

Fate and effects of microplastics in soils

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2025-03-24

MARII Webinar series:

Closing the Microplastic Information Gap

Environmental impacts of microplastics



UK Centre for
Ecology & Hydrology



Introduction

1. Why soils?
2. What do we mean by hazards and risks?
3. What tools do we have and what can we learn from others?
4. Some examples of increasing realism!



Why soils?

As much as **3 – 10x the emissions to land** than to marine environment (Earth Action, 2023)

>1,500 species documented to **ingest microplastics** including 277 terrestrial and freshwater species (Santos et al., 2021).

Intentionally added (micro)plastics in agriculture (encapsulates, coatings) and of plastic more widely (e.g. mulching)

→ direct emissions

→ interesting from a policy perspective?



Eroded landfill site on the Thames, UK



Open burning of mulch films in Florida, USA

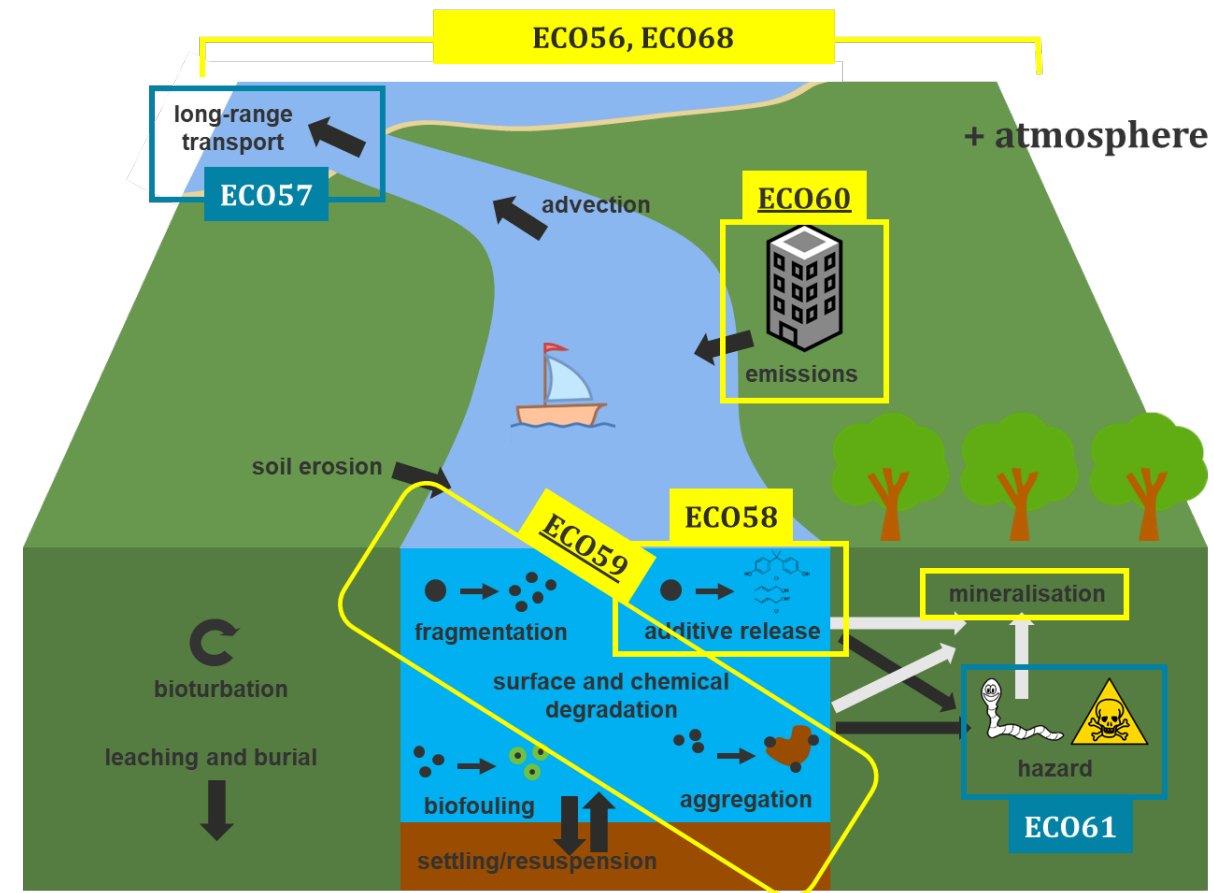
What happens in Vegas... doesn't stay in Vegas?

What happens on land, doesn't always stay on land!

Monitoring and modelling can both help us:

- Find **hotspots** of risk
- Identify **sources**
- Target **interventions**
- Predict **futures**

Plastic pollution is a **global problem** and we need to think **holistically** – soils are a hitherto understudied part of this

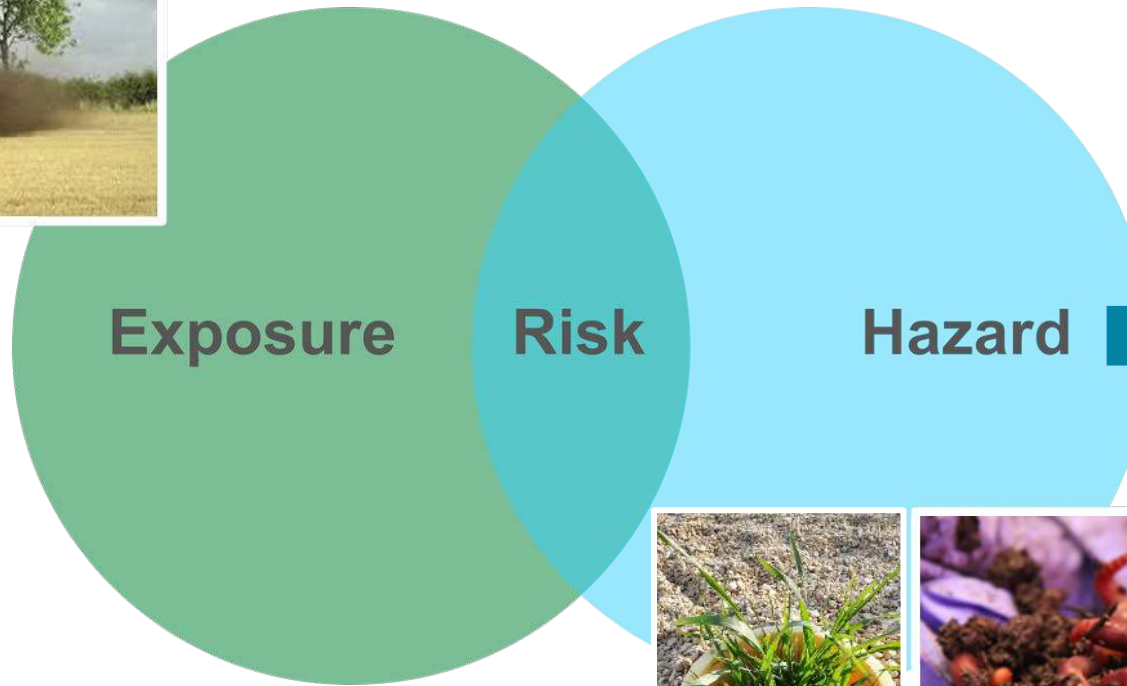


Cefic LRI cluster of projects modelling exposure

What do we mean by hazards and risks?



Monitoring
Modelling

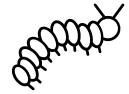
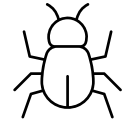


Effects



Toxicity testing

(Micro)plastic interactions with biota



- Potential to accumulate.
- Potential to cause adverse effects.



