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MICROPLASTICS AQUATIC LIFE CRITERIA REVIEW AND DEVELOPMENT FOR REGULATORY DECISION MAKING

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Introduction

- Microplastics (MPs) have been detected across environmental media
- We need to understand toxicity and risk to humans and animals/biota in the environment
- Screening levels and thresholds need to be developed
- Diversity in particle characteristics creates challenges in assessing toxicity and developing data to be used in threshold development

What are thresholds used for?

- Regulatory-based decision making
  - Risk assessment (human health, ecological)
  - Site cleanup
- Compliance
  - Stormwater permitting
  - Industrial water/wastewater permitting
- Stormwater management
- Waterbody impairment designation
- Natural resource damage assessments (NRDA)
- Property transactions/due diligence
- Product stewardship





Microplastic Toxicity Data – A Brief History

- Southern California Coastal Water Resource Project (SCCWRP) developed the Toxicity of Microplastics Explorer (ToMEx) – a living database for available MP toxicity data for aquatic organisms and human health (Hampton et al., 2022)
- Risk-based management framework with draft aquatic life thresholds (using data from ToMEx) was published in 2022 (Mehinto et al., 2022)
- ToMEx 2.0 update in 2023; crowd-sourced data mining and quality review, updated aquatic life thresholds (Hampton et al., 2025)
- International Joint Commission Great Lakes Science Advisory Board (SAB) published a monitoring and management framework in 2024

Microplastic Toxicity Data – A Brief History

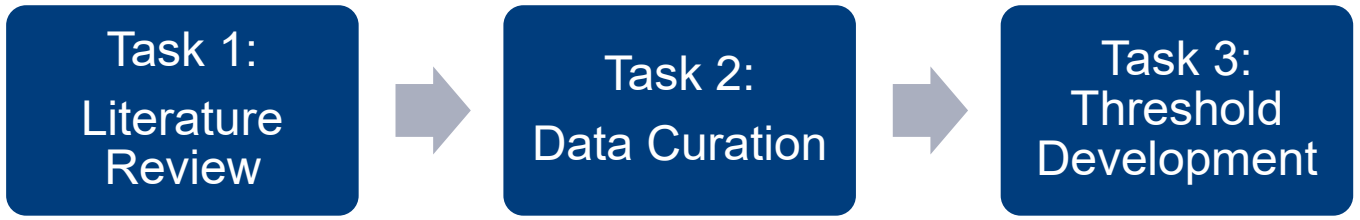
- Hampton et al. (2025)
  - Thresholds based on food dilution and tissue translocation for 4 monitoring levels
  - Fresh and marine waters
- SAB (2024)
  - Thresholds based on food dilution and tissue translocation
  - Fresh water and sediment, used species relevant to Great Lakes
- Realigning and rescaling used
  - Used to account for differences in MPs used in tox tests
  - Realigning to environmentally relevant mixtures and rescaling lab studies using single particles

Limitations:

- Some marine species included in freshwater thresholds
- All biological endpoints combined
- Effect concentrations of any statistical significance was included
- Effect concentrations based on nominal data included

Aquatic Life Thresholds

Objective: Evaluate the information available within ToMEx 2.0 with regards to the quality and abundance of data typically used for regulatory aquatic life criteria for toxic chemicals



Literature Review

Task 1: Literature Review → Task 2: Data Curation → Task 3: Threshold Development

Downloaded available data from ToMEx 2.0 and conducted literature search (March 2025)

