Assessing Risks of Microplastics in Drinking Water and the Aquatic Environment to Inform Risk Management Strategies in California

2023 ICCA MARII Workshop

Seattle, USA

June 13, 2023

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

Photo: Mandy Barker

Keys to Successful Environmental Management

(these are just my opinions!)

Transparency

Iteration

Innovation

Engagement

Collaboration

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

California Senate Bill 1422 (2018)

CALIFORNIA Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

Deadlines

July 1,2020

- Define ‘microplastics’

July 1,2021

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

Human and Ecological Health Effects Workshop

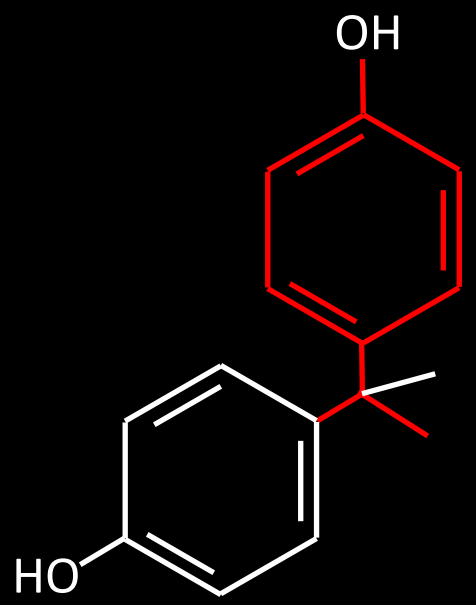
Dose Metrics

Particle Characteristics

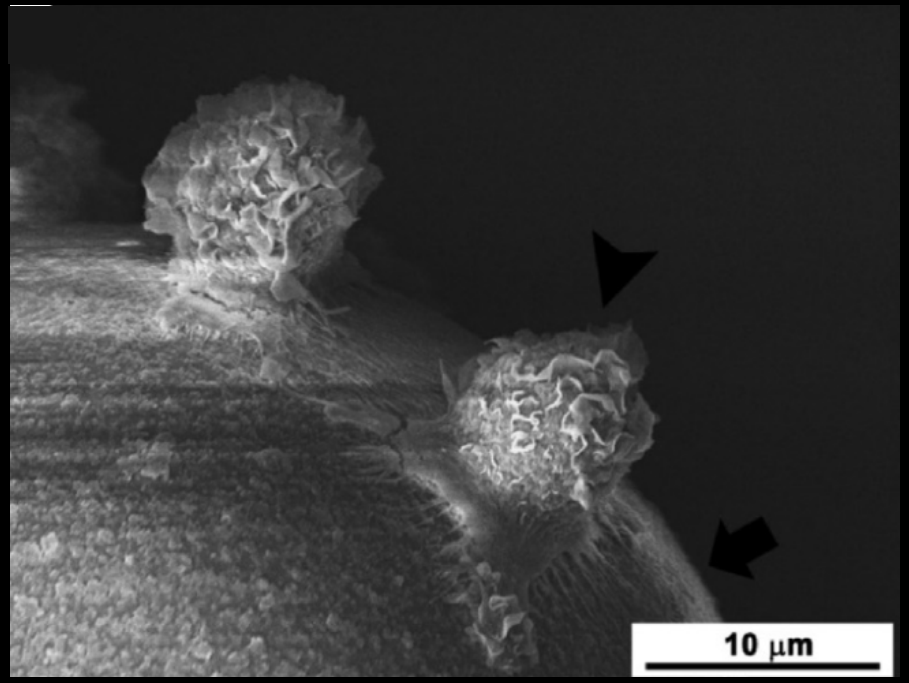
Adverse Effects

Threshold Framework

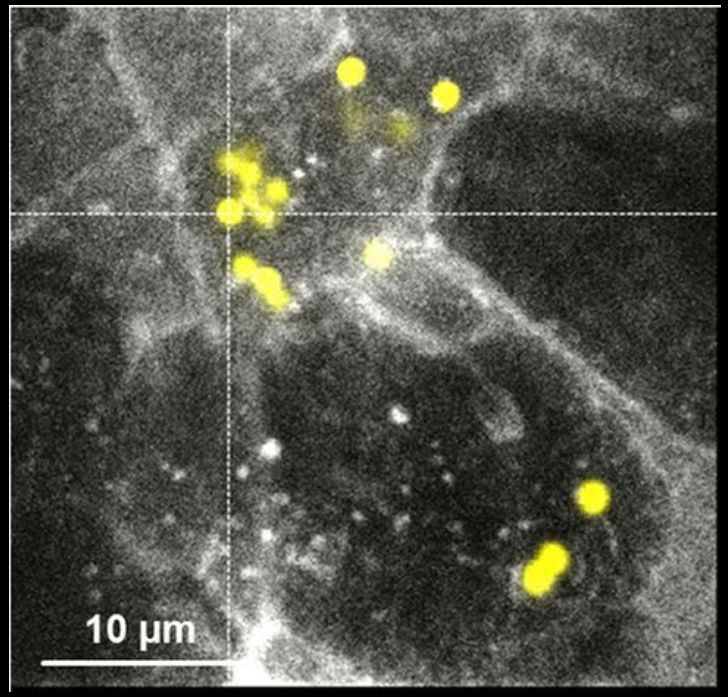
Microplastic Hazards



Bisphenol A



Jeon et al. (2021). *Environmental Pollution*



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

Chemical

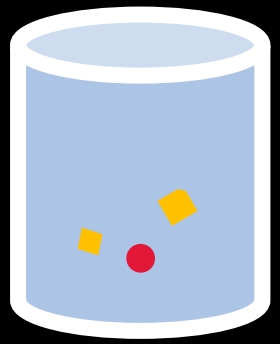
Biological

Particle

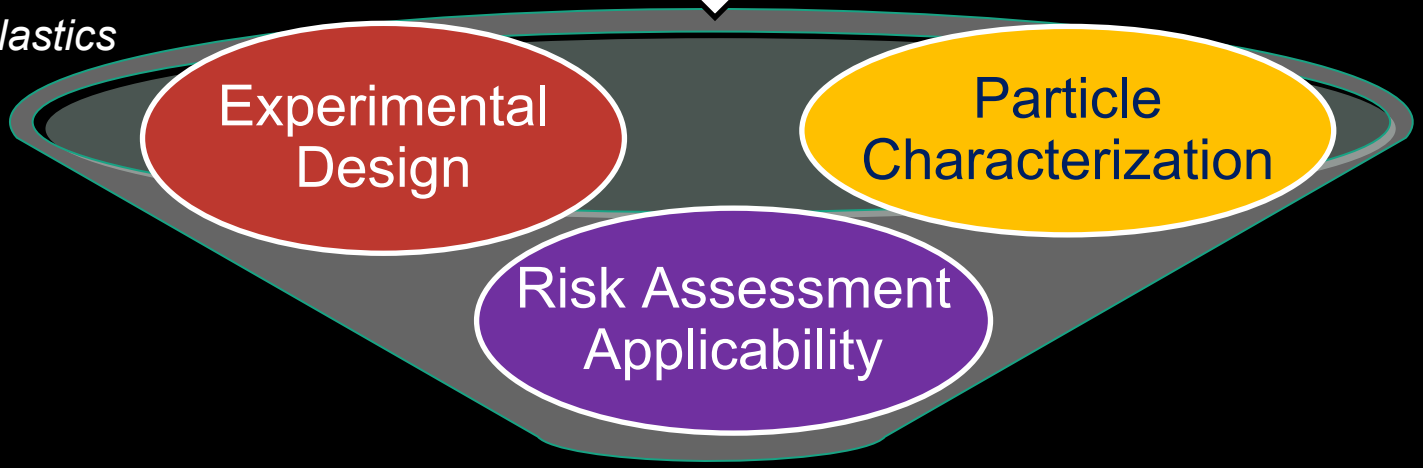
Mammalian Toxicity Study Screening

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

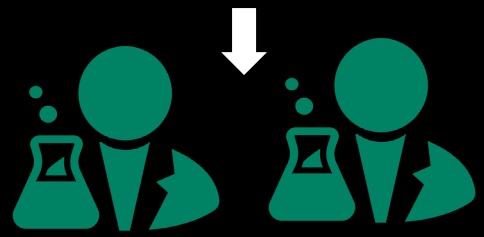
Gouin et al (2022), *Microplastics & Nanoplastics*



Drinking Water



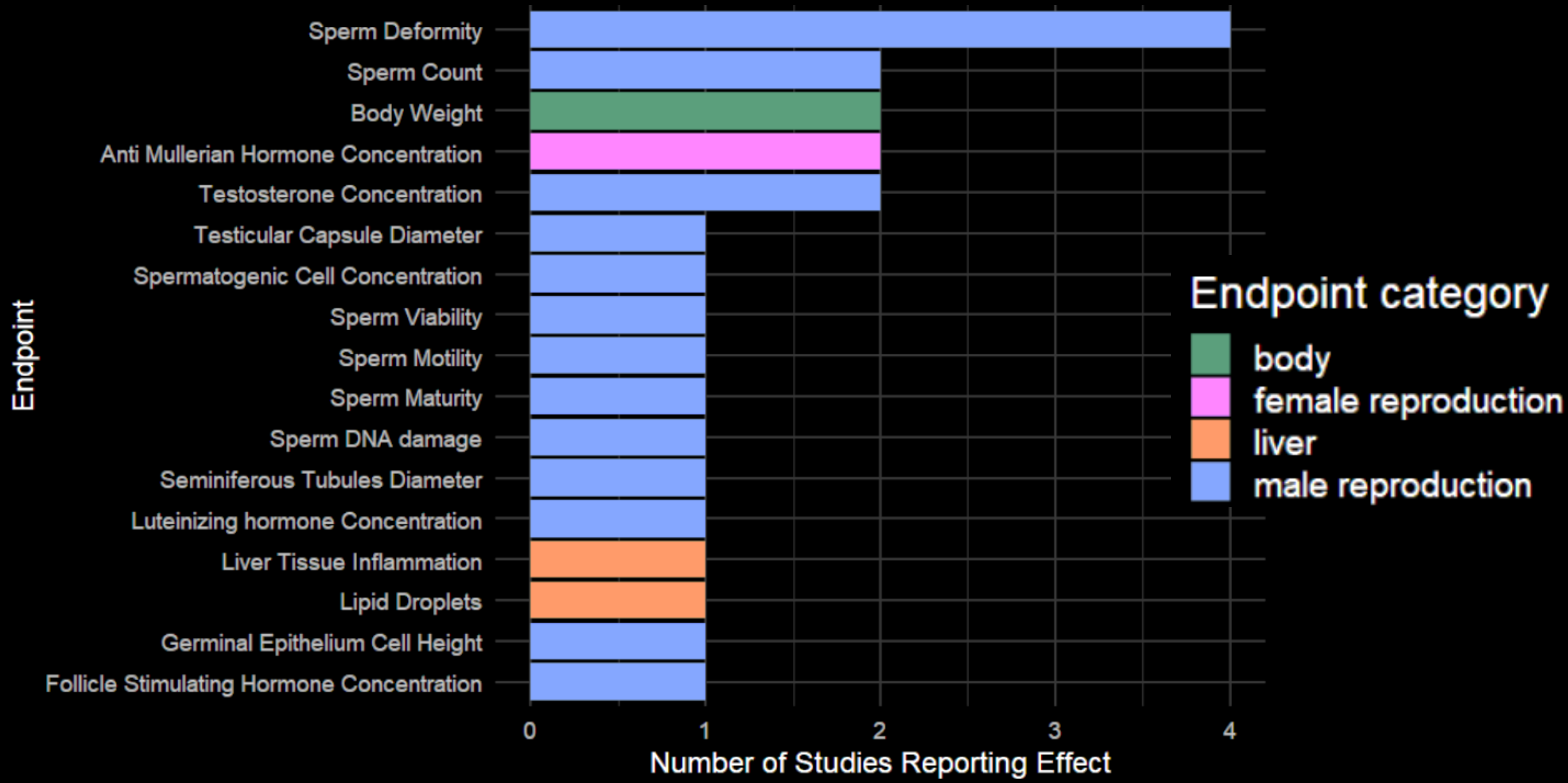
Fit for purpose studies
(n = 12)



