Analysis, prevalence and impact of microplastics in freshwater and estuarine environments: an evidence review.

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Deltares
Enabling Delta Life

Systematic review procedure to address three questions

- *Are the current sampling and analytical methods scientifically robust and appropriate?*
- *What are the sources of the microplastics found in freshwater environments?*
- *What is/are the impact(s) of microplastics on freshwater and estuarine biota?*

[Microplastics = all plastic particles sizes ≤ 5 mm including nano-sized (≤ 0.1 µm) plastic particles?]

Systematic review procedure

Objective way of searching for, reviewing and summarising evidence to help answer specific questions

Pre-defined protocol
Set of clearly defined questions
Set of pre-defined search terms
Consistent approach for evaluating the relevance of evidence to the questions
Consistent approach for evaluating the robustness of evidence

Capturing the evidence base

PICO elements
Population
Intervention
Comparator
Outcome

An initial wide search to establish the population of evidence in published and grey literature

Population			
plastic*	freshwater*	wetland	potable
micro*	river*	marsh	reservoir
microplastic	stream*	swamp	aquifer
nanoplastic	brook	wastewater*	groundwater
*plastic	lake*	drinking water	sewage
	pool	aquatic	outfall
	pond	ecosystem*	estuar*
			transitional

with Boolean Operators

BioOne
COPAC
DART-Europe E-theses Portal
EBSCO Open dissertations
EThOS: Electronic Theses Online Service
European Commission Research Publications
European Sources Online
GoogleScholar
MedLine
Jstor
SciFinder
Open Access Theses and Dissertations
OpenGrey
PubMed
PLoS
Scopus
SciFinder
Web of Science
holdings of relevant environmental regulators

>3000 unique sources
(after removal of duplicates)

Stages of evidence gathering

Identification

Screening

Eligibility

Identification

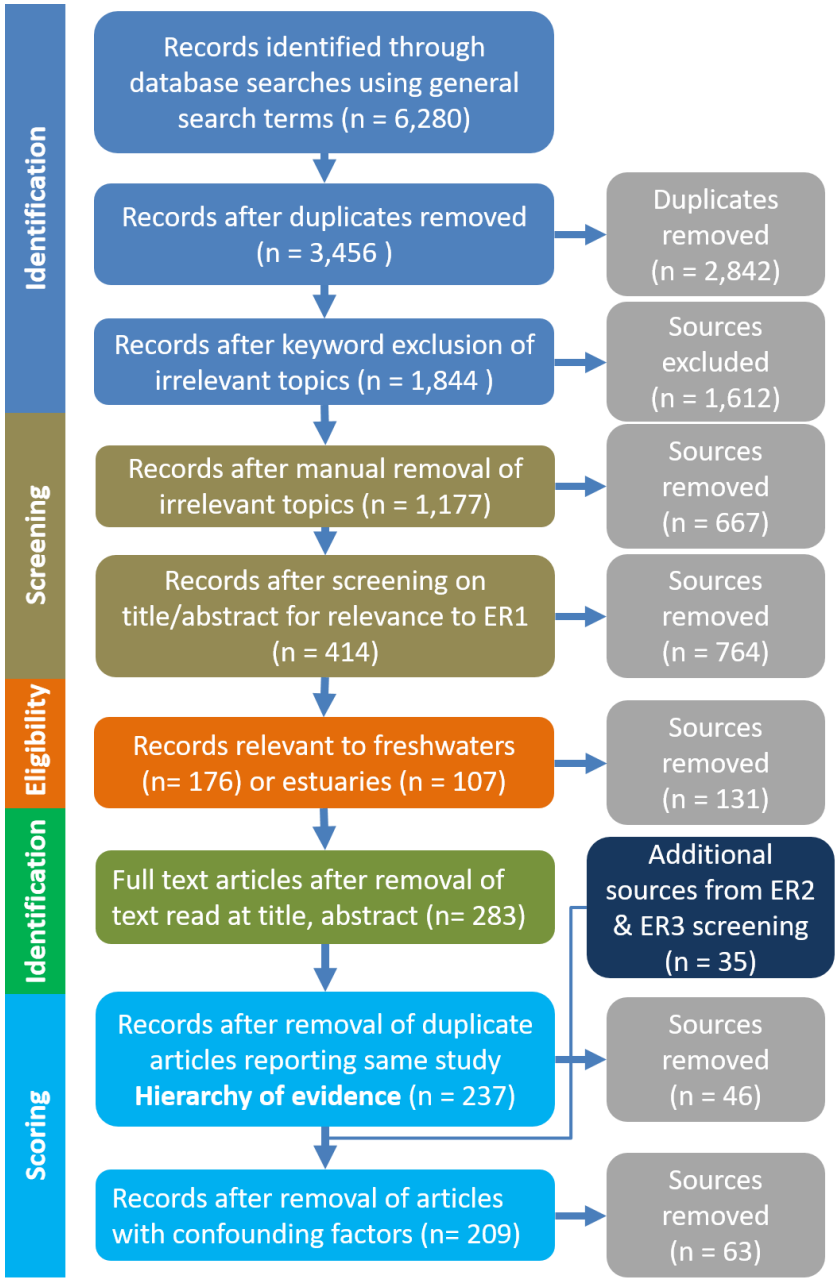
Scoring

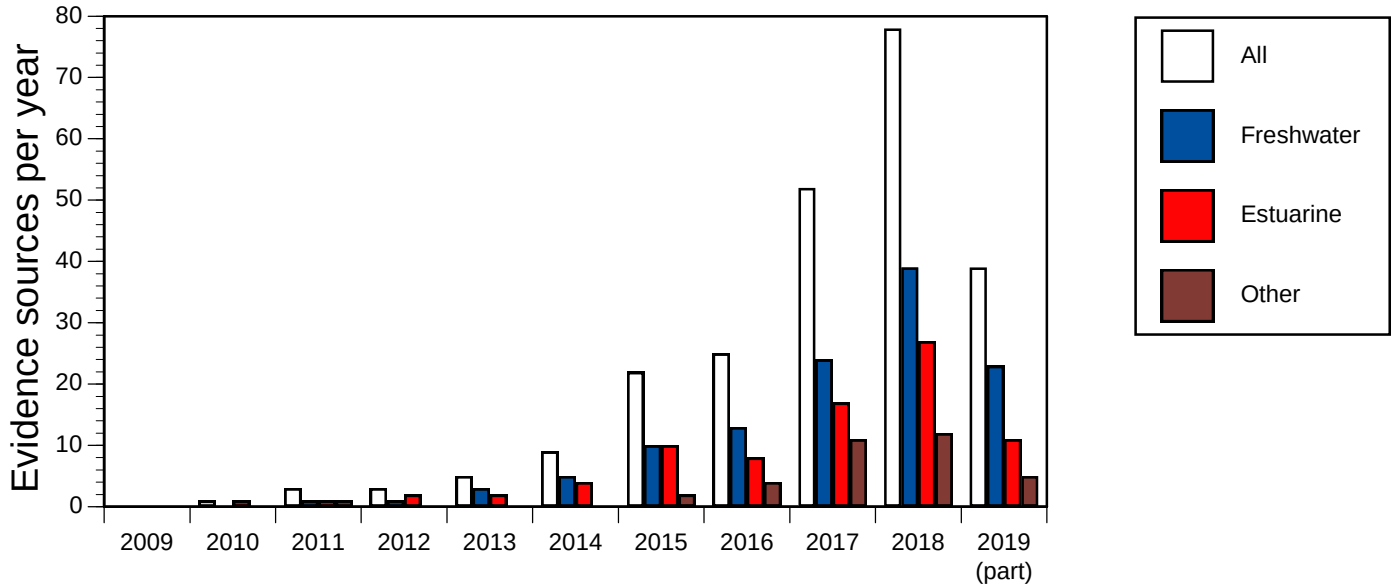
Are the current sampling and analytical methods scientifically robust and appropriate?

A second set of pre-defined search terms relevant to the question

Population	**Intervention**	**Comparator**	**Outcome**
aggregate*	spectroscop*		count
colloid*	raman		quantif*
floc*	particle analysis		abundance
plankton*	pyrolysis		concentrat*
sediment*	sampl*		density
diet*	separat*		substance
content	identif*		state
*fibre	flotat*		morphology
*fiber	floatat*		dimension
*bead	microscop*		composition
fragment*	digest*		
pellet*	centrifug*		
flake*	buoyan*		
nurdle			
dust			

Map of evidence identified as relevant

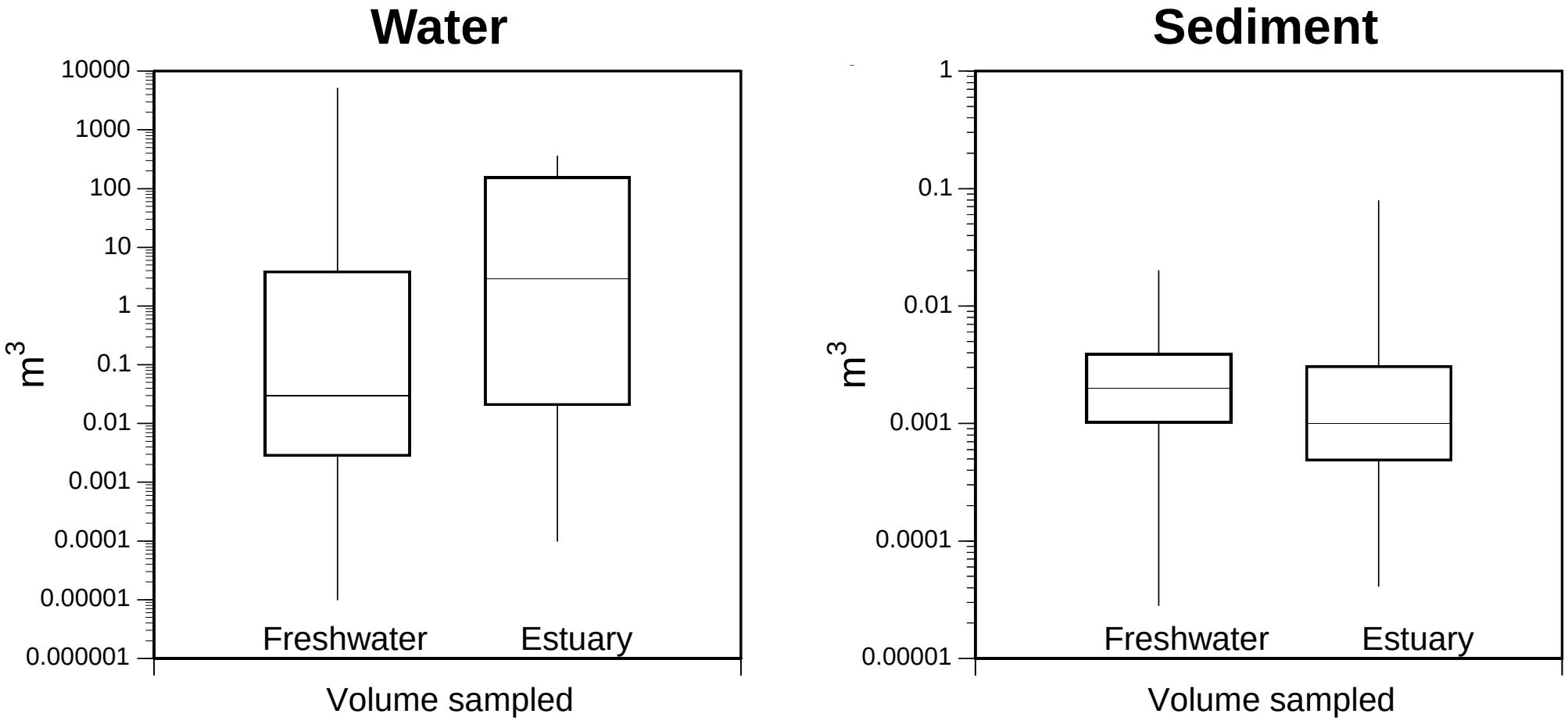




[Cut-off date April 2019]