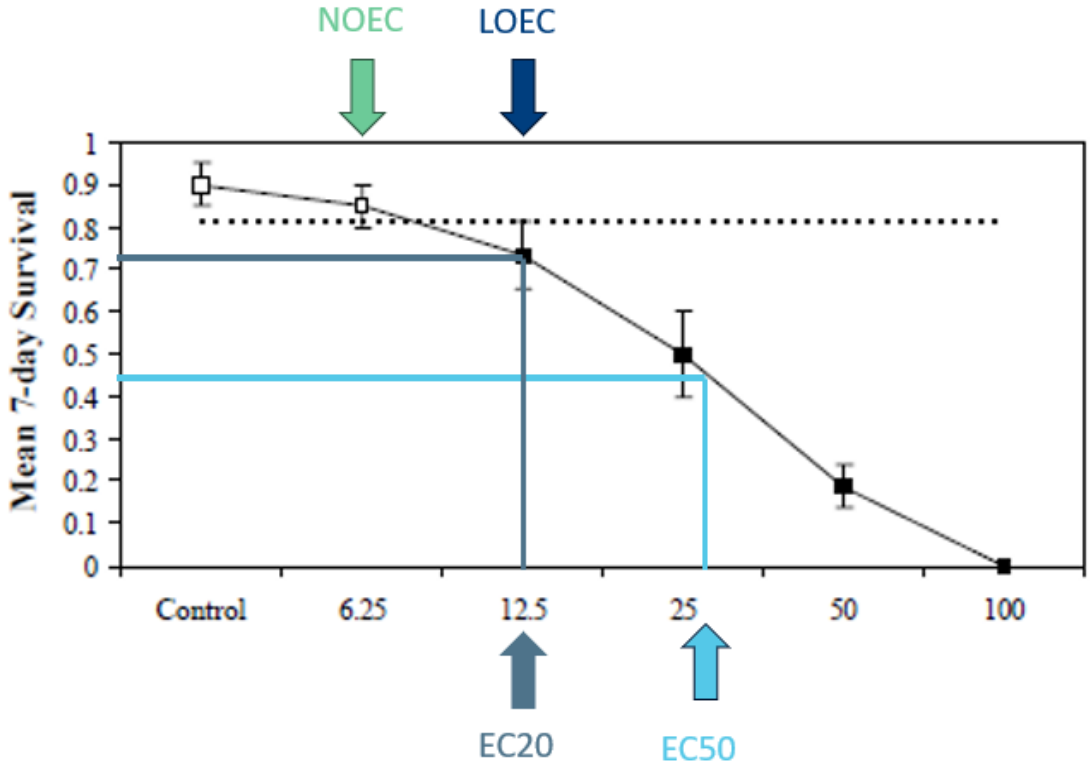
Filtered studies using following criteria:

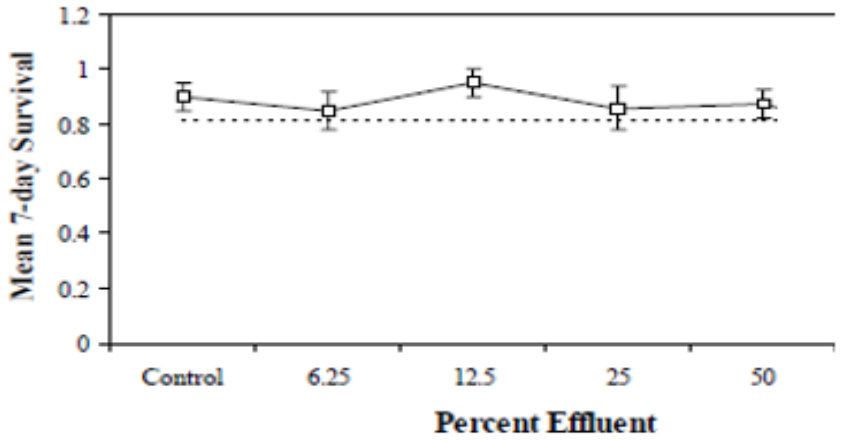
- Passed MP quality criteria (ToMEx 2.0 / De Ruitjer)
- At least 5 concentrations
- Chronic exposures
- Population level effects (growth/development, survival, reproduction)
- 34 studies from ToMEx, 2 additional studies

Conduct quality review on the papers:

- Cross checked the accuracy of data in the database
- Reviewed effects data and dose-response curves
- Evaluated the % reduction relative to control for statistically significant effects

