Higher-tier community effects of nano- and microplastics in the context of risk assessment

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Who am I?

- BSc in Biology at the Autonomous University of Madrid (Spain)
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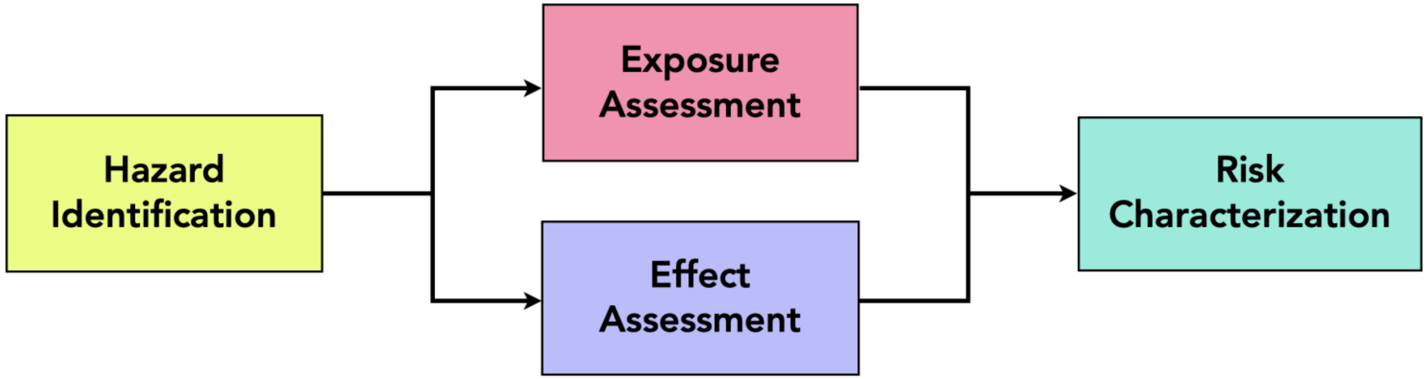
Environmental Risk Assessment



$$RQ = \frac{PEC \ o \ MEC}{PNEC}$$

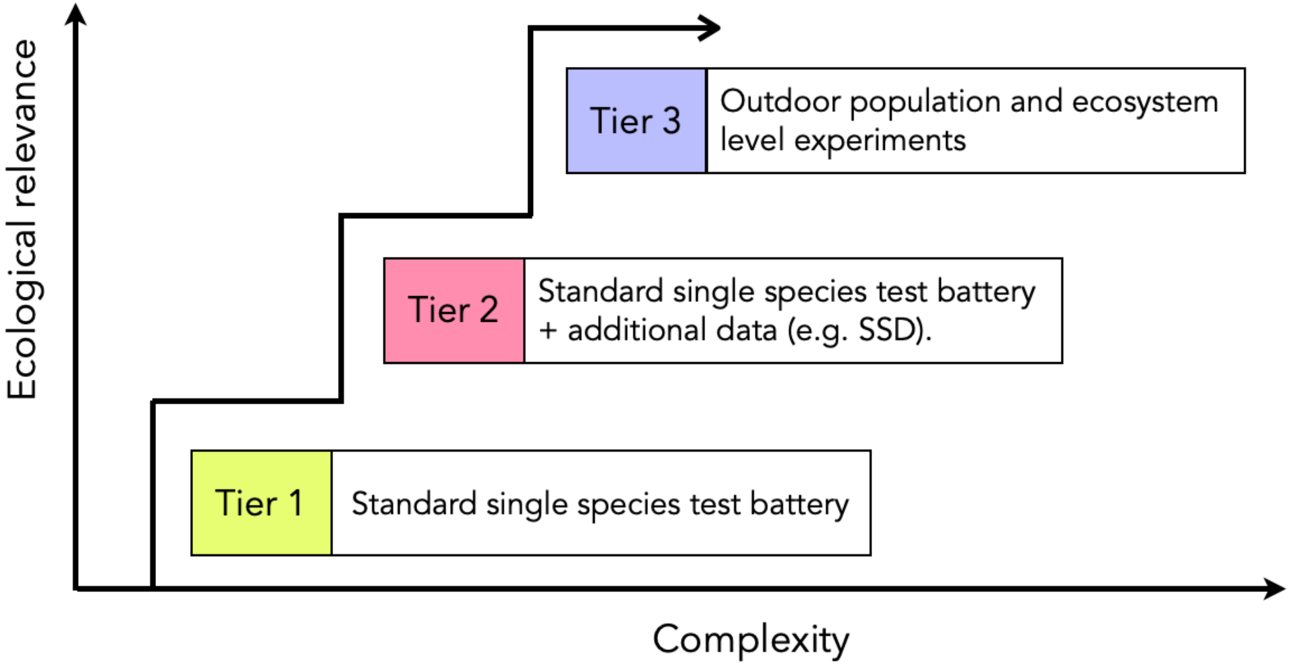
> 1 **RISK**

< 1 **NO RISK**

PEC/MEC : Predicted or Measured Environmental Concentration

PNEC: Predicted No Effect Concentration

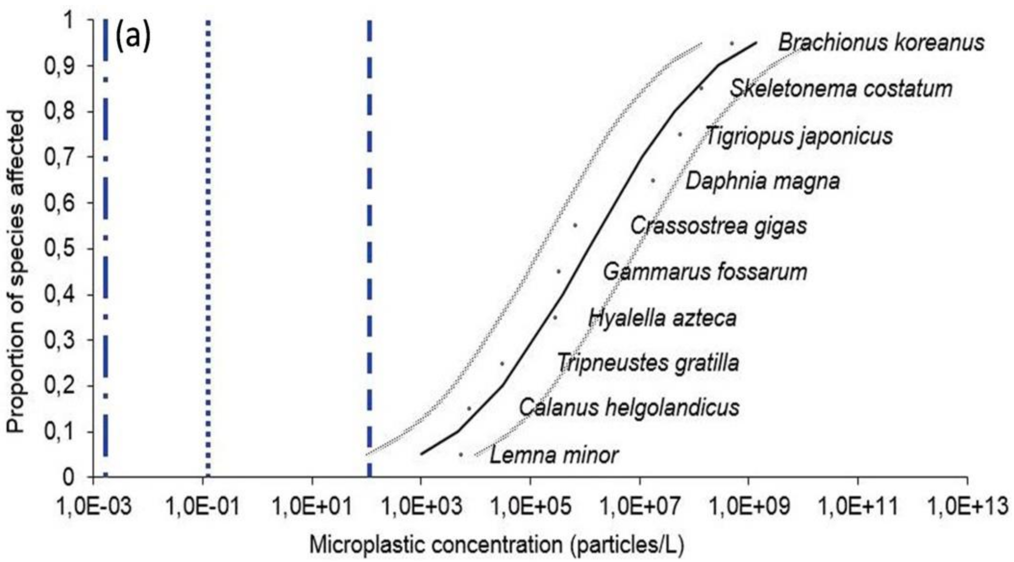
Tiered Effect Assessment



- **Ecologically relevant**
- **Complex**
- **Difficult to conduct**
- **Less data avilable**

Tier 2: Species Sensitivity Distributions (SSDs)

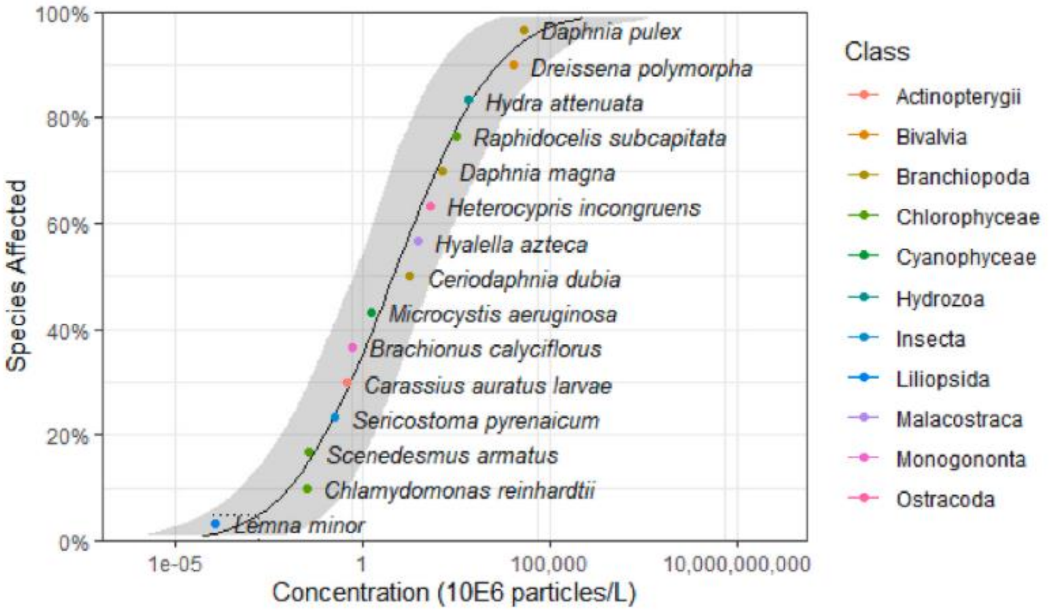
Besseling *et al*., 2019.



- **HC5: 1015 particles/L**

- **Limited data available**
- **Multidimensionality of MPs not considered**
- **Effect mechanisms not considered**

Koelmans *et al.* 2023.