Expert review

Coffin et al (2022), *Microplastics & Nanoplastics.*

Reliable Endpoints for Microplastics Effects in Mammals



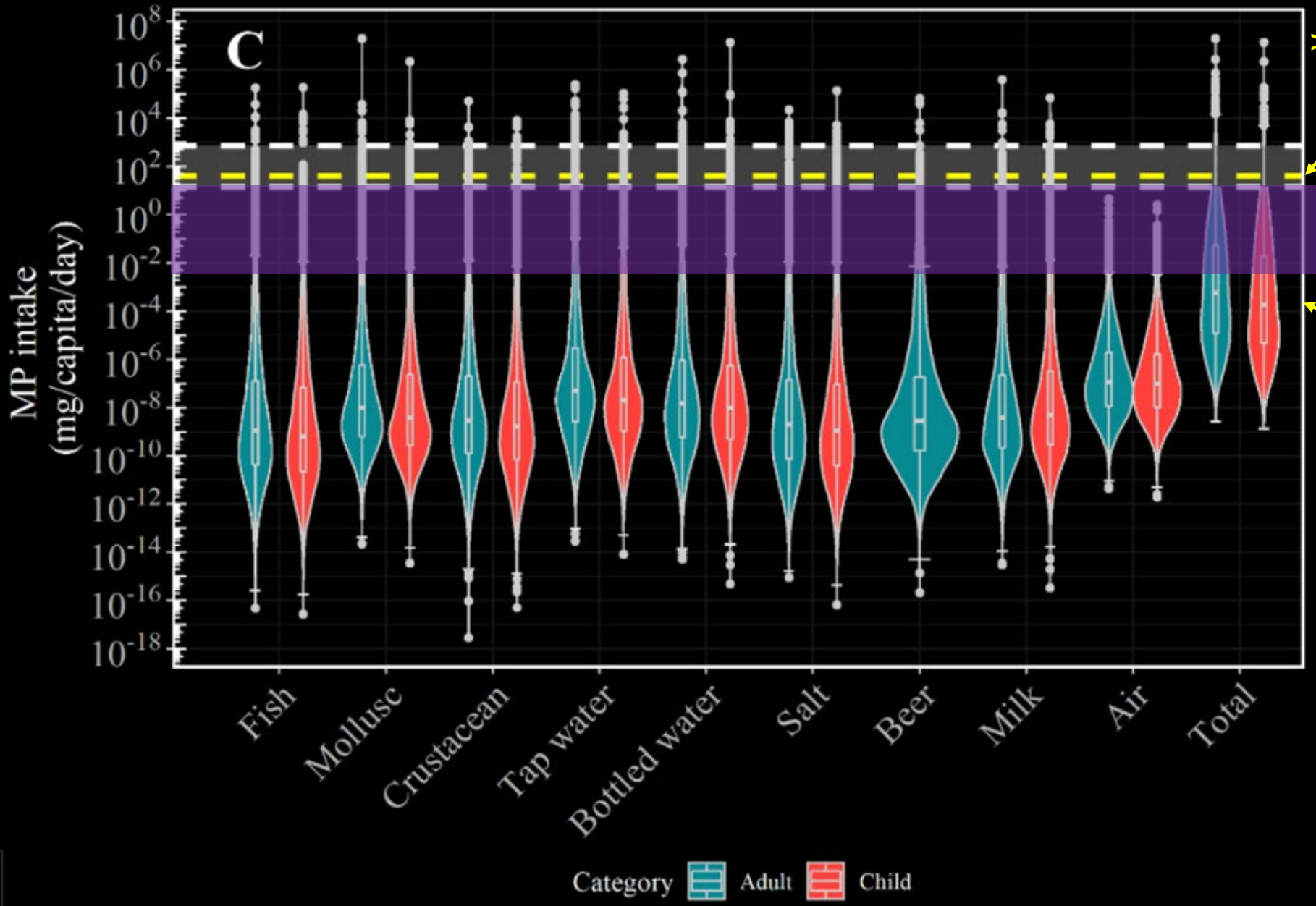
Coffin et al (2022), *Microplastics and Nanoplastics.*

Dose-Response Assessment

Coffin et al, *Microplastics and Nanoplastics* (2022)

point of departures (PODs) derived using EPA's BMDS; Error bars = 95% CI BMD

Wide Uncertainties and Variability for Exposure



>99th percentile: Credit Card/week

Benchmark dose range

>Median: Grain of salt/week

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

Not Currently Possible to Derive Regulatory Levels

1. Effects database inadequate
   - poor particle characterization
   - limited polymers, shapes, sizes tested

Drinking Water

2. Uncertain Effect Mechanisms
   - necessary for extrapolation to diverse particle types
3. Incomplete exposure data
   - limited food data
   - no harmonized drinking water data

Coffin et al (2022), *Microplastics and Nanoplastics.*

California's Inter-Lab Validation Study

Two Methods

FTIR Spectroscopy

Raman Spectroscopy

26 Laboratories

Four Matrices

Drinking Water

Ocean Water

Fish Tissue

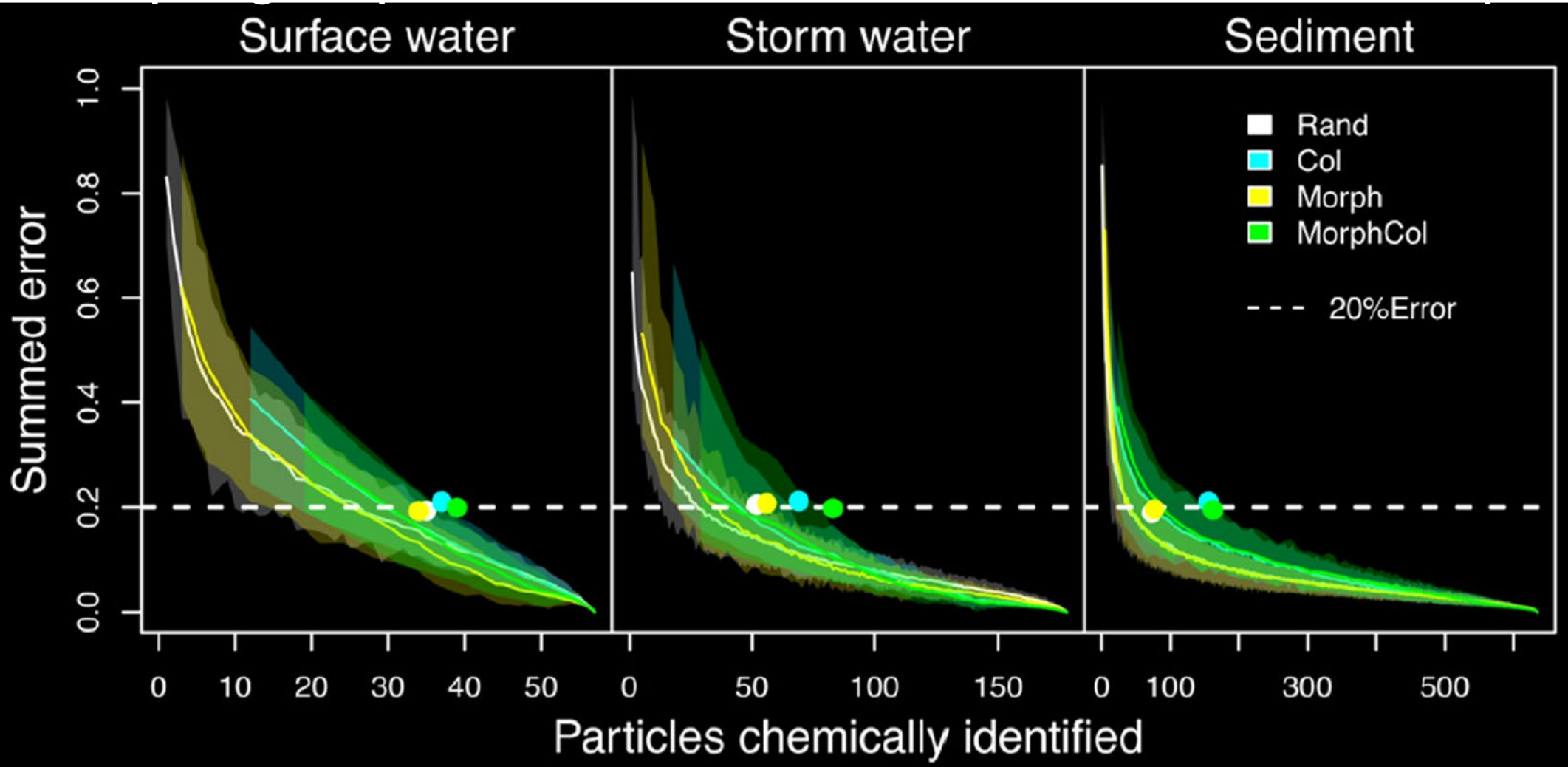
Sediment

Method Strengths and Weaknesses

	Optical Microscopy	Infrared Spectroscopy	Raman Spectroscopy
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. 2022 (*Chemosphere)*

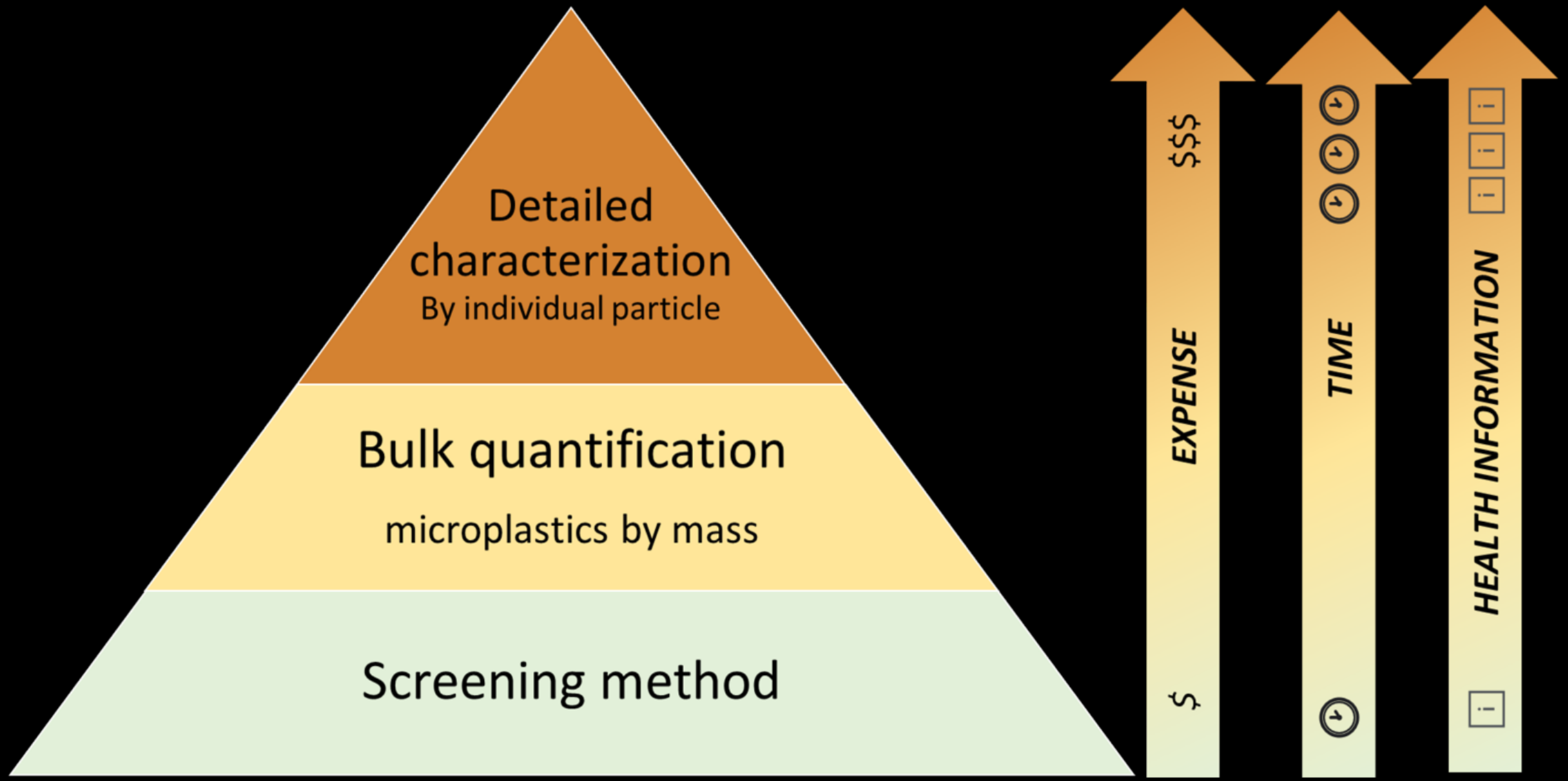
Subsampling required to achieve 20% RSD is Matrix-Dependent



3 sets of ≥30 particles per sample required for subsampling in SWB-MP-Rev1

De Frond *et al.* (2023). *Chemosphere*

Fit-for-Purpose Tiered Monitoring Framework



Coffin (2023). “The emergence of microplastics: charting the path from research to regulations.” *Environmental Science: Advances.*

Statewide Monitoring Plan Adopted 2022

CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

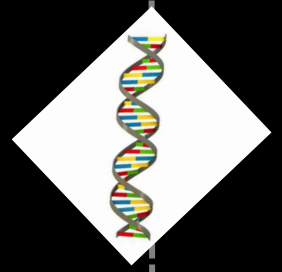
POLICY HANDBOOK ESTABLISHING A STANDARD METHOD OF TESTING AND REPORTING OF MICROPLASTICS IN DRINKING WATER

August 9, 2022

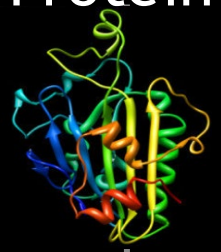
Prepared by:
THE DIVISION OF DRINKING WATER
STATE WATER RESOURCES CONTROL BOARD
STATE OF CALIFORNIA

Drinking Water Treatment is Size-Dependent

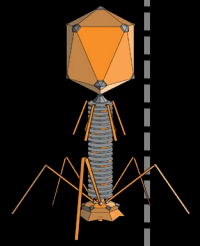
DNA



Protein

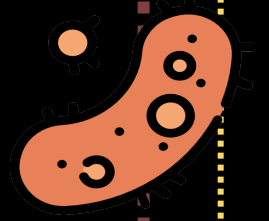


Virus



Red blood cell

Bacteria



Dust mite

Reverse Osmosis

Ultrafiltration

Flocculation/Sedimentation

Nanofiltration

Microfiltration

FTIR LOQ

Raman LOQ

Translocatable sizes

1 nm | 10 nm | 100 nm | 1 µm | 10 µm | 100 µm

Iterative Monitoring Approach in Drinking Water

Pilot Phase

- Sampling method comparison
- Range-finding
- Sample training

Summer 2022

Fall 2023

Summer 2023

Interim

Phase One

- Few water systems
- Source waters only
- Surrogate development

Fall 2025

Interim

Fall 2026

Phase Two

- Additional systems
- Treated waters
- Tiered monitoring

Fall 2028

Dates subject to change.