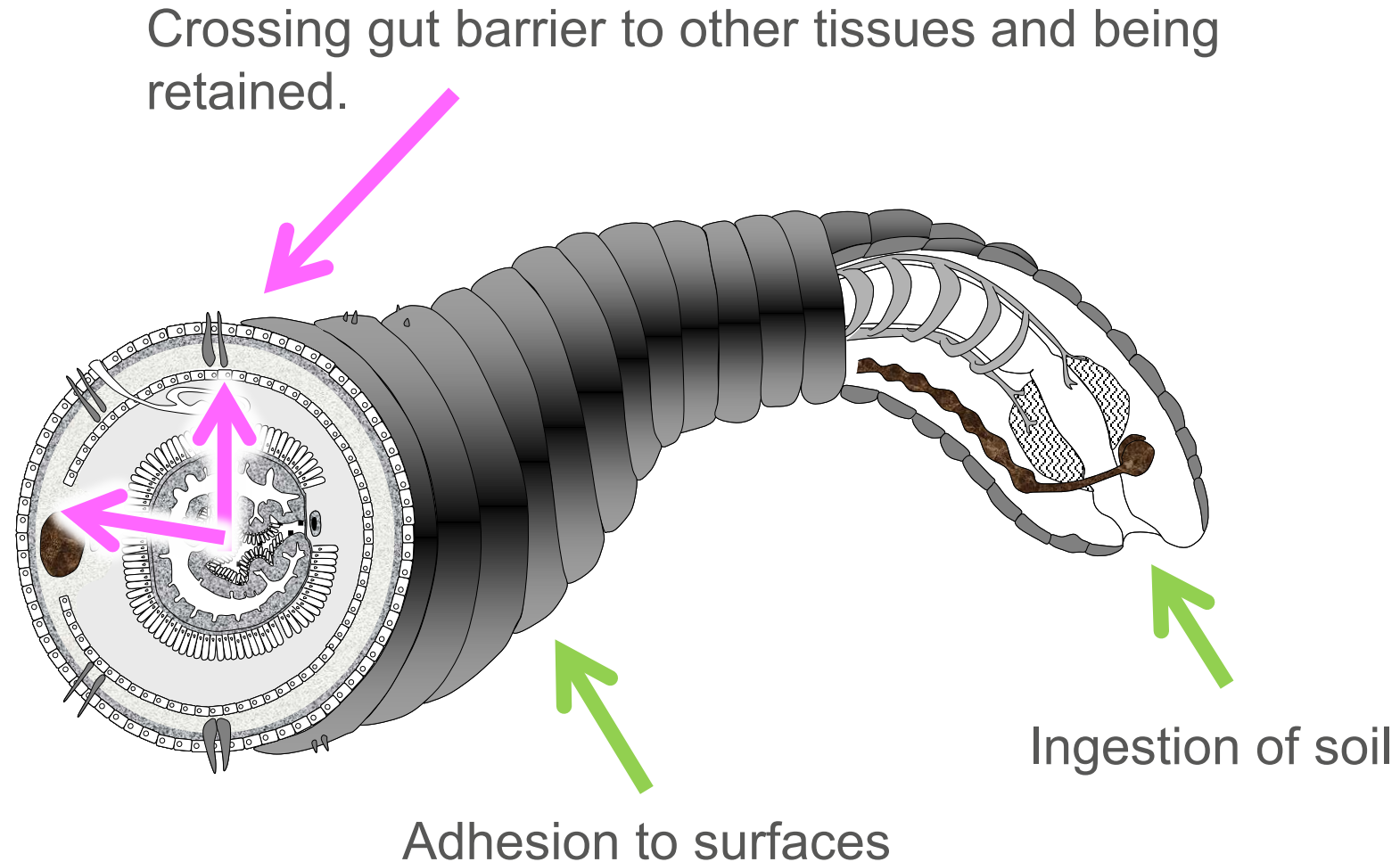
Accessibility vs accumulation

Uptake via ingestion but not crossing gut barrier or surface adhesion

= **accumulation**

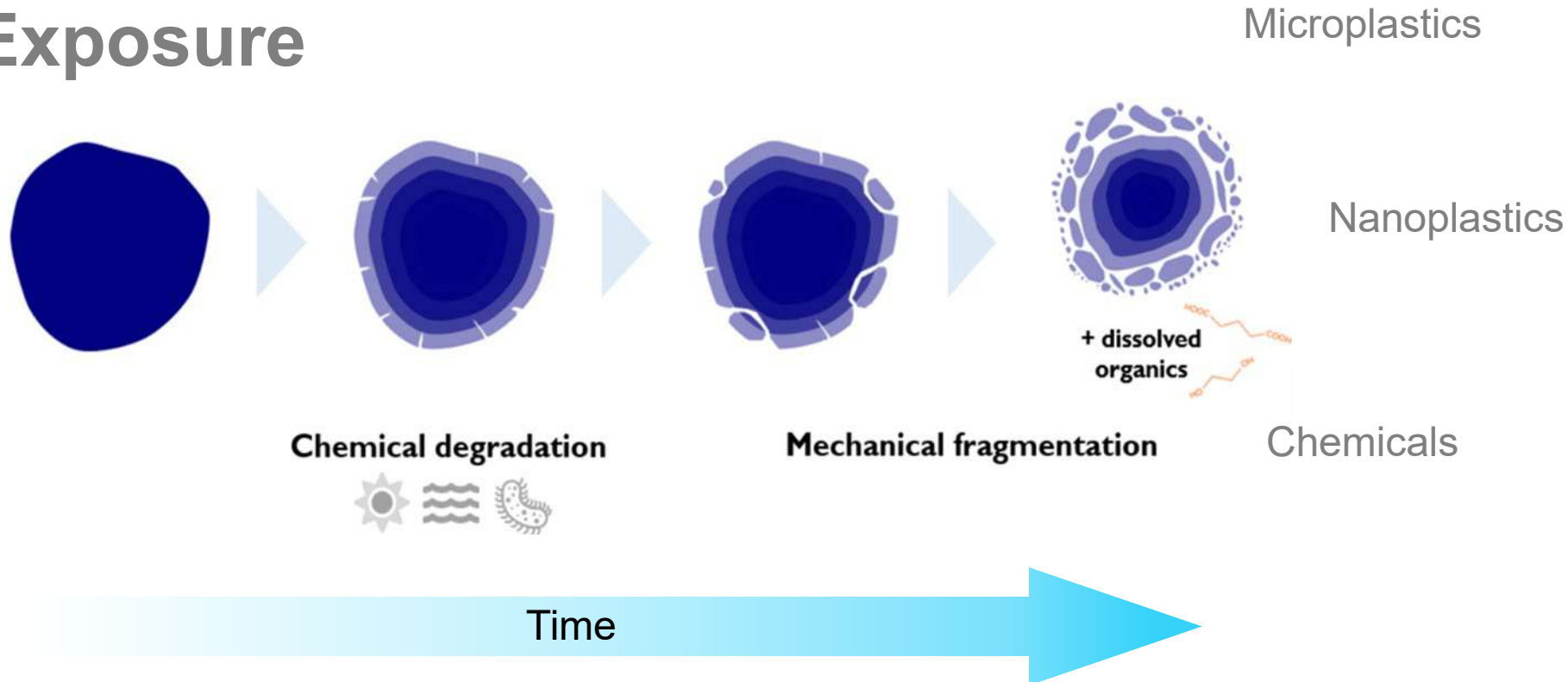
Assimilation from the gut to other tissues

= **bioaccumulation**



Why do we see effects on organisms?

Exposure



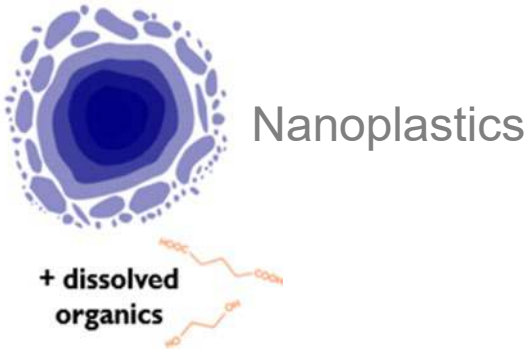
- **Physical**

- **Chemical**

- **Indirect**

What can we learn from nano?

