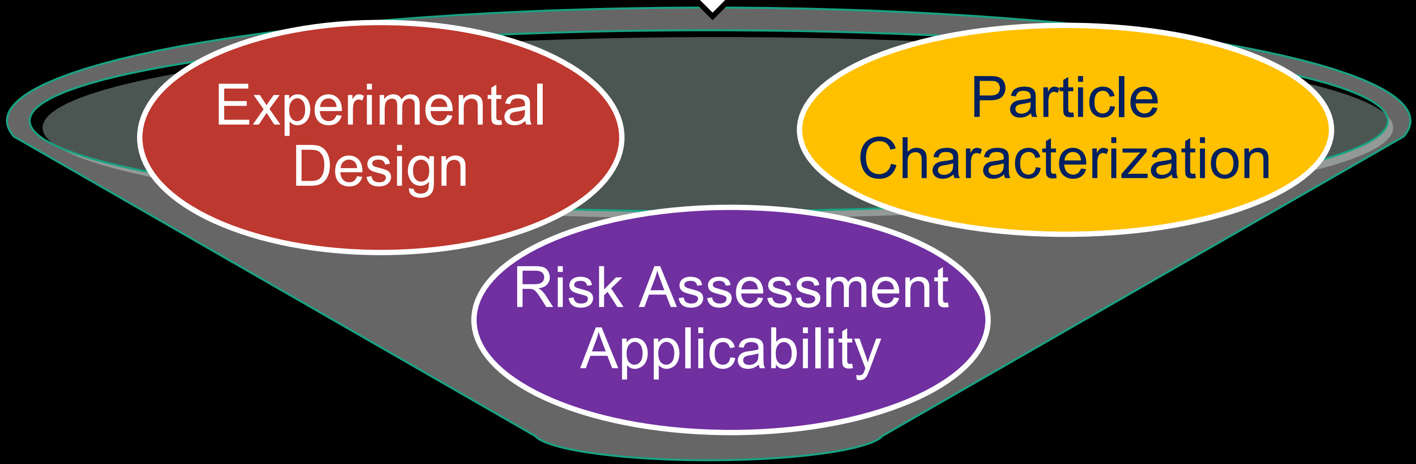




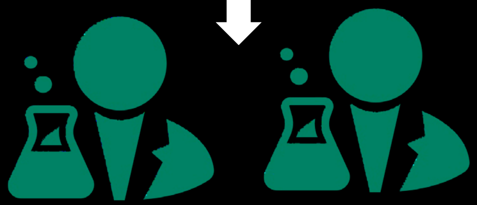
Stock et al. (2019). *Archives of Toxicology*

Screening and Prioritization

Ingestion-based *in vivo* mammalian microplastics toxicity studies
(n = 29)

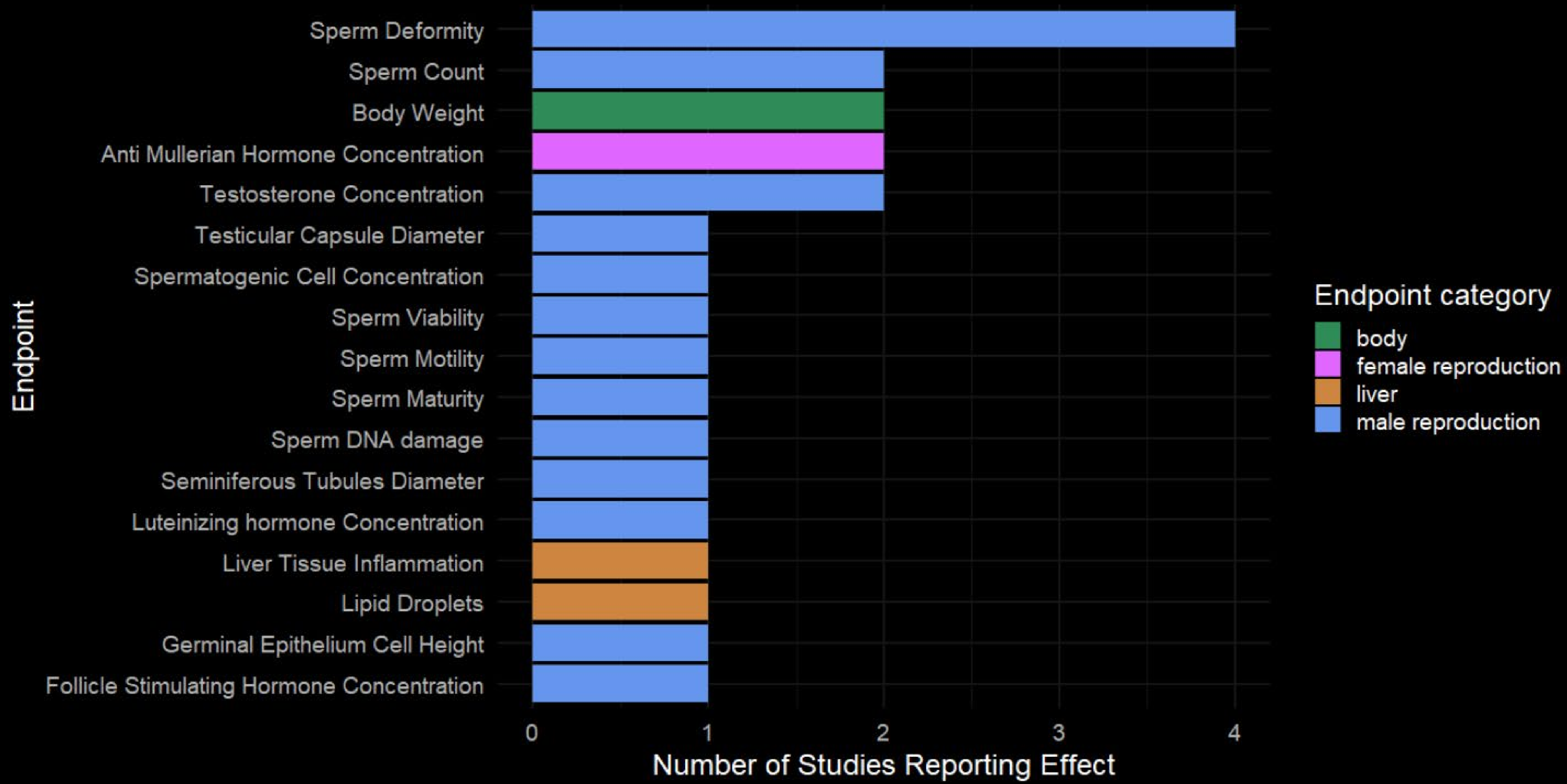


Fit for purpose studies
(n = 12)



Expert review

Reliable Endpoints*



*Based on reviews from 8 outside experts

Effect Mechanisms Poorly Understood

Some Commonly observed mechanisms

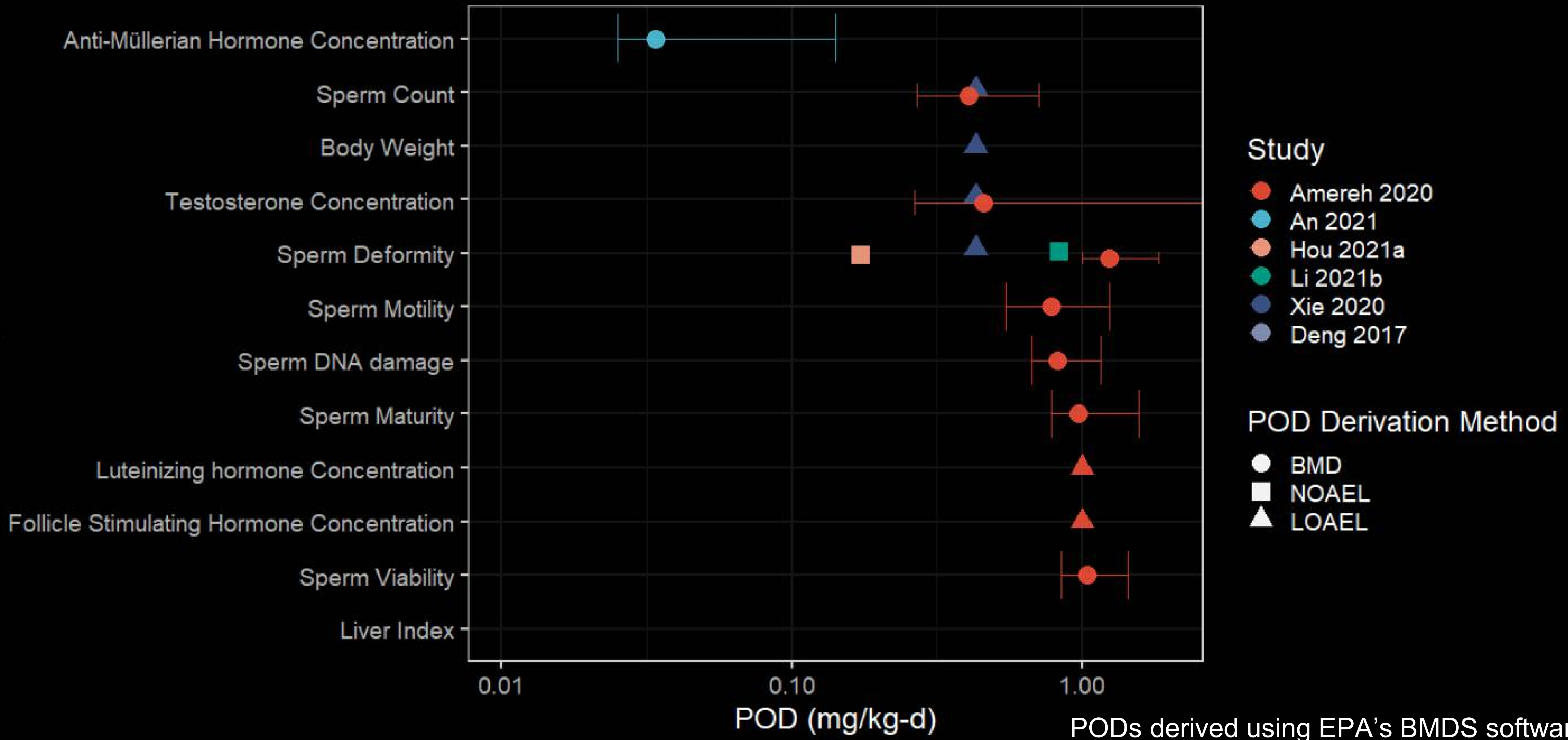
- Reactive oxygen species
- Oxidative stress
- Inflammation
- Cell death
- Lipid metabolism
- Energy metabolism