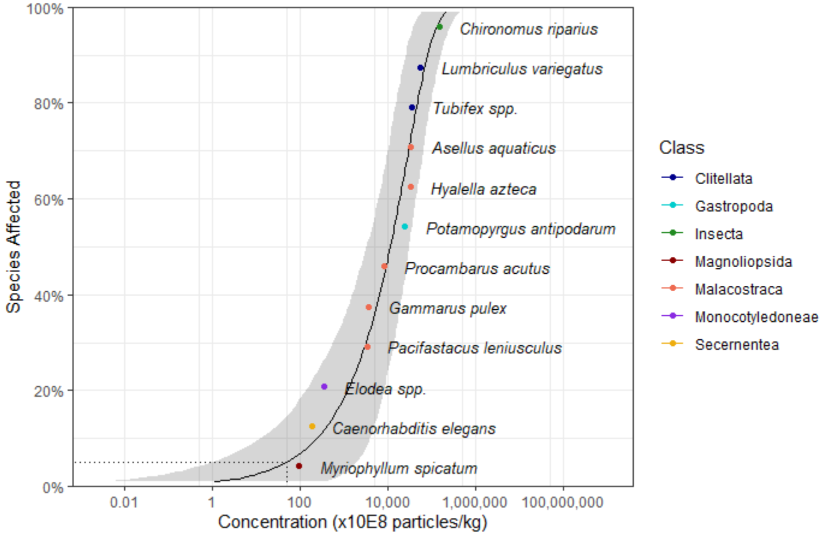


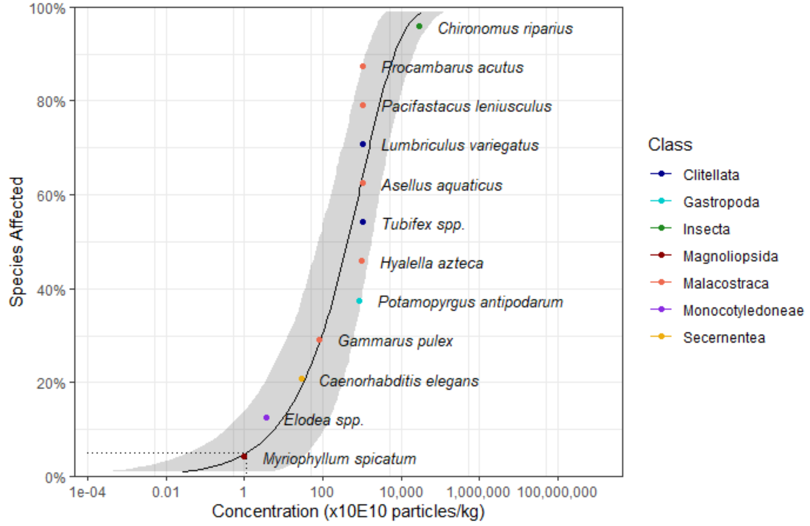
- **HC5 for food dilution: 547 particles/L**
- **HC5 for translocation: 1688 particles/L**

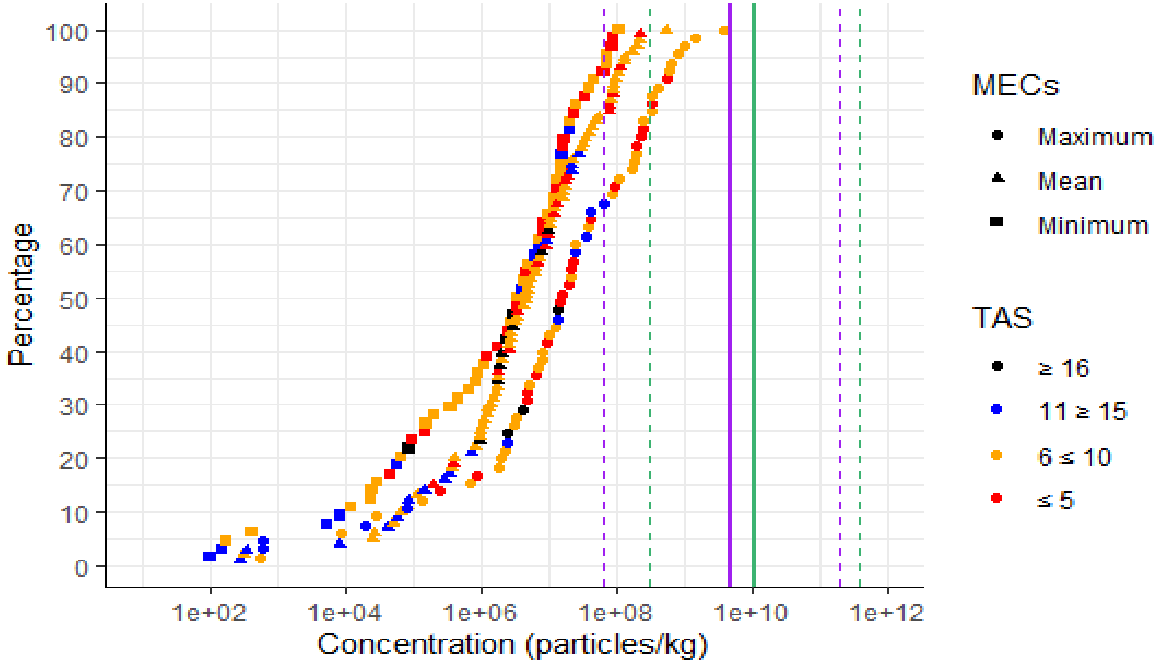
- **More data available**
- **Multidimensionality of MPs considered**
- **Effect mechanisms considered**

Tier 2: SSDs used to characterize environmental risks

Redondo-Hasselerharm *et al*., 2023.







HC5 for food dilution: 4.9 × 10^{9} particles/kg of sediment

HC5 for translocation: 1.1 × 10^{10} particles/kg of sediment

$$PNEC = \frac{HC5}{AF}$$

No AFs available for MPs

Tier 3: Outdoor community experiments

Tier 3: Community effects in freshwater ecosystems

SCIENCE ADVANCES | RESEARCH ARTICLE

ECOLOGY

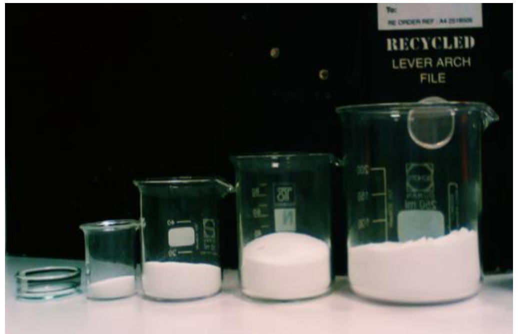
Nano- and microplastics affect the composition of freshwater benthic communities in the long term

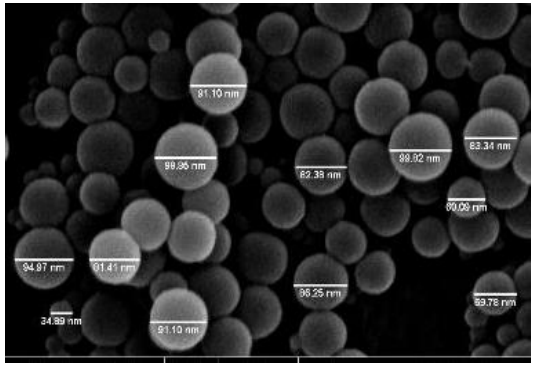
P. E. Redondo-Hasselerharm[1]*, G. Gort[2], E. T. H. M. Peeters[1], A. A. Koelmans[1]

Tier 3: Community effects in freshwater ecosystems

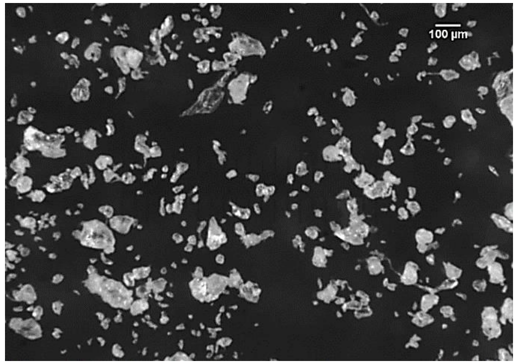
- **2 plastic types:** Nanoplastics, Microplastics
- **5 concentrations**: 0, 0.005, 0.05, 0.5, 5 % sediment dry weight
- **2 exposure times:** 3 months, 15 months