Exposure



Time

- Internal and external fate of particles is important¹
- Solubility – tools to attribute chemical from physical effects²
- Adverse outcome pathways (AOP)
- Grouping and/or read-across?³

¹ Cross et al., 2024. An integrated approach to testing and assessment (IATA) to support grouping and read-across of nanomaterials in aquatic systems

² Song et al., 2022. Similarity assessment of metallic nanoparticles within a risk assessment framework: a case study on metallic nanoparticles and lettuce

³ Jeliaskova et al., 2021. How can we justify grouping of nanoforms for hazard assessment? Concepts and tools to quantify similarity

What tools do we have to understand effects and impacts?

Ecotoxicology

Analytical chemistry

Risk assessment

Exposure assessments

Molecular biology

Remote sensing

Modelling

New approach methodologies

Field scale trials

Etc...

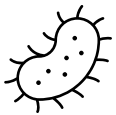
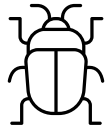
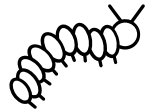
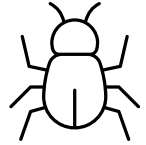


Taking ecotoxicology as an example – what can we learn?





Physical effects



Particle characteristics

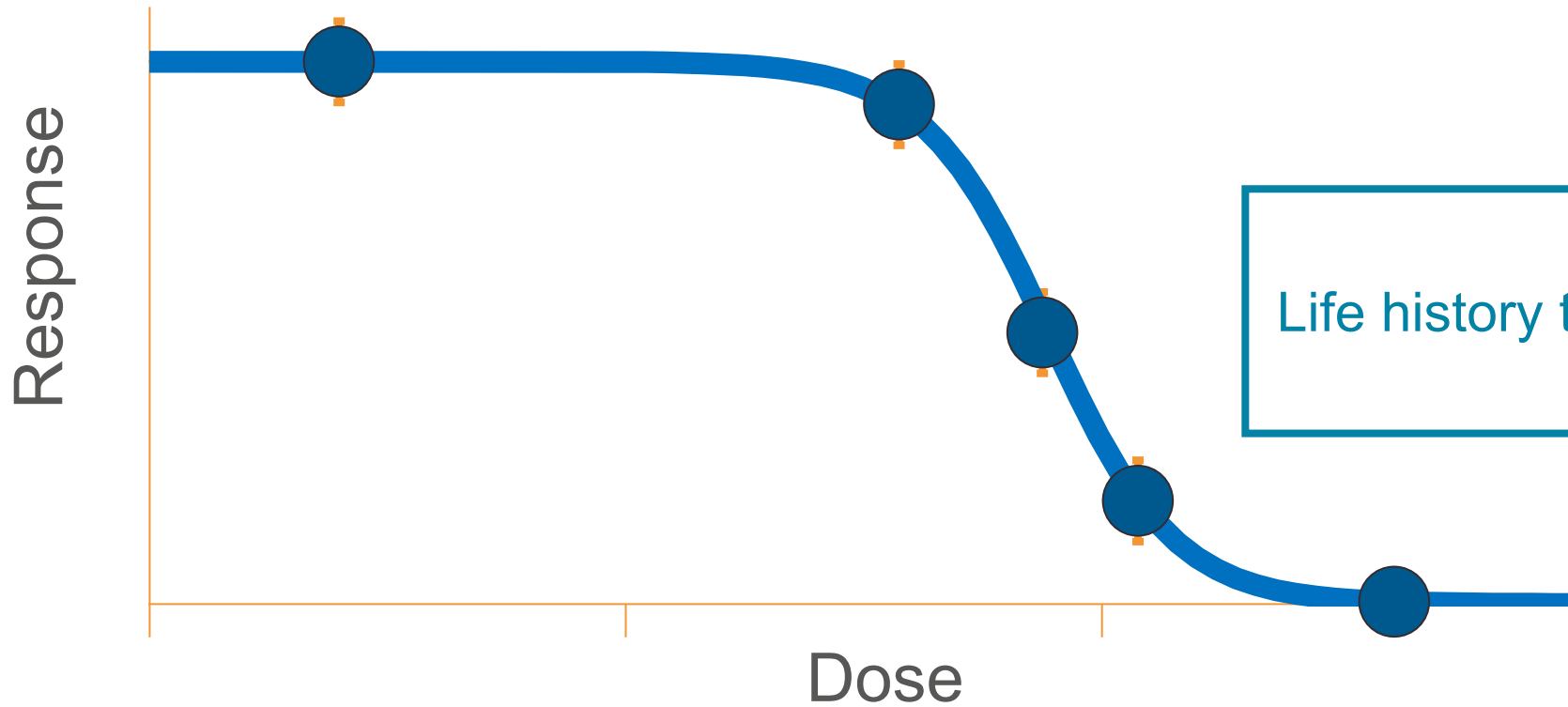
Size
Shape
Polymer types
Surface

Organism traits

(Relative) size
Physiology
Feeding traits
Life-stage



Dose response



Endpoints

Life history traits

- Survival
- Reproduction
- Growth
- Behaviour
- Biochemistry...
- ...

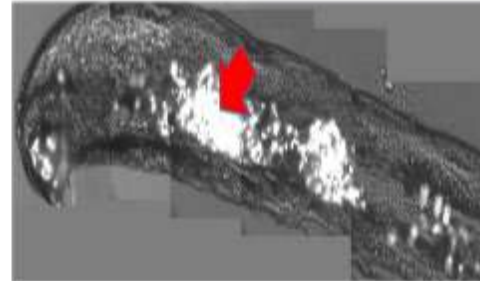
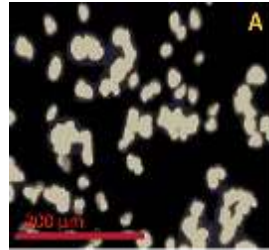
Ingestible size is important for particle driven effects



Enchytraeus crypticus

Pot worm
~ 7 mm in length

13-18 μm

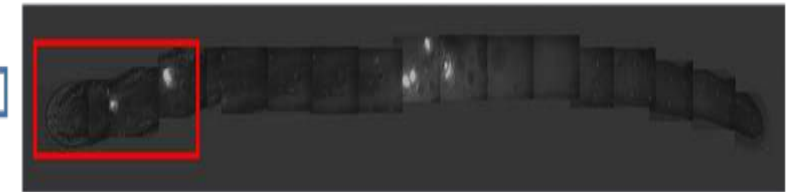
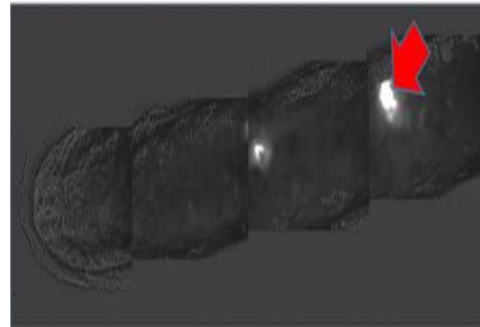
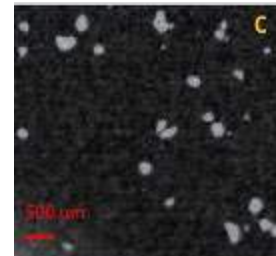