Example Dose Response Curves – NOECs, LOECs, ECX





Unbounded NOEC

NOEC – no observed effect level
LOEC – lowest observed effect level
EC20 – effect concentration 20% from control
EC50 – effect concentration 50% from control

Study Quality Challenges

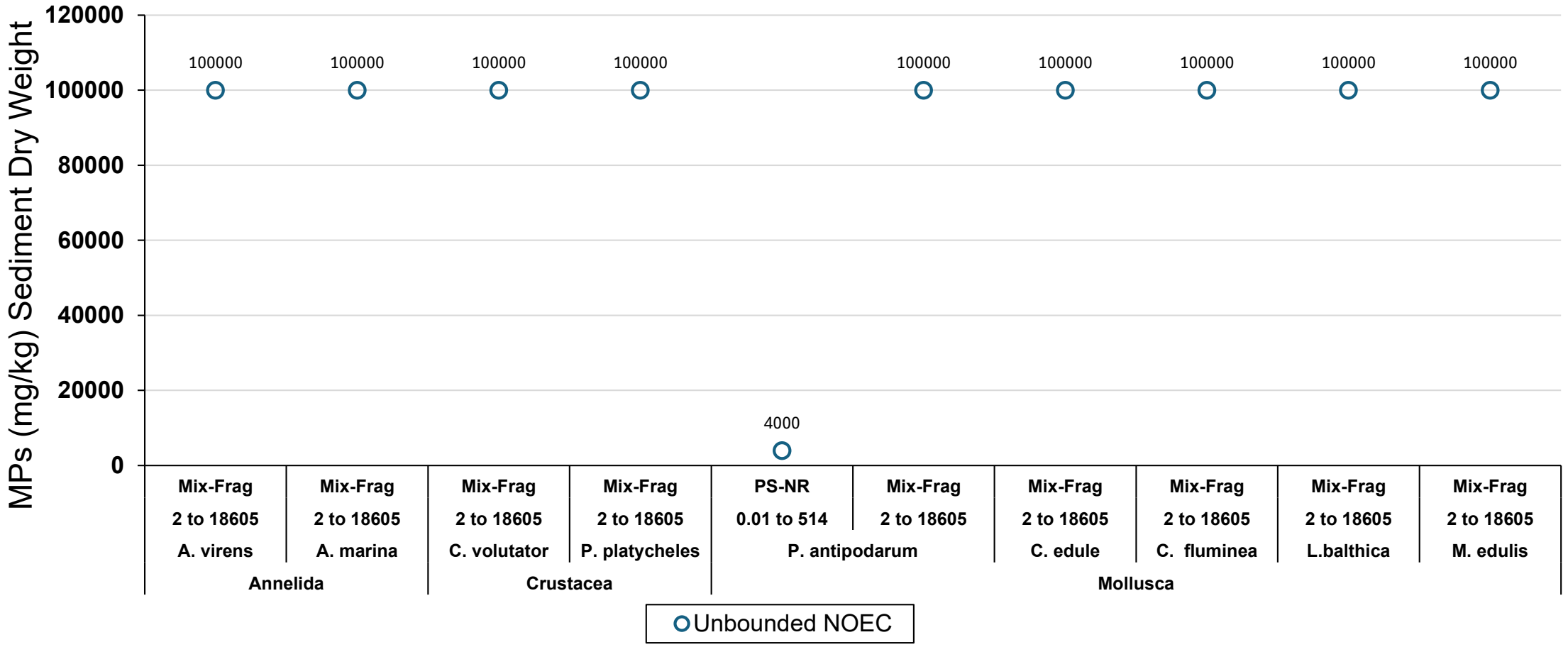
Task 1: Literature Review

- Only 2 of 36 studies (<6%) measured concentrations in the test chambers
  - Many studies were reported as measured when only the stock was measured
- Errors in ToMEx database
- Erroneous data interpretation (within studies)
  - Small effects (<8%) calculated and reported as EC50s
  - Effects extrapolated beyond the data range
- Potentially erroneous measured values
  - MP/L and mg/L unit conversions (most studies only included one or the other)
  - Study example where lowest observed effect concentration (LOEC) may be over estimated