Framework

1. **Hazard Identification**
   a. Screening & prioritization
   b. Identify effects
2. **Dose-response Assessment**
   a. Benchmark dose modelling
   b. Physiological based particokinetic modelling
   c. Uncertainty adjustment
3. **Exposure Characterization**
   a. Biomonitoring
   b. Concentrations in exposure media
4. **Risk Characterization**
   a. Data alignment

- Completed
- High uncertainties
- Missing Data

Benchmark Dose Modelling Results



PODs derived using EPA's BMDS software
Error bars represent 95% CI for BMD

Rodent to Human Uncertainty Adjustments

$$Reference\ Dose\ (\frac{mg}{kg-day}) = \frac{Point\ of\ departure(\frac{mg}{kg-day})}{Uncertainty\ Adjustments\ (3{,}000)}$$

Uncertainty Adjustments

Database deficiency ($\sqrt{10}$)

Inter-species (10)

Intra-species (10)

Framework

1. **Hazard Identification**
   a. Screening & prioritization
   b. Identify effects
2. **Dose-response Assessment**
   a. Benchmark dose modelling
   b. Physiological based particokinetic modelling
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3. **Exposure Characterization**
   a. Biomonitoring
   b. Concentrations in exposure media
4. **Risk Characterization**
   a. Data alignment

■ Completed
■ High uncertainties
■ Missing Data

Incomplete Exposure Data

- Limited food and inhalation data
- Non-harmonized methods used for existing data
- No California-specific data

Default assumption:

20% contribution from drinking water

Framework

1. **Hazard Identification**
   a. Screening & prioritization
   b. Identify effects
2. **Dose-response Assessment**
   a. Benchmark dose modelling
   b. Physiological based particokinetic modelling
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   a. Biomonitoring
   b. Concentrations in exposure media
4. **Risk Characterization**
   a. Data alignment

- Completed
- High uncertainties
- Missing Data

Relating Effects Studies to Exposures

Environmental Microplastics

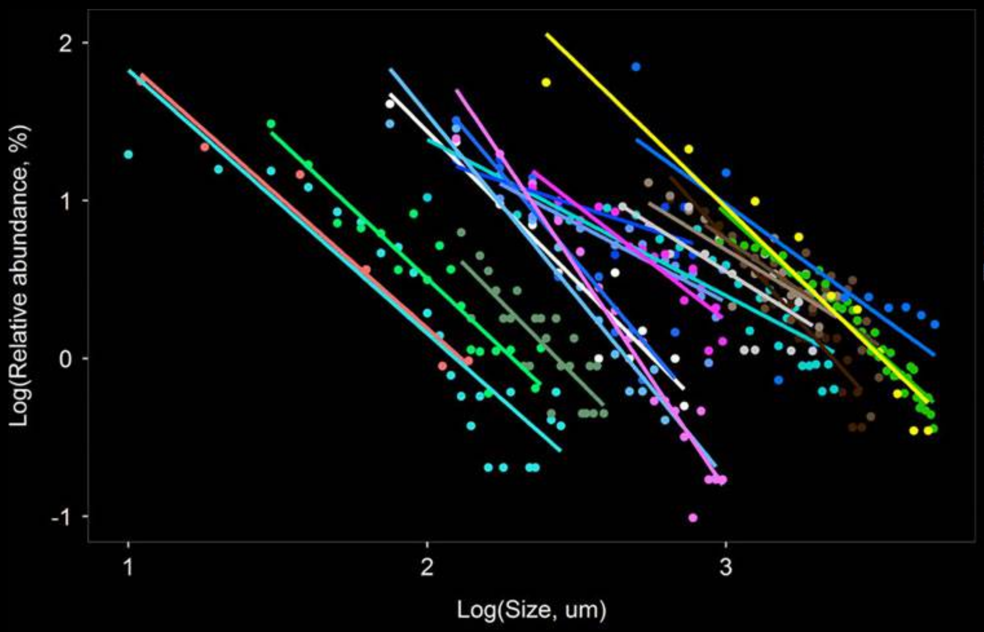
≠

Effect Studies

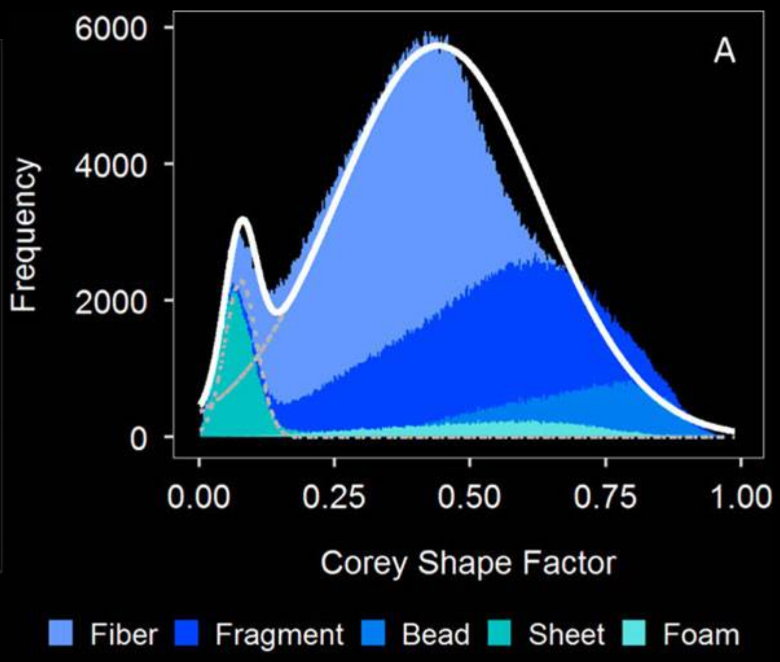
Aligned data using methods in Kooi et al (2021), *Water Research*

Solution: Align Exposure Data w/ Probability Distributions

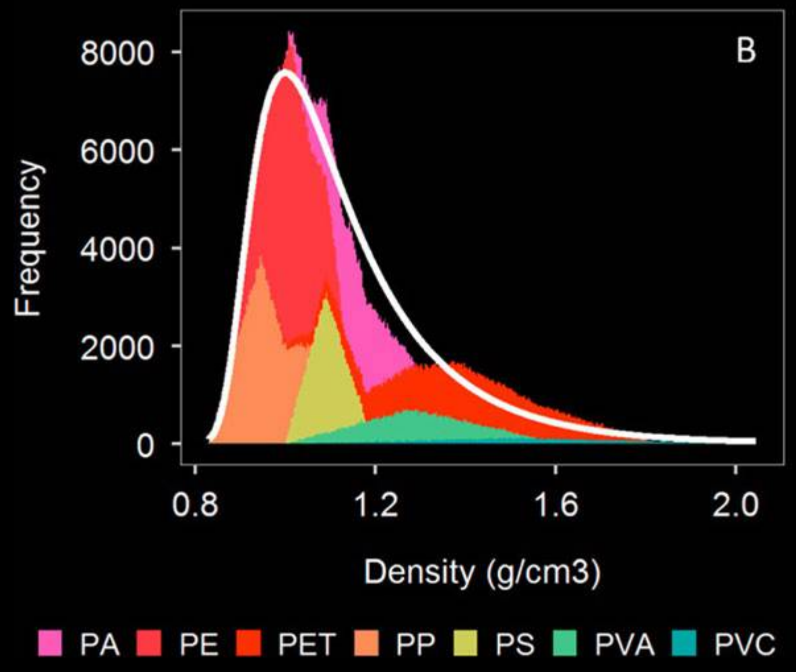
Size



Shape

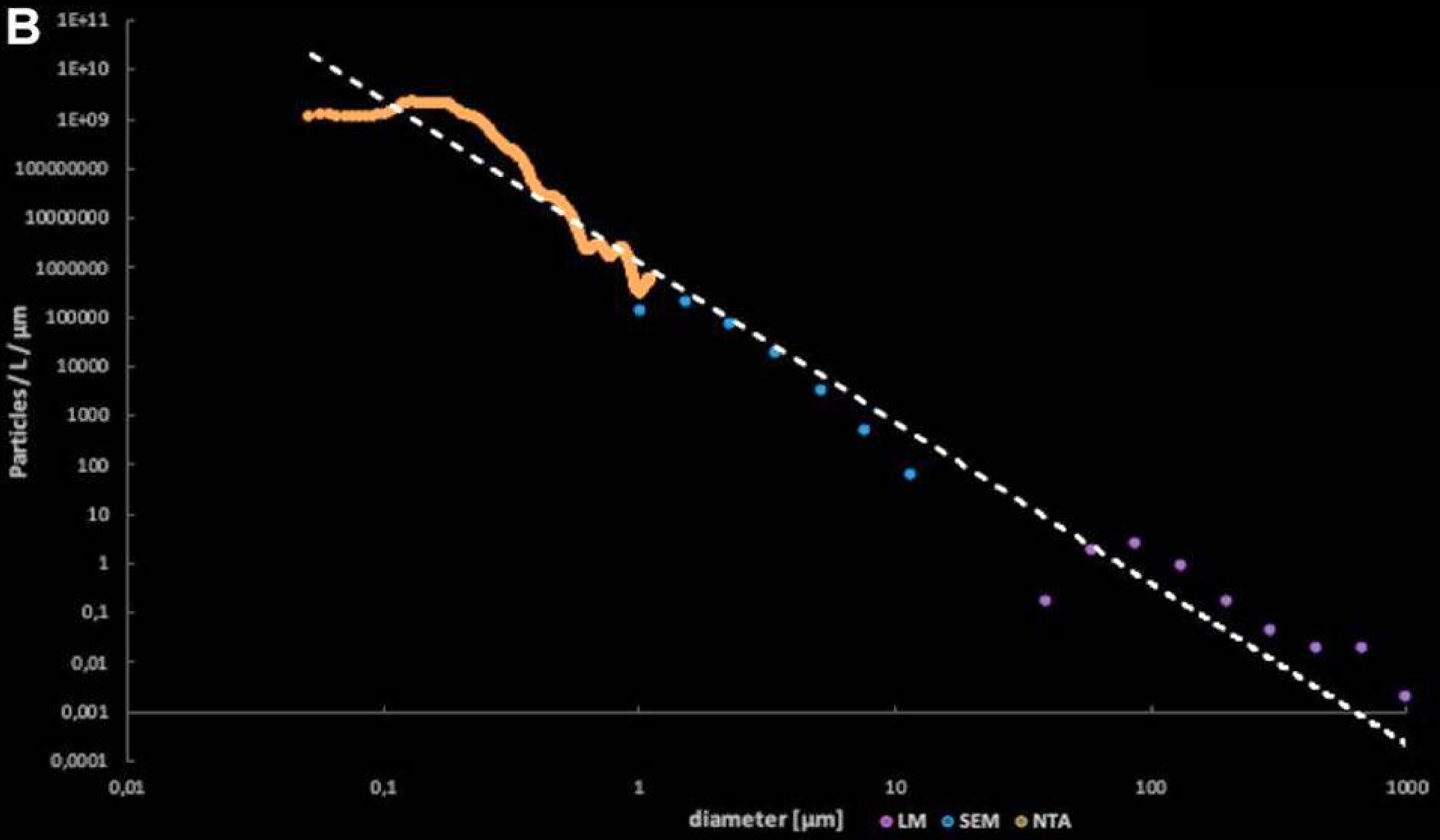


Density



Kooi and Koelmans, *ES&T Letter* (2019)