Natural sediment





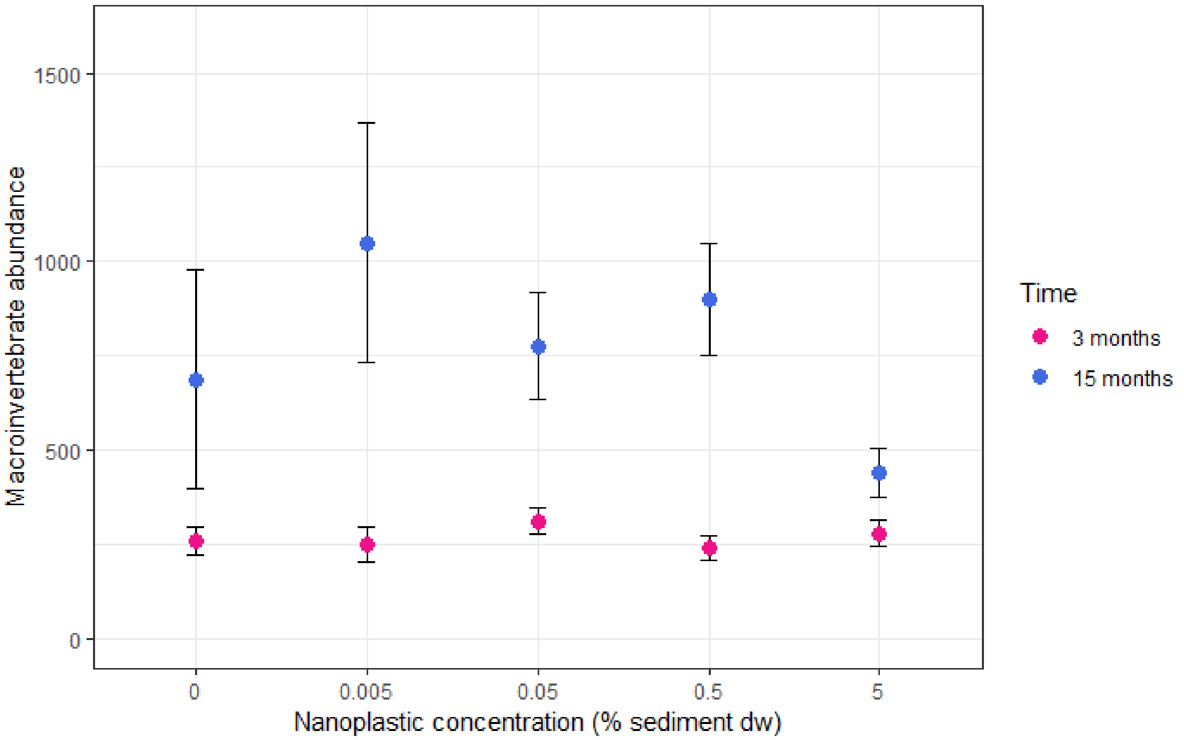
PS nanoplastics (96 nm)

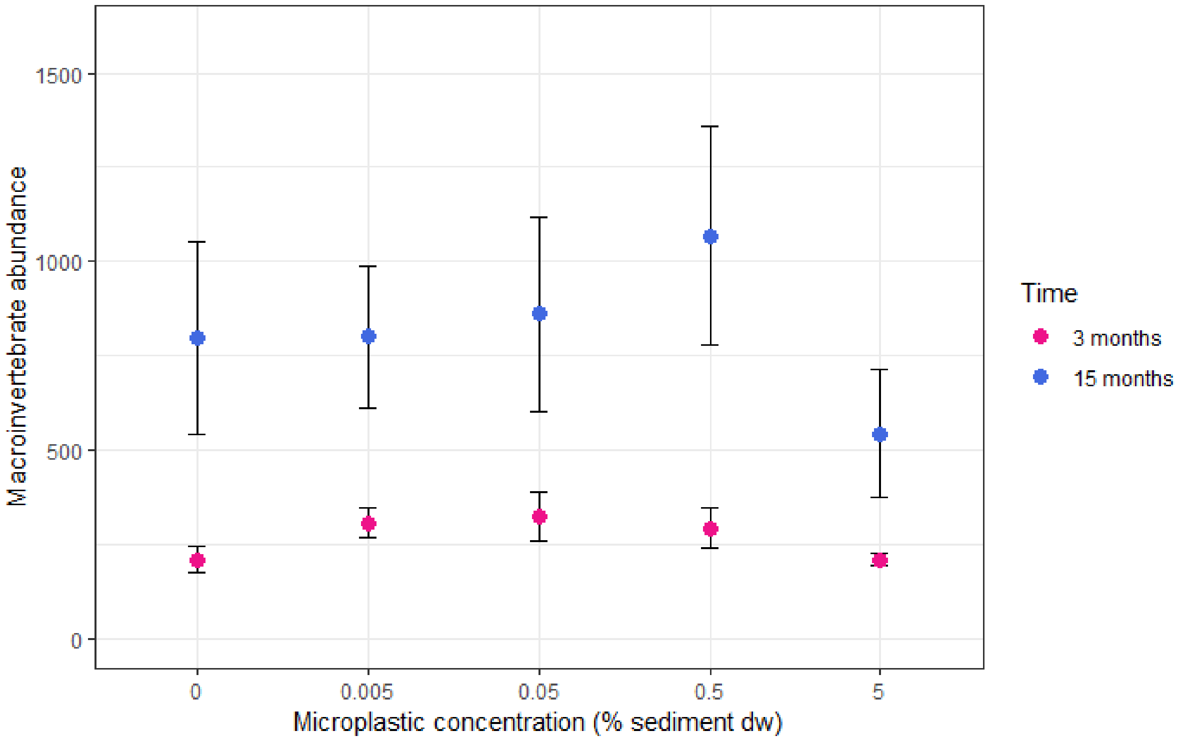


PS microplastics (20 – 516 µm)

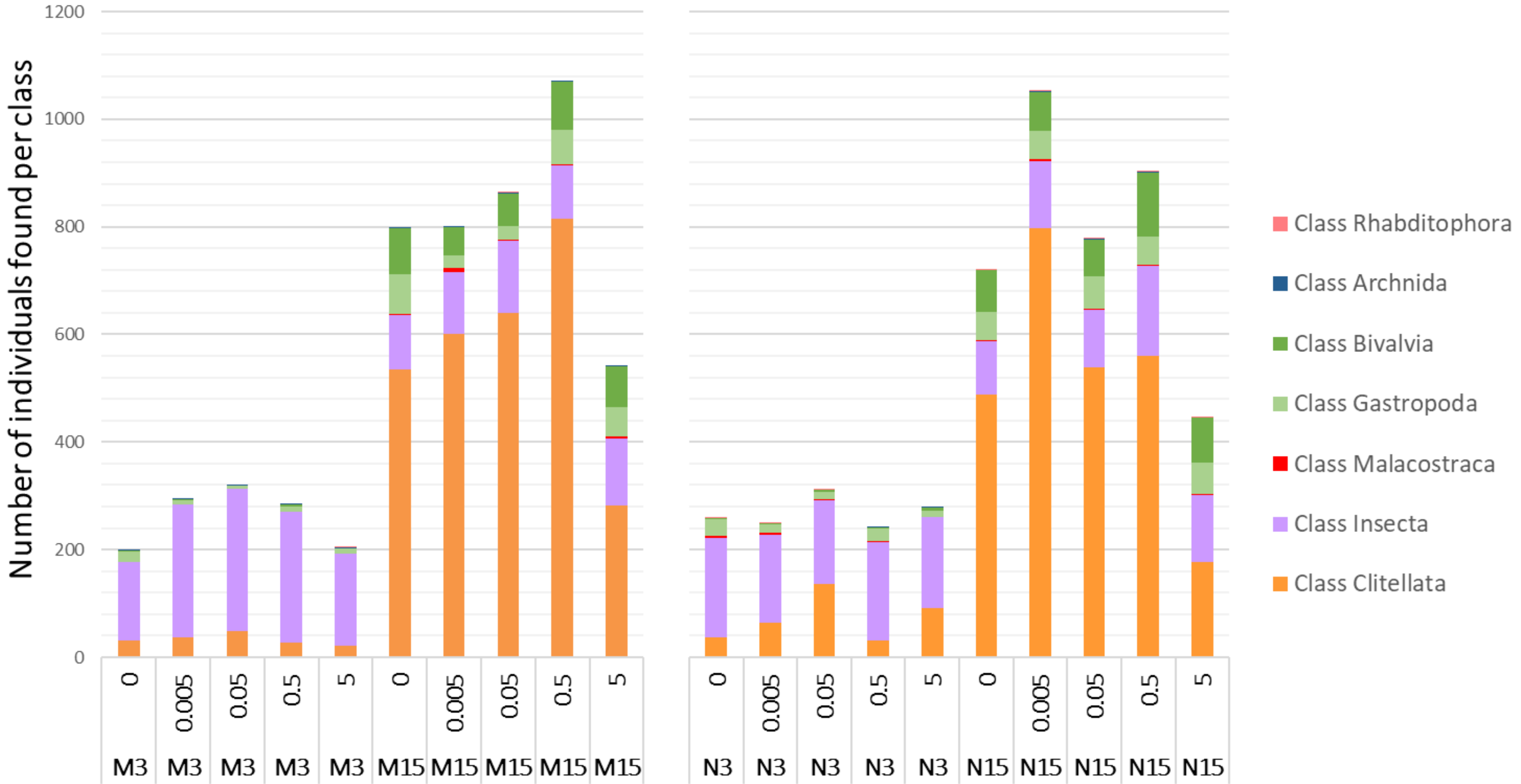
Tier 3: Community effects in freshwater ecosystems