Note: ToMEx provides effects as reported by the study authors

Available Effect Data in Marine Sediment

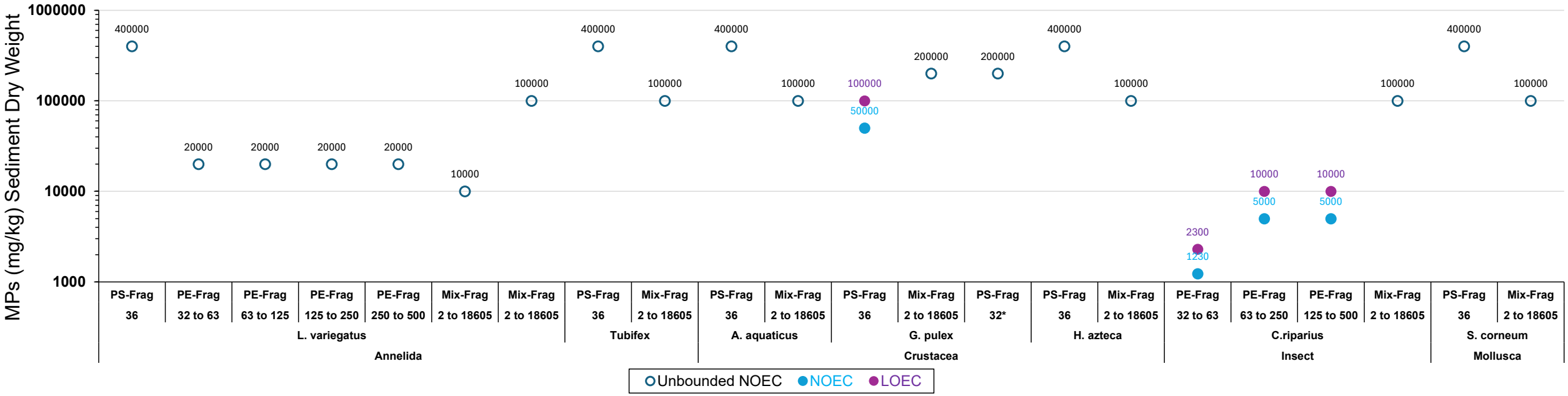
Task 1: Literature Review → Task 2: Data Curation → Task 3: Threshold Development