Anterior

Posterior



90-150 μm



Mouthpart = ~ 72 μm x ~ 90 μm

Ingestible size is important for particle driven effects



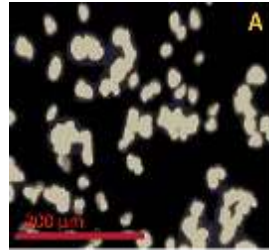
Reproduction



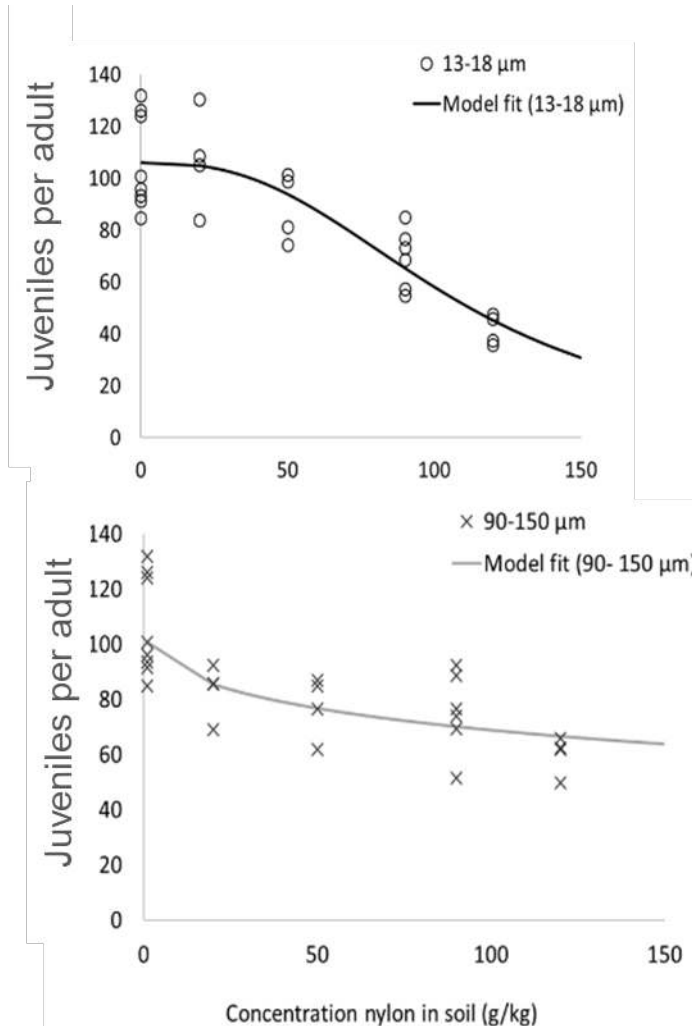
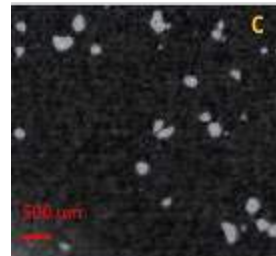
Enchytraeus crypticus

Pot worm
~ 7 mm in length

13-18 μm



90-150 μm



Effect concentrations
(EC₅₀)

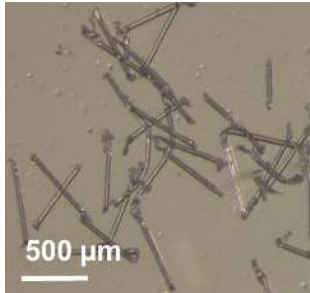
108 g/kg

10 % w/w

>120 g/kg

>12 % w/w

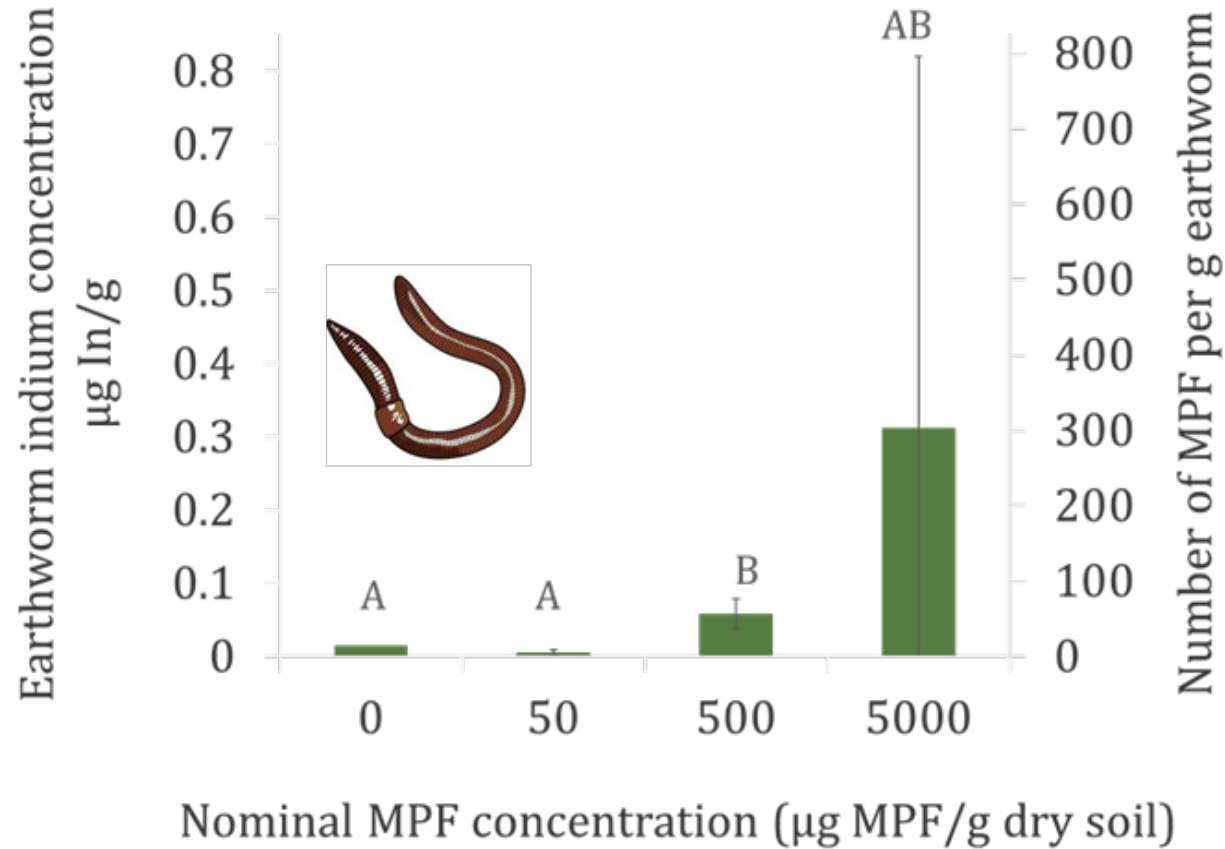
Bringing exposures to more realistic levels



Metal-doped Microplastic fibres (MPF)



Lumbricus terrestris
~ 15 cm in length

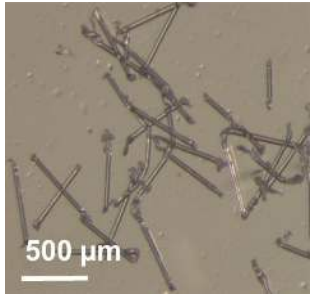


(0.005 – 0.5 % w/w)



Trophic transfer

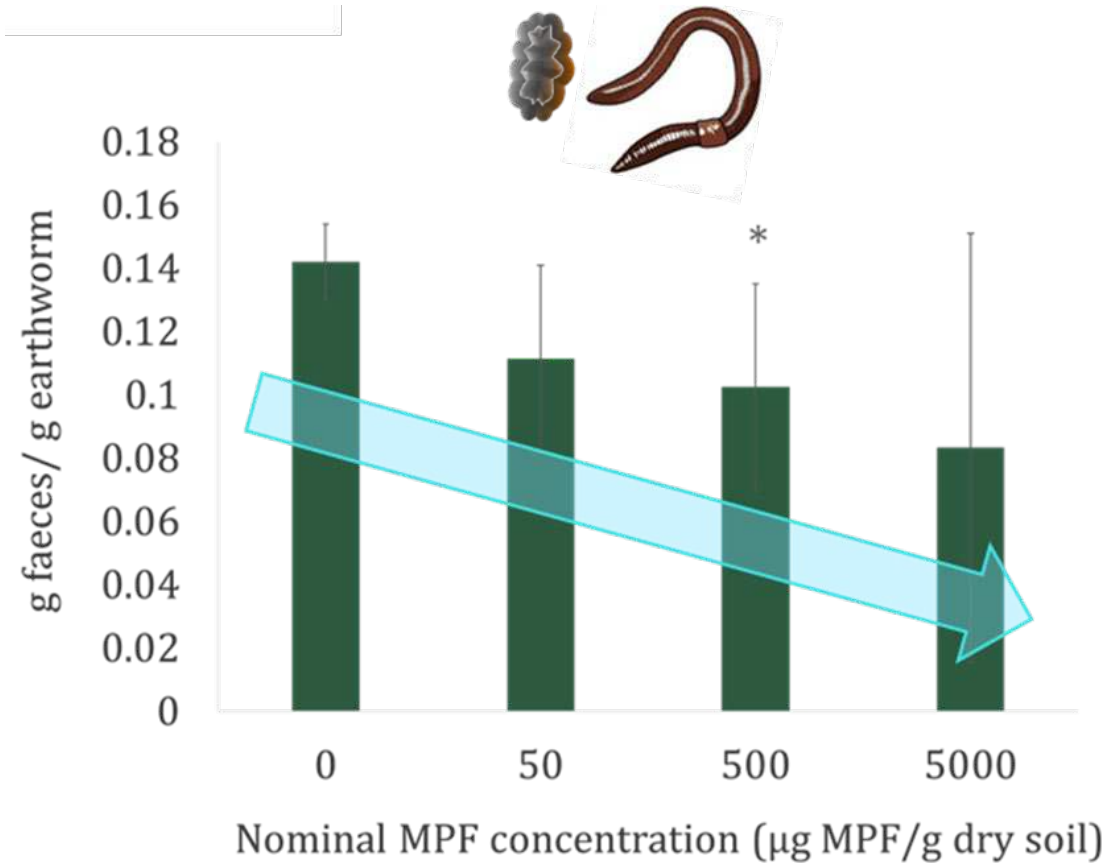
Can non-standard endpoints shed light on mechanisms?