Tier 3: Community effects in freshwater ecosystems

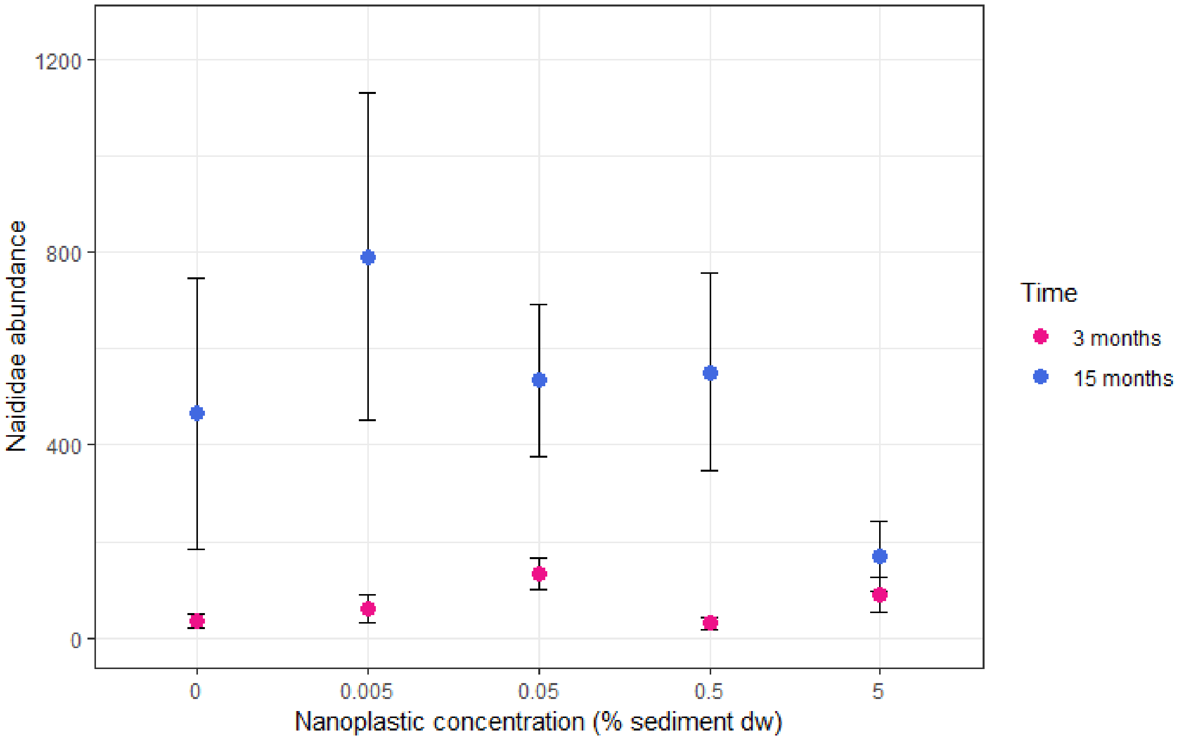


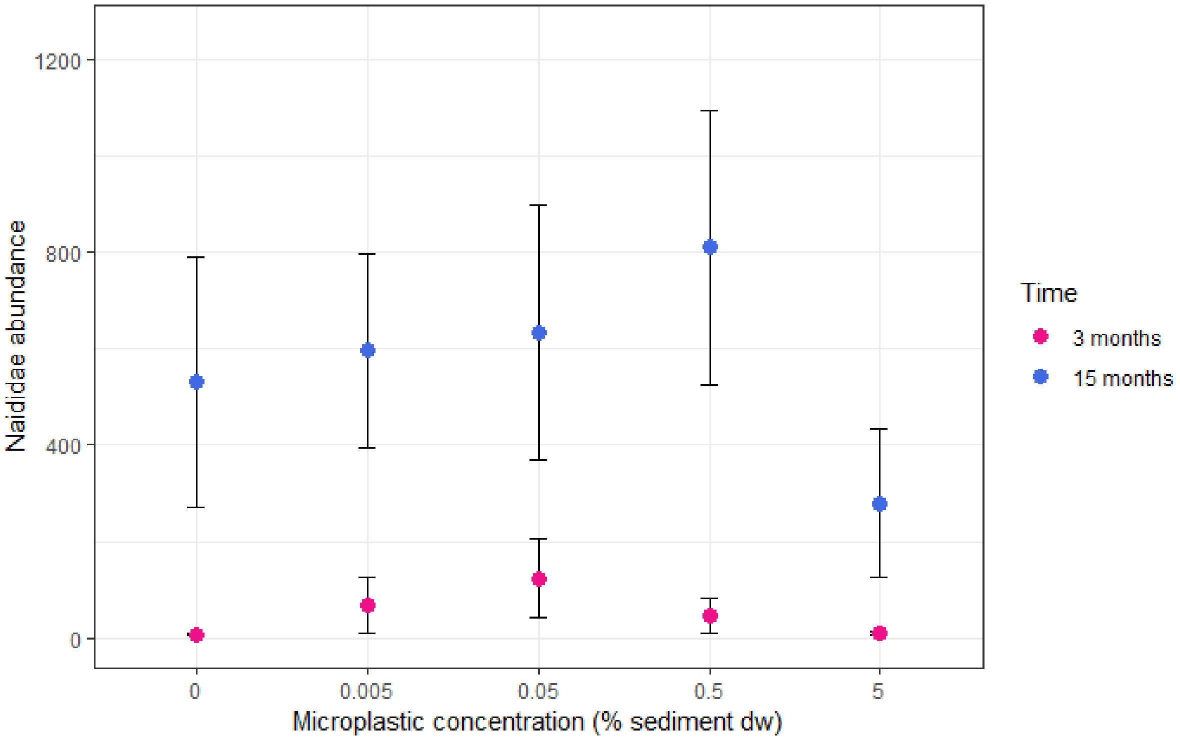


Tier 3: Community effects in freshwater ecosystems

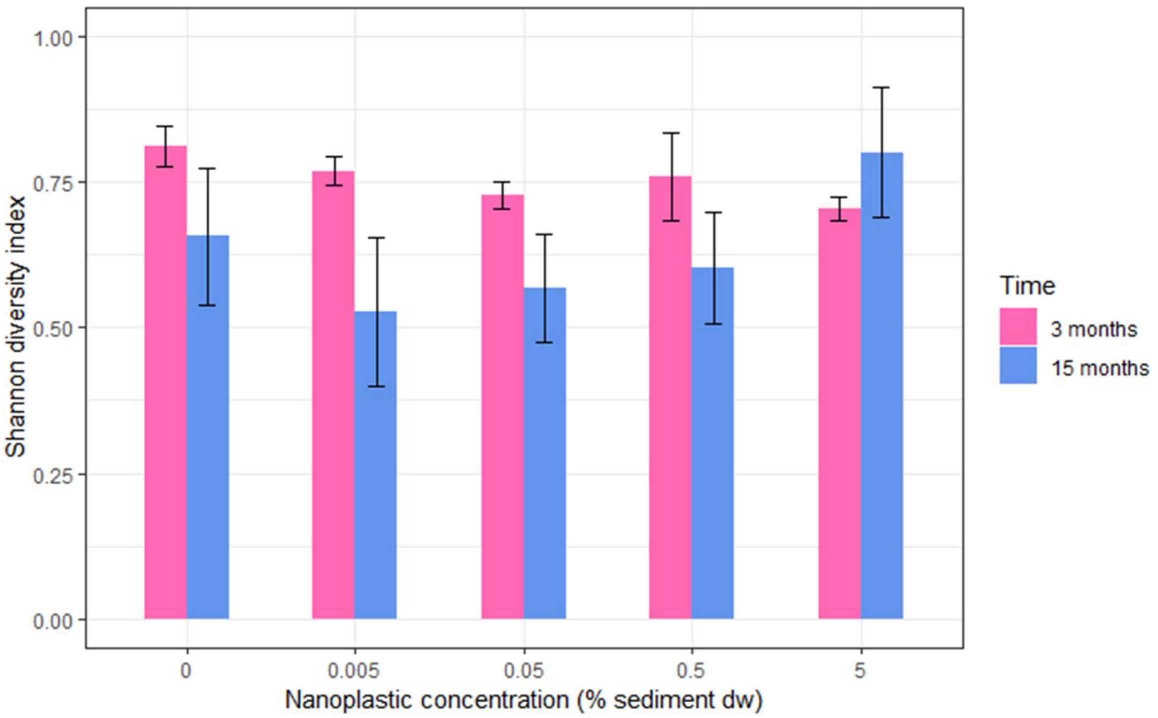


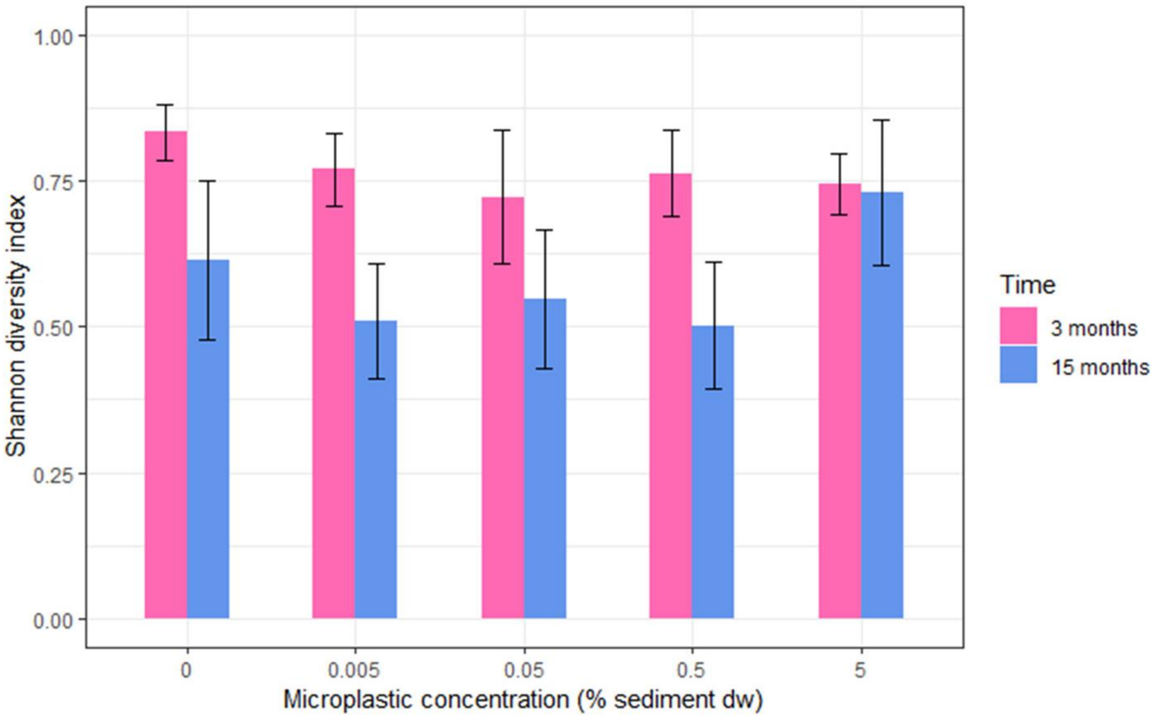
Tier 3: Community effects in freshwater ecosystems