Volume sampled

[Note Log Scale]



Relationships among particle size, volume of water sampled and reported concentration

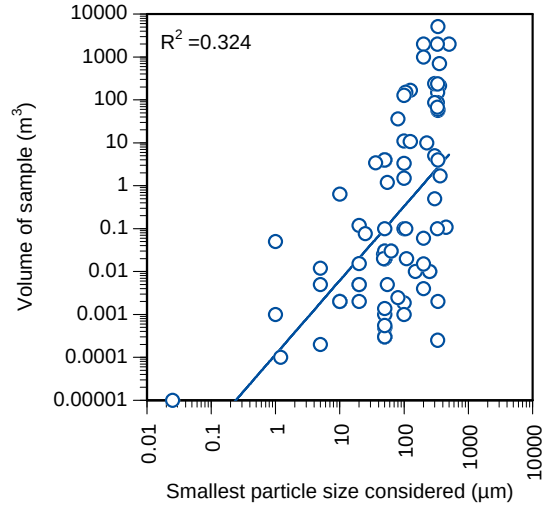
Points represent mean per study / technique / habitat

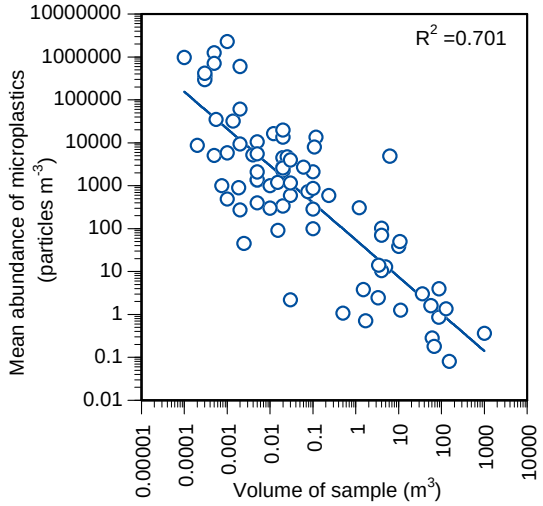
Particle Size – Sample Vol

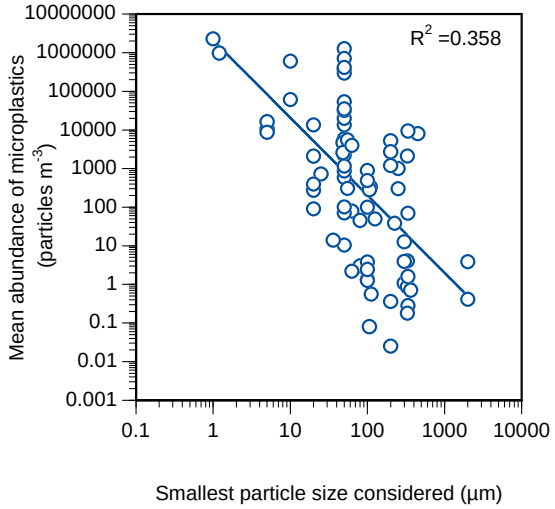
Sample Vol – Conc

Particle Size – Conc

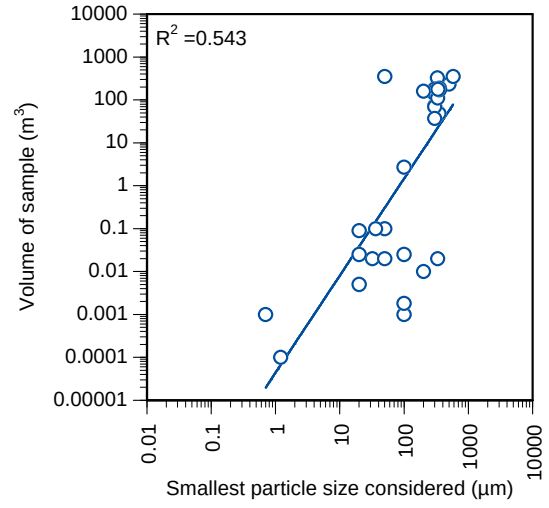
Freshwater

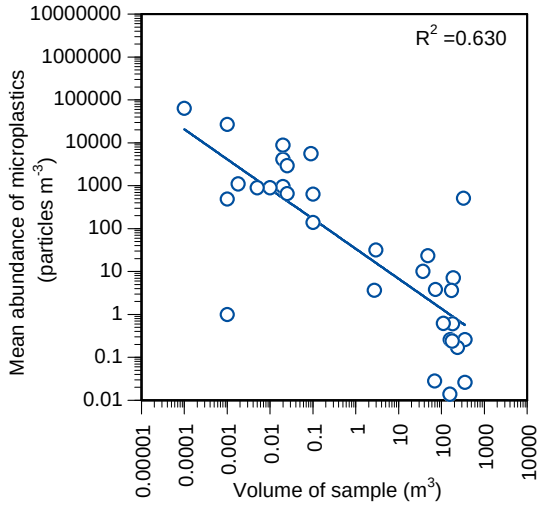


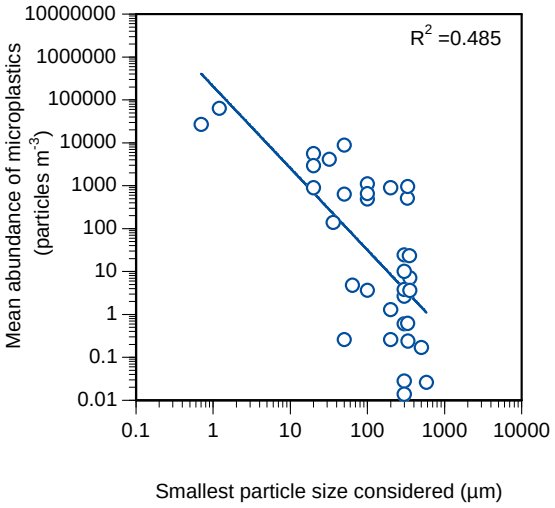




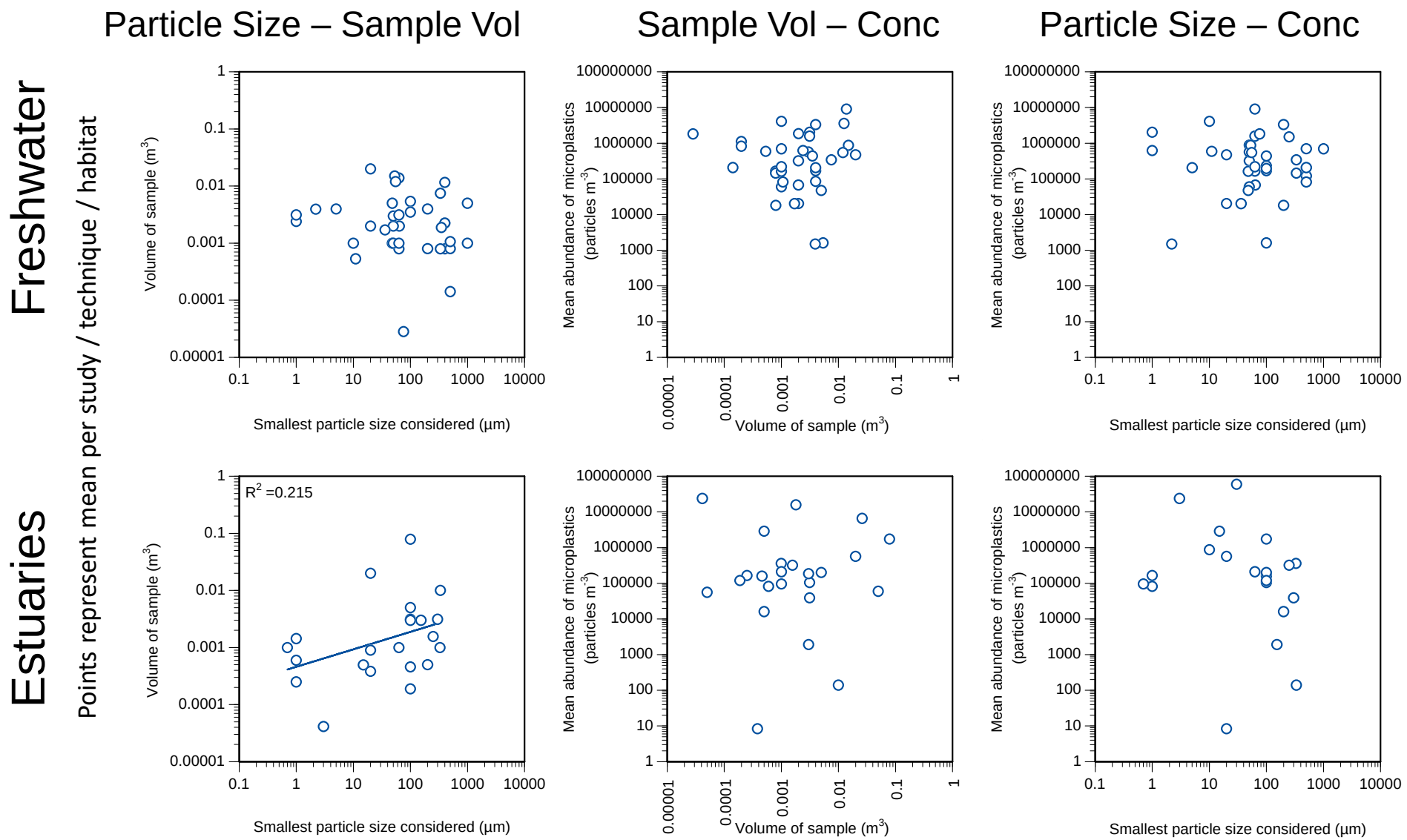
Estuaries







Relationships among particle size, volume of sediment sampled and reported concentration



The size range of particles captured by the sampling and processing method used influences the mean abundance of microplastic particles reported.