Safe NOEC values are > 4,000 – 100,000 MPs (mg/kg) sediment dry weight

Available Effect Data Freshwater Sediment

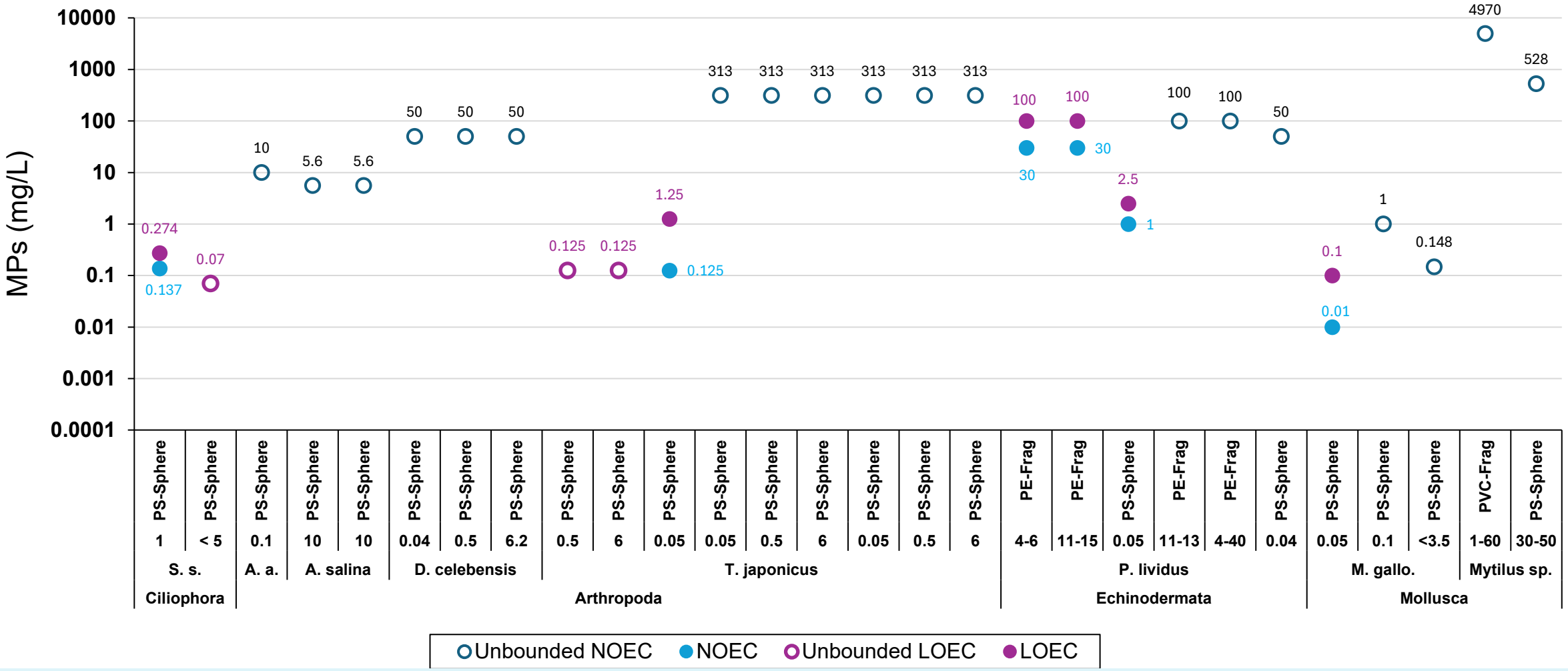
Task 2: Data Curation



Safe NOEC values are > 1,230 – 400,000 MPs (mg/kg) sediment dry weight

Available Effect Data Marine Water

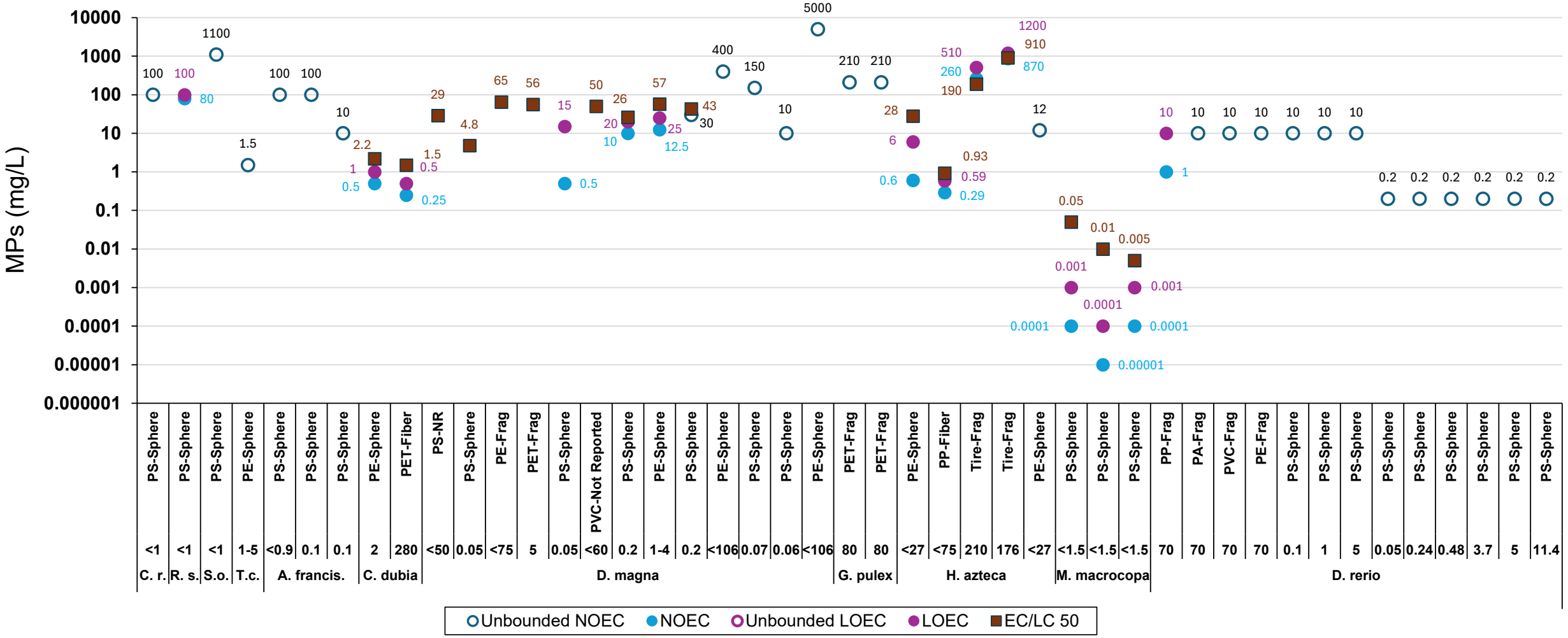
Task 2: Data Curation



Safe NOEC values are > 0.001 – 4,970 mg/L

Task 2: Available Effect Data Freshwater

Task 2: Data Curation



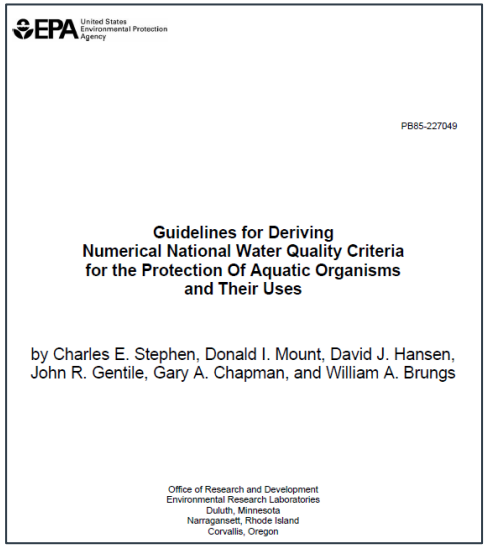
Safe NOEC values are > 0.00001 – 5,000 mg/L

Threshold Approaches

Task 1: Literature Review → Task 2: Data Curation → Task 3: Threshold Development