Tier 3: Community effects in freshwater ecosystems

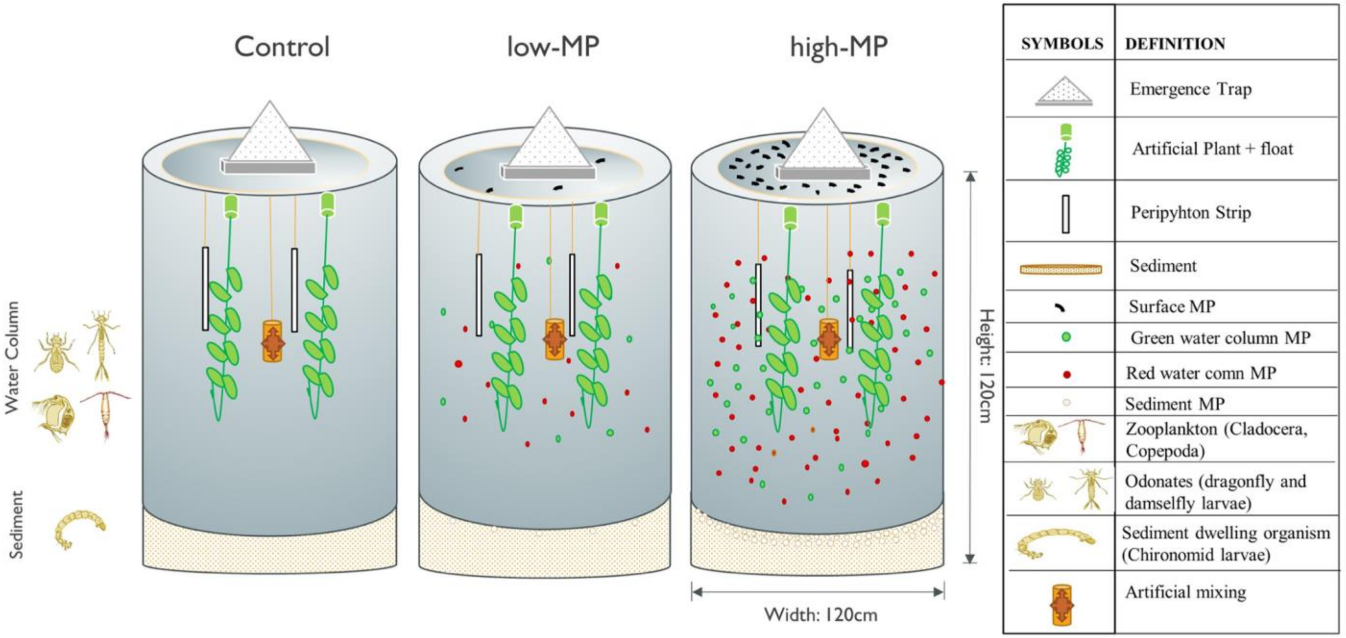


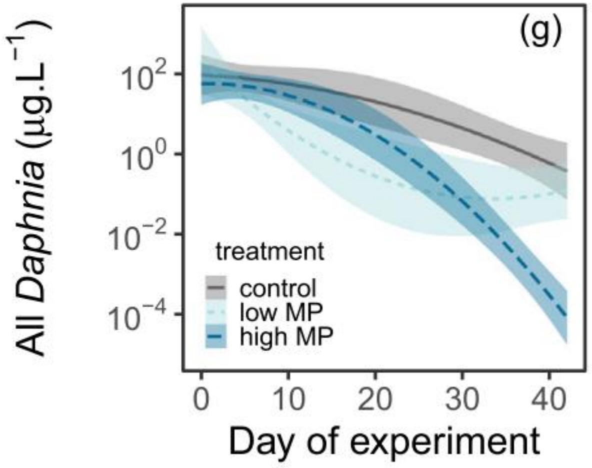


Tier 3: Community effects in freshwater ecosystems

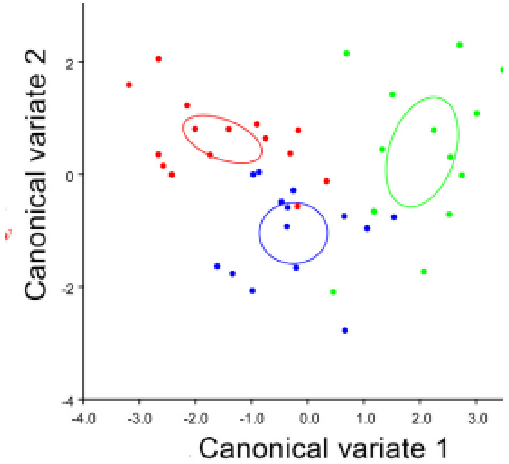
<u>Yıldız *et al.*, 2022</u>

- **Mixture of MPs:** < 500 µm
  - **PE + PP** added to surface and column
  - **PS, PVC, PA, PET** added to sediment
- **3 concentrations**: control, low, high
- **1 exposure time:** 42 days





Biomass



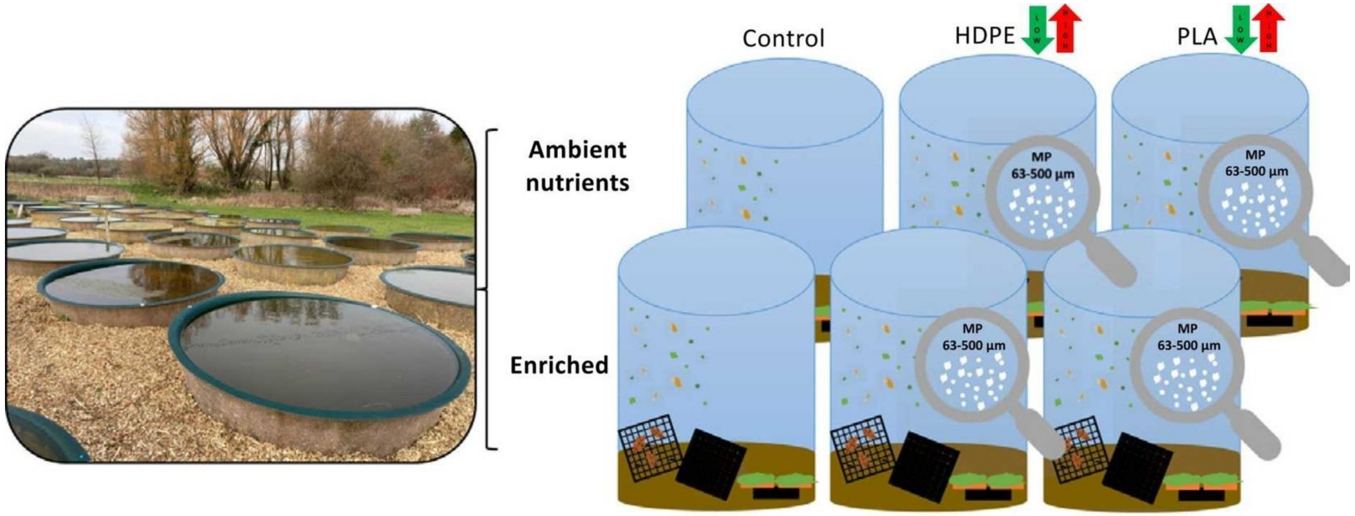
Control
Low MP concentration
High MP concentration

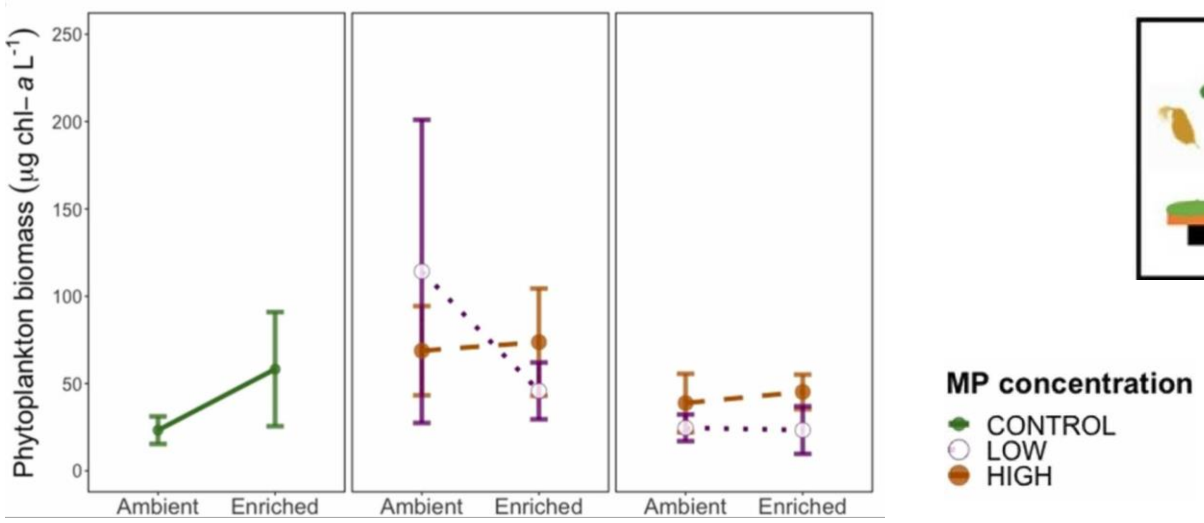
Wing morphologies

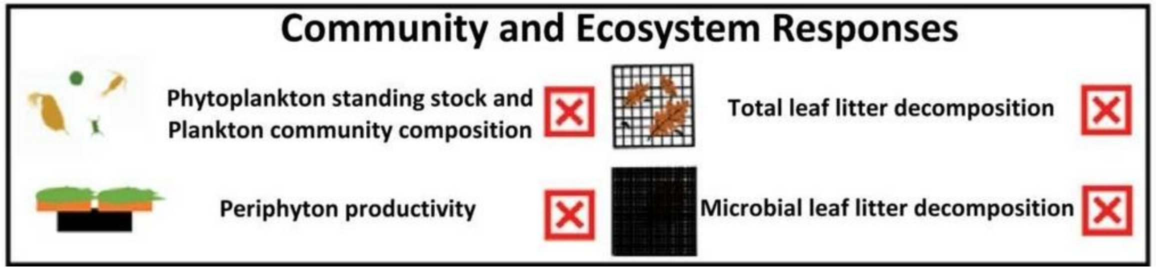
Tier 3: Community effects in freshwater ecosystems