Exponential Size Distribution Extends <1μm



Mattsson *et al* (2021). *Frontiers in Marine Science*

Aligned Drinking Water Screening Levels

DRAFT VALUES. DO NOT CITE

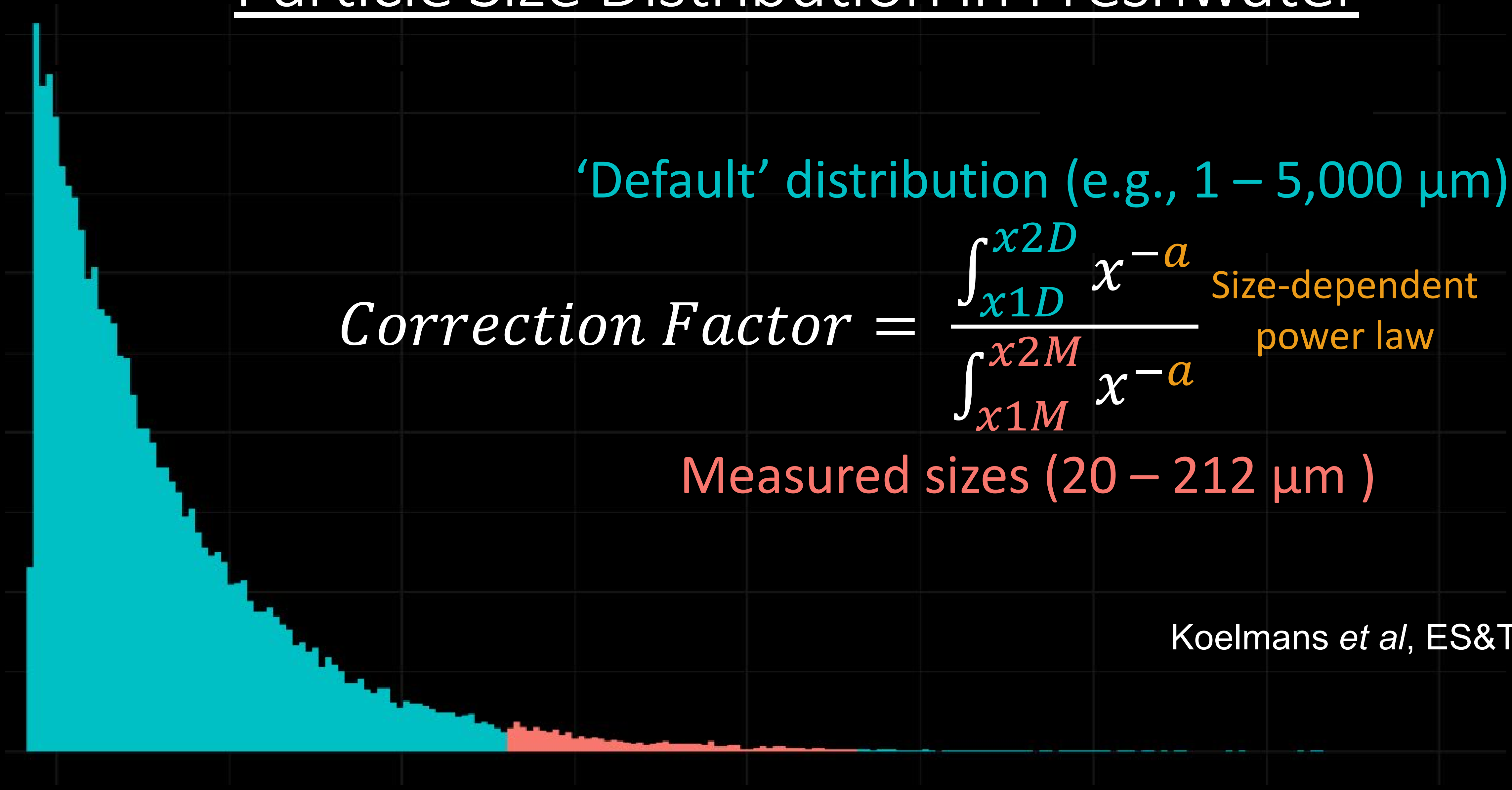
Coffin et al (*in prep*)

RfD (mg/kg-d)	SL (ug/L)	Mass-aligned SL (particles/L)	Surface area-aligned SL (particles/L)	Specific surface-area aligned SL (particles/L)	Volume-aligned SL (particles/L)
0.025	0.0019	640	3,300	3,500	760

Non-regulatory Drinking Water Screening Level (most conservative estimate)

Alignments performed according to Kooi et al (2021), *Water Research*

Particle Size Distribution in Freshwater



'Default' distribution (e.g., 1 – 5,000 µm)

$$Correction\ Factor = \frac{\int_{x1D}^{x2D} x^{-a}}{\int_{x1M}^{x2M} x^{-a}}$$

Size-dependent power law

Measured sizes (20 – 212 µm)

Koelmans *et al*, ES&T, 2020

Distribution from Kooi et al (2021)

Method Inter-laboratory Validation Study

DRAFT VALUES. DO NOT CITE

Coffin et al (*in prep*)

Method	Empirical reporting limit (particles)	Correction Factor to align to 0.5-5,000 µm (unitless)	Aligned reporting limit (particles)
Raman	5.8 (20 - 212 µm)	720	4,200 particles
FTIR	5.8 (50 - 212 µm)	3,900	22,00 particles

Drinking Water

Most conservative value

Reporting limits from de Frond et al (*in review*)
Alignments done according to Kooi et al (2021), *Water Research*

Suggested Sampling Volume for Monitoring

DRAFT VALUES. DO NOT CITE

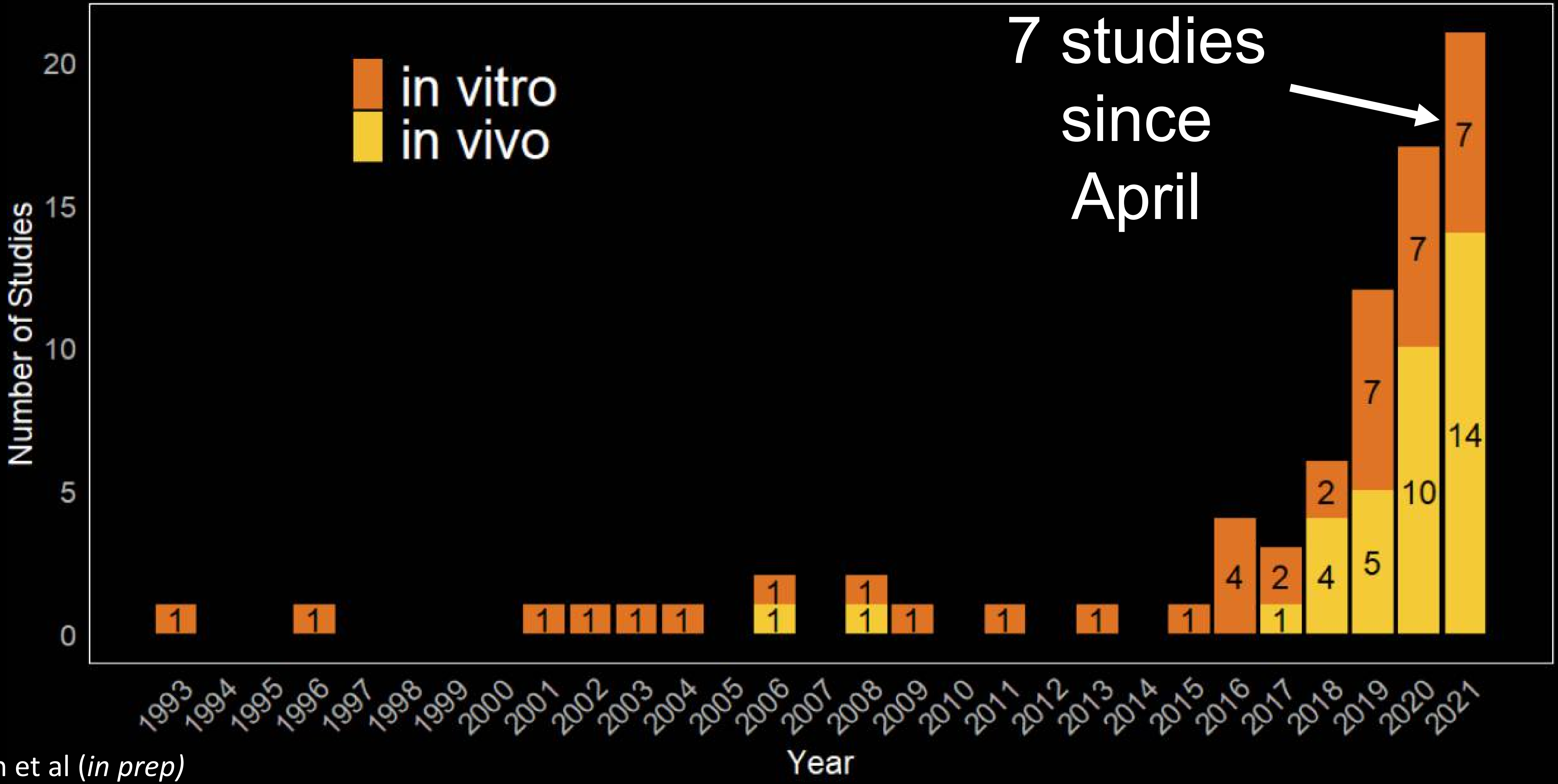
$$\frac{22{,}000\ particles}{600\ particles/L} \sim$$ **40 L (0.007 to 10,000)**