Geomean Approach

- Calculated an overall geomean of the genus mean value
- Genus mean value represents one effect concentration for each species
- All available MP types/shapes/sizes in all available organisms, based on NOECs, nominal data included


EPA United States Environmental Protection Agency

PB85-227049

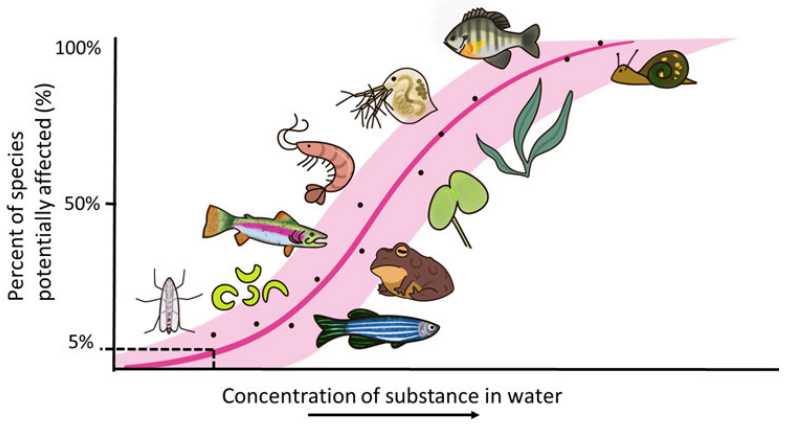
Guidelines for Deriving
Numerical National Water Quality Criteria
for the Protection Of Aquatic Organisms
and Their Uses

by Charles E. Stephen, Donald I. Mount, David J. Hansen, John R. Gentile, Gary A. Chapman, and William A. Brungs