Marchant *et al.*, 2023

- **2 plastic types:** 12.5 – 500 µm HDPE and PLA
- **3 concentrations**: 0, 1000 and 220000 particles/L
- **2 nutrient conditions**: ambient and enriched
- **1 exposure time:** 12 weeks



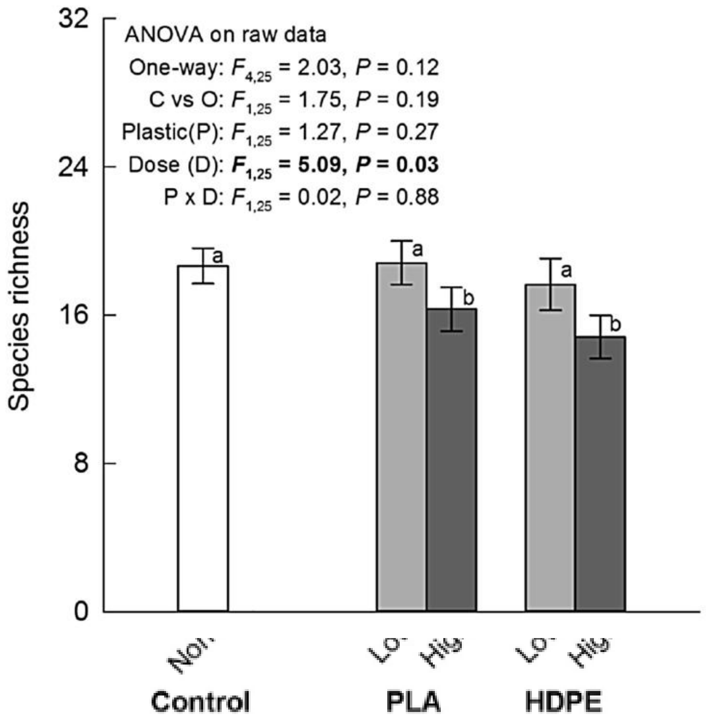




Tier 3: Community effects in marine ecosystems

<u>Green *et al.*, 2016.</u>

- **2 plastic types:** PLA (0.48 – 316 µm) and HDPE (0.6 – 363 µm)
- **3 concentrations**: 0, 0.8 and 80 µg/L
- **1 exposure time:** 60 days



Littorina sp. (periwinkle)

Idotea balthica (isopod)

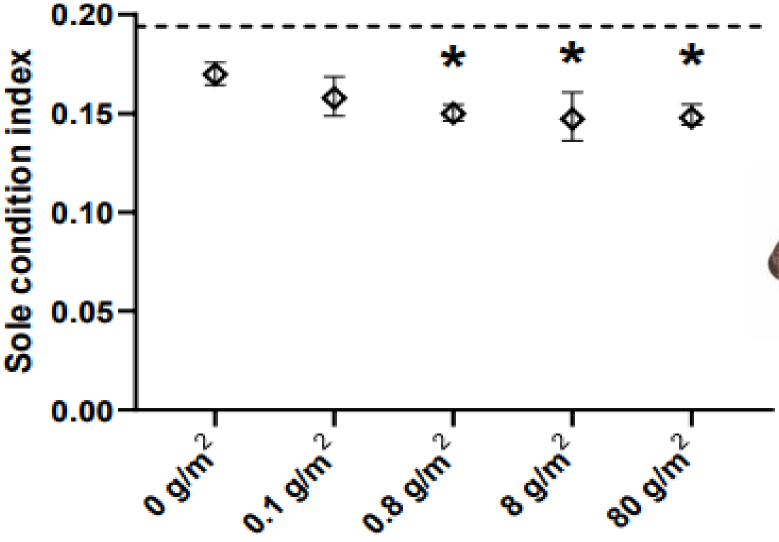
Scrobicularia plana (clam)

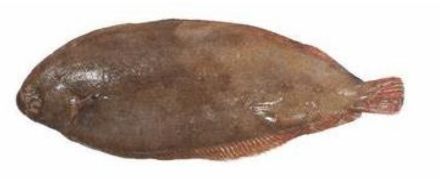


Tier 3: Community effects in marine ecosystems

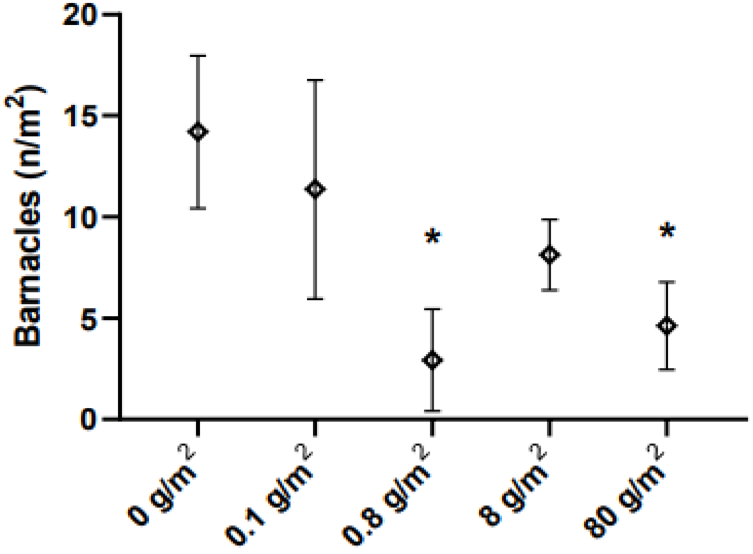
<u>Foekema *et al.*, 2022.</u>

- **1 plastic type:** 700 µm PS spheres
- **5 concentrations**: 0, 0.1, 0.8, 8, 80 g/m^3
- **1 exposure time:** 2 months