Comparison among studies is not possible without consideration of the size of particles considered.

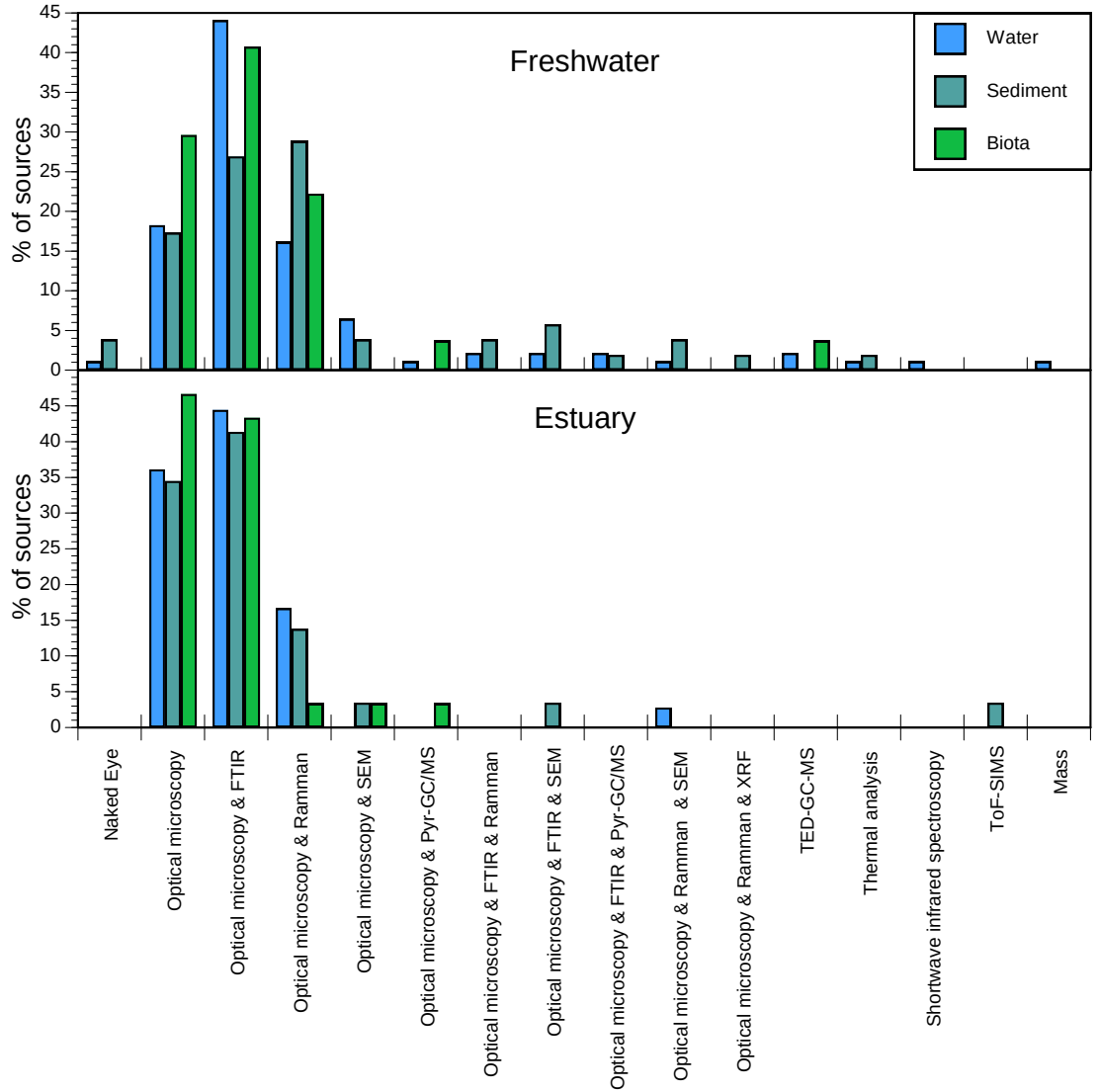
A range of sample volumes may be necessary to quantify the abundance of different sized particles adequately.

More research into appropriate sample volumes for sediment is required.

Techniques used to quantify and characterise microplastic particles

A range of techniques have been used to quantify and characterise particles:

Spectroscopic
(e.g. FTIR, Raman, near infrared)
Thermoanalytical
(e.g. Py-GC-MS, TED-GC-MS)
Chemical
(e.g. ICP-MS)
Each return information on different characteristics of the microplastics present in the sample



Due to the variety of techniques that have been used to quantify and characterise microplastics, as well as variation in the volume sampled and size of particles considered, it is not possible to assess differences in the microplastic profile among studies using the data currently available.

Reliability of Studies

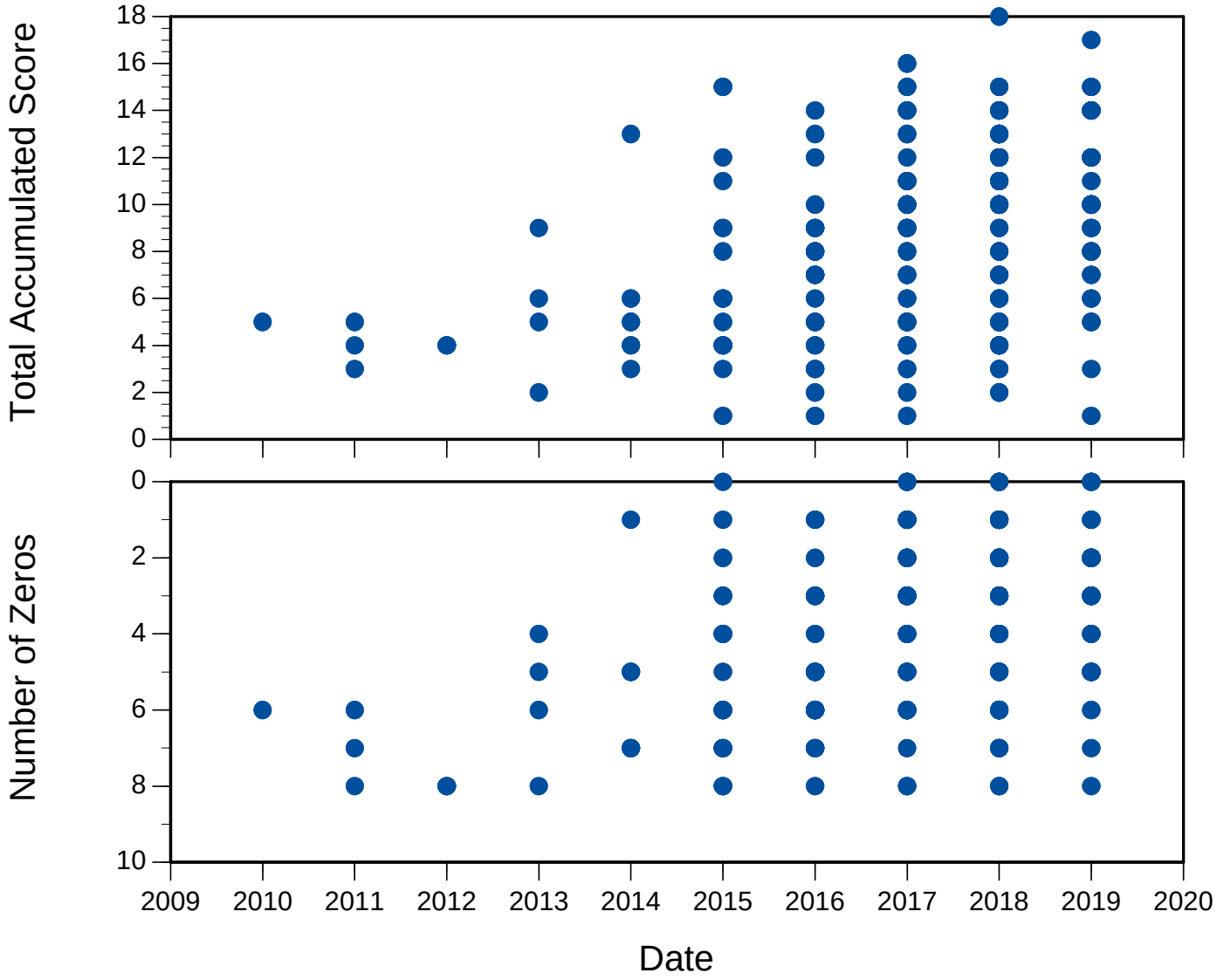
Scored 0 – 2 per criterion following Hermsen et al. (2018) and Koelmans et al. (2019)

1. Sampling methods
2. Sample size
3. Sample processing and storage
4. Laboratory preparation
5. Clean air conditions
6. Negative control
7. Positive controls
8. Target component (for Biota only)
9. Sample treatment
10. Polymer identification

Change in Reliability Scores over time

Two measures of reliability:

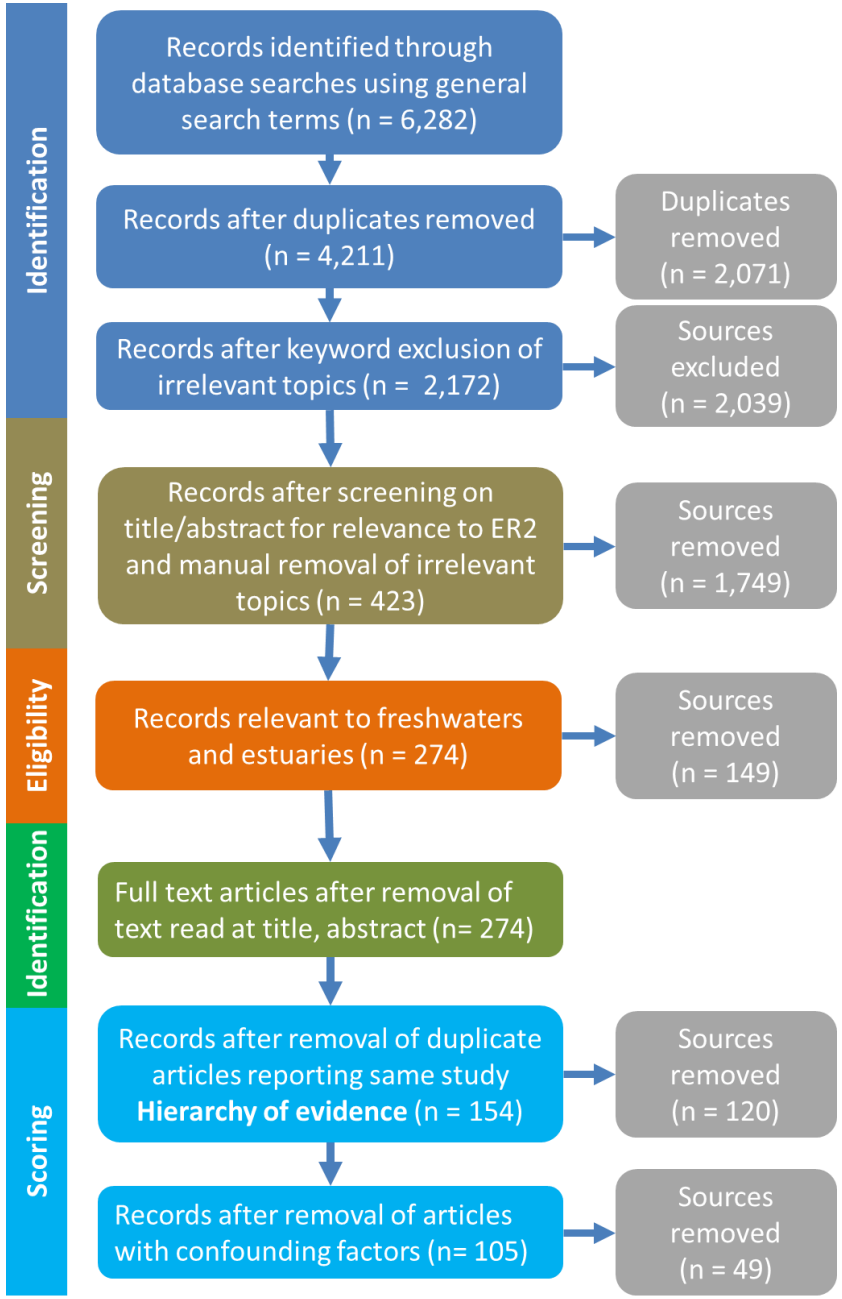
Total Accumulated Score (0 – 18)
Number of Zeros (9 – 0)