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Species Sensitivity Distributions (SSD) Approach

- Followed USEPA guidelines
- Only included the most common microplastic shape/size and used LOECs, if possible; nominal data included
- For discussion purposes since there aren't enough species to meet the requirements



Freshwater and Marine Sediment

Task 3: Threshold Development

Water / Sediment	# of Species	Selected Threshold (mg/kg dw)	Selected Threshold (Particles / kg dw)	Species	Genus Mean Value (mg / kg dw)	Genus Mean Value (Particles / kg dw)	Type of Benchmark	Size of MPs (µm)	Type-Shape of Particles
Marine Sediment	9	100,000	5.9E+08	*Alitta virens*	100,000	5.9E+08	Unbounded NOEC	9 to 5386	Mix-Frag
				Arenicola marina	100,000	5.9E+08	Unbounded NOEC	9 to 5386	Mix-Frag
				Corophium volutator	100,000	5.9E+08	Unbounded NOEC	9 to 5386	Mix-Frag
				Porcellana platycheles	100,000	5.9E+08	Unbounded NOEC	9 to 5386	Mix-Frag
				Potamopyrgus antipodarum	100,000	5.9E+08	Max Unbounded NOECs	9 to 5386	Mix-Frag
				Cerastoderma edule	100,000	5.9E+08	Unbounded NOEC	9 to 5386	Mix-Frag
				Corbicula fluminea	100,000	5.9E+08	Unbounded NOEC	9 to 5386	Mix-Frag
				Limecola balthica	100,000	5.9E+08	Unbounded NOEC	9 to 5386	Mix-Frag
				Mytilus edulis	100,000	5.9E+08	Unbounded NOEC	9 to 5386	Mix-Frag
Freshwater Sediment	7	280,000	3.7E+10	*Lumbriculus variegatus*	400,000	9.6E+10	Max unbounded NOECs	36	PS-Frag
				Tubifex	400,000	9.6E+10	Max unbounded NOECs	36	PS-Frag
				Asellus aquaticus	400,000	9.6E+10	Max unbounded NOECs	36	PS-Frag
				Gammarus pulex	126,000	2.0E+10	Geomean of NOECs	9 to 5386, 32, 36	PS/Mix-Frag
				Hyalella azteca	400,000	9.6E+10	Max unbounded NOECs	36	PS-Frag
				Chironomus riparius	100,000	5.9E+08	Max unbounded NOECs	9 to 5386	Mix-Frag
				Sphaerium corneum	400,000	9.6E+10	Max unbounded NOECs	36	PS-Frag

Acronyms
Frag: fragment
Max: maximum
Mix: mixture
mg/kg dw: milligrams per kilogram dry weight
NOEC: no observed effect concentration
Particles/kg dw: particles per kilogram dry weight
PS: polystyrene
µm: micrometer