California Senate Bill 1263 (2018): Statewide Microplastics Strategy

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Eco-toxicity Thresholds Derivation

in vivo aquatic microplastics toxicity studies
(n = 167 studies; 117 species)

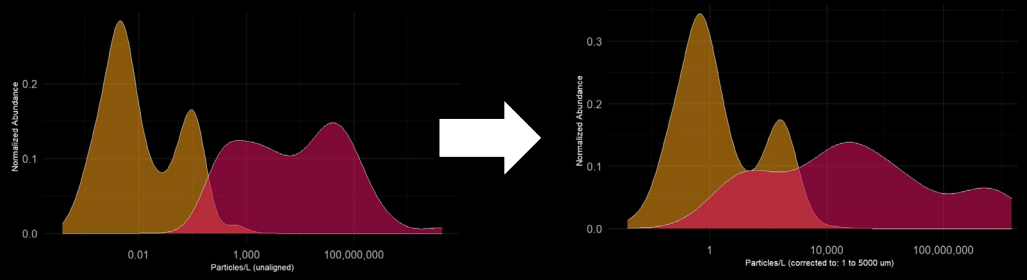
De Ruijter et al. (2019)

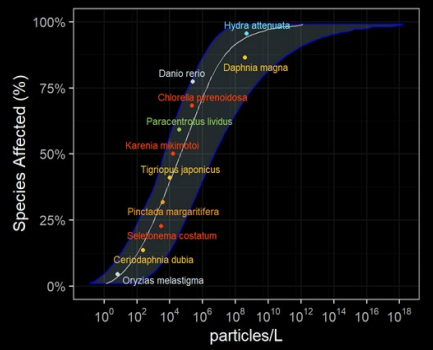
Fit for purpose studies
(n = 22 studies; 16 species)

Expert review

Data Alignment

Species sensitivity distribution modelling





Mehinto et al (2022), *Microplastics & Nanoplastics.*

Microplastics Aquatic Toxicity Thresholds

Threshold	**Food Dilution** (particles/L)	**Tissue Translocation** (particles/L)
1- Investigative monitoring	0.3	60
2- Discharge monitoring	3.0	320
3- Management planning	5.0	890
4- Source control measures	34	4,100

*Based on species sensitivity distributions with 27 studies, 14 species and 6 taxa for all endpoints

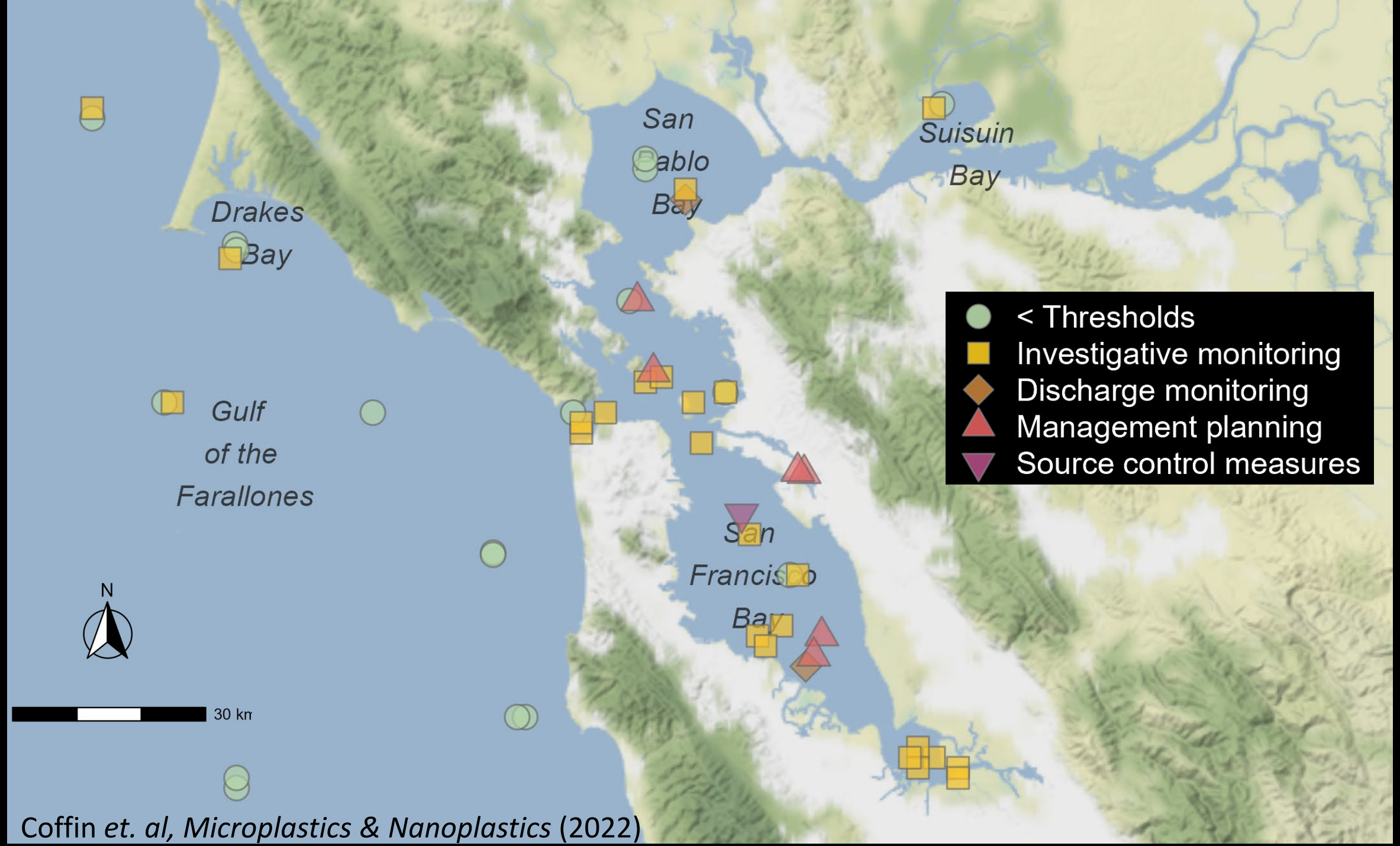
** Concentrations aligned to 1 to 5,000 µm size range

Mehinto *et. al, Microplastics & Nanoplastics* (2022)

Characterizing Ecological Risks in San Francisco Bay, California

Photos: Erika Delemarre

Coffin et al. (2022). *Microplastics & Nanoplastics*

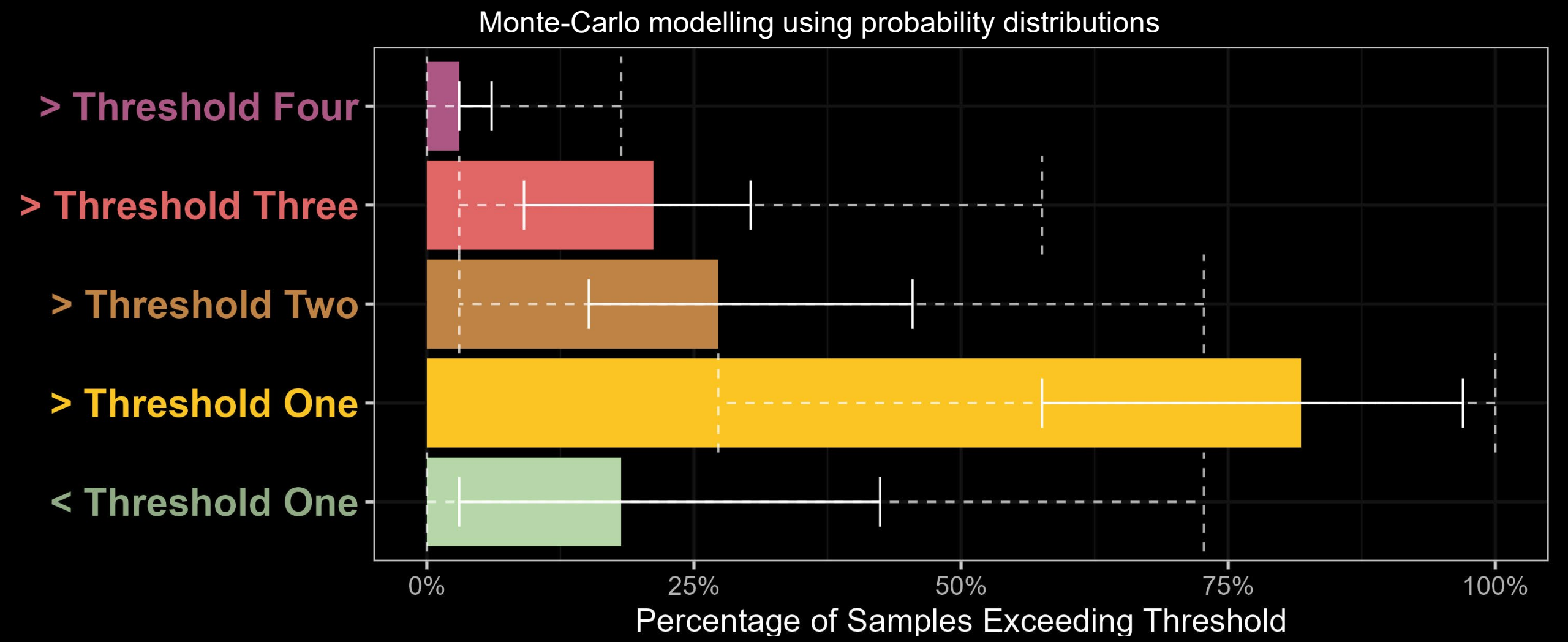


Coffin *et. al, Microplastics & Nanoplastics* (2022)

Microplastics Tracking in San Francisco Bay

Rusty Holleman (2019)

Probabilistic Risk Characterization of San Francisco Bay

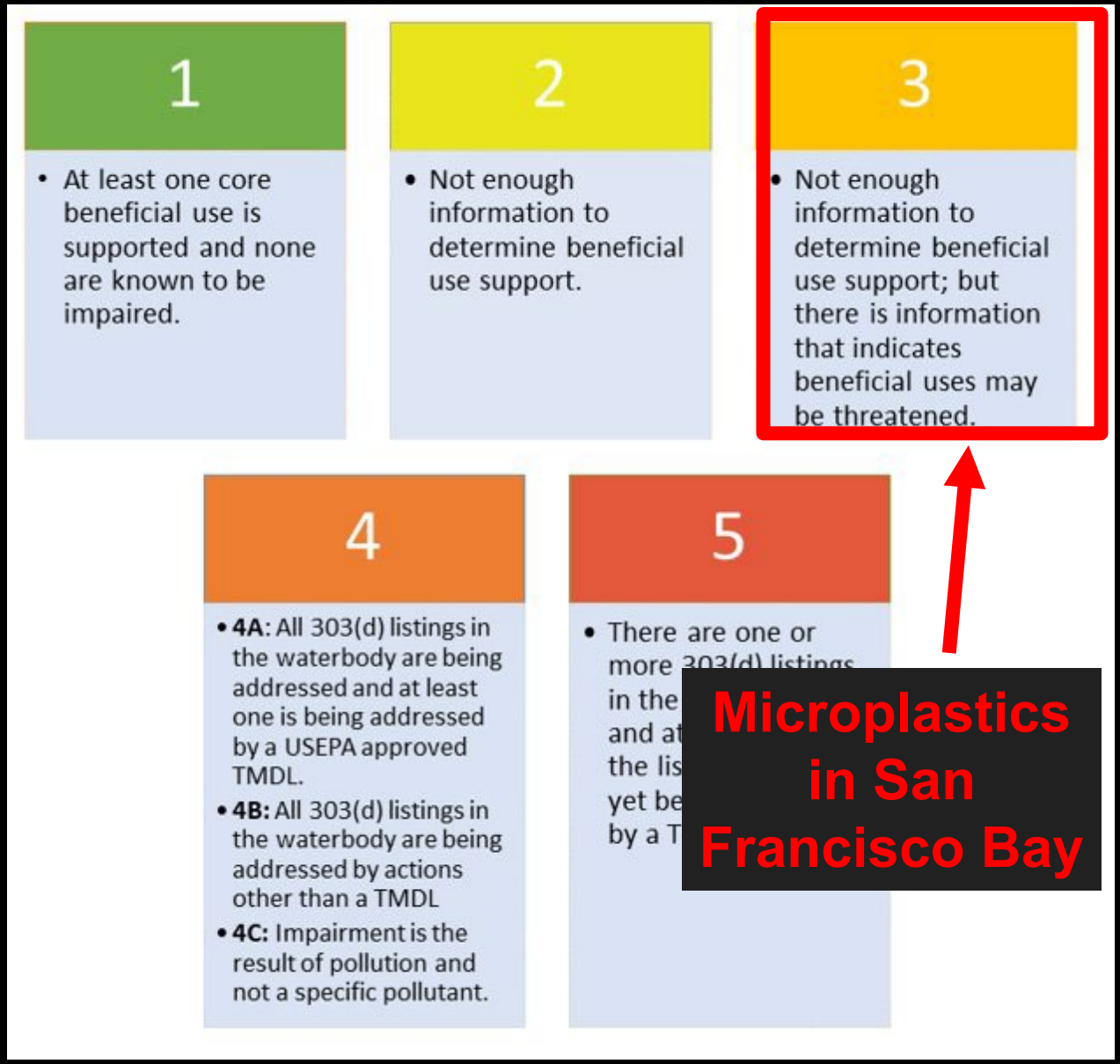


Coffin *et. al, Microplastics & Nanoplastics* (2022)