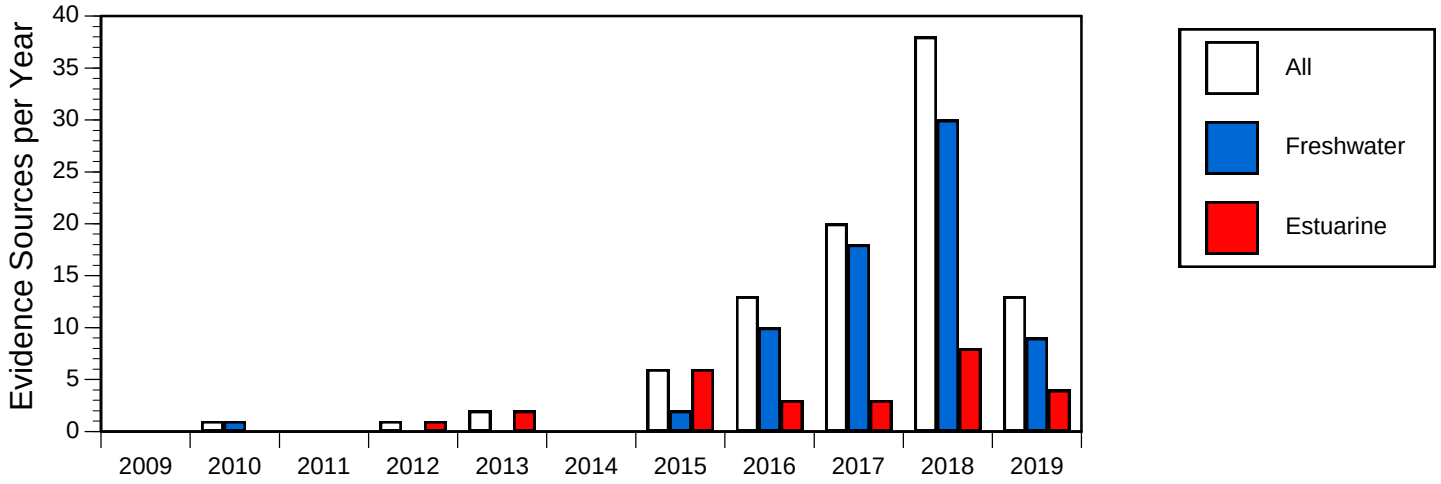


Reliability of studies of microplastics in freshwaters and estuaries has increased over time

What is/are the impact(s) of microplastics on freshwater and estuarine biota?

Map of evidence identified as relevant





[Cut-off date April 2019]

Reliability of Experimental Studies

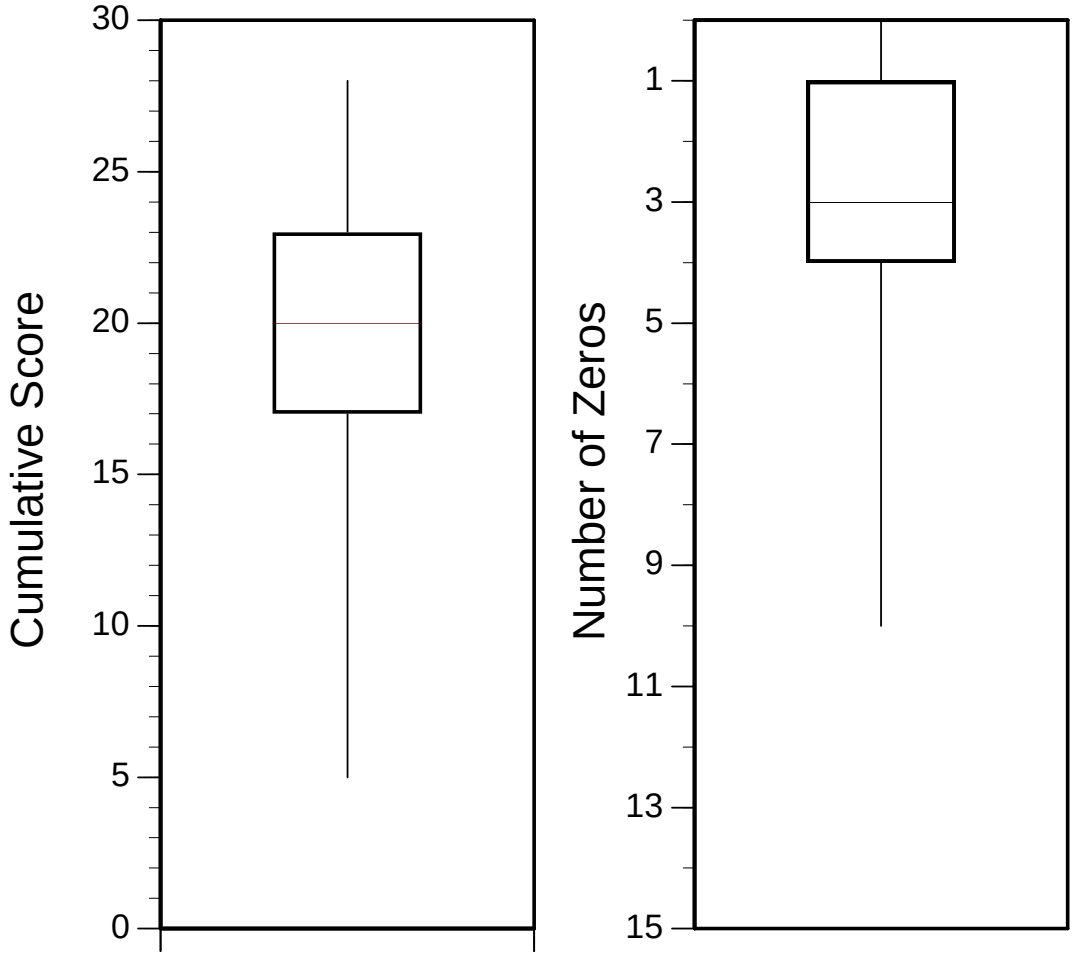
Scored 0 – 2 per criterion following CRED (Criteria for reporting and evaluating ecotoxicity data) method of Moermond et al. (2016)

1. Validity criteria
2. Adequate controls
3. Identity of test substance
4. Source of test substance
5. Identity of test organisms
6. Source of test organisms
7. Appropriate for test substance
8. Appropriate for test organism
9. Gradient of exposure
10. Exposure duration
11. Verification of exposure
12. Biomass loading
13. Adequate replication
14. Appropriate statistical methods
15. Raw data available

Reliability of Experimental Studies

Total Cumulative Score (0 – 30) and
Number of Zero scored categories (15 – 0)

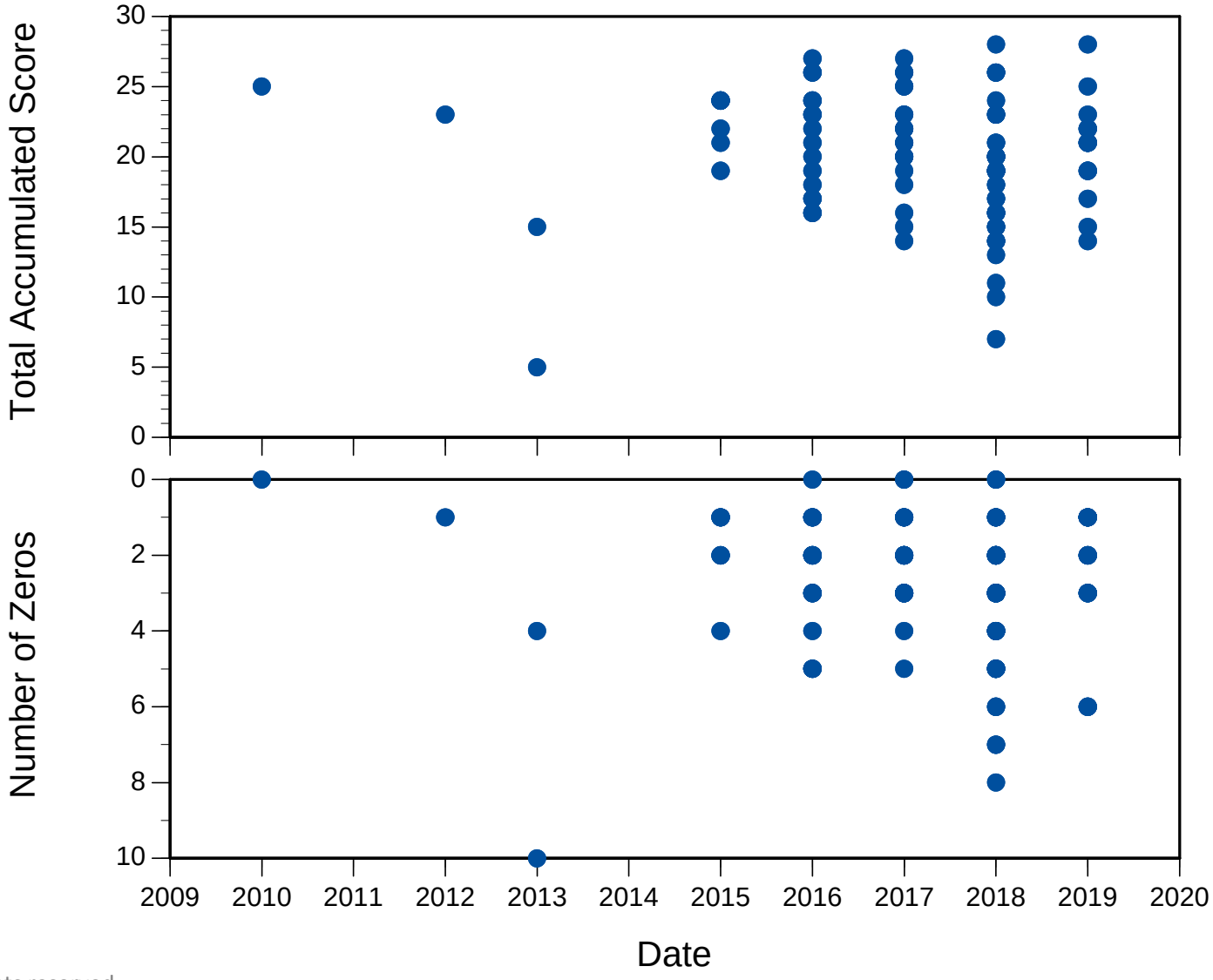
Box indicates 25th and 75th percentiles, whiskers minimum and maximum, and line median size of particles (n = 103)



Change in Reliability Scores over time

Two measures of reliability:

Total Accumulated Score (0 – 30)
Number of Zeros (10 – 0)



The majority of studies of the impact of microplastics on freshwater and estuarine biota were unreliable in several aspects.