Suggested *minimum* sampling volume

Range based on sensitivity analysis

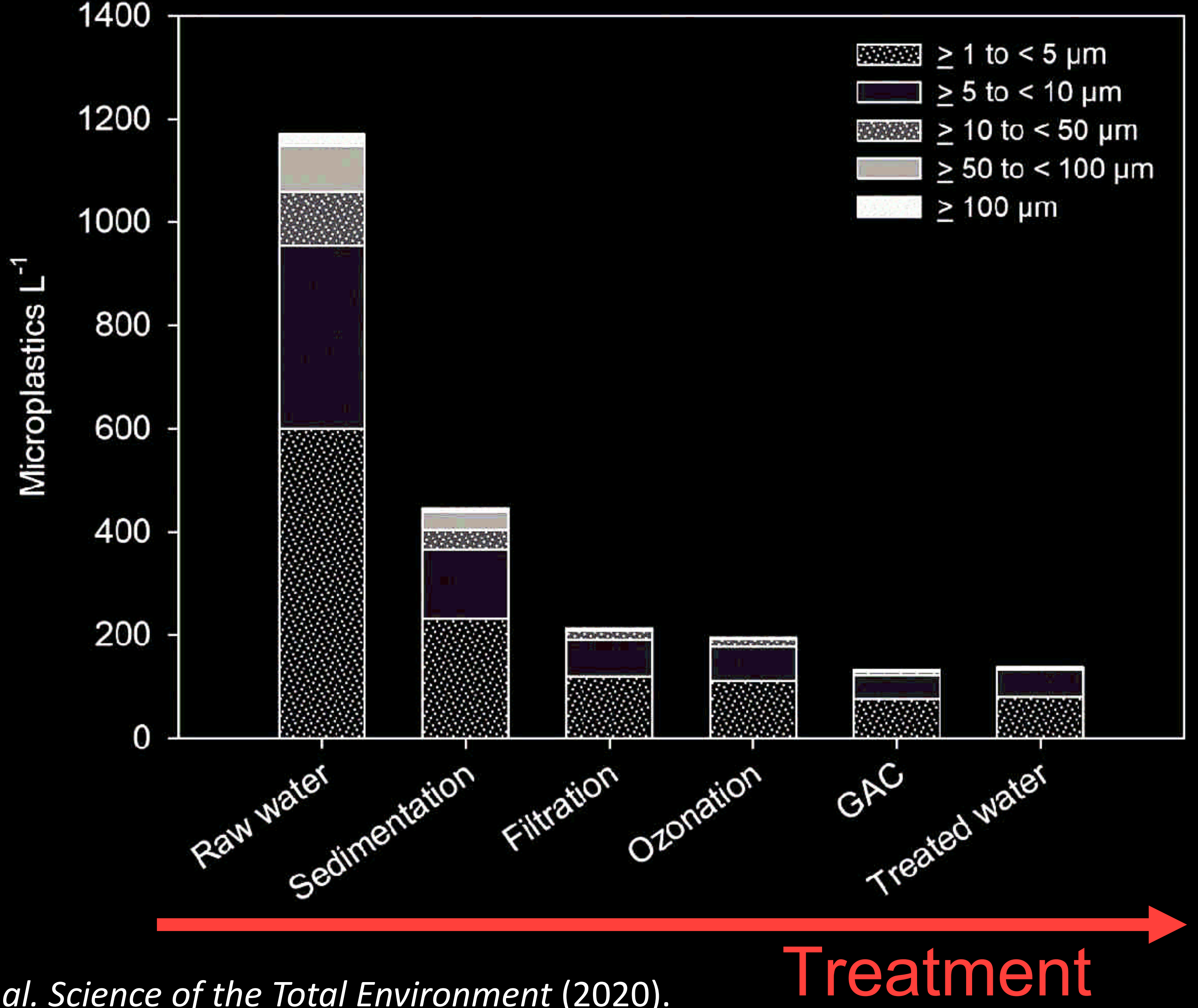
1,000 liters suggested for drinking water based on representativeness (Koelmans et al, *Water Research* 2019)

Rapidly Changing Science



Coffin et al (*in prep*)

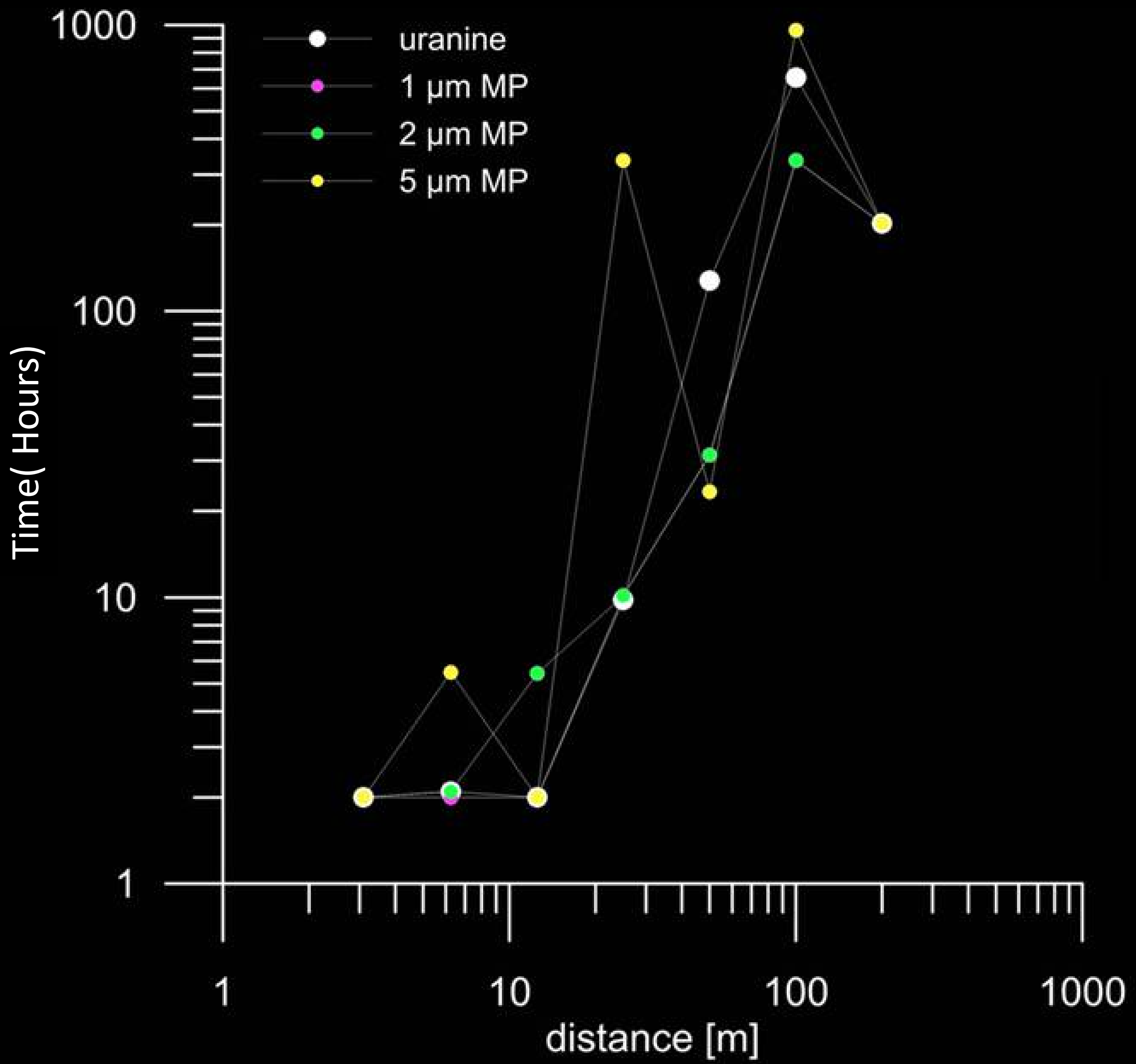
Drinking Water Treatment Removes >10 μm Microplastics



Pivokonsky *et al. Science of the Total Environment* (2020).

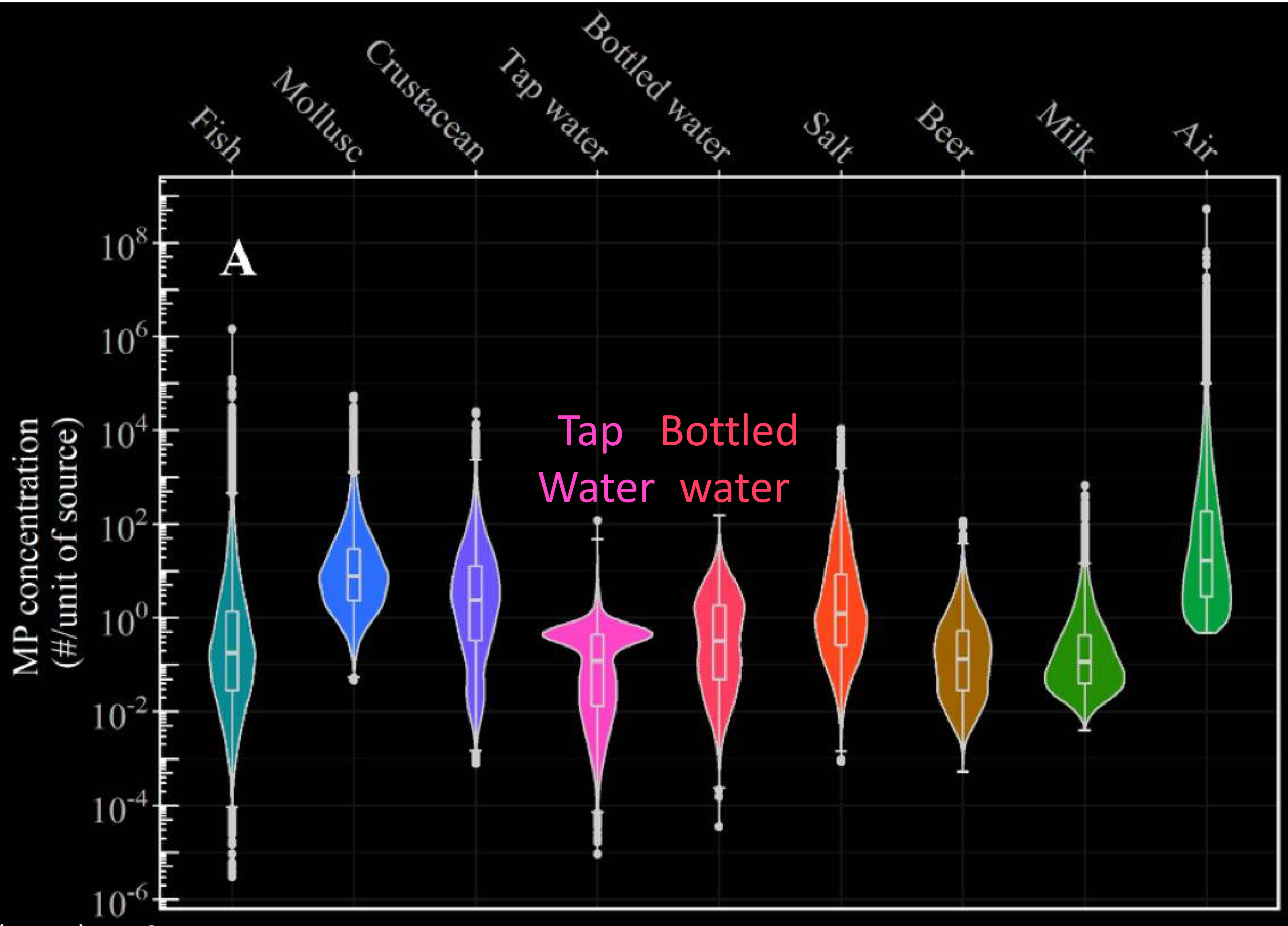
Microplastics Can Travel Long Distances in Sand-and-Gravel Aquifers

- Microplastics travel ≥200 meters in groundwater
- Peak concentrations of MPs can exceed those of conservative solutes, in particular for the longer flow distances.