Solea solea

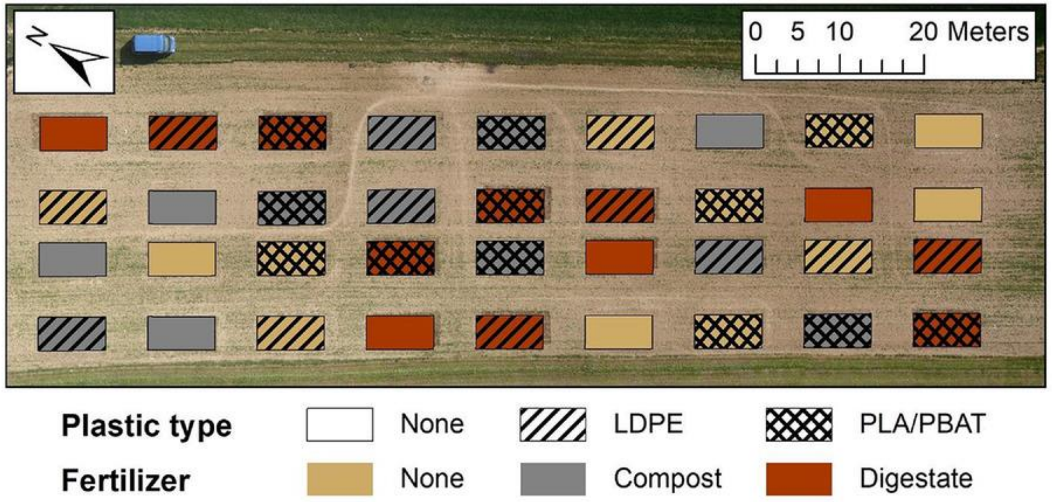


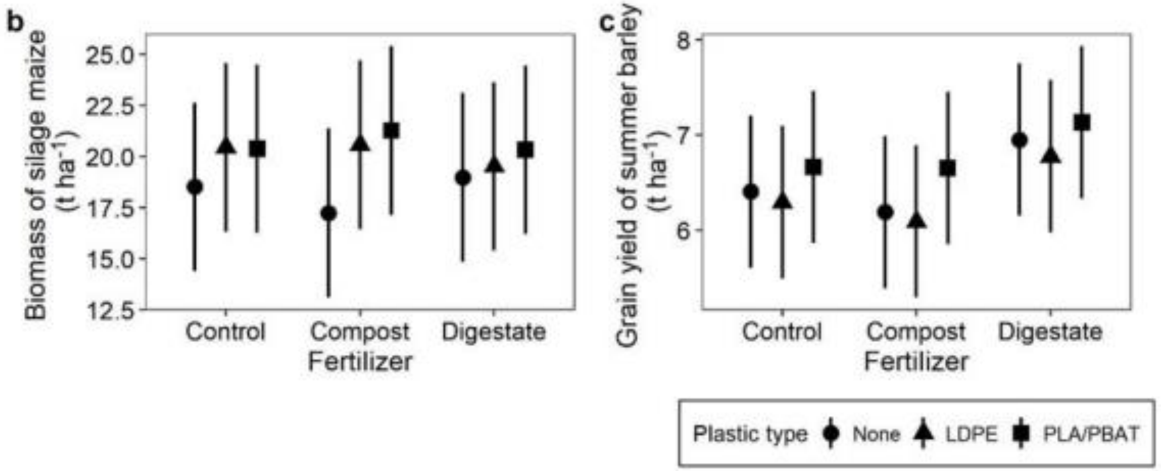
Semibalanus balanoides

Tier 3: Community effects in terrestrial ecosystems

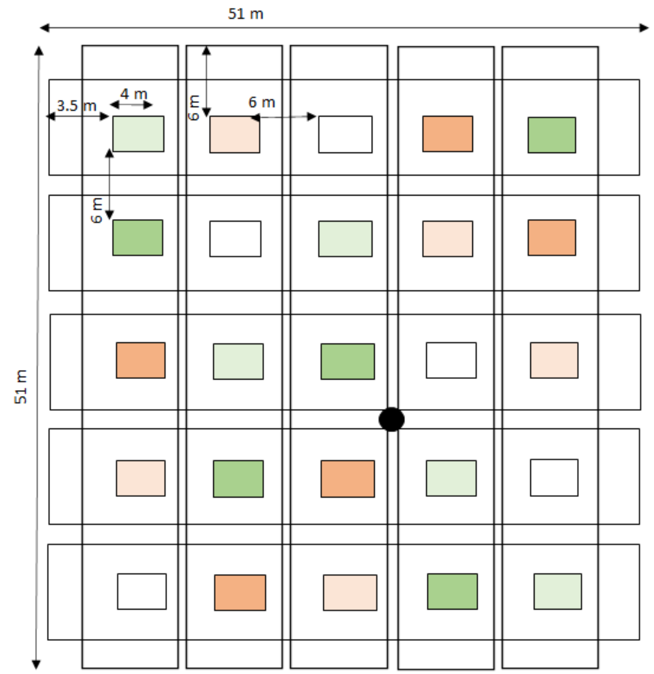
<u>Schöpfer *et al*., 2022.</u>

- **2 plastic types:** LDPE and PLA/PBAT
- **2 concentrations of MPs**: 0 and 20 kg/ha
- **2 fertilizer types**: compost and digestate (10 t/ha)
- **1 exposure time:** 1.5 years





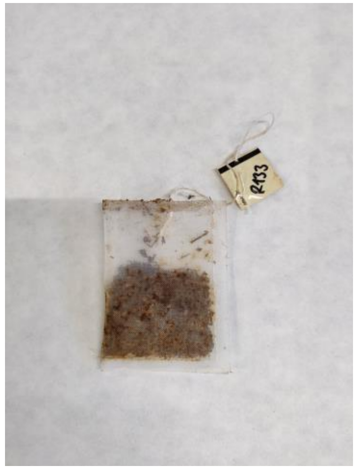
Tier 3: Community effects in terrestrial ecosystems



- MP1C1: PE microplastic (MP) concentration 1
- MP1C2: PE microplastic (MP) concentration 2
- MP2C1: Biodegradable MP concentration 1
- MP2C2: Biodegradable MP concentration 2
- C0: Control

Tier 3: Community effects in terrestrial ecosystems

Endpoints	Description
Litter degradation	"Teabag" experiment with teas of different decomposition rates
Impacts on plants during growth season	Plant characteristics at flag leaf stage
Agricultural performance at harvesting	Grain yield, harvest index and grain quality factors
Fate of microplastics and plastic additives	Distribution of microplastics and plastic additives in soils, earthworms and earthworm faeces
Soil ecosystem in post harvesting: - **Soil properties**	Bulk density, soil moisture content, soil aggregation
- **Microbial community and activity**	DNA amplicon sequencing, microbial activity
- **Soil invertebrates**	Earthworm and microarthropod abundance and community structure. Accumulation of microplastics in earthworm body and faeces.



Tier 3: PNEC calculation

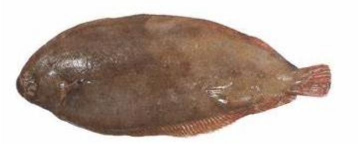
- **NOEC Naididae**: 5 g/kg sediment DW (Redondo-Hasselerharm *et al*., 2020)
- **NOEC Chironomidae:** 0.007 g/m^2 in water surface (PE, PP), 2 g/m^3 in water column (PE), and 8 g/m^2 in sediment (PS, PVC, PA, PET) (Yıldız *et al*., 2022).
- **NOEC Daphnia**: 0.07 g/m^2 in water surface (PE, PP), 20 g/m^3 in water column (PE), and 80 g/m^2 in sediment (PS, PVC, PA, PET) (Yıldız *et al*., 2022).
- **NOEC Periwinkles** (*Littorina sp.*), **Isopods** (*Idotea balthica*) and **Clams** (*Scrobicularia plana*): 80 µg/L (Senga-Green, 2016)
- **NOEC Barnacles** (*Semibalanus balanoides*) and **Sole** (*Solea solea*) : 0.8 g/m^3 (Foekema *et al*., 2022)

$$PNEC = \frac{Lowest\ NOEC\ population\ or\ NOEC\ community}{AF}$$







No AFs available for MPs

Tier 3: Assessment Factor

Technical Guidance for Deriving Environmental Quality Standards (2011): **AF 1 – 5.**

Selecting an AF to apply to a mesocosm NOEC

According to the REACH guidance, the AF applied to mesocosm studies or (semi-) field data will need to be reviewed on a case-by-case basis (footnote 'f' to Table 3.2), but no guidance is given with respect to the *range* of AFs to be applied. Brock et al. (2008) compared micro/mesocosm experiments for several chemicals in which long-term exposure was simulated. They estimated a geographical extrapolation factor based on the ratio of the upper and lower limit of the 95% confidence interval of NOECs for toxic effects. These factors ranged between 1.4 and 5.4. This suggests that, where there is (a) only a single model ecosystem study, and (b) sensitive taxa are included in the study of a compound with a specific mode of action, an assessment factor of 5 would account for variation in the NOECs. When additional, confirmative mesocosm studies are available, the AF may be lowered. Further discussion around the selection of AFs on mesocosm studies is to be found in Giddings et al (2002).

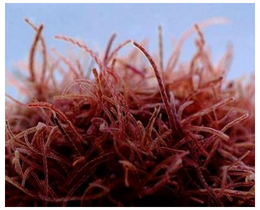
EFSA Guidance on Tiered Risk Assessment for Plant Protection Products: **AF 2 – 4.**

Table 8: Proposal for the derivation of the $RAC_{sw;ac}$ (triggered by tier 1 acute core data) addressing the ETO on the basis of an appropriate micro-/mesocosm experiment. Note that, in the same study, several treatment levels may result in effect class 1 responses for sensitive measurement endpoints. In that case, the highest treatment level showing an overall effect class 1 response should be selected for ETO-RAC derivation. Alternatively, if, in the same study, several treatments result in effect class 2 responses in the first instance, the lowest treatment level showing an overall effect class 2 response should be selected for ETO-RAC derivation. On a case-by-case basis, and with expert judgement, it may be decided to select a higher treatment level as overall effect class 2 concentration.

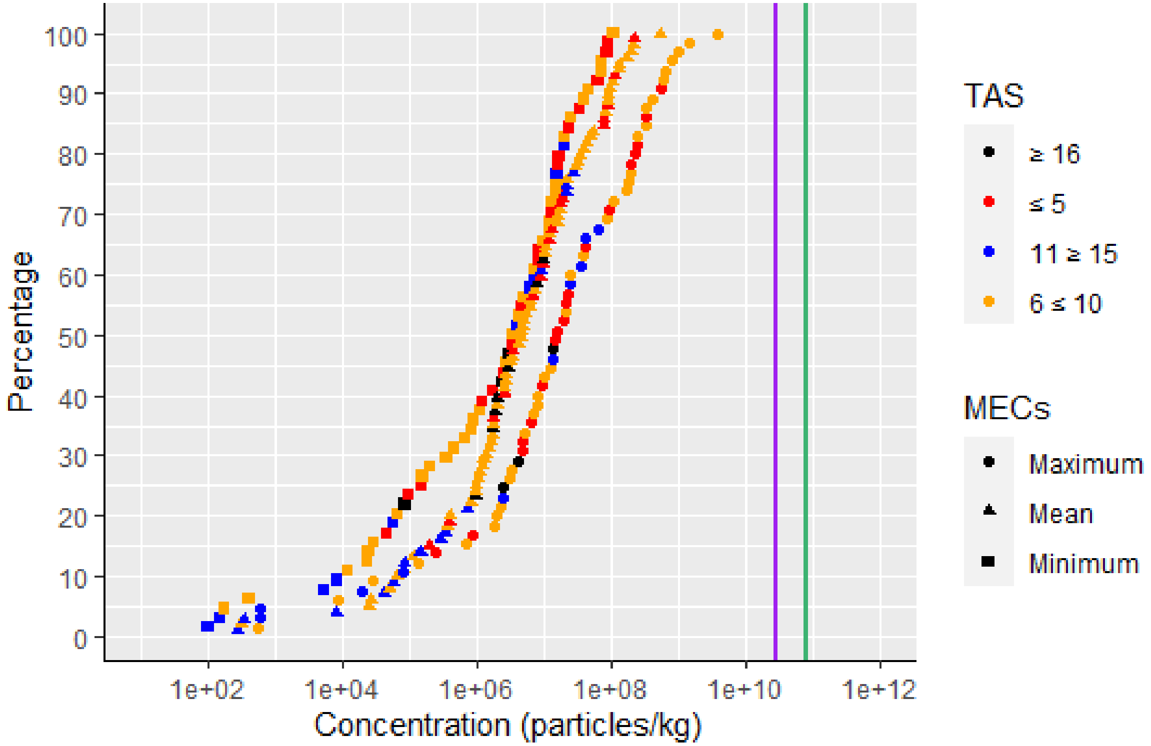
	Assessment factor for ETO-$RAC_{sw;ac}$ derivation (ecological threshold option)	**Field exposure concentration to compare with the $RAC_{sw;ac}$**
Effect class 1 concentration		
Is rate of dissipation of the a.s. in test system	2[(a)]	$PEC_{sw;max}$