Potential Regulatory Implications

The 303(d) List:

- Impaired waterbodies that do not meet water quality standards
- Informs remediation, e.g. - total maximum daily loads (TMDLs)
  - TMDLs often inform monitoring



Predicting Toxicity with Artificial Intelligence

Training Data

- Particle Characteristics
- Test Parameters
- Organismal Characteristics
- Effects

Machine Learning

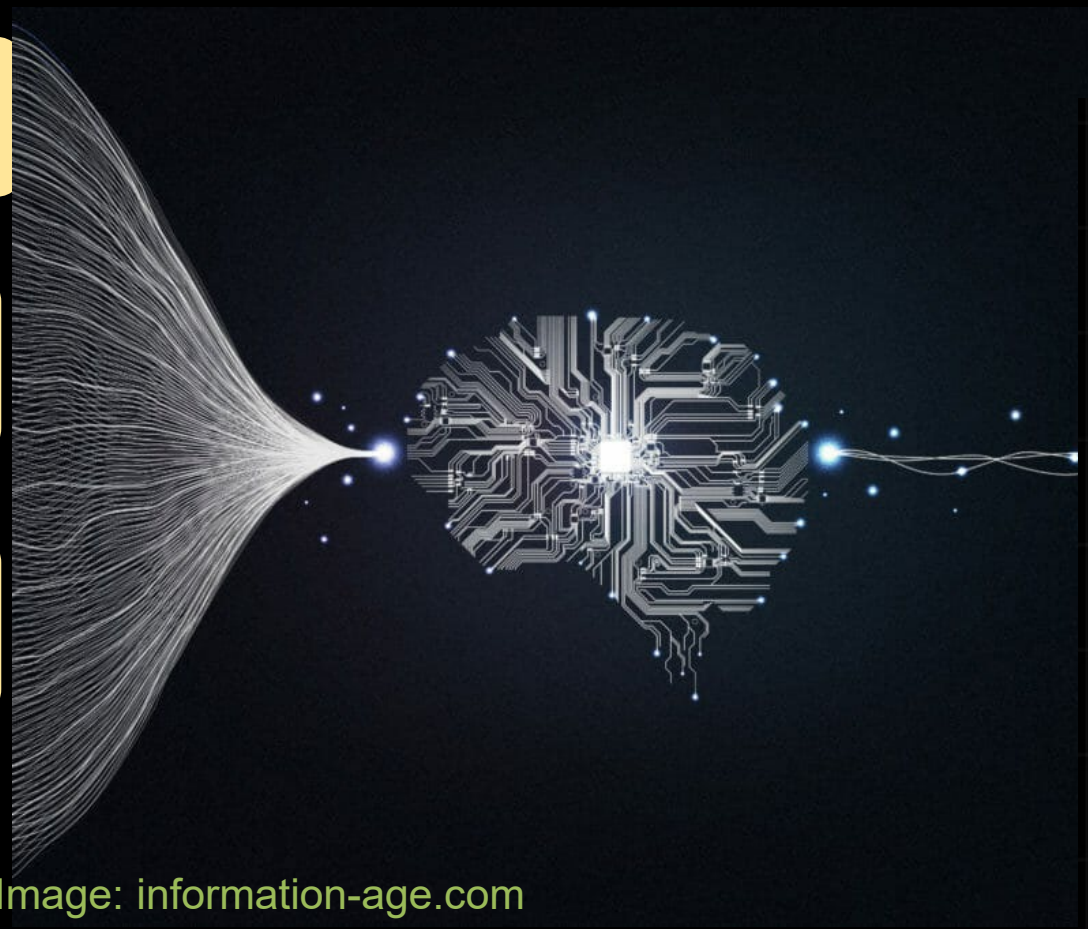
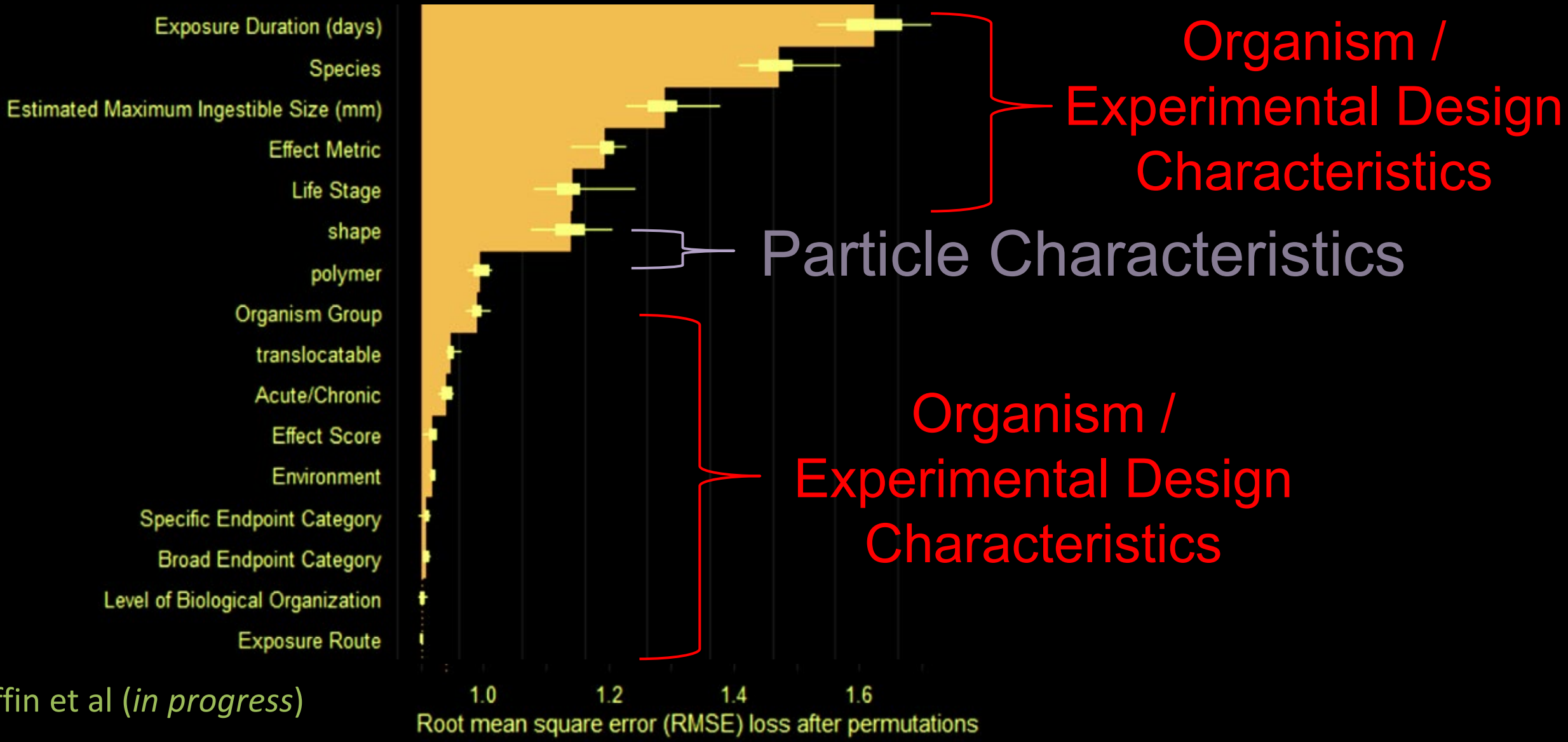


Image: information-age.com

Toxicity Predictions

Coffin et al (*in progress*)

What Factors Drive Toxicity?



Coffin et al (*in progress*)

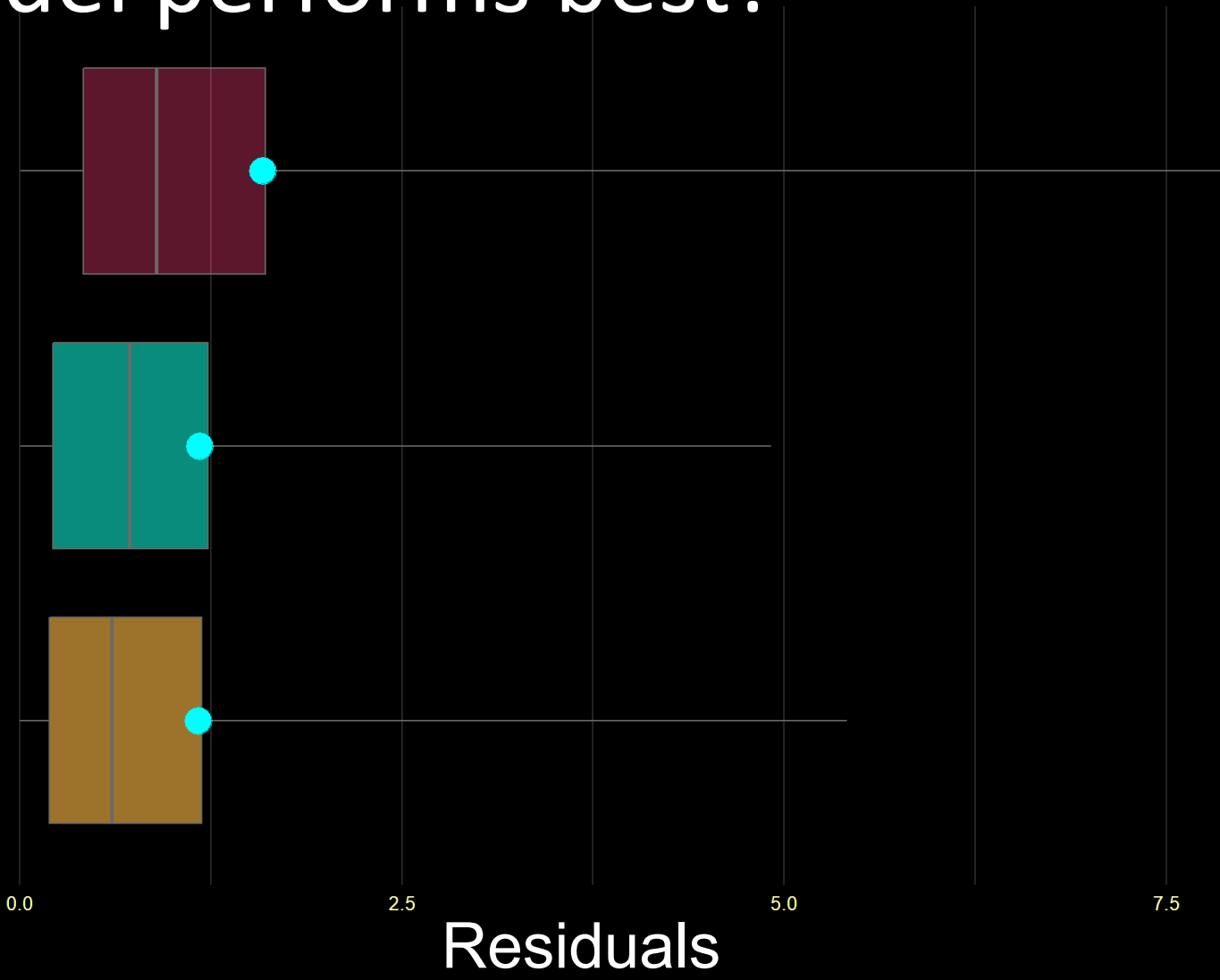
Can a model improve toxicity predictions?

Which model performs best?