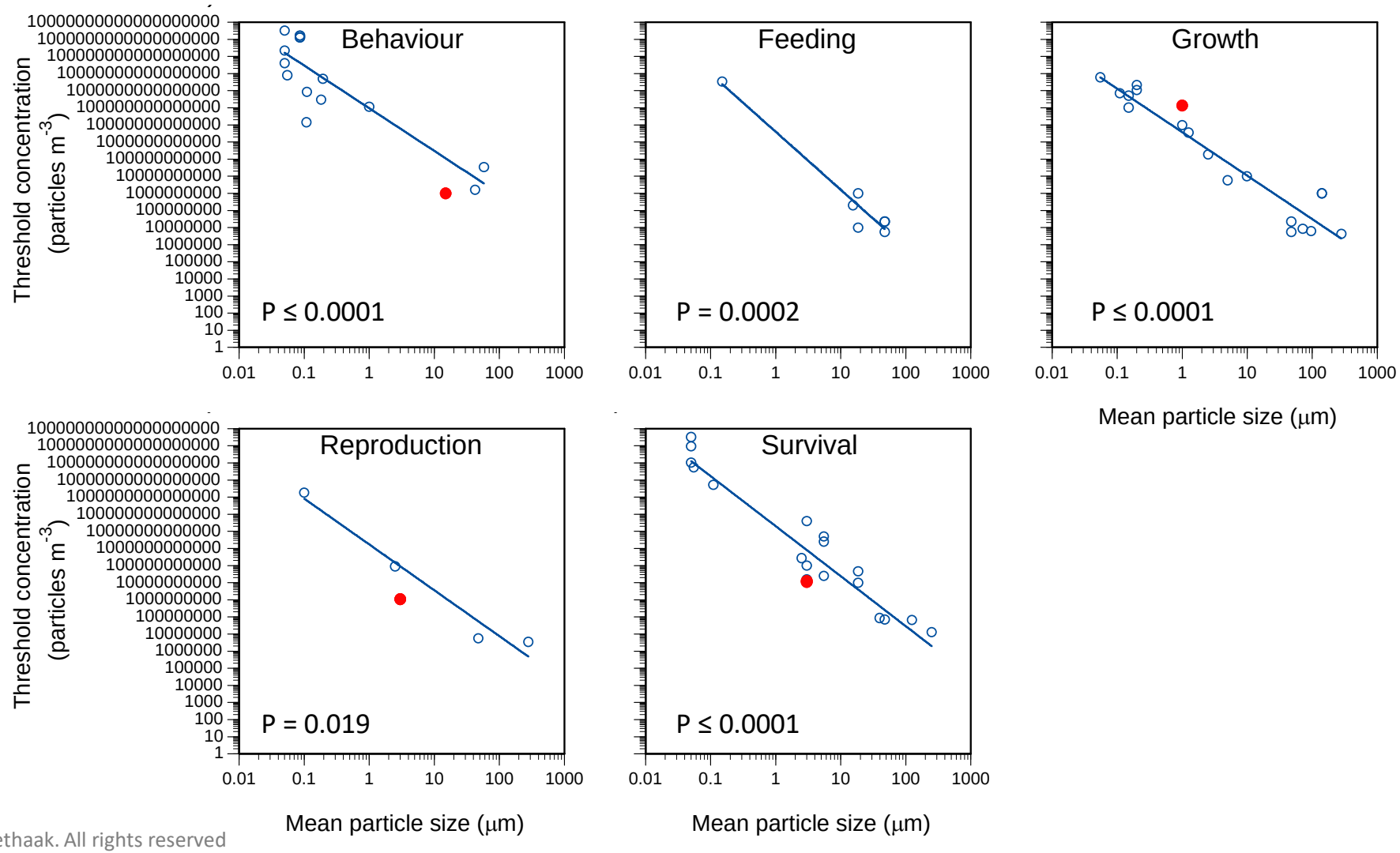
Published studies have become less reliable over time.

Relationships between particle size and reported ecotoxicological threshold concentrations

Ecotoxicological endpoints behaviour, feeding, growth, reproduction, survival

Lines fitted by least squares regression

Less reliable studies (<median score) shown (red symbols) but excluded



Under experimental conditions, high concentrations microplastics can have a negative impact on the feeding, behaviour, growth, reproduction and survival of freshwater and estuarine biota.

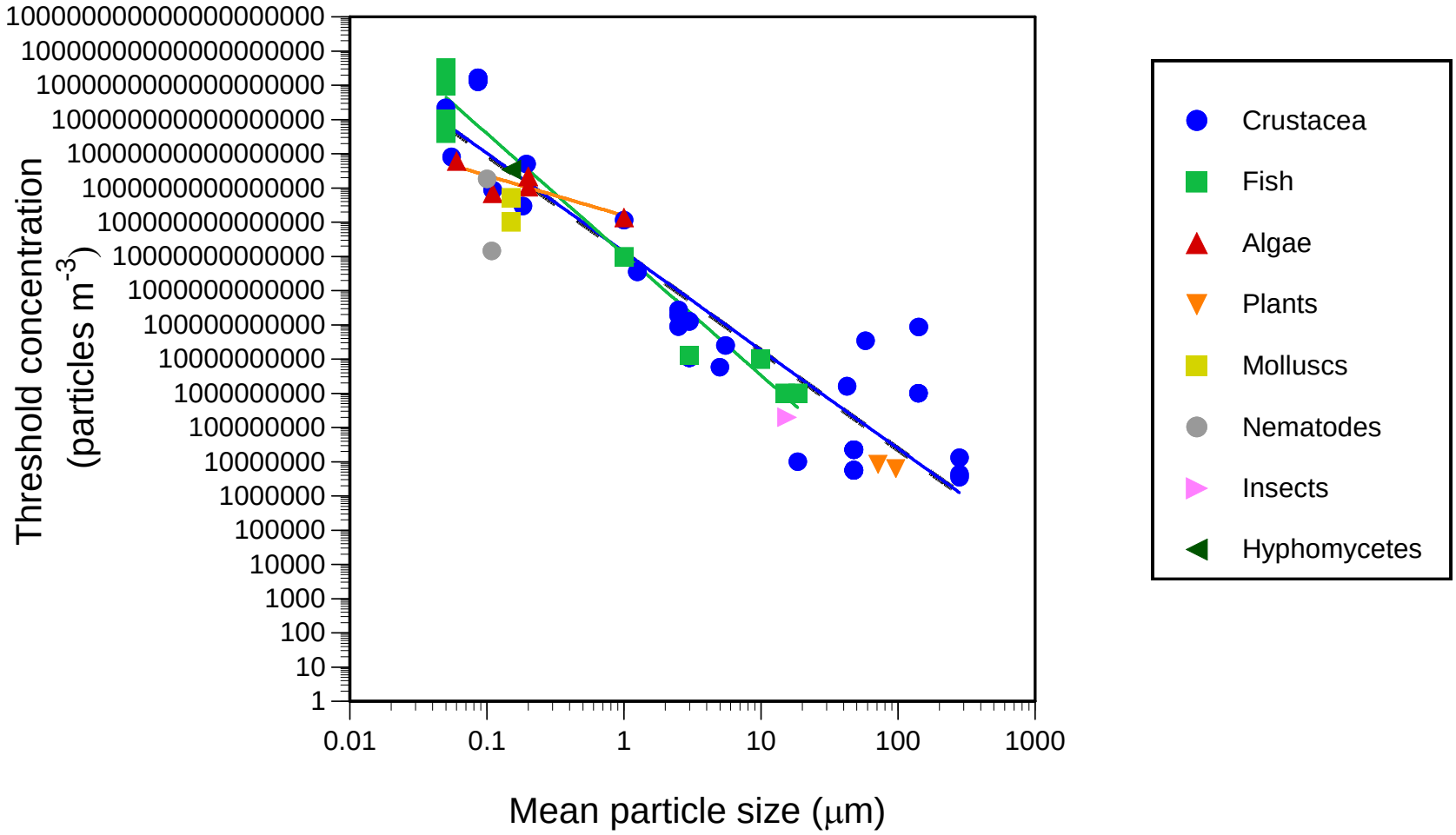
The concentration required to cause such impacts is related to the size of the particles of microplastic.