Freshwater and Marine

Task 3: Threshold Development

Type	# of Species	Selected Threshold (mg/L)	Selected Threshold (Particles/L)	Species	Selected Benchmark (mg/L)	Selected Benchmark (Particles/L)	Type of Benchmarks	Size Range (µm)	Type-Shape
Marine	7	9.4	5.9E+09	***Strombidium sulcatum***	**0.137**	**2.0E+08**	**NOEC**	**1**	**PS-Sphere**
				Amphibalanus amphitrite	10	3.5E+09	Unbounded NOEC	0.1	PS-Sphere
				Artemia salina	5.6	1.0E+07	Unbounded NOEC	10	PS-Sphere
				Tigriopus japonicus	0.125	1.5E+09	Geomean 3 chronic tests, 1 NOEC, 2 unbounded LOECs	0.05 to 6	PS-Sphere
				Paracentrotus lividus	28	2.3E+10	Geomean of NOEC and unbounded NOECs	0.04 to 40	PS-Sphere, PE-Frag
				Diaphanosoma celebensis	50	7.3E+14	Max of unbounded NOECs	0.04	PS-Sphere
				Mytilus species	4,970	1.5E+09	Max of unbounded NOECs	1 to 60	PVC-Frag
Freshwater	11 (10 excluding moina)	8.2 (27)	4.2E+10 (1.5E+11)	*Chlamydomonas reinhardtii*	100	9.5E+14	Unbounded NOEC	0.06	PS-Sphere
				Raphidocelis subcapitata	80	1.4E+14	NOEC	0.08 to 0.12	PS-Sphere
				Scenedesmus obliquus	1,100	5.7E+15	Unbounded NOEC	0.07	PS-Sphere
				Tetraselmis chuii	1.5	1.9E+08	Unbounded NOEC	1 to 5	PE-Sphere
				Artemia franciscana	100	2.8E+15	Unbounded NOEC	0.4	PS-Sphere
				Ceriodaphnia dubia	0.35	1.6E+05	Geomean of NOECs	2 to 280	PE-Sphere, PET-Fiber
				Daphnia magna	150	7.8E+14	Unbounded NOEC	0.07	PS-Sphere
				Gammarus pulex	**207**	**4.0E+06**	**Max of unbounded NOECs**	**80**	**PET-Frag**
				Hyalella azteca	12	2.0E+07	Unbounded NOEC	10 to 27	PE-Sphere
				Danio rerio	1.4	1.8E+09	Geomean of unbounded NOECs and one NOEC	0.05 to 70	PS-Sphere, PP-Frag, PA-Frag, PVC-Frag, PE-Frag
				Moina macrocopa	0.00005	8.3E+04	Geomean of NOECs	1 to 1.2	PS-Sphere

Notes

Bolded entries represent thresholds from studies that measured the concentration of microplastics in the exposure water.

Acronyms

Frag: fragment
LOEC: lowest observed effect concentration
Max: maximum
mg/L: milligrams per liter
NOEC: no observed effect concentration
PA: polyamide
Particles/L: particles per liter
PE: polyethylene
PET: polyethylene terephthalate
PP: polypropylene
PS: polystyrene
PVC: polyvinyl chloride
µm: micrometer

Summary

- ToMEx is a helpful database of studies on the effects of MPs to aquatic life
- There is a wide variety of quality in the underlying data, and much of it is not sufficient for regulatory criteria development – ToMEX should not be used for environmental decision-making without rigorous evaluation to ensure it is fit for use
- We conducted a subsequent analysis using the most robust available data
    - Data from different particle characteristics were used to develop thresholds for freshwater, marine water, freshwater sediment, marine sediment
    - Data realignment and rescaling was not applied to these thresholds
    - These no-effect thresholds can be used as an interim screening level for regulatory decision-making as we work to derive more information

Recommendations for Toxicity Testing Design

Best practices for researchers designing and conducting ecotoxicity tests, recommending:

- Population-level endpoints
- Number of doses
- Spacing of doses
- Measuring MPs in test matrix, do not just rely on measuring stock
- Controls – negative and positive

Consider referring to criteria guidance documents



A Few Additional Thoughts…

Thresholds are used in many different real-world applications – when developing thresholds, consider the end goal and what decisions need to be made

Need for more robust environmental data for data realignment and rescaling

Communication and clarity important as we move forward with screening level/threshold development –understand how to develop, use, apply current methodology

Continue increased collaboration of scientists from different sectors and different backgrounds

Geosyntec consultants

Thank you!



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