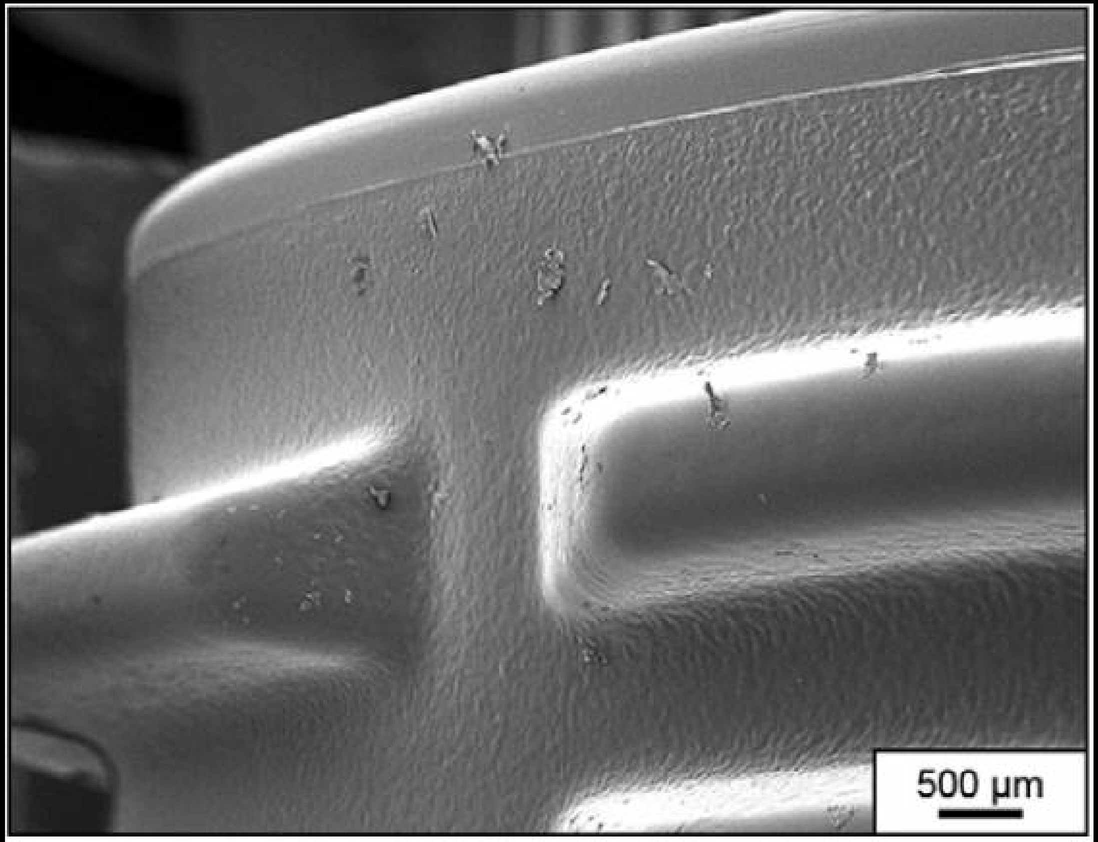
Goeppert and Goldscheider (2021). *Journal of Hazardous*

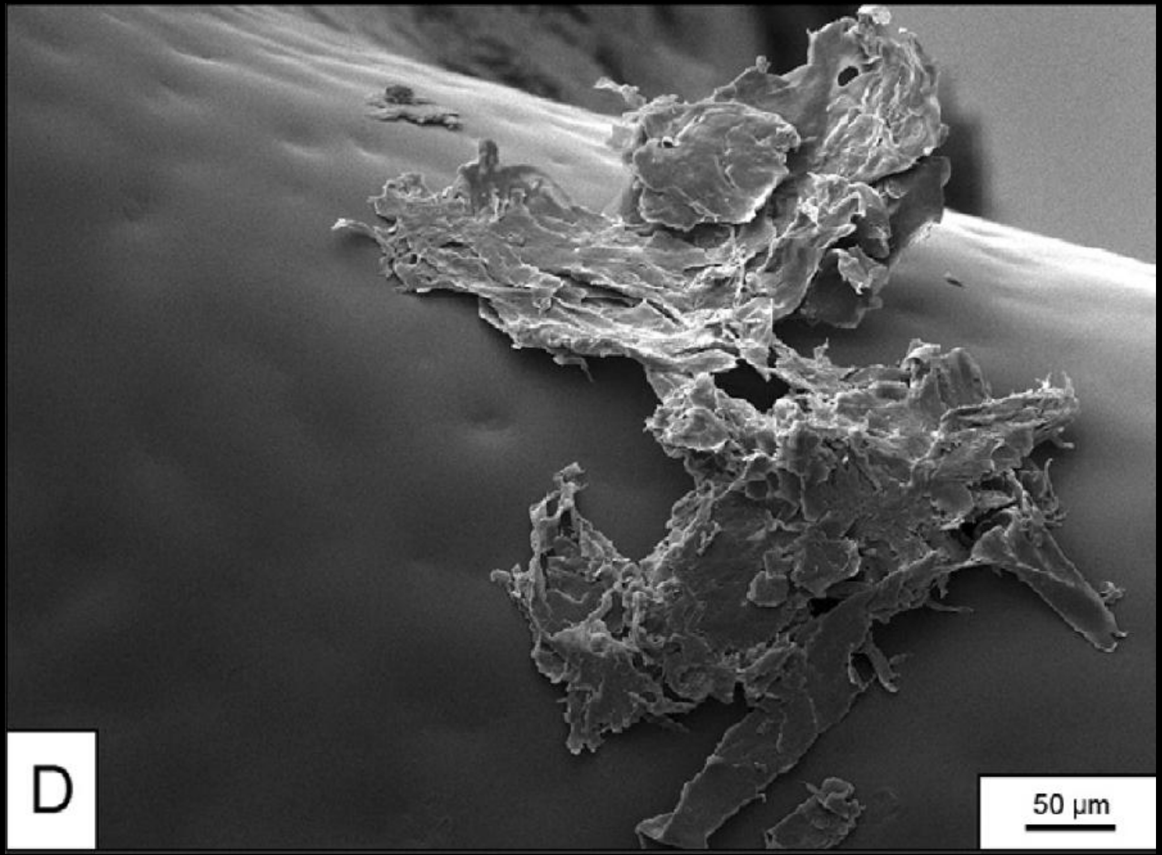
More Microplastics in **Bottled Water** than **Tap Water**



Mohamed Nor *et al.* (2021). *ES&T*

Plastic Packaging Releases Microplastics





Opening a plastic water bottle releases **14-2,400** microplastic particles

Sobhani, *et al. Sci Rep* (2020)
Winkler, *et al. Water Research* (2020)

California Senate Bill 1422 (2018)

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Two-Phased Monitoring Approach in Drinking Water

Depth Phase

- Source waters
- Characterize particle distributions
- Develop tier 1 methods

2022

2024

Breadth Phase

- Many water systems
- Tiered monitoring approach

2026

Typical Monitoring

Tentative approach. Dates subject to change.