Effect of taxonomic group on size specific threshold concentrations

Sufficient data to test effect of taxonomic group on relationship between particle size and threshold concentration for Crustacea, fish and algae using ANCOVA

	F value	p
Particle Size	569.85	≤ 0.0001
Particle Size * Endpoint	0.30	0.8778
Particle Size * TaxaGp	1.71	0.2109

No effect of taxonomic group or ecotoxicological endpoint on relationship with particle size

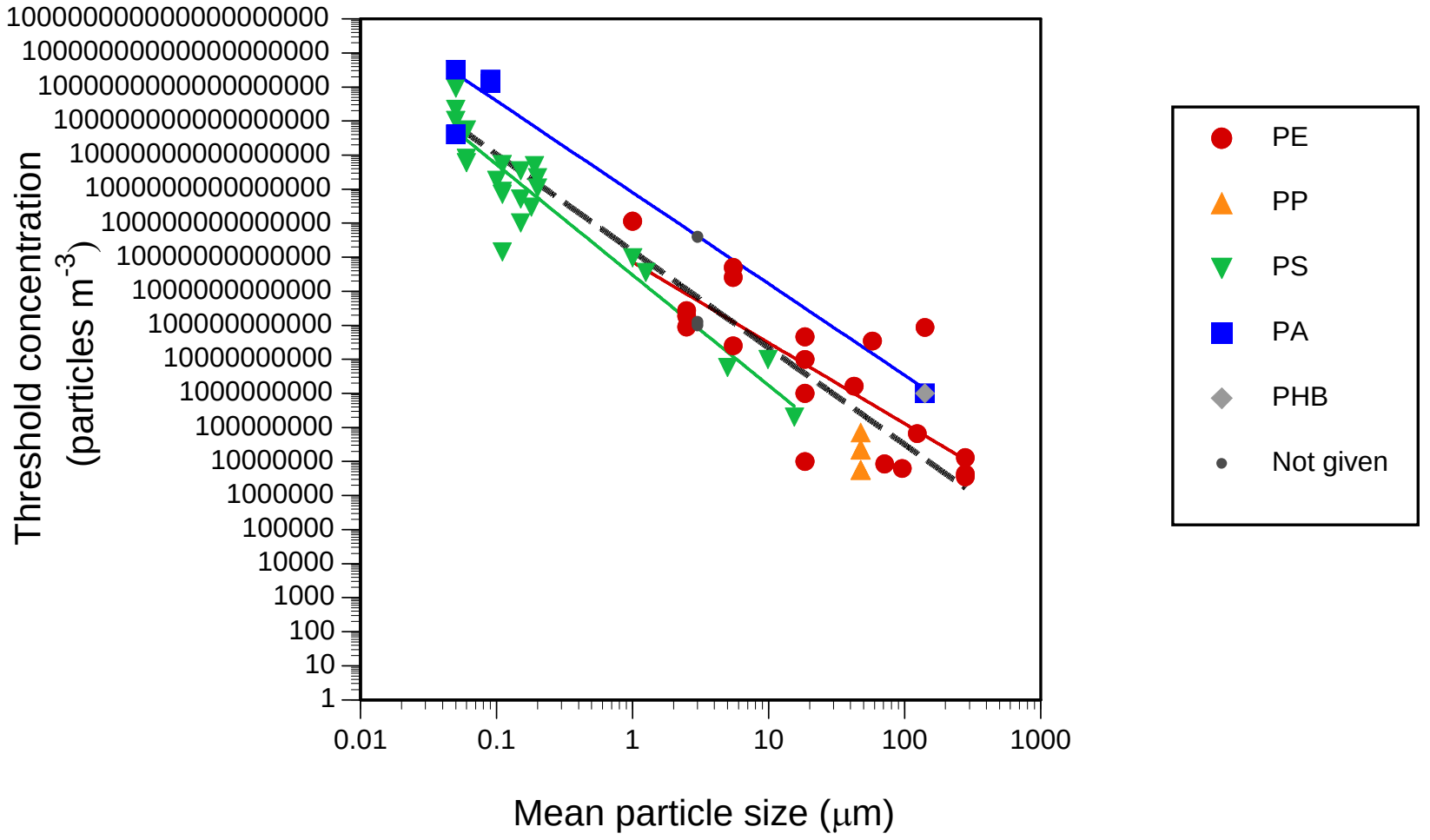


Effect of polymer on size specific threshold concentrations

Sufficient data to test effect of polymer on relationship between particle size and threshold concentration for polyethylene (PE), polystyrene (PS), polyamide (PA) using ANCOVA

	F value	p
Particle Size	807.84	≤ 0.0001
Particle Size* Endpoint	0.80	0.5360
Particle Size* Polymer	0.91	0.4106

No effect polymer or ecotoxicological endpoint on relationship with particle size



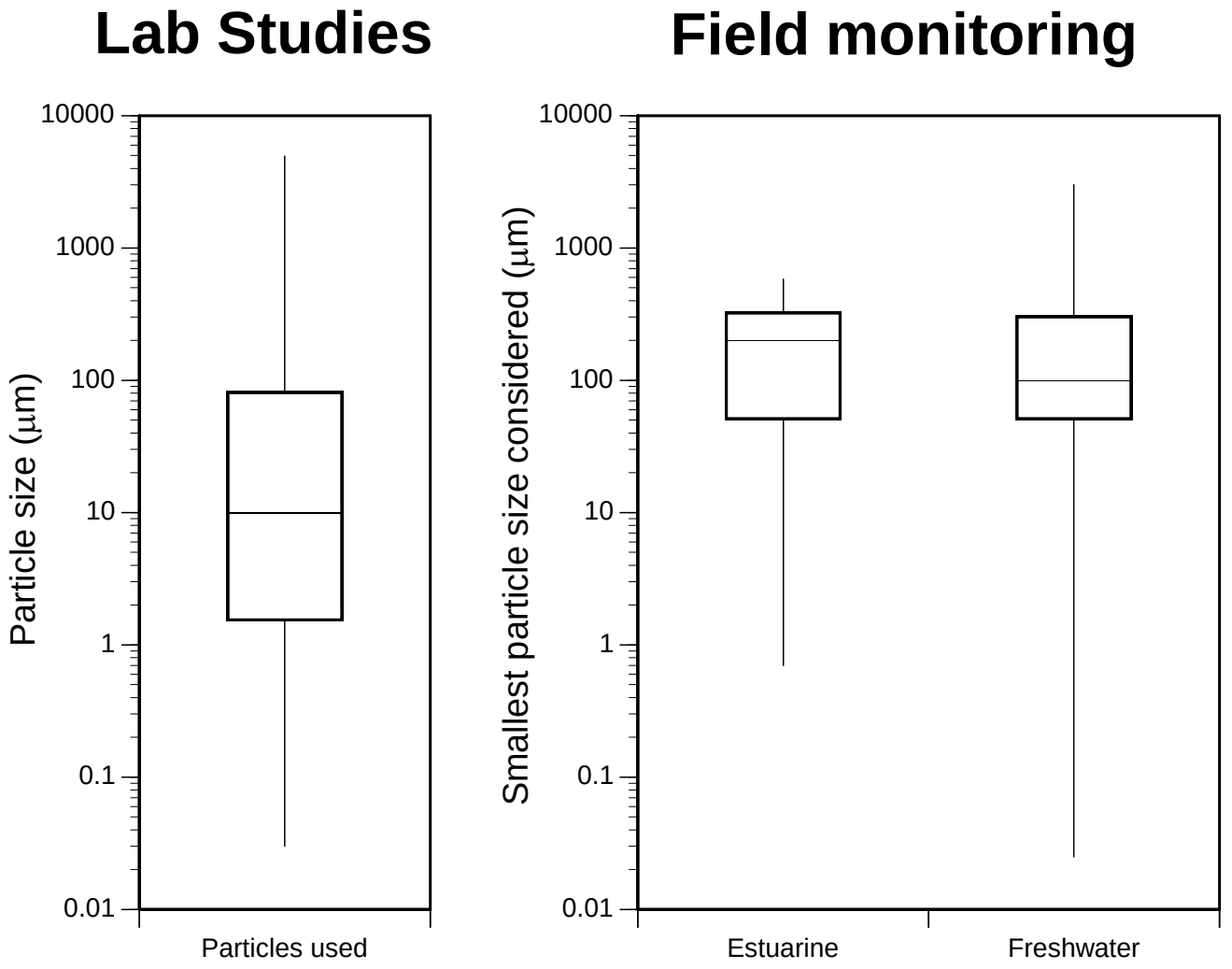
Differences in reported thresholds could not be attributed to differences in the taxonomic group of the test organism or to the polymer used.

Size of particles used in ecotoxicological studies

Size of particles used in ecotoxicological studies (n = 125), and smallest particles considered in studies of microplastics in estuaries and freshwaters (n = 185).

Nanoparticles ≤0.1 µm.

Box indicates 25th and 75th percentiles, whiskers minimum and maximum, and line median size of particles.



The majority of laboratory based toxicological studies have been undertaken using plastic particles that do not reflect the size of the microplastic particles that have been described from environmental samples collected in estuaries and freshwaters.

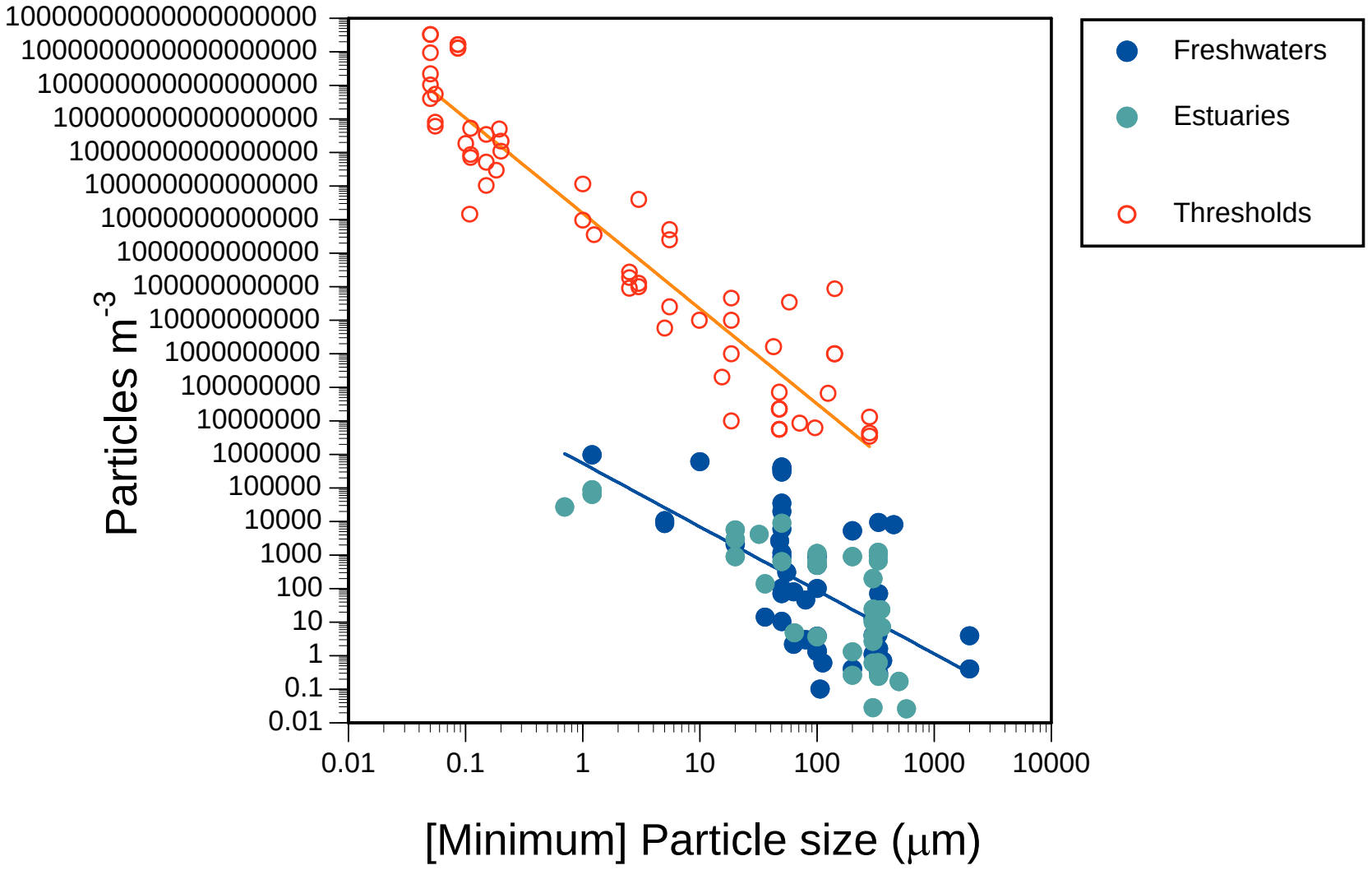
This mismatch adds uncertainty to our understanding of risk from microplastics.