General Linear Model
$R^2 = 0.62$

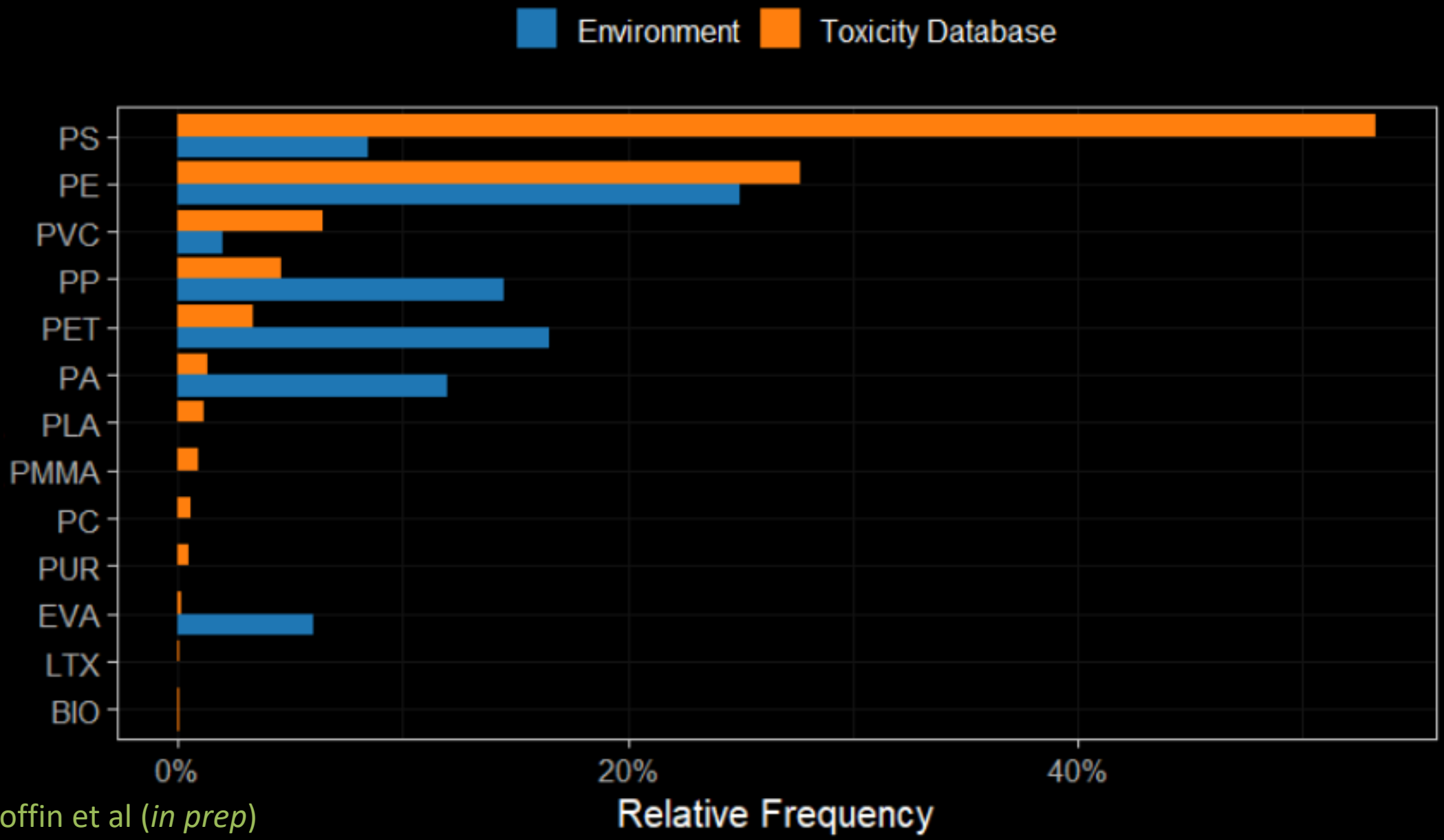
eXtreme Gradient Boosted Trees
$R^2 = 0.82$

Random Forest
$R^2 = 0.84$



Coffin et al (*in progress*)

Unrealistic Polymers in Database



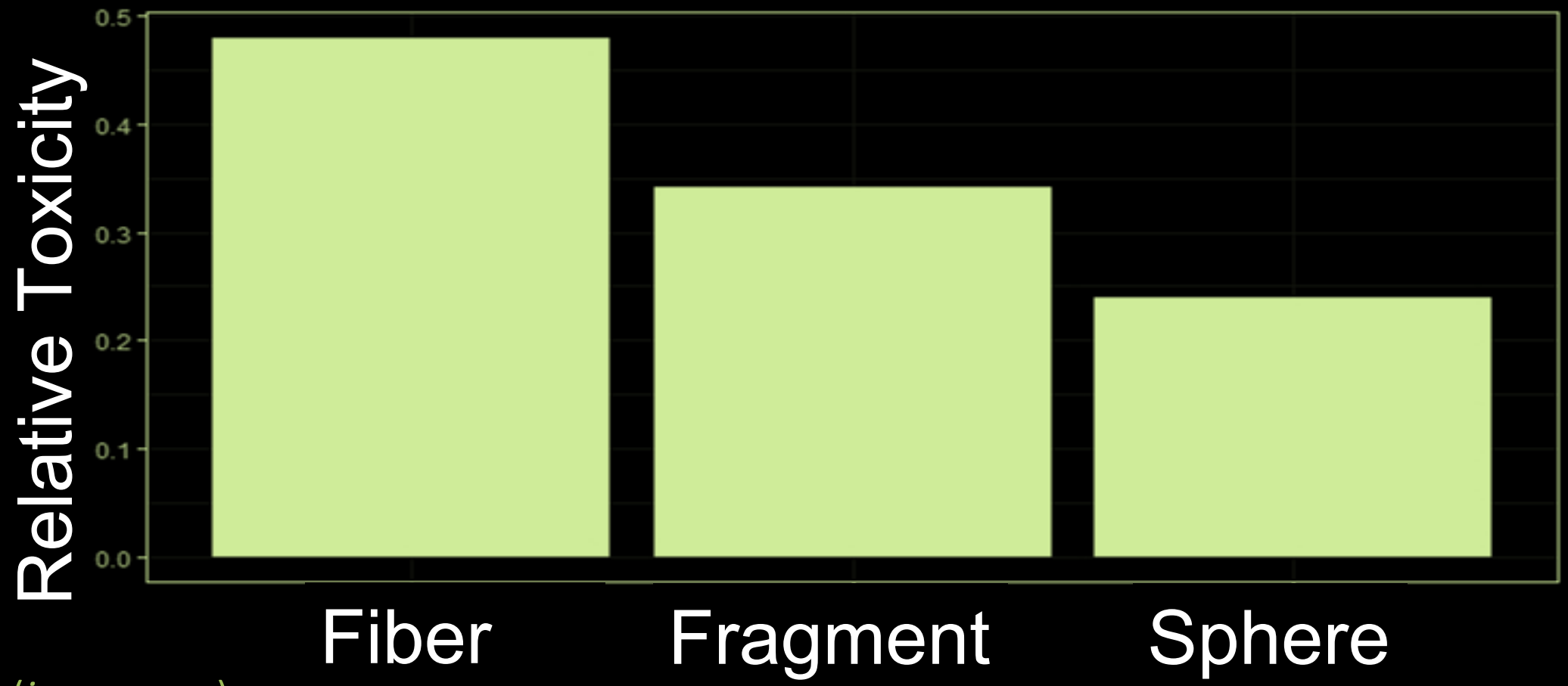
Coffin et al (*in prep*)

Unrealistic Shapes in Database

Coffin et al (*in prep*)

What parameters drive toxicity?

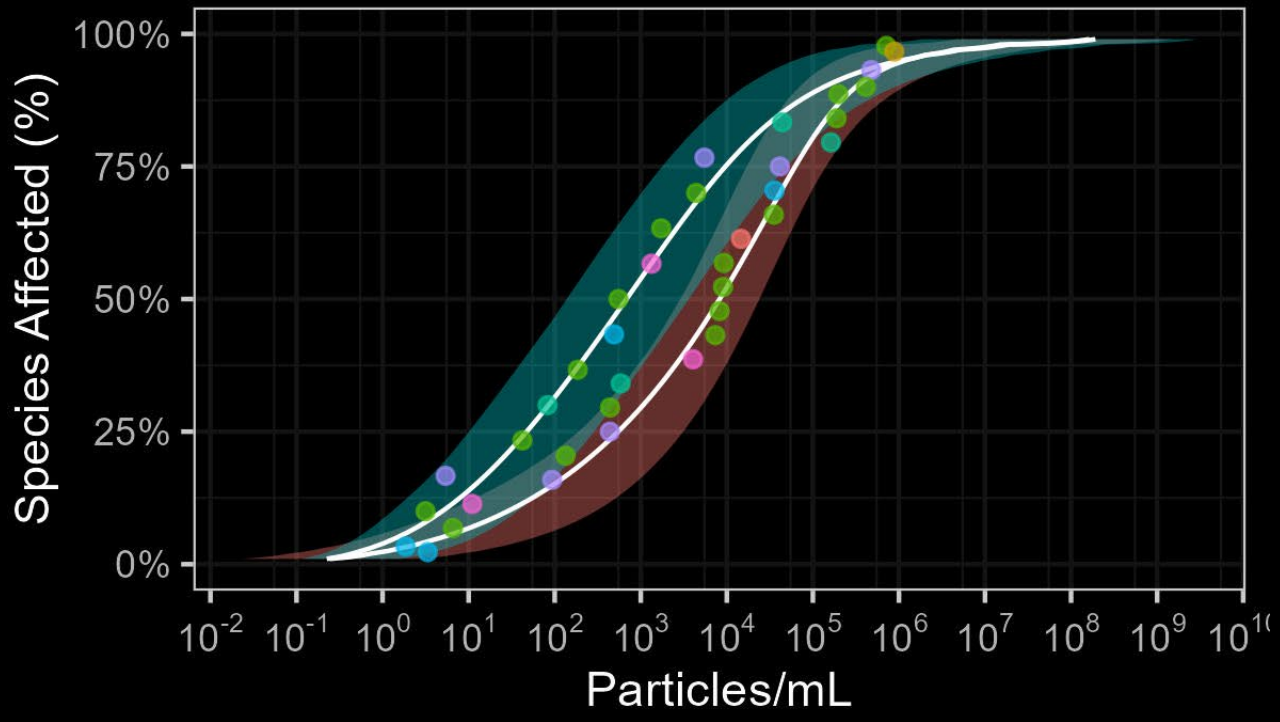
Model-Predicted Toxicity by Shape



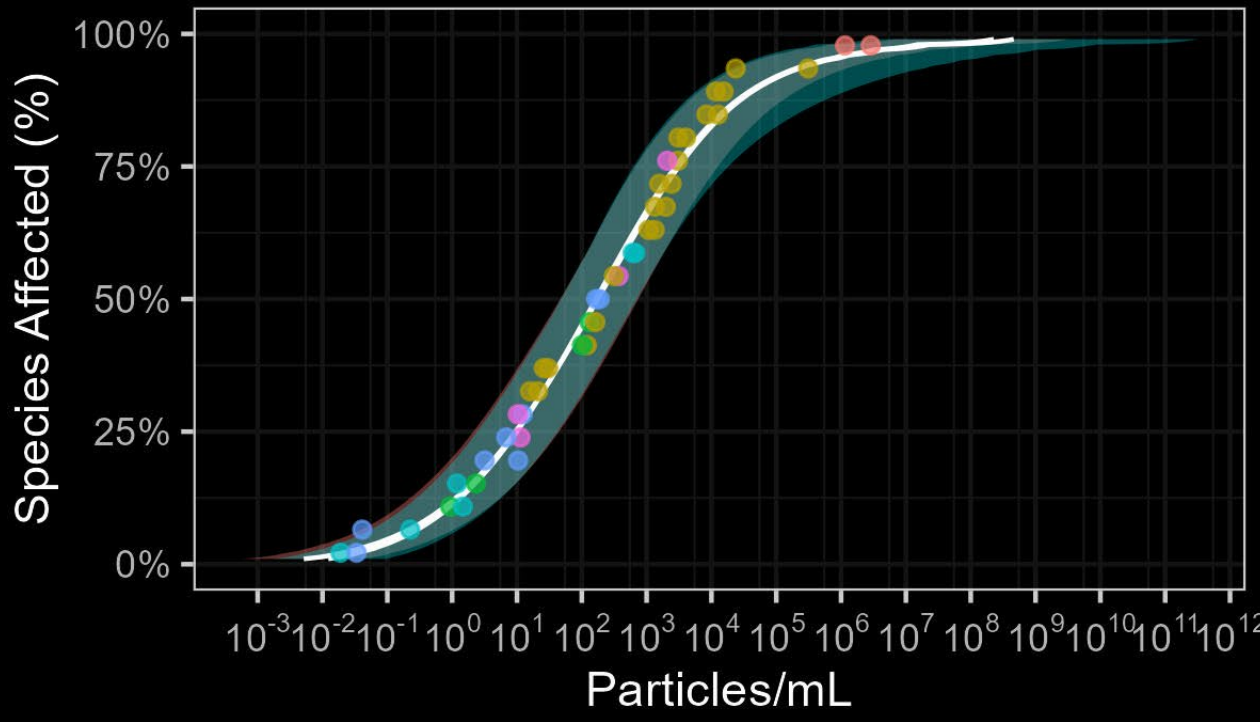
Coffin et al (*in progress*)

Can a model improve toxicity predictions?