California Senate Bill 1263 (2018): Statewide Microplastics Strategy

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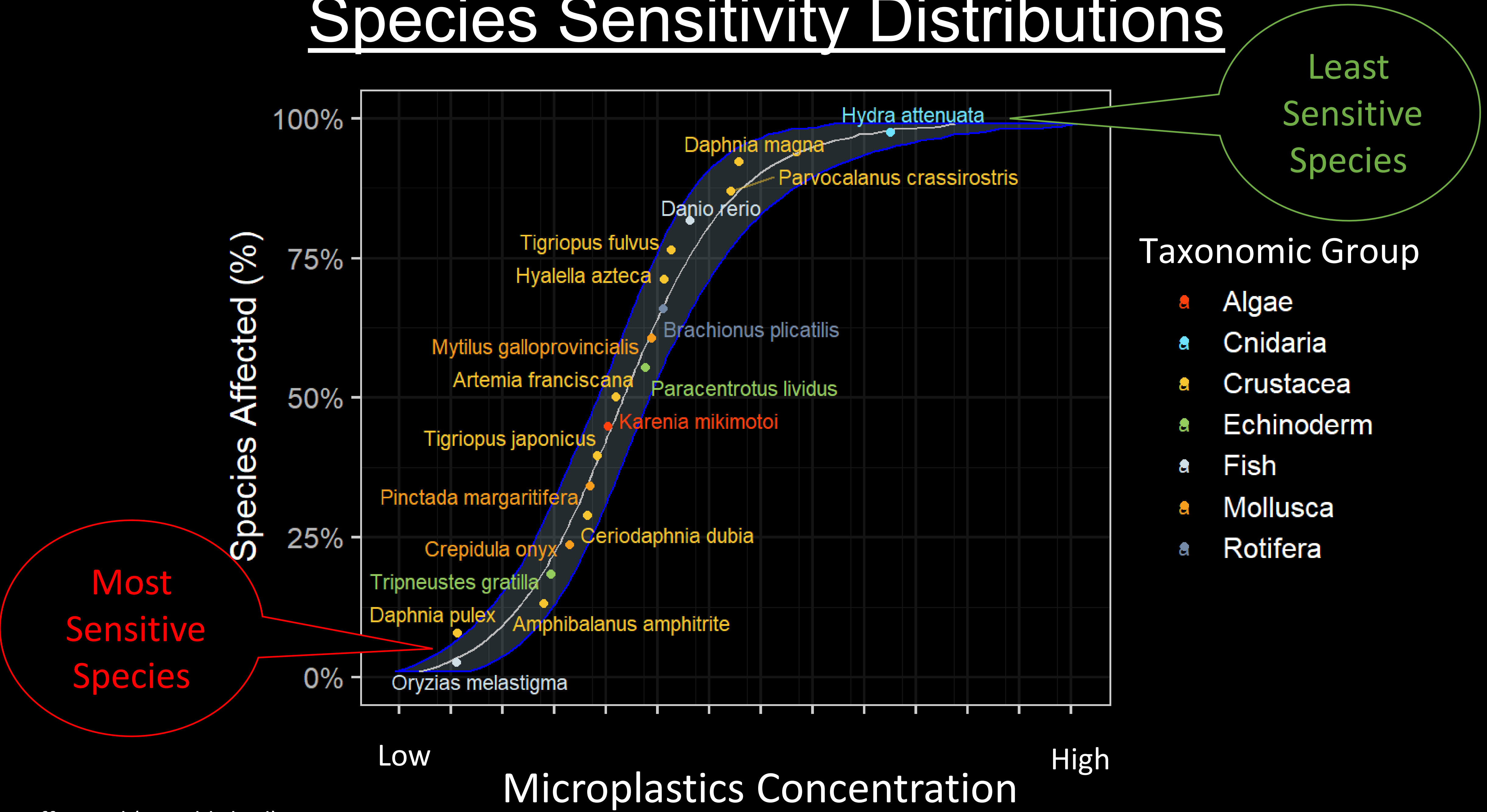
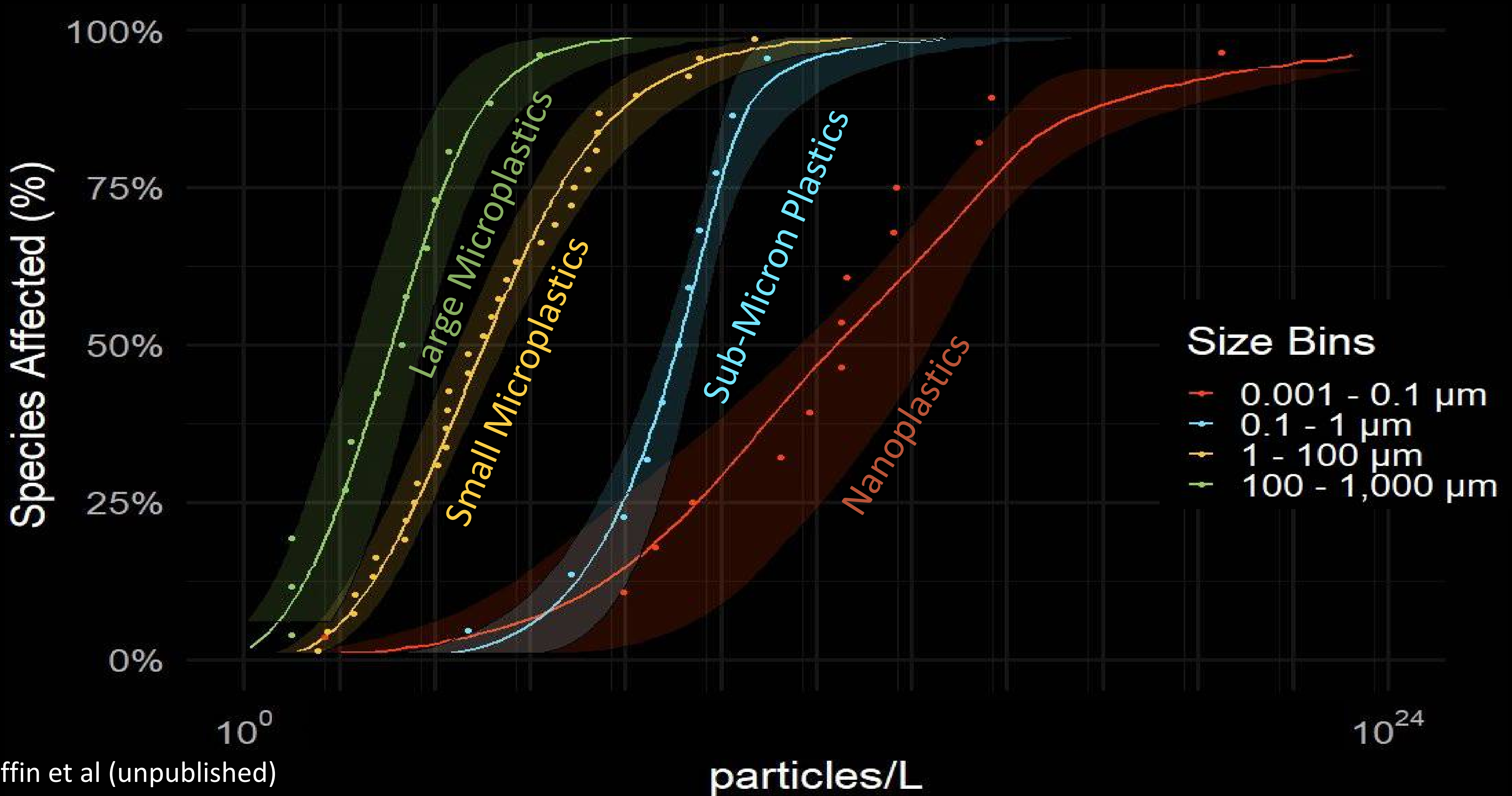
Species Sensitivity Distributions



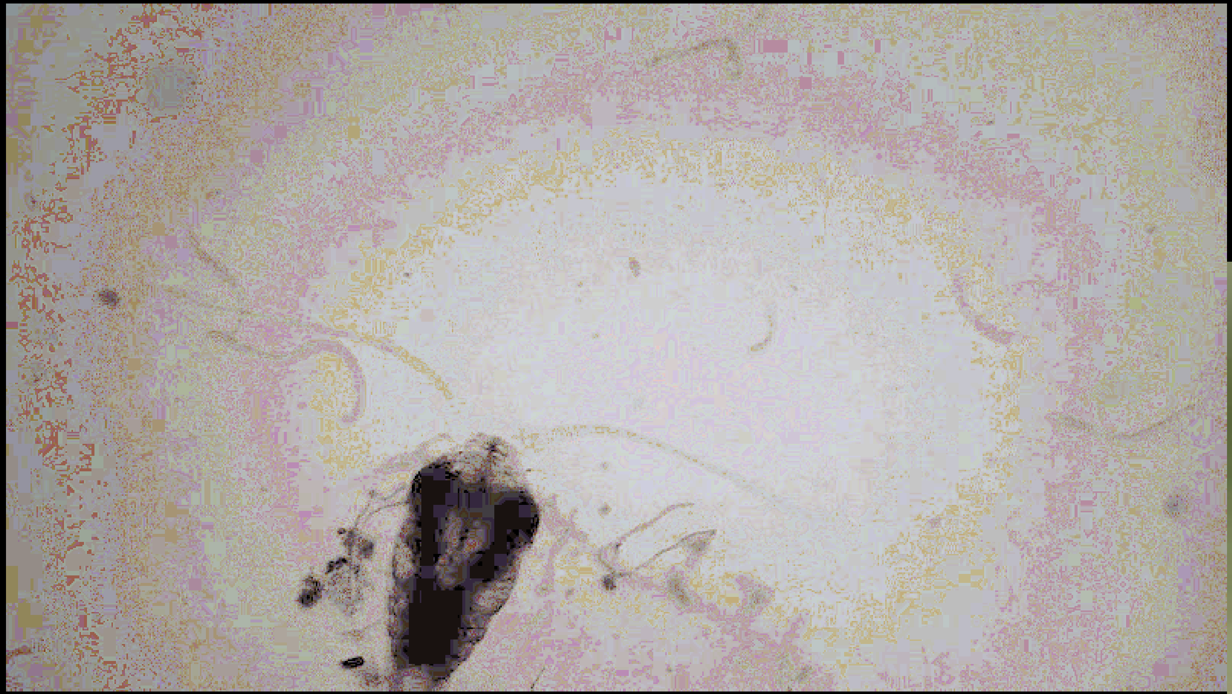
Coffin et al (unpublished)

But Microplastics Toxicity Depends on **Size…**



Coffin et al (unpublished)