Concentrations used in ecotoxicological studies

Threshold concentrations reported from laboratory studies

Mean concentrations reported from field collections of microplastics in estuaries and freshwaters

Lines fitted by least squares regression



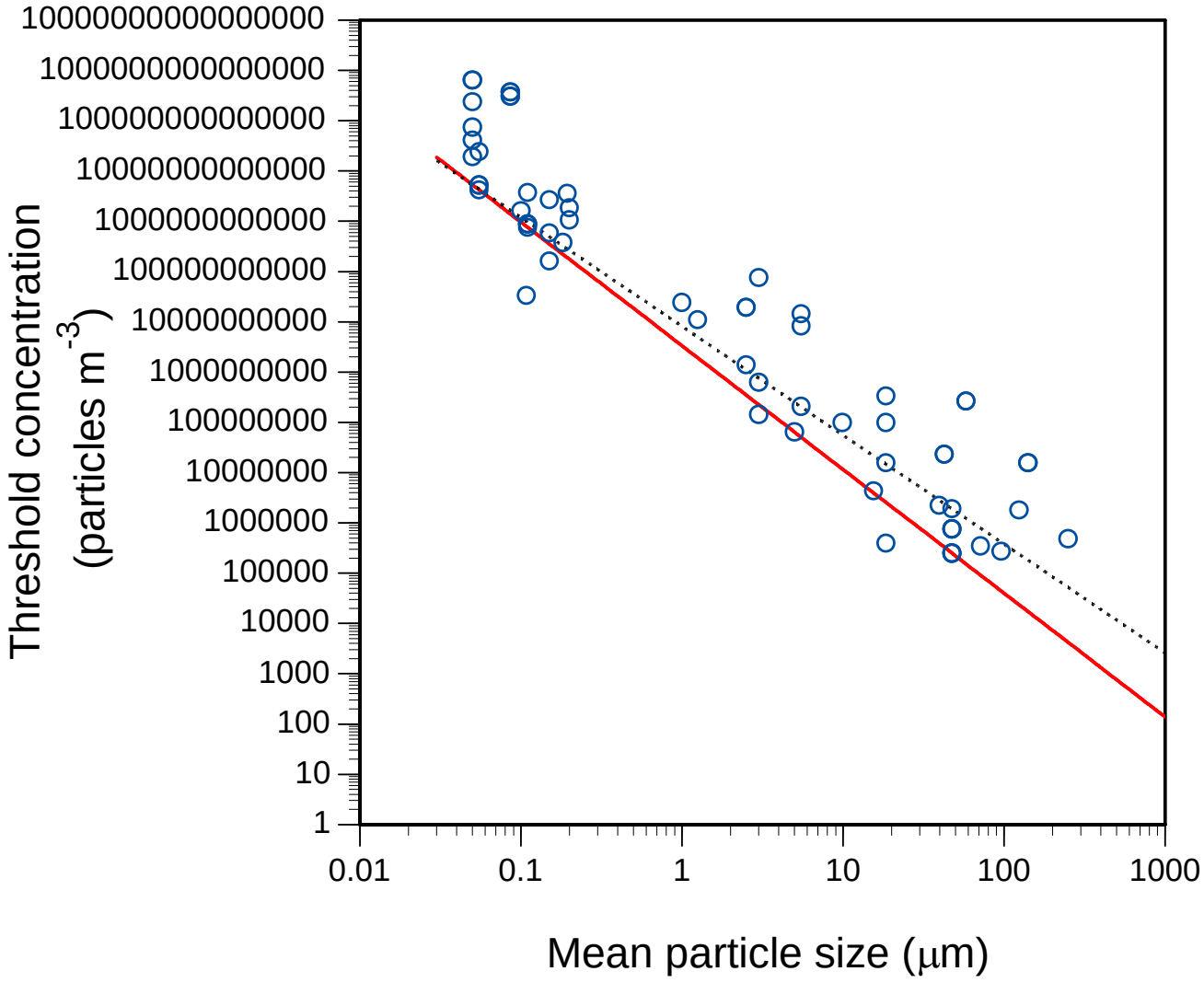
Laboratory based toxicological studies have been undertaken using concentrations of microplastics that are many orders of magnitude greater than the concentrations that have been reported from samples collected from freshwater and estuarine environments.

Size specific threshold concentrations

Species Sensitivity Distribution approach not appropriate

Size Specific Thresholds fitted to 10%ile by quantile regression,
i.e. concentration that is lower than 90% of reported lethal (dashed line) and all thresholds (red line) for that specific particle size

Less reliable studies (<median score) excluded

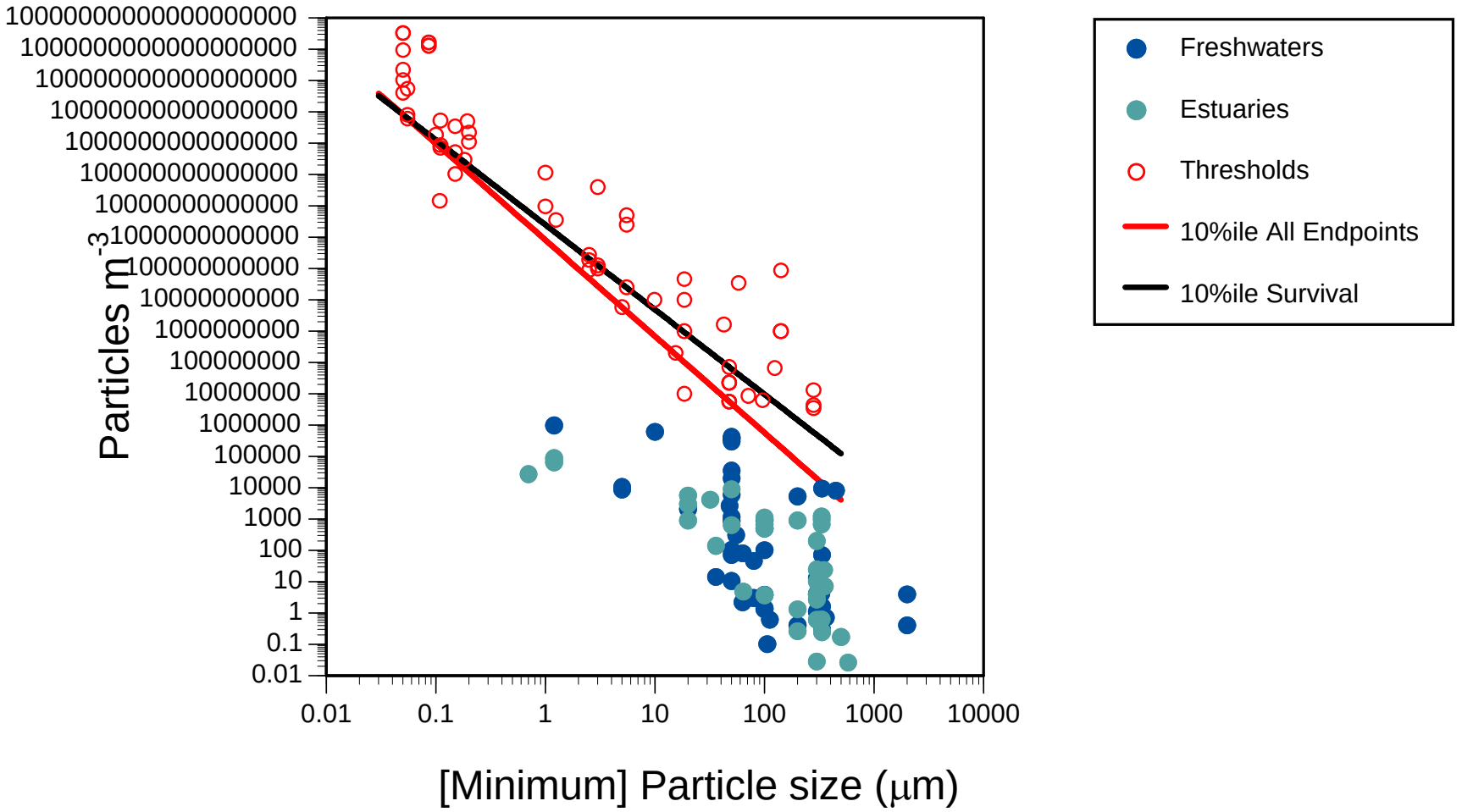


Establishing Risk

Comparison of reported environmental concentrations and size specific thresholds

Size Specific Thresholds fitted to 10%ile by quantile regression,
i.e. concentration that is lower than 90% of reported lethal and all thresholds.