Metal-doped Microplastic fibres (MPF)



Lumbricus terrestris
~ 15 cm in length



(0.005 – 0.5 % w/w)

Mass of faeces produced is reducing and more variable

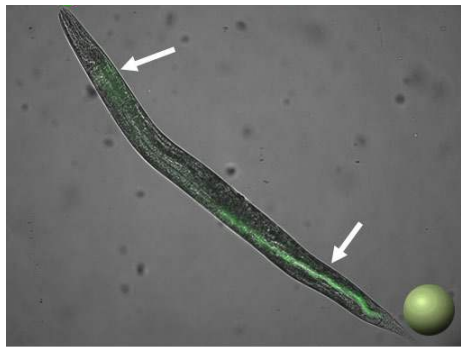
Links to the food dilution mechanism?

Fibres retained in the worms > could be explained by soil retention

Non-standard endpoints

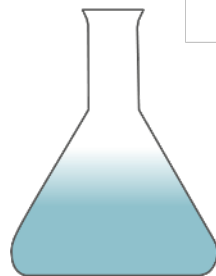
What about nanoplastics?

Polystyrene NPs

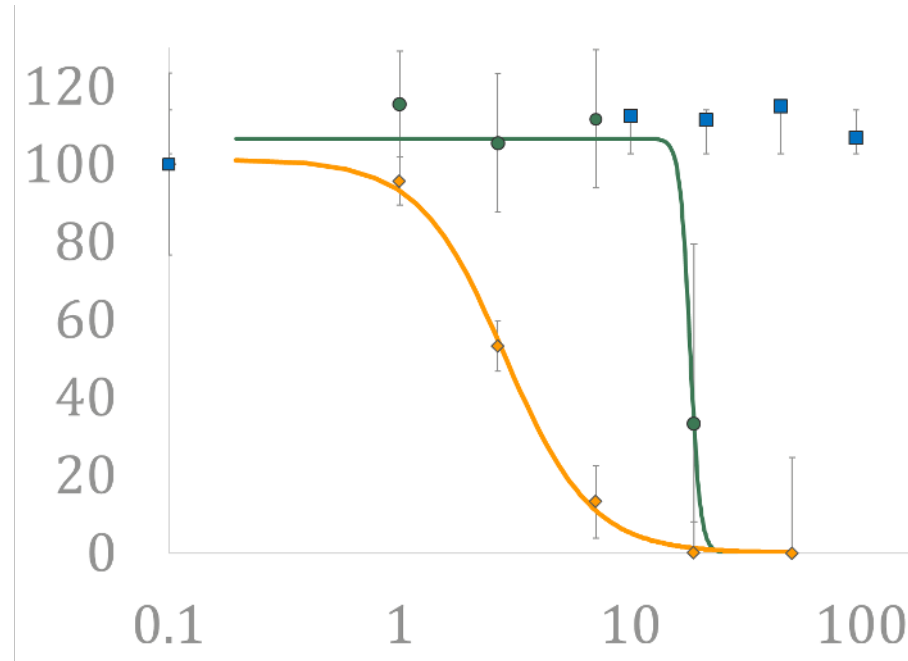


Nematode:
C. elegans

Schultz et al 2021 ES&T



Offspring (% control)



Concentration [mg/l]



Reproduction

- negative
- neutral
- ◆ positive

**Effect concentrations
~10 - >1000 mg/l**

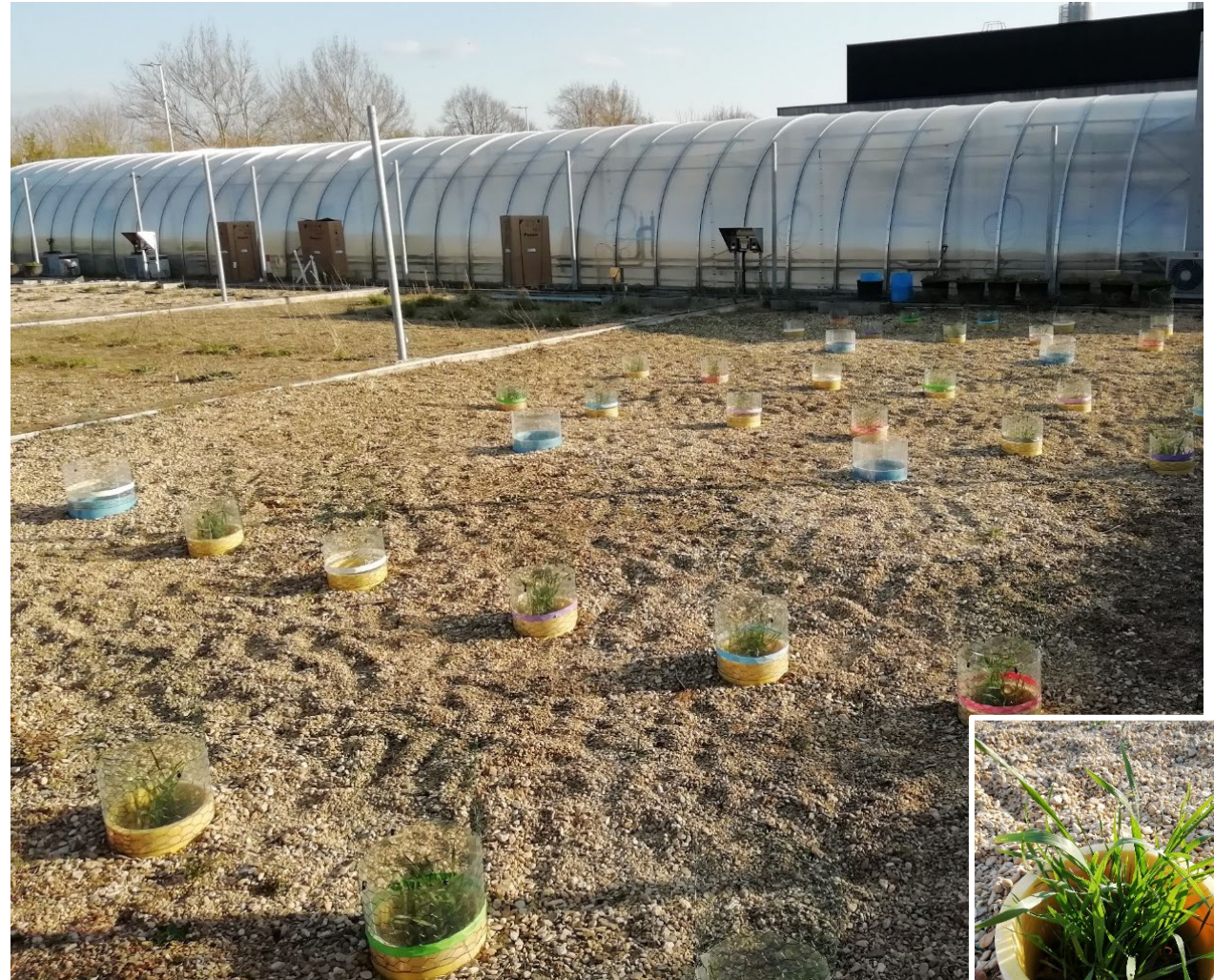
0.001 % w/v

What if complexity and realism are increased?