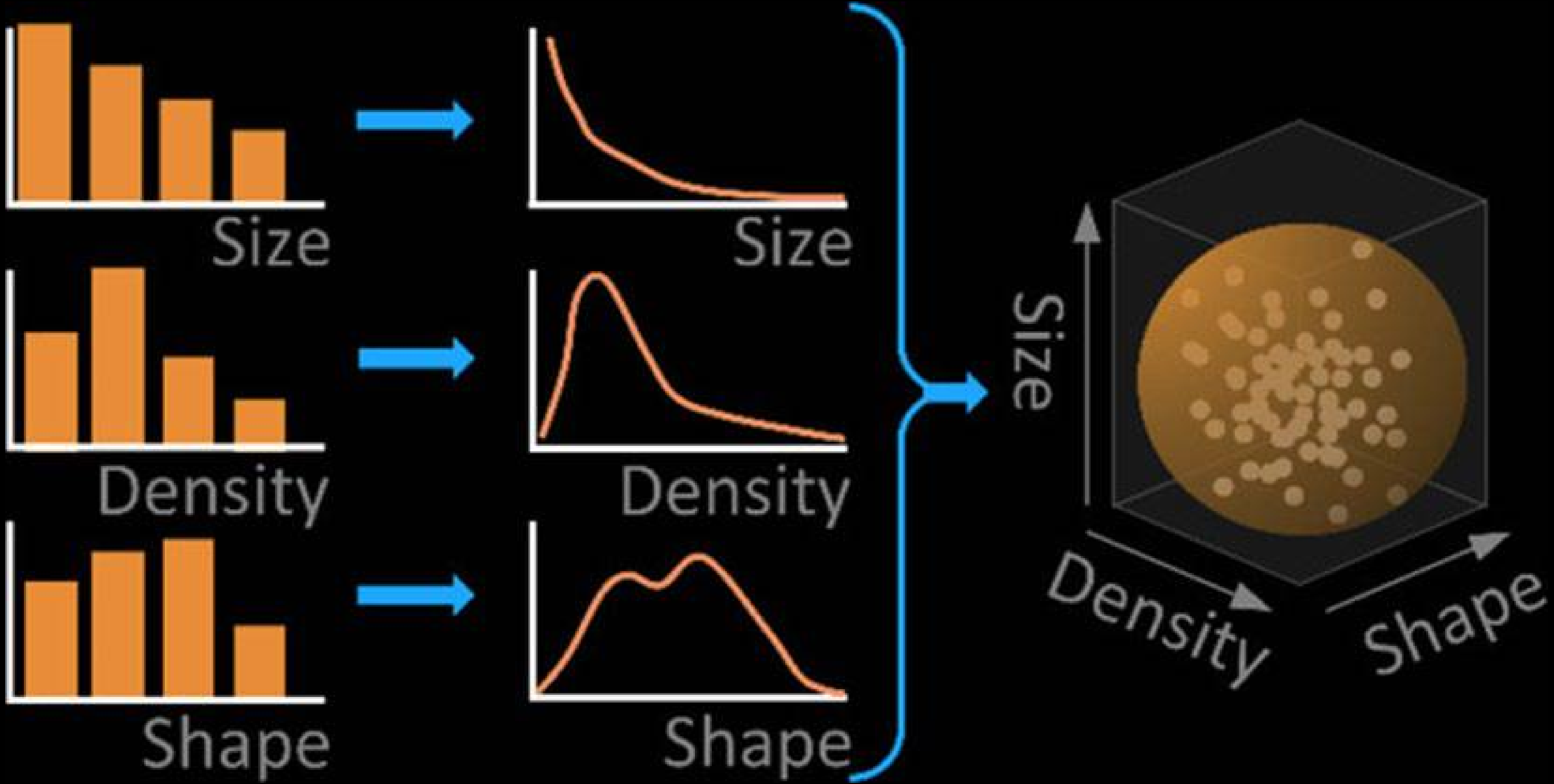
Photo: Mandy Barker



Plymouth Marine Laboratory

Chris Jordan

Aligning Data with Probability Distributions



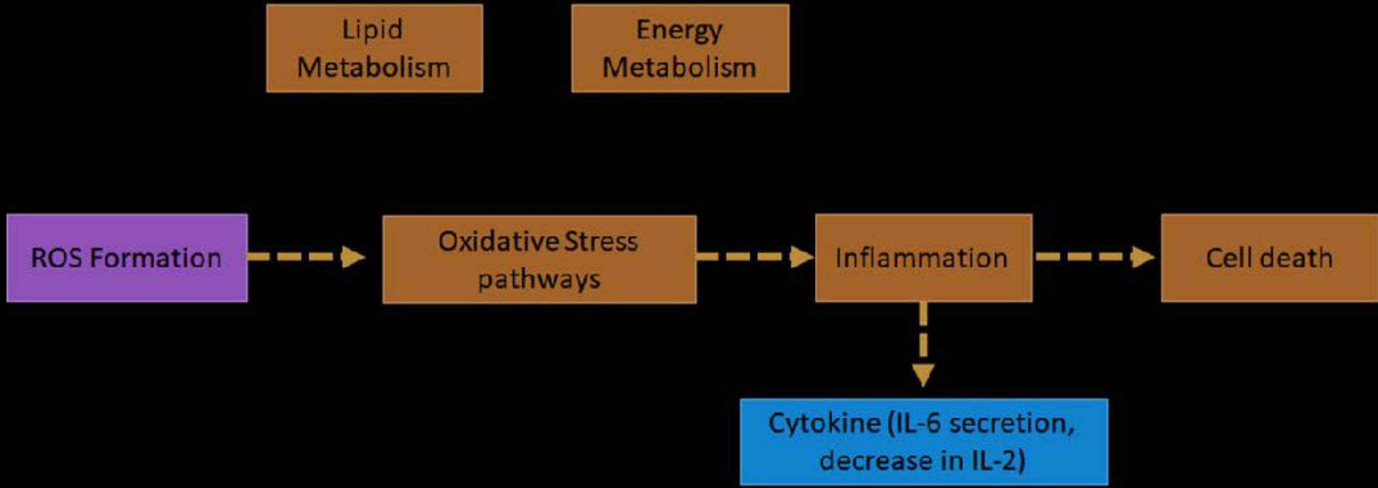
Kooi and Koelmans, *ES&T Letters* (2019)

Align by Ecologically Relevant **Effect Mechanisms**

Food Dilution

Photo: Marcus Eriksen

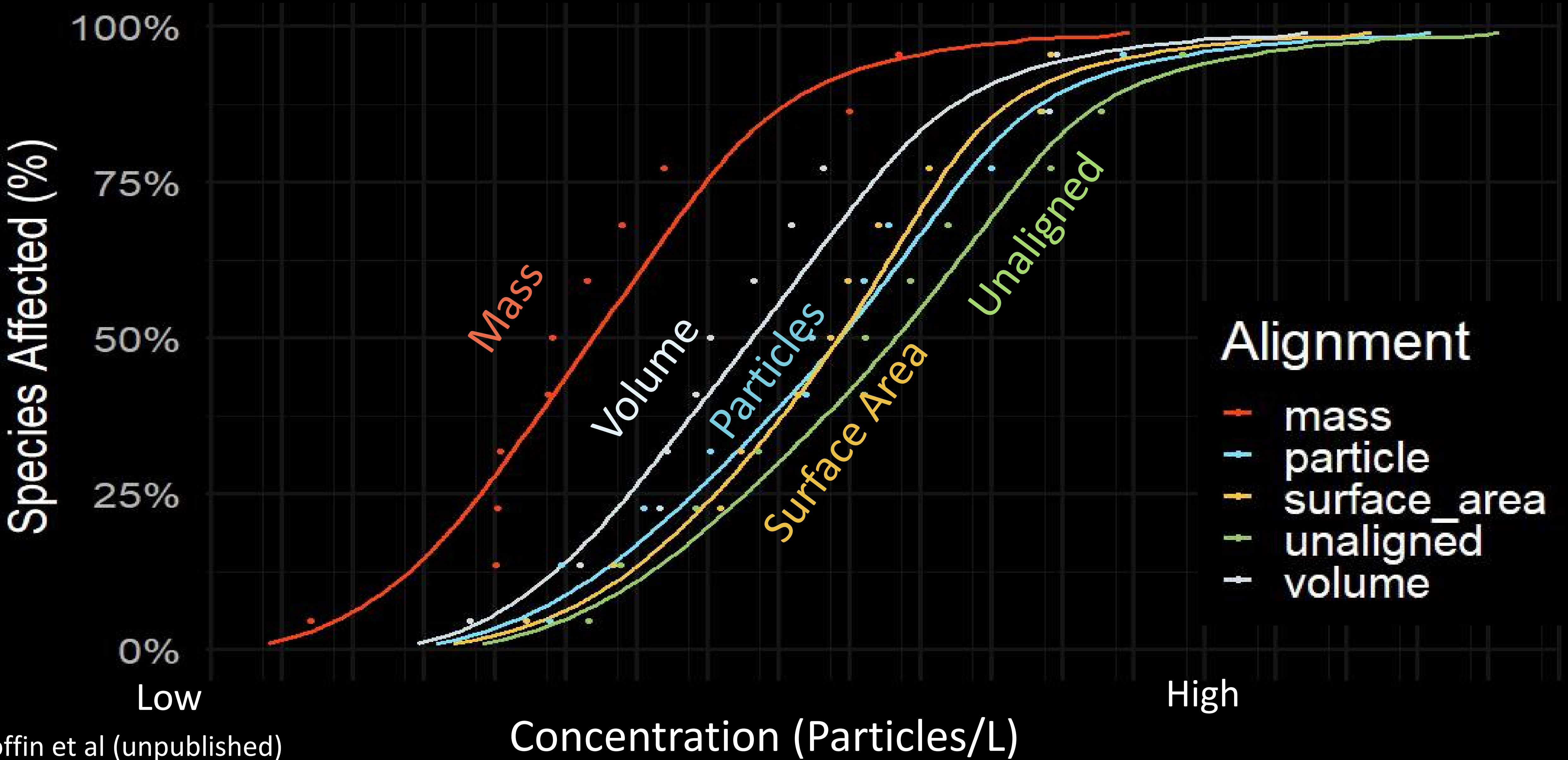
Oxidative Stress



Relevant Metric:	Volume	Surface Area

Kooi, Primpke, Mintenig, Lorenz, Gerdts, Koelmans (2021). *Water Research*

SSDs 'Aligned' By Exposure Metrics



Coffin et al (unpublished)

Toxicity of Microplastics Explorer

TōMEx
Logo created by J.C. Leapman.

- Welcome
- Overview
- Search
- Exploration
- SSD
- Study Screening
- Resources
- Contact
- Human Health
- Follow Us on Twitter!

@ToMExApp

Data Selection

Species sensitivity distributions (SSDs) are cumulative probability distributions that estimate the percent of species affected by a given concentration of exposure using Maximum Likelihood and model averaging. A useful metric often used for setting risk-based thresholds is the concentration that affects 5% of the species, the 5% Hazard Concentration (HC). For more information on SSDs, refer to Posthuma, Suter II, and Traas (2001).