Tissue Translocation (R^2= 0.82)

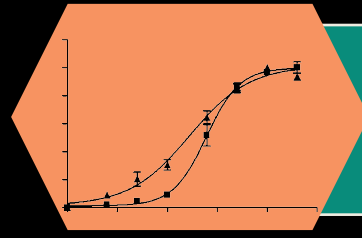


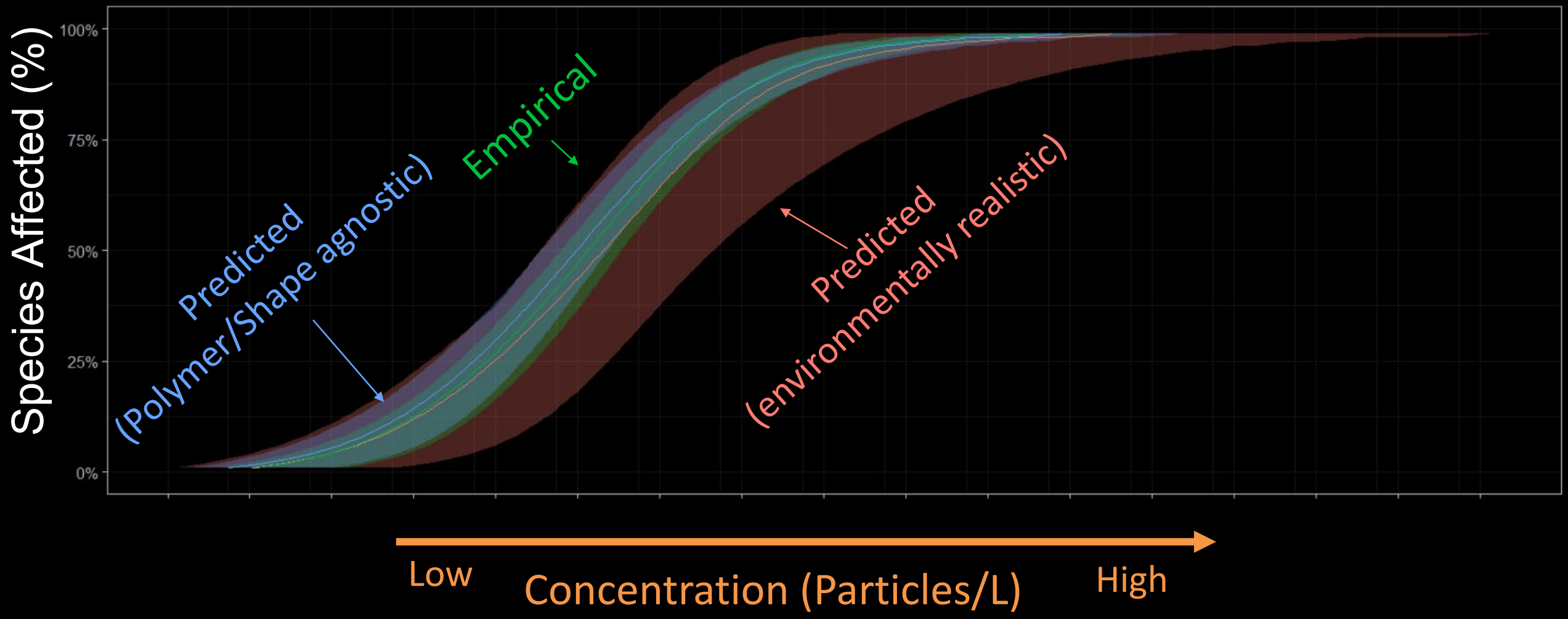
Food Dilution (R^2= 0.87)



Coffin et al (*in progress*)

Can a model improve toxicity predictions?





Coffin et al (*in progress*)

California Senate Bill 1263 (2018): Statewide Microplastics Strategy

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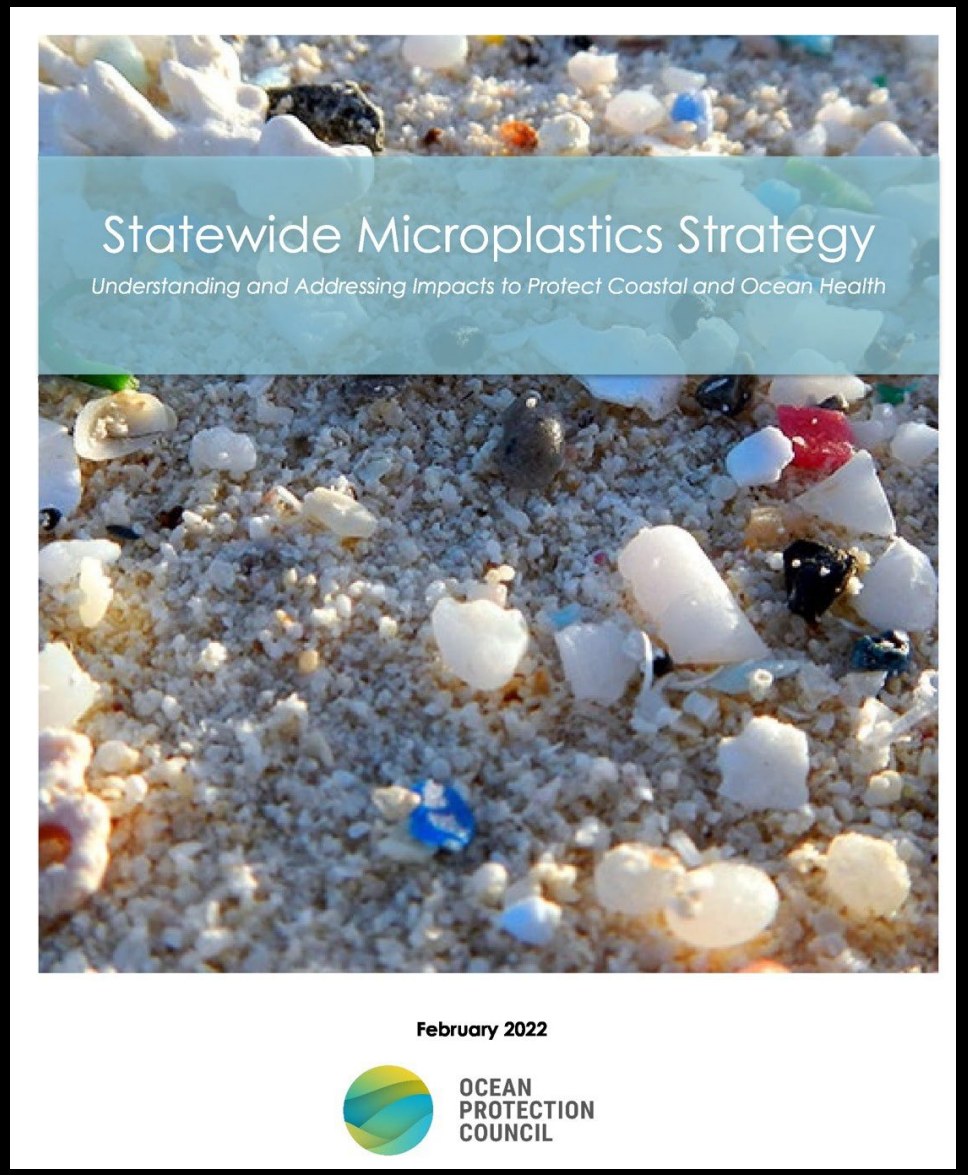
Statewide Microplastics Strategy: 2-Track Approach

Track 1: Solutions

- **Pollution Prevention**
  Eliminate plastic waste at the source
- **Pathway Interventions**
  Intervene with the mobilization of microplastics into CA waters
- **Outreach & Education**
  Inform public of microplastics sources, impacts, solutions

Track 2: Science to Inform Future Action

- **Monitoring**
  Understand and identify statewide trends
- **Risk Thresholds & Assessment**
  Understand thresholds for aquatic life & humans are impacted
- **Sources & Pathways Prioritization**
  Identify & prioritize solutions based on dominant pathways
- **Evaluating New Solutions**
  Develop & implement new solutions



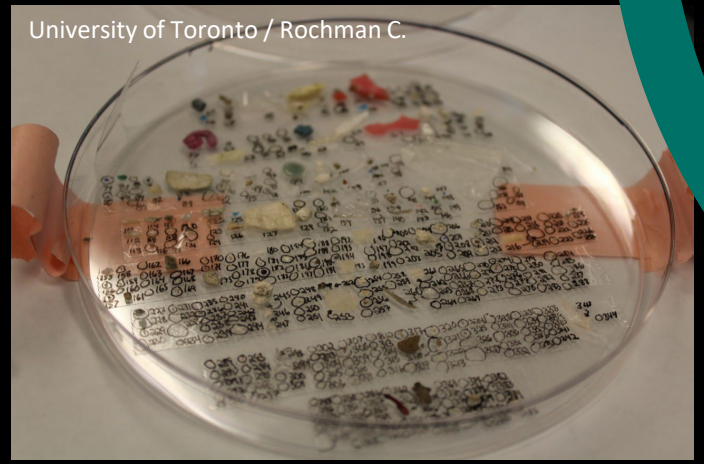
Science to Inform Future Action: Research Priorities

1. Monitoring

2. Risk Thresholds & Assessment

3. Sources & Pathways Prioritization

4. New Solutions



Comprehensive Packaging Extended Producer Responsibility Bill Signed June 30, 2022

Recycling/compostable:

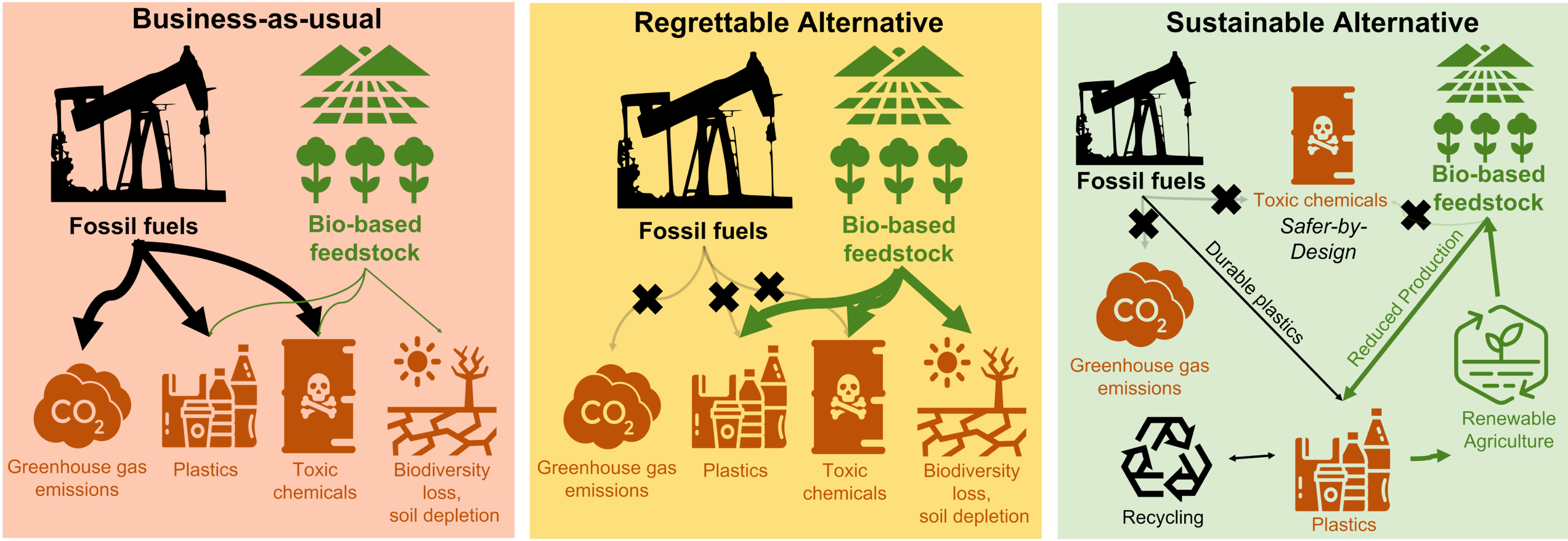
- 30% by 2028
- 65% 2032

- Independent Producer Responsibility Organizations

- $5 bill over 10 yrs from industry to mitigate impacts

Gov. Gavin Newsom (seated) signs SB 54 on June 30, 2022. State Sen. Ben Allen far left. Assemblywoman Luz Rivas to Newsom's right.
Courtesy of State Sen. Ben Allen

Science needed to avoid Regrettable Substitutions



Balan *et al.* “Scientists’ Statement on Chemicals in a Changing Climate” (*In Press*)