Mesocosms

- ↑ Multiple species.
- ↑ Interactions between species.
- ↑ Interaction with abiotic factors.
- ↑ Consider fate as well as effects.
- ↓ Labour intensive.
- ↓ Fewer treatments.

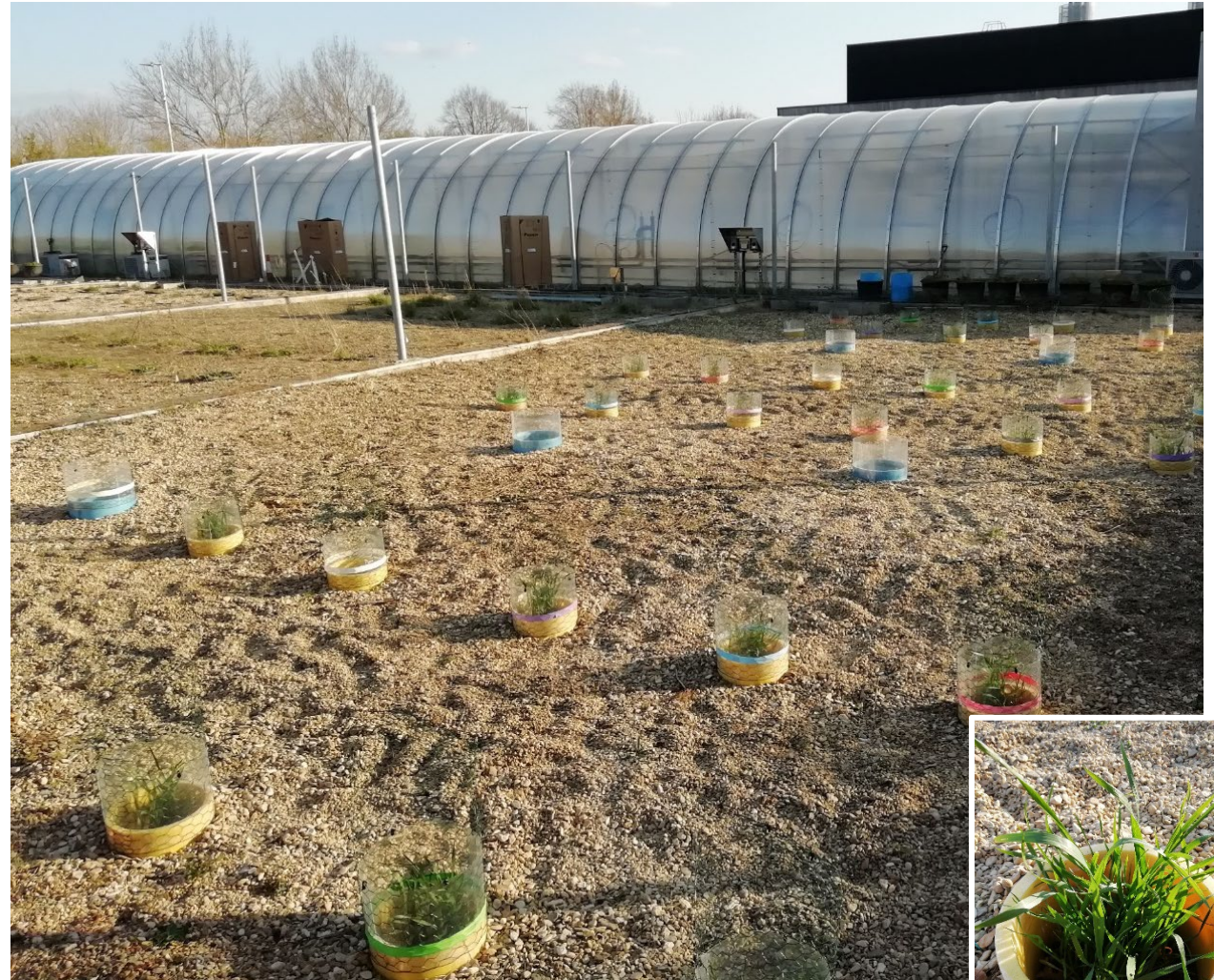


Mesocosms

Nanomaterials in soil
- sludge application to land



Schultz et al in prep





Generating a realistic exposure – particle mixtures in sewage sludges



- 100 nm polystyrene (PS)
- 50 nm Ag nanoparticles.

Mesophilic anaerobic digestion



Lime stabilisation: add lime to raise the pH to above 12 for at least 2 hours.

Mesocosms

- Sludge spiked with different nanoparticles including nanoplastics.
 - Sludge is mixed into soil in top layer simulating the plough layer.
-
- Soil not spiked with nanomaterials.



Cu = Copper oxide NP 40 mg/kg soil

0.3 % sludge in topsoil.

Ag₂S = sulfidised Ag NP 10 mg/kg soil

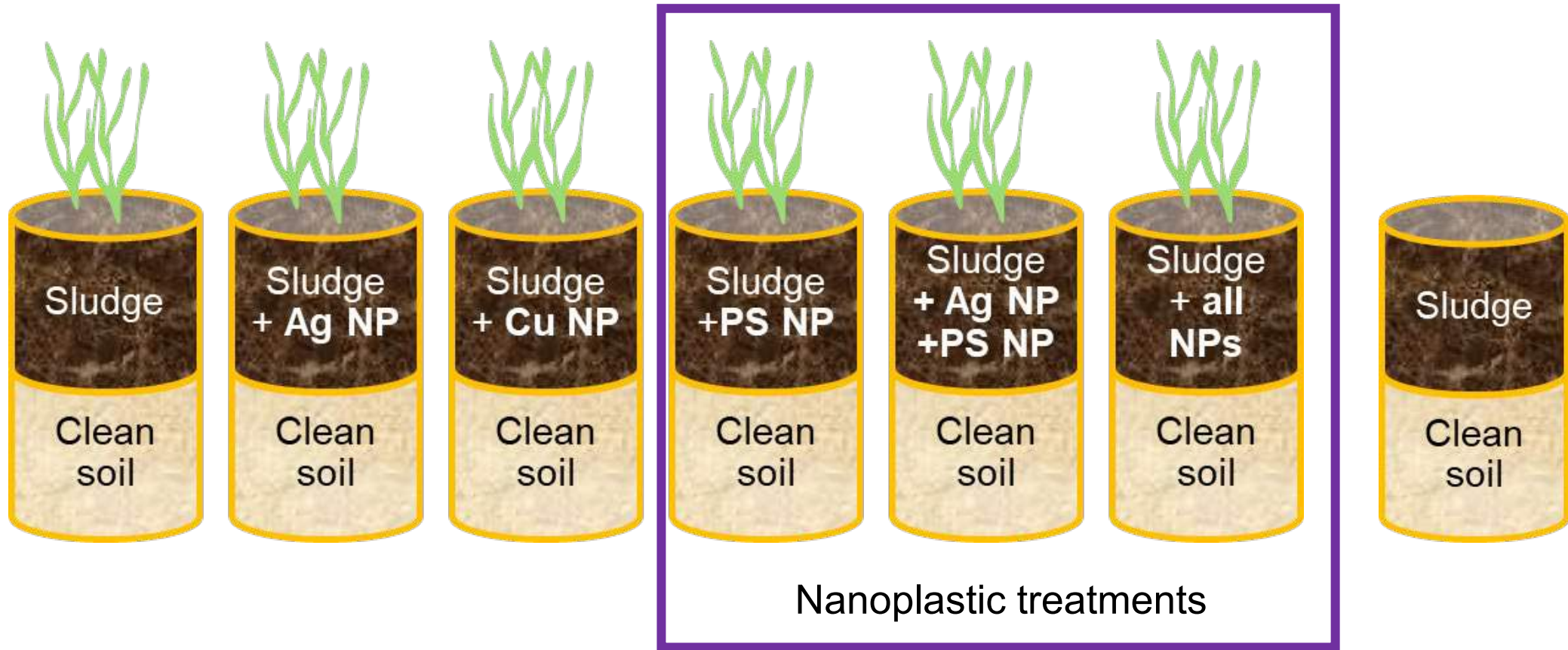
PS = polystyrene NP 100 mg/kg soil

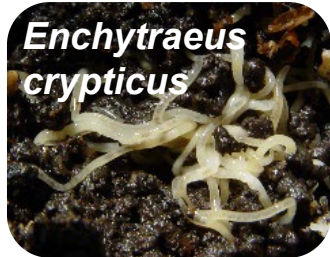
0.01 % nanoplastic (w/w)