Data Type | Effect | Biology | Particles | Study Screening | Dose Metric | Alignment (Advanced) | SSD Options (Advanced)

Data Type:

Particle Only

Submit Current Selection | Reset Filters

Selected Data Summary

SSD Results: Plot

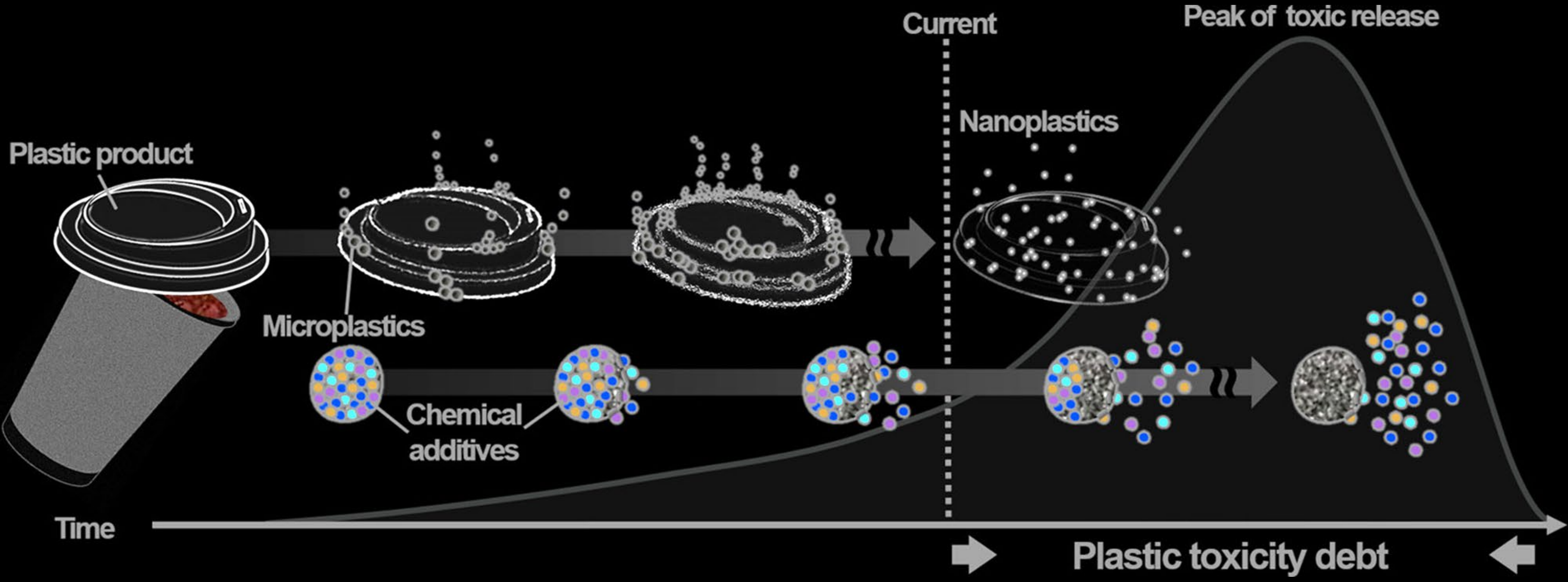
SSD Results: Table

Copy | CSV | Excel

Predicted species sensitivity distribution concentrations with uncertanties.

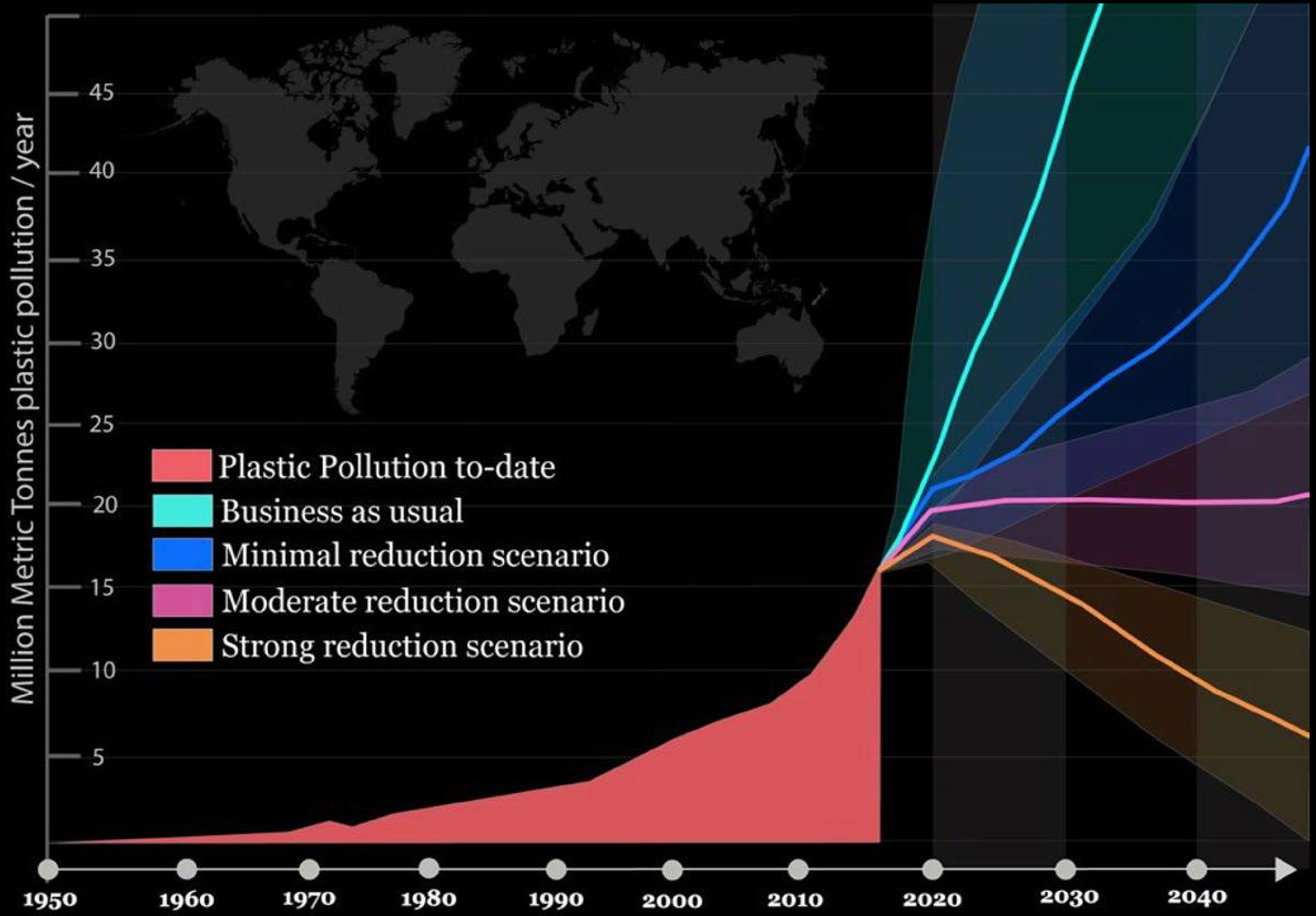
Percent	Estimated Mean Concentration Particles/mL	Standard Error Particles/mL	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Distribution
14	0.199	0.255	0.0493	0.776	average
15	0.237	0.301	0.0587	0.919	average
16	0.279	0.353	0.0693	1.08	average
17	0.326	0.41	0.0813	1.26	average
18	0.379	0.473	0.0946	1.45	average
19	0.437	0.544	0.11	1.67	average
20	0.502	0.622	0.126	1.92	average
21	0.573	0.708	0.145	2.18	average
22	0.652	0.803	0.165	2.48	average
23	0.74	0.907	0.188	2.8	average
24	0.836	1.02	0.212	3.16	average
25	0.941	1.15	0.239	3.55	average

Microplastics will Increase Long After Inputs Reduced



Rillig *et al.* (2021). *ES&T*

Plastic Pollution has Increased Exponentially



Lebreton & Andrady, *Palgrave Comms.* (2020).

Precautionary Approach

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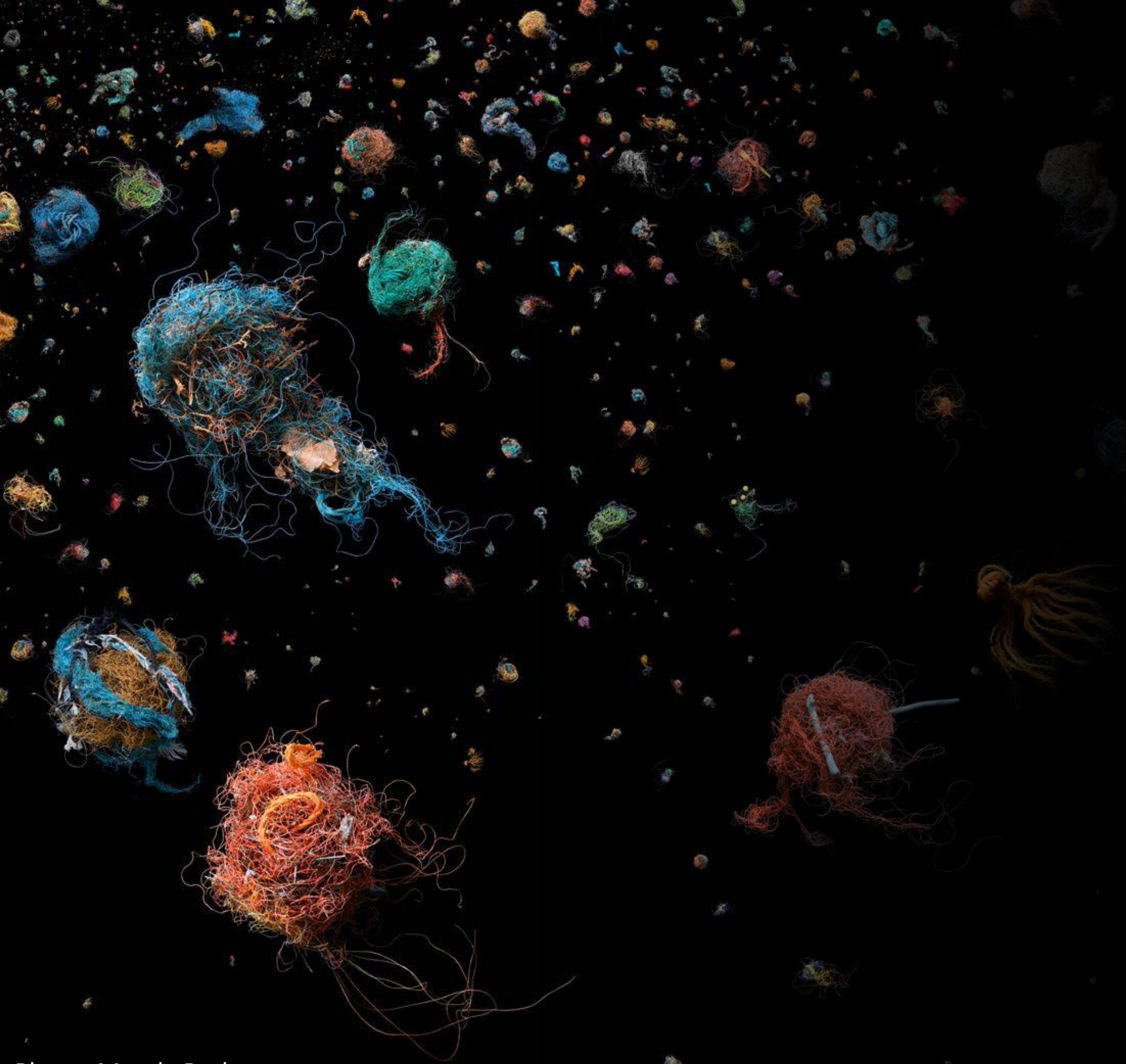

Photo: Mandy Barker

Thank you for your attention!

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STATE WATER RESOURCES CONTROL BOARD
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