Tier 3: PNEC calculation

- **NOEC Naididae**: 5 g/kg sediment DW (Redondo-Hasselerharm *et al*., 2020)

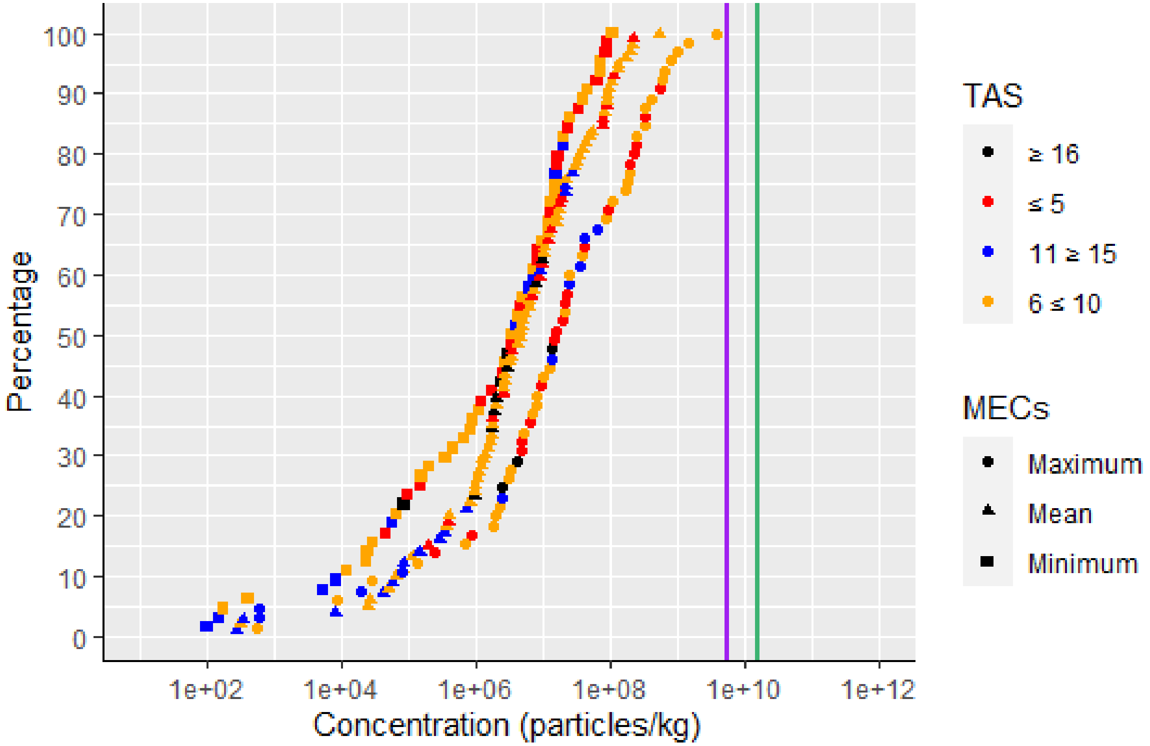


PNEC = NOEC (no AF used)



NO RISK

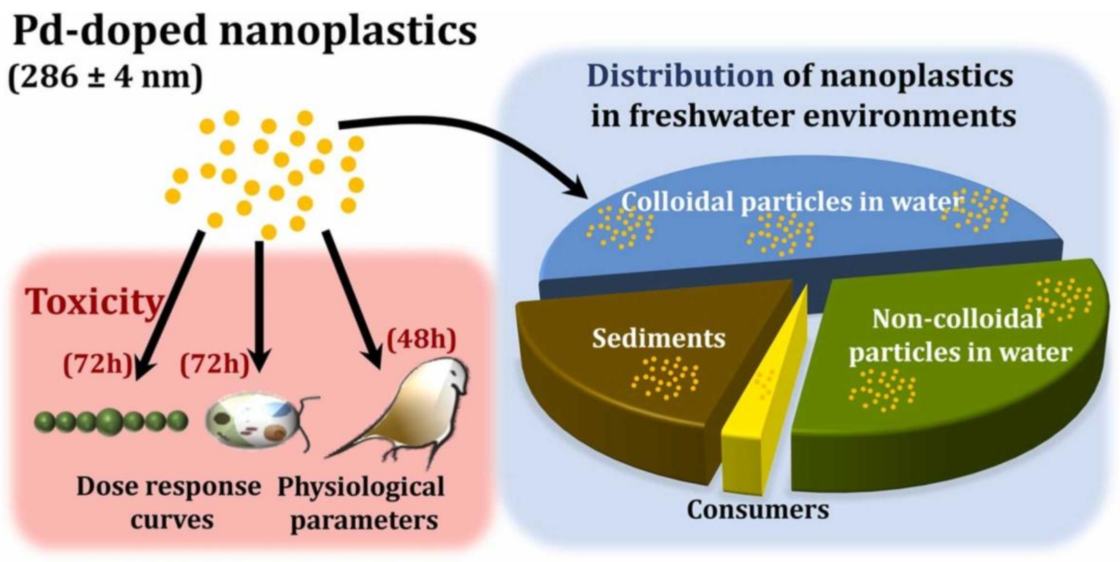
PNEC = NOEC/AF=5

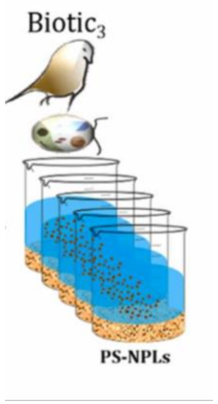


NO RISK

Tier 3: What about nanoplastics?

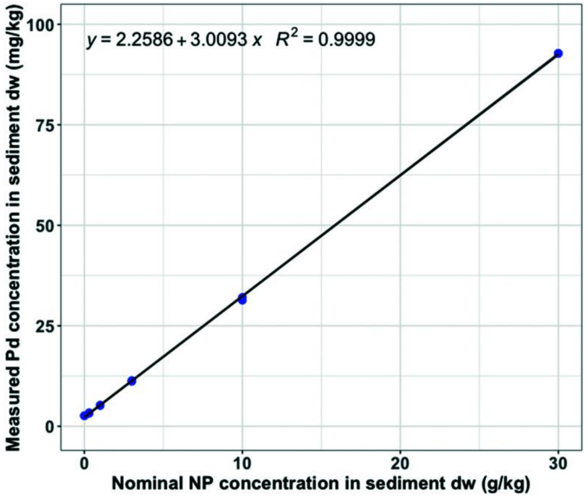
Tamayo-Belda *et al.* 2023

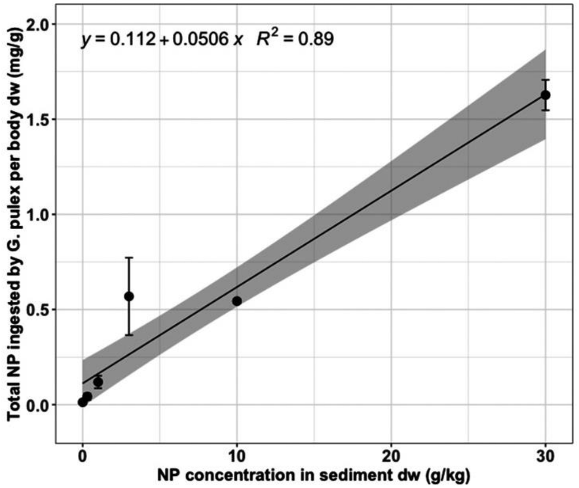




- No other outdoor population or community experiments found
- Difficult and expensive to generate large quantities of NPs, and to analyze

Redondo-Hasselerharm *et al.* 2021





Conclusions

- **Tier 2** Risk Assesment more reliable over time due to:
  - Larger datasets available, allowing for a **better screening of the data** (ecosystems, endpoints, QA/QC)
  - **Alignment** of the exposure and effect data
  - Consideration of **effect mechanisms**

- **Tier 3**, several outdoor ecosytem experiments conducted with MPs. However:
  - Only one experiment **> 3 months**
  - All experiments conducted in **plastic containers**
  - Microplastic **fate and ingestion** often not assessed
  - Difficulties to identify **effect mechanisms**
  - Need to apply **alignments** to current available data
  - Risk assessment done showed **no risks** at current MP concentrations in sediment

- **Guidelines for the testing of NMPs in mesocosms and their use in risk assessment needed**

Thank you for your attention!

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Ministry of Health, Welfare and Sport

Ministry of Infrastructure and the Environment

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