Concentrations reported from field collections of microplastics in estuaries and freshwaters

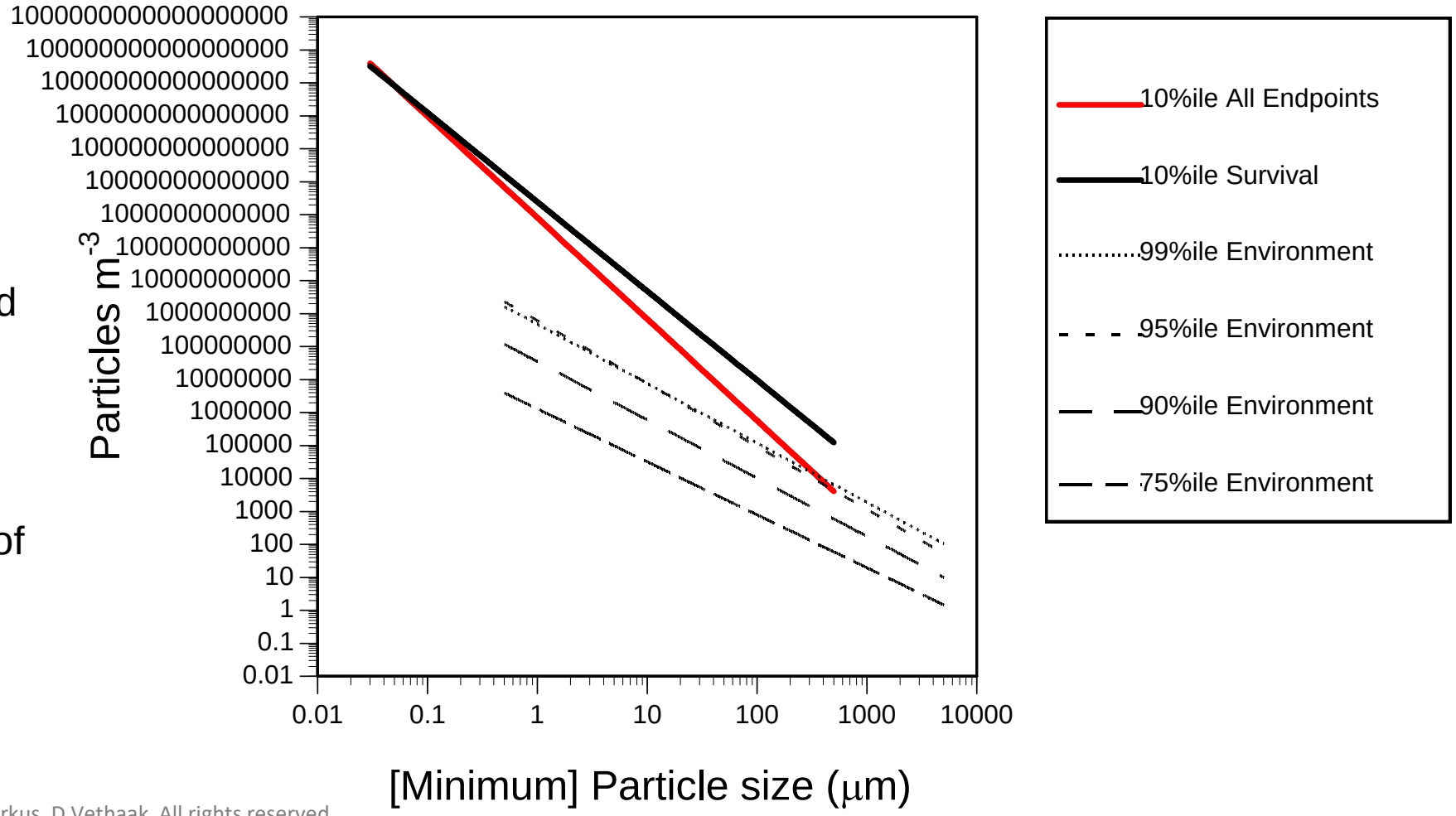


Establishing Risk

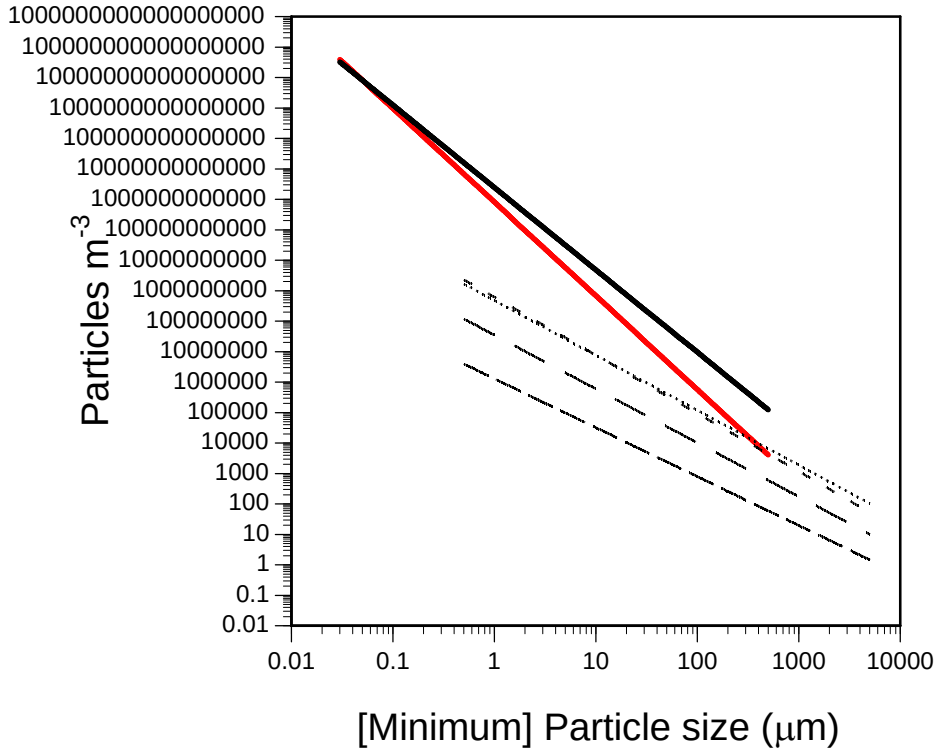
Comparison of reported environmental concentrations and size specific thresholds

Size Specific Thresholds fitted to 10%ile by quantile regression,
i.e. concentration that is lower than 90% of reported lethal and all thresholds.

Quantiles (99%, 95%, 90%, 75%) fitted to concentrations reported from field collections of microplastics in estuaries and freshwaters



The calculated size specific threshold concentration for lethal effects was higher than 99% of reported environmental concentrations, suggesting that lethal effects of microplastics on freshwater and estuarine biota are highly unlikely.



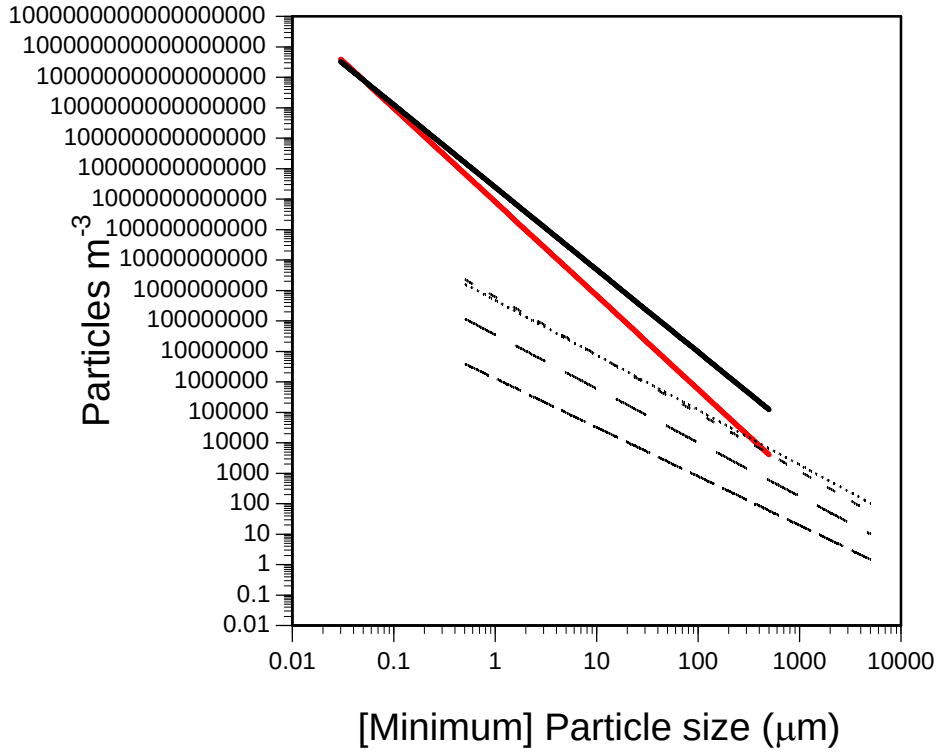
Over certain size ranges the calculated size specific threshold concentration for sublethal effects was exceeded by the highest 10% of concentrations reported from environmental samples, suggesting that there may be a possible risk of some sublethal effects in a small proportion of sites.

Three Reports to be available from Department for Environment, Food and Rural Affairs here

Evidence Reviews on Analysis, Prevalence & Impact of Microplastics in Freshwater and Estuarine Environments **Evidence Review 1** ***Are the current sampling and analytical methods scientifically robust and appropriate?***

Evidence Reviews on Analysis, Prevalence & Impact of Microplastics in Freshwater and Estuarine Environments **Evidence Review 2** ***What are the sources of the microplastics found in freshwater environments?***

Evidence Reviews on Analysis, Prevalence & Impact of Microplastics in Freshwater and Estuarine Environments **Evidence Review 3** ***What is/are the impact(s) of microplastics on freshwater and estuarine biota?***



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Acknowledgments

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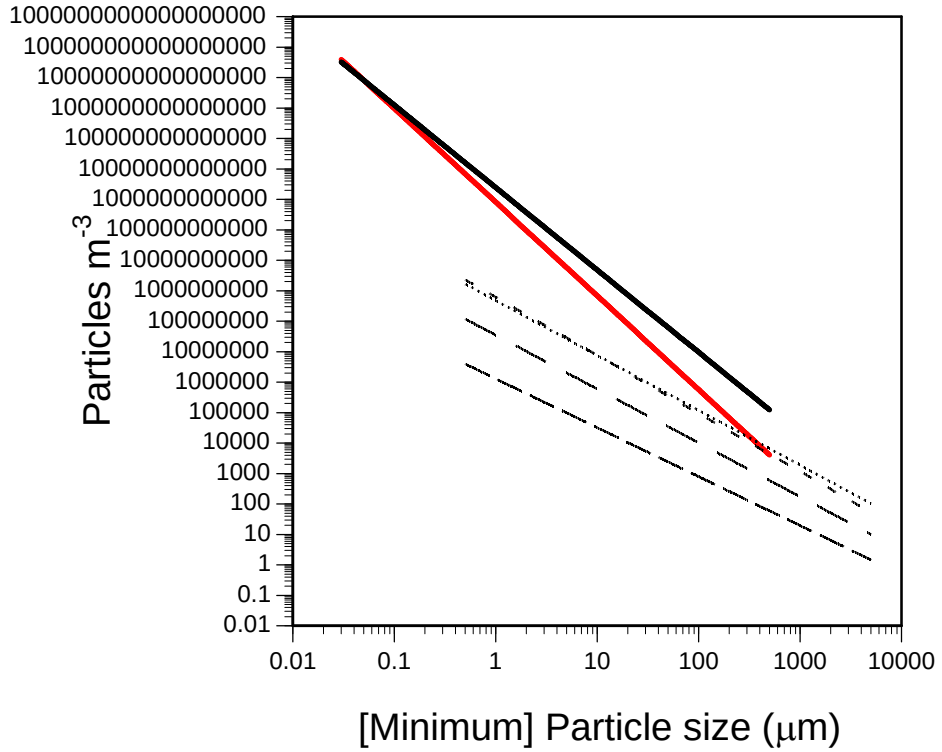
We acknowledge the experts who contributed their opinions to the reviews.



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