30 cm

Aim: Investigate **fate and effects** of nanoparticles (including nanoplastics) in soils

Mesocosm treatments





plants

surface dwellers

endogeics – upper soil dwellers

anecic – deep burrowers

Outdoors for 5 months

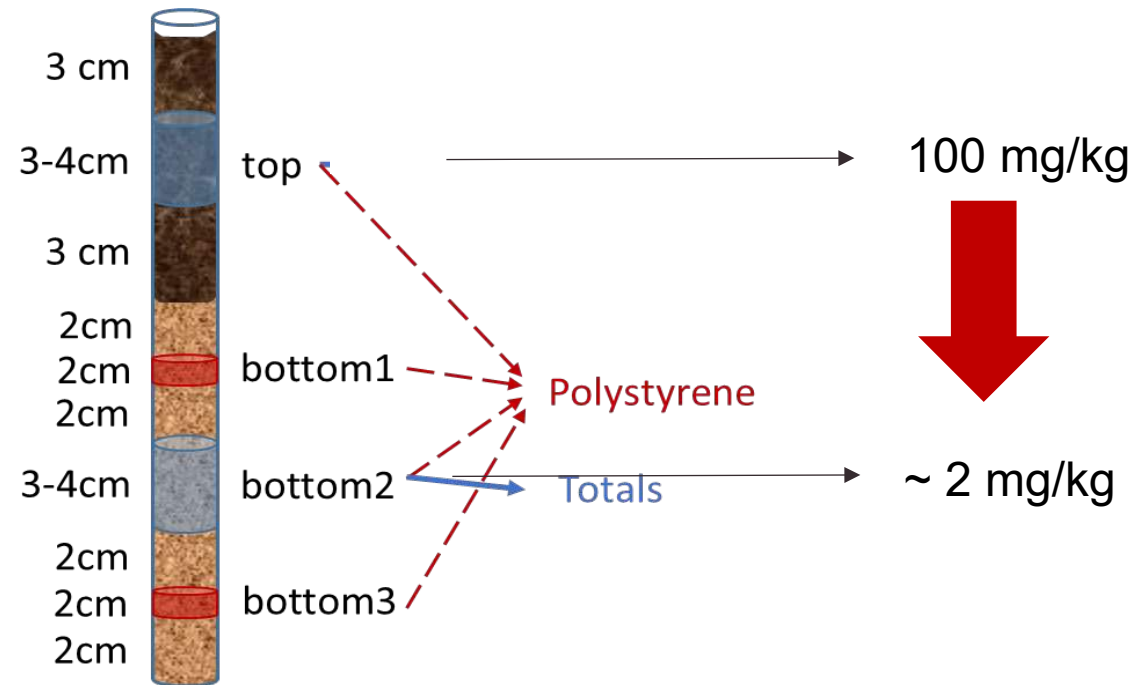


November

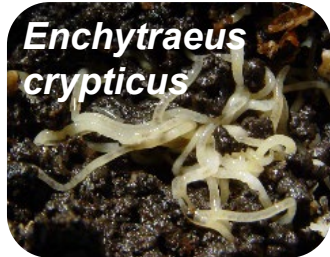


April

Transport in soil



Some vertical transport occurring



Observations

Uptake and life history effects

Internal concentrations,
Growth, reproduction, population size

Chemistry

Fate of nanoparticles

Gut microbiome

Earthworms

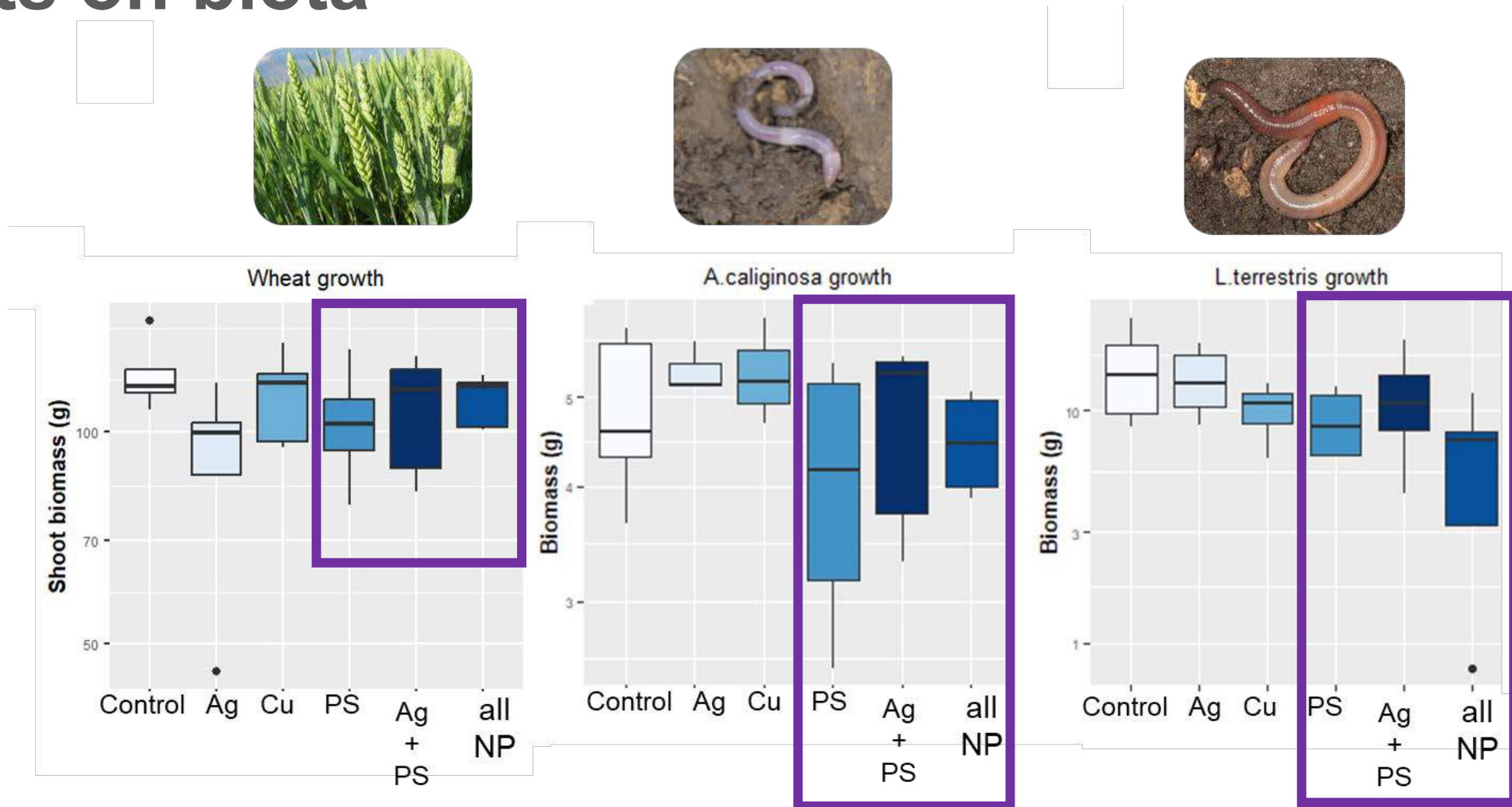
Soil community

Microbial/fungal and invertebrate community

Effects on biota



Schultz et al in prep

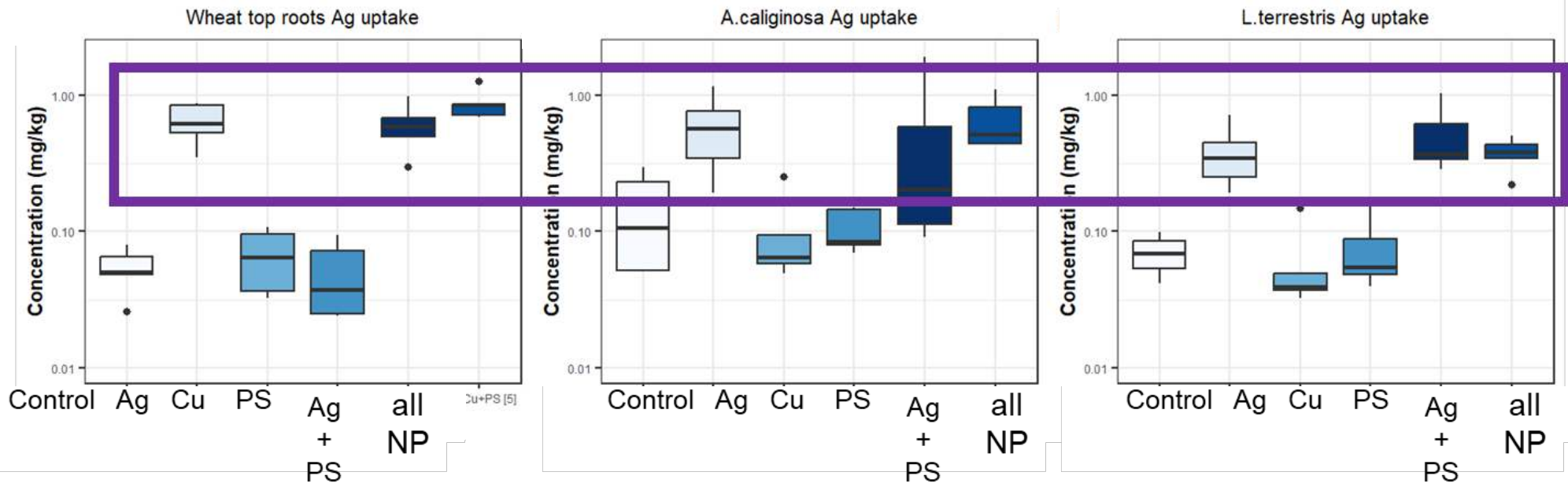


More variability where nanoplastics were present but
no significant effects

Uptake to biota - Silver



Schultz et al in prep



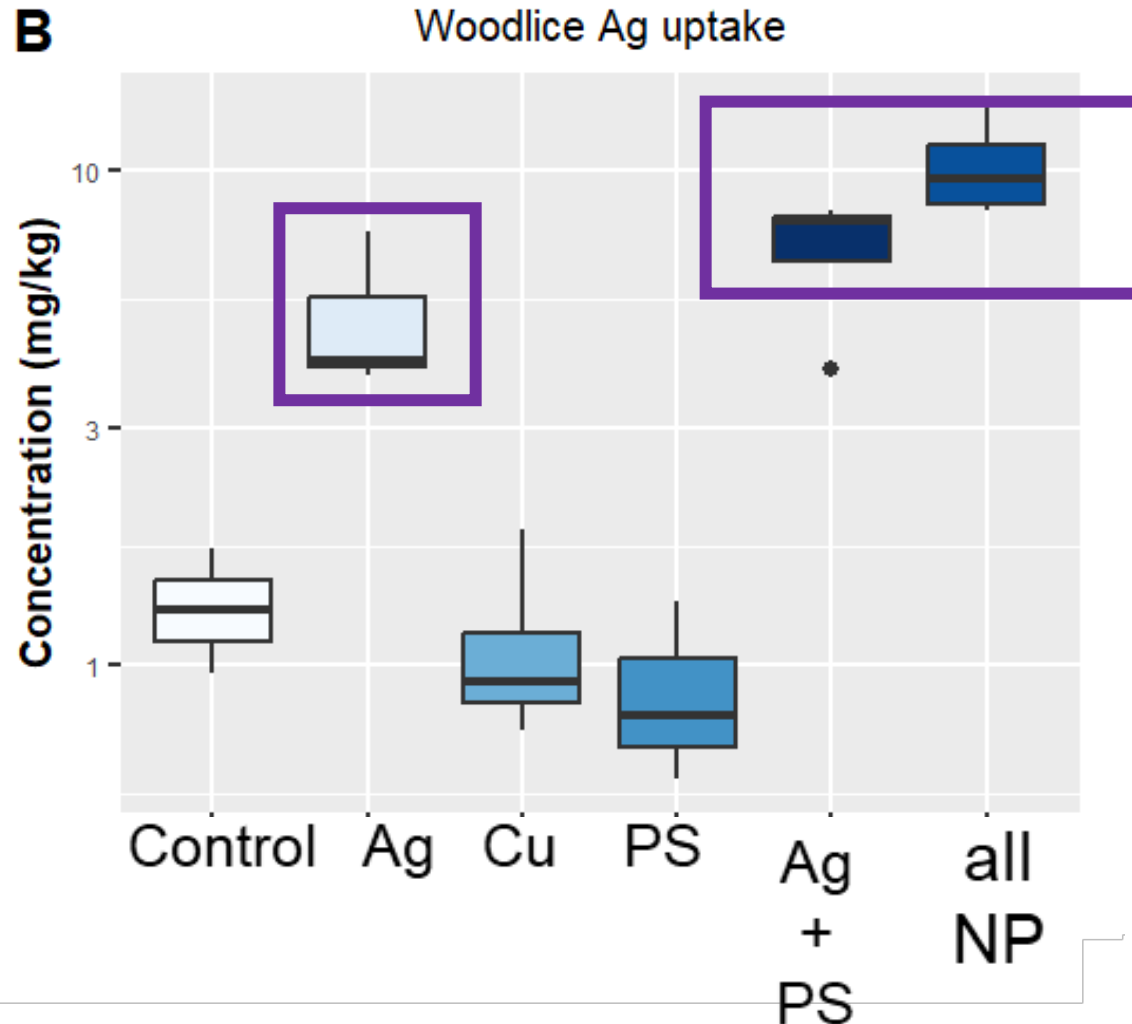
no significant change

Uptake to biota

Surface dweller



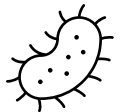
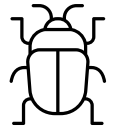
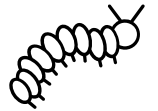
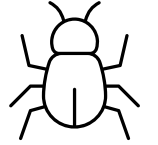
Schultz et al in prep



Higher silver accumulation in the presence of nanoplastics

Physiology, life history, species specific vulnerabilities?

Summary



Lab



Mesocosm

- ☞ Effects on organism life history traits at high concentrations.
- ☞ Testing approaches beyond life-history traits needed.
- ☞ Plastics persist – longer-term assessments needed – linking sub-lethal effects with mechanisms of action and adverse outcomes.
- ☞ Biological fate of chemicals can be affected by presence of plastics.

What have we learnt and what next?

- Ecotoxicity – insights into **apical effects and mechanisms**
- Mesocosms = greater realism, indicate **chronic sublethal exposures** are relevant
- To bring this towards risk assessment, **alignment needed** between exposure information and hazard information
- Concepts from nano → grouping; particle vs chemical driven effects; new approach methodologies could **accelerate progress**



Thank you for your attention!

Acknowledgements

Elma Lahive, Carolin Schultz, David Spurgeon, Elmer Swart, Sarah Roberts + the whole Environmental Pollution team