Microplastics Monitoring Subcommittee

Local and global community exchange of information and data for microplastics monitoring methods and tools

Quarterly Meetings

- **Sampling and analysis playbook**
- **Communication toolbox**
- **Laboratory accreditation & data analysis**

waterboards.ca.gov/resources/email_subscriptions/swrcb_subscribe

One4All: Open-Source Data Harmonization Portal

Accredited Labs

Environmental Laboratory Accreditation Program
STATE WATER RESOURCES CONTROL BOARD

Data Ingestion

Microplastic Web

ckan

CEDEN

Application Integration

Data Integration

SDWIS

OPEN SPECY

TōMEx

DRAFT flowchart

MOORE INSTITUTE
for Plastic Pollution Research

Eliminating Contamination with In-Line Filtration

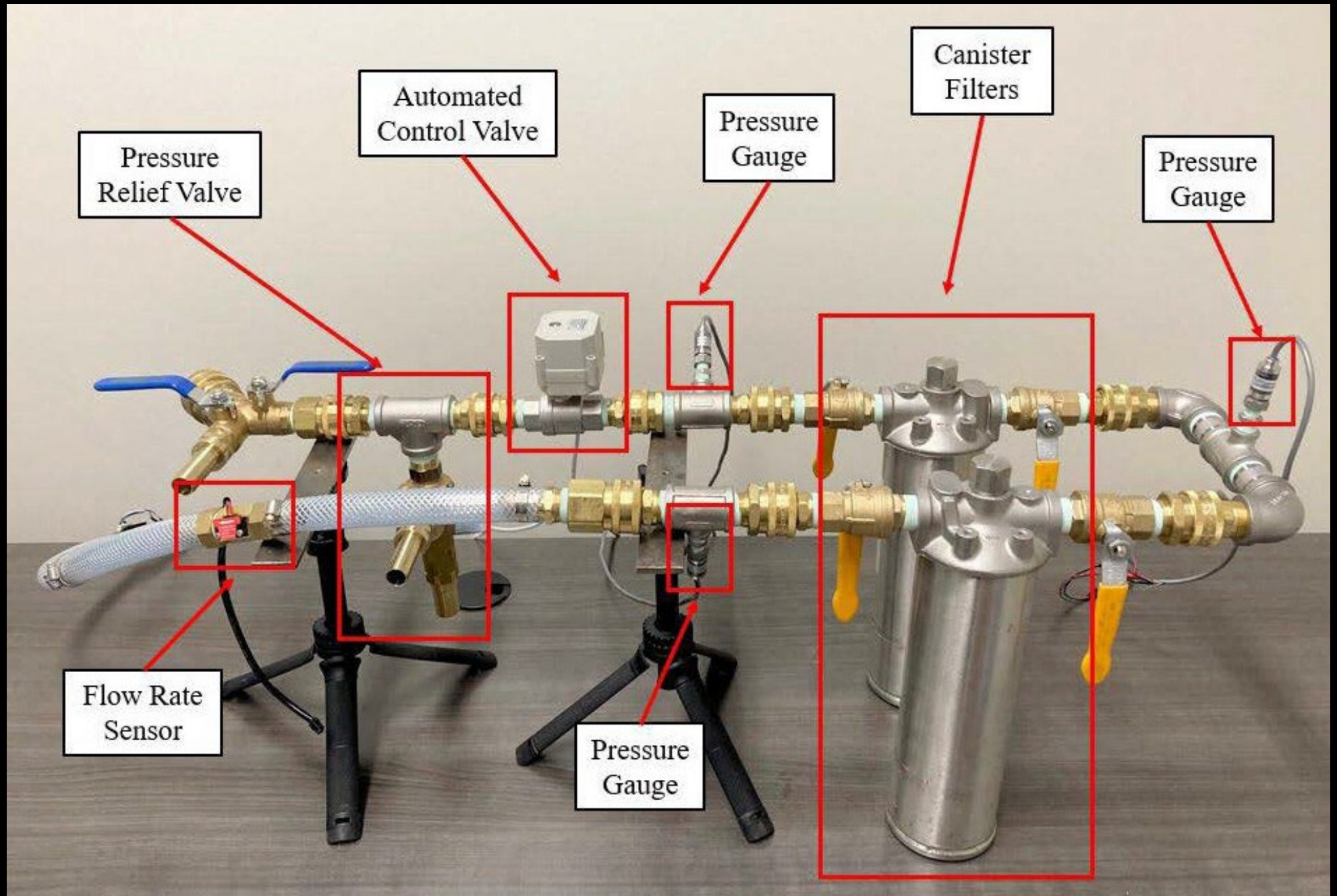
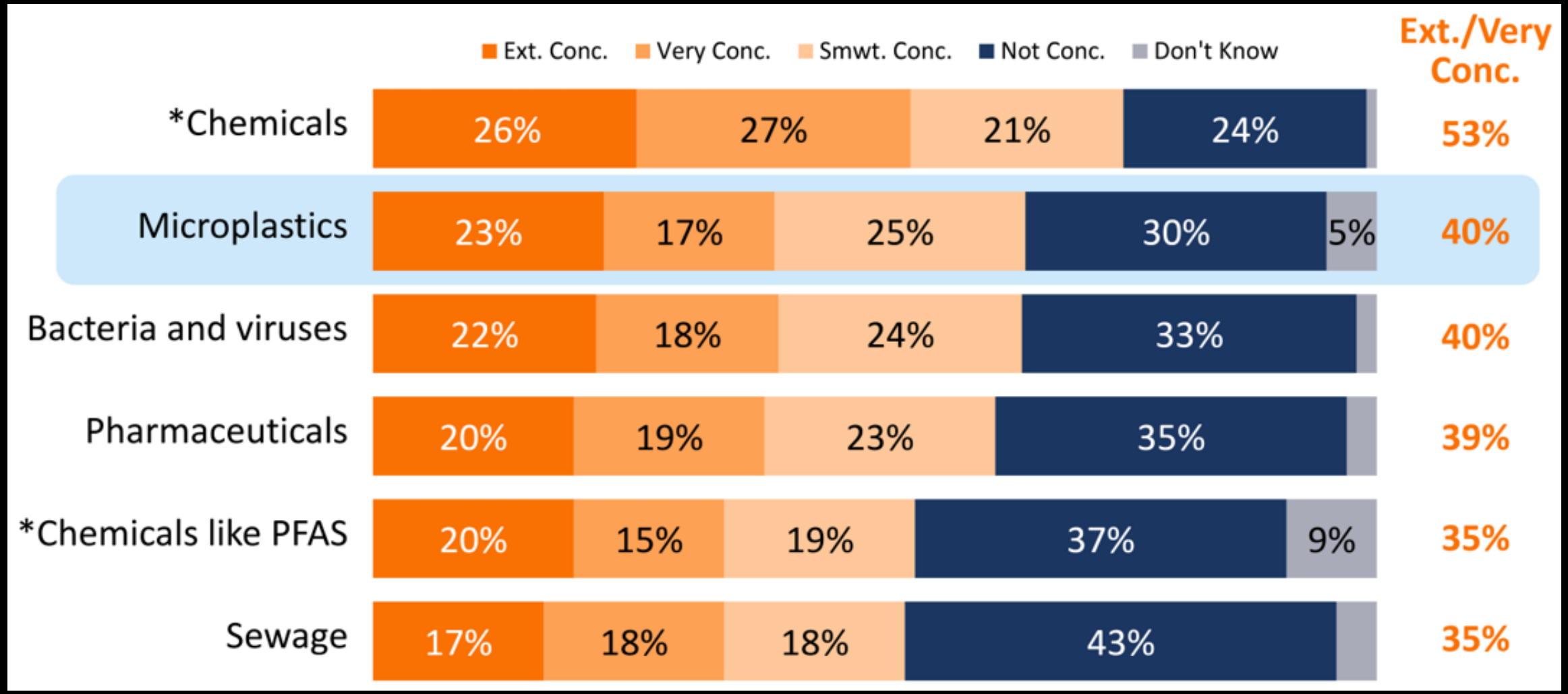


Image courtesy of Dr. Robert Andrews

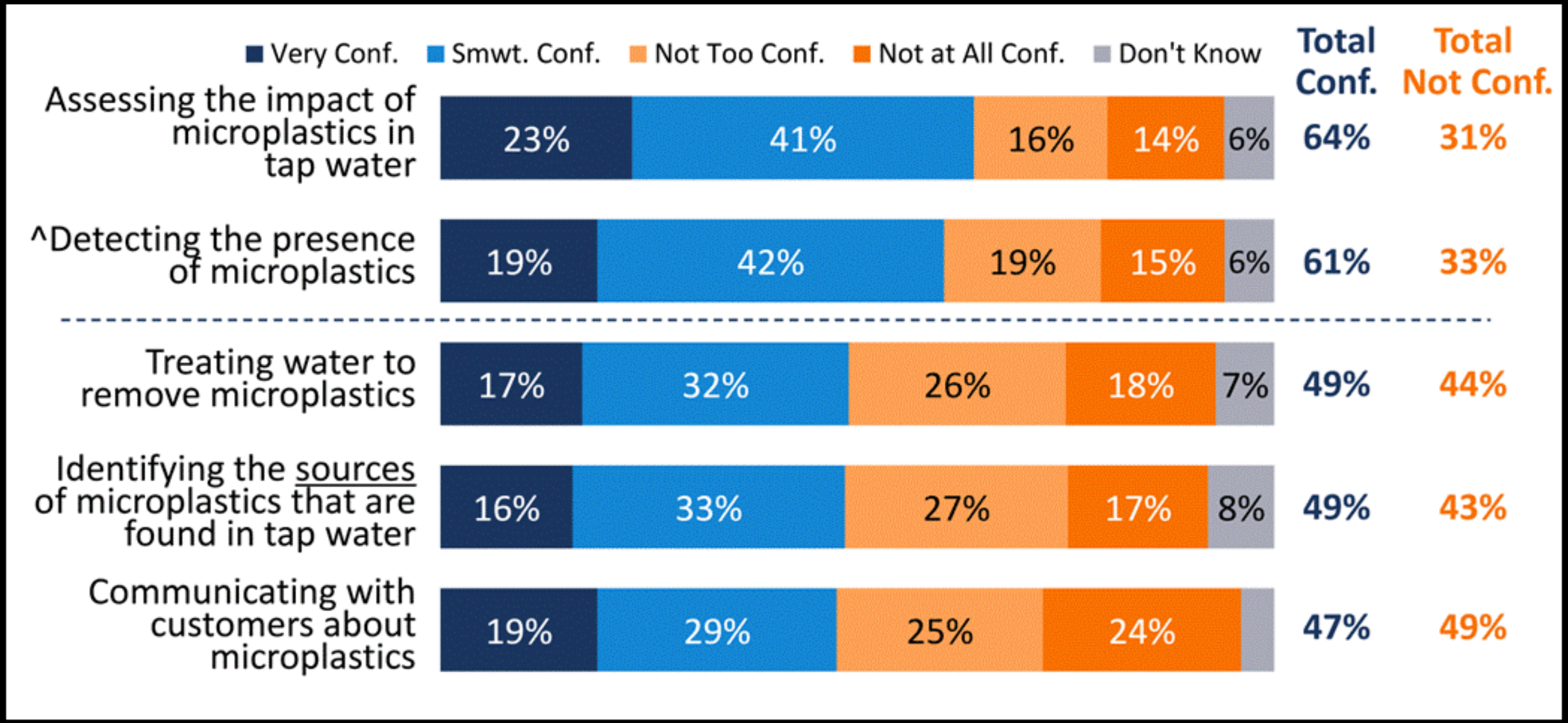
Public concern regarding these contaminants in drinking water



WRF 5155: Arcadis/Katz & Associates/ FM3 Research

UNPUBLISHED

Public Confidence in Water Utilities' Abilities to:



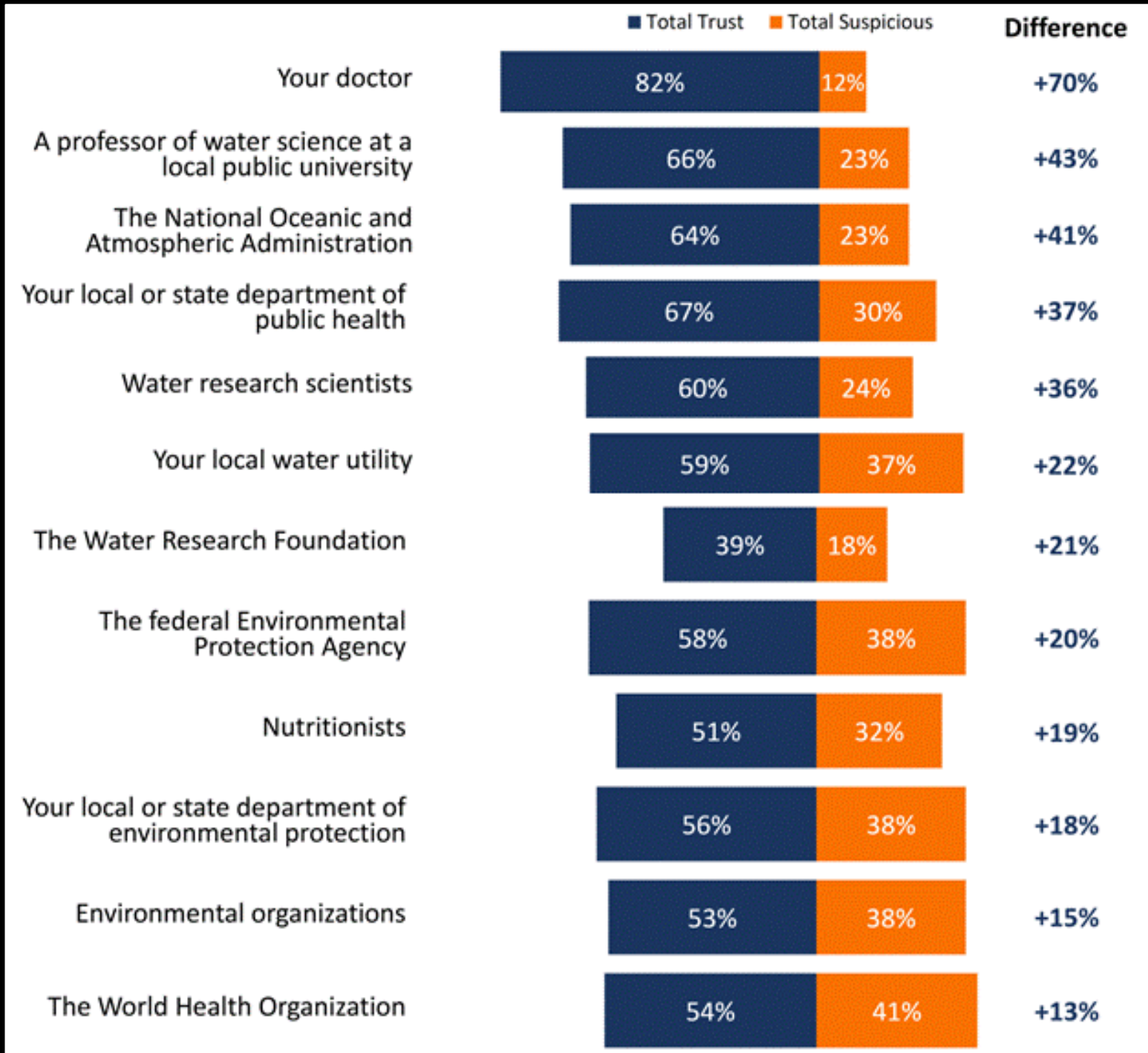
WRF 5155: Arcadis/Katz & Associates/ FM3 Research

UNPUBLISHED

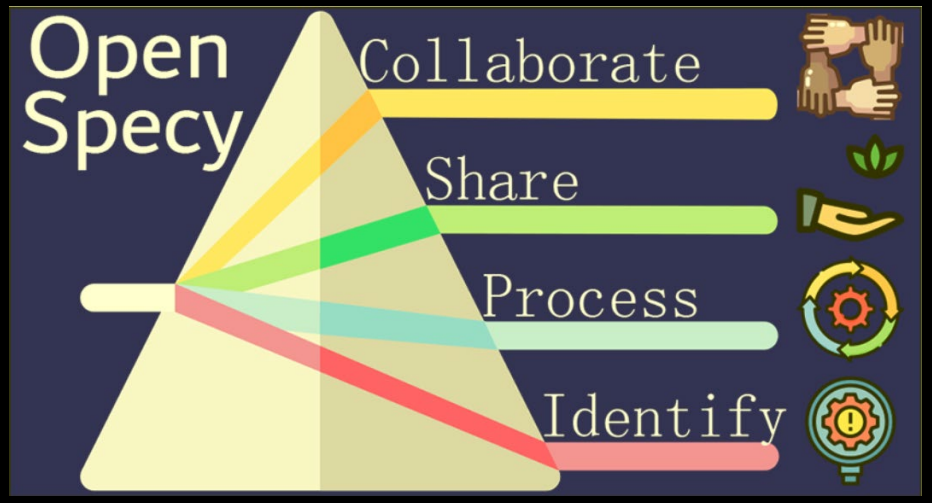
Public Trust vs. Suspicion of Science Messengers

UNPUBLISHED

WRF 5155:
Arcadis/Katz & Associates/ FM3 Research



The Microplastics Community is Built on **Sharing Freely**



#OpenLitterMap

OpenDrift

TACO

Plastic DB

simple

OceanParcels

TōMEx

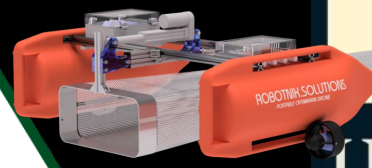
BEAT THE MICRO BEAD

EAS-E SUITE

PAN-AFRICAN MICRO(NANO) PLASTIC RESEARCH NETWORK

TIDES
Trash Information and Data for Education and Solutions

micro investigators



IKHAPP
International Knowledge Hub Against Plastic Pollution

OpenOceans Global
A Not-for-Profit Corporation

Open Science Attracts a Diverse Set of Researchers

The best way to include a diverse group of stakeholders is to ***remove existing barriers,*** *and* ***design for inclusion.***

Urbina-Blanco *et al.* (2020). *Nature Chemistry*

PLASTIVERSE

Plastiverse.org

@ThePlastiverse

Tools
Blog
Forum
Calendar
Community

TOOLS

A vast number of software, databases, methods, and other resources have been developed to enable plastic pollution research. This page is a curated and living index of tools that we believe to be relevant and useful to the field. If you are aware of something missing or incorrectly described, please let us know!

Type

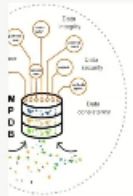
- Database (59)
- Tool (32)
- Device (21)
- Map (14)
- Report (9)
- Citizen Science (8)
- Protocol (8)
- Network (6)
- Webinar (6)
- Artificial Intelligence (4)
- Blog (3)

Under development
SO/CD 16094-2
Stage: 30.99

ISO/CD 16094-2

Water quality — Analysis of microplastic in water — Part 2: Vibrational spectroscopy methods for waters with low content of suspended solids including drinking water

Standardized analytical method for qualitative and quantitative identification of microplastics using



Marine Plastic Data Base

Marine Plastic Database

MPDB

Limited access relational database for microplastics with controlled vocabulary and schema.

Fact Sheets on Food Packaging Materials and Recycling

Fact sheets about applications, material properties, chemical safety, and end-of-life options for food packaging materials.

Removing barriers on plastic research

Logo created by J.C. Leapman.

- Welcome
- Overview
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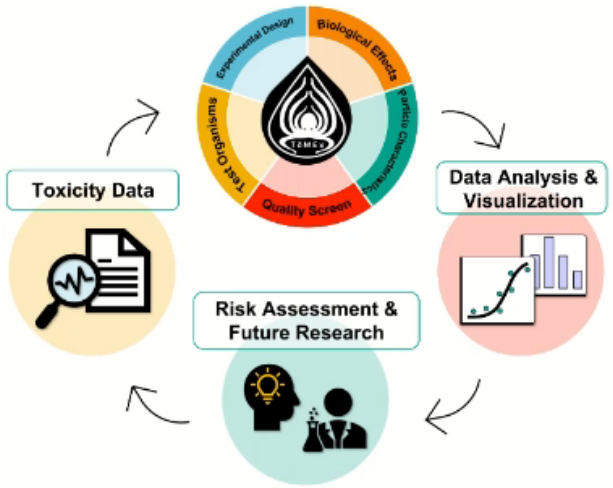
- SSD
- Study Screening
- Calculators
- Predictions
- Resources
- Contact
- Human Health
- Follow Us on Twitter!

Welcome to the Toxicity of Microplastics Explorer, Aquatic Organisms Database!



What is the Microplastics Toxicity Database?

This database is a repository for microplastics toxicity data for the California Microplastics Health Effects Workshop.

This web application allows users to explore toxicity data using an intuitive interface while retaining the diversity and complexity inherent to microplastics. Data is extracted from existing, peer-reviewed manuscripts containing toxicity data pertaining to microplastics.

Use the side panel on the left of the page to navigate to each section. Each section provides different information or data visualization options. More specific instructions may be found within each section.

Why was the Microplastics Toxicity Database and Web Application created?

The database and application tools have been created for use by the participants of the Microplastics Health Effects Workshop.The purpose of this workshop is to identify the most sensitive and biologically critical endpoints associated with microplastics exposure, prioritize which microplastics characteristics (e.g., size, shape, polymer) that are of greatest biological concern, and identify critical thresholds for each at which those biological effects become pronounced. Workshop participants will also make reccomendations for future research investments. Workshop findings will be published in a special issue of Microplastics and Nanoplastics . These findings will be used directly by the state of California to fulfill legislative mandates regarding the management of microplastics in drinking water and the aquatic environment.

Contributors

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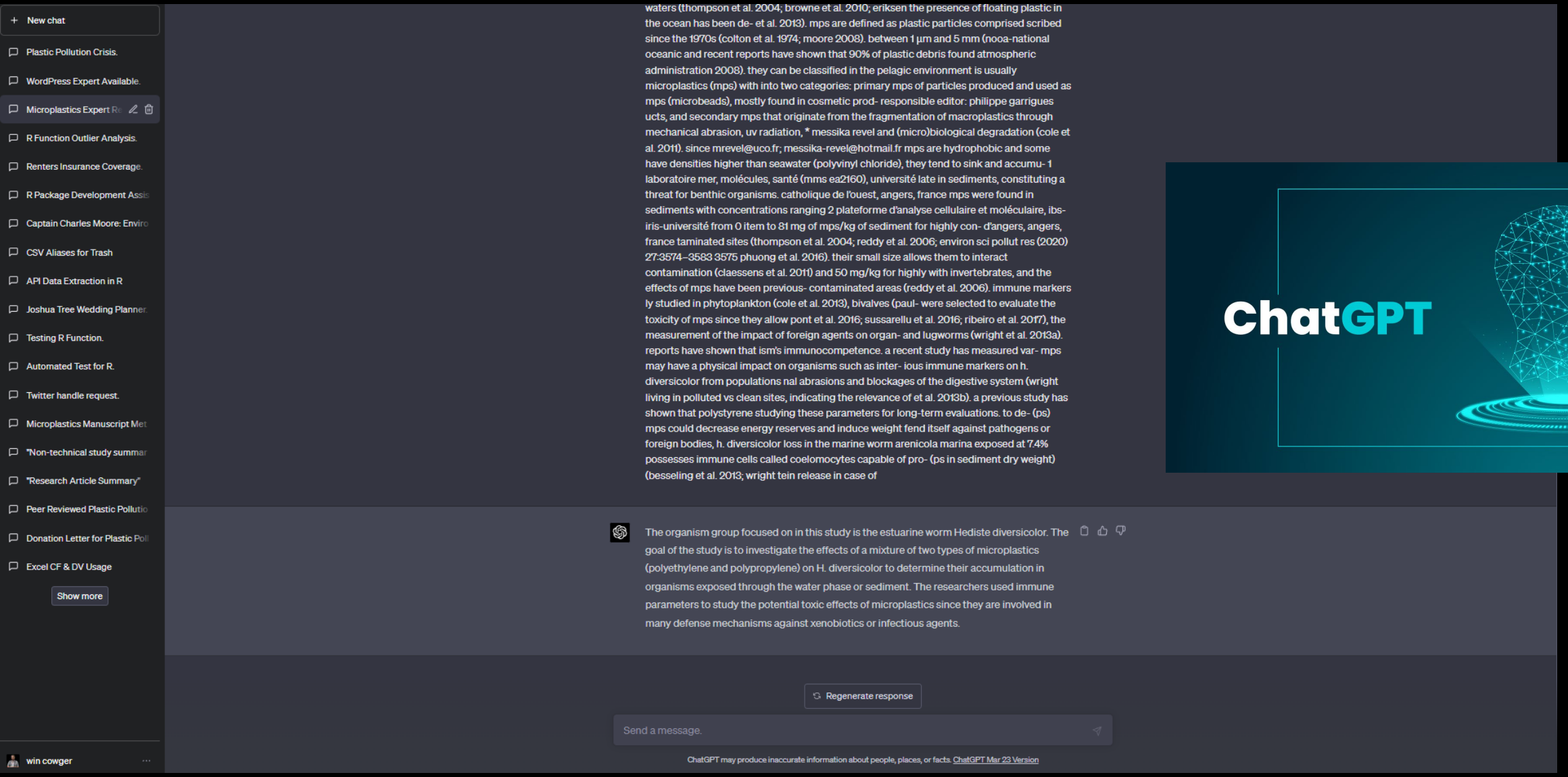
Emily Darin , Southern California Coastal Water Research Project

ToMEx 2.0 Coming Soon!

@ToMExApp

Thornton-Hampton et al. (2022), *Microplastics & Nanoplastics*

Leveraging AI to Accelerate Progress



Preliminary Findings: Mixed Results

UNPUBLISHED. DO NOT CITE

Photo: Mandy Barker

Thank you!

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Slides available here:
researchgate.net/profile/Scott-Coffin-2