Nano- and microplastic exposure effects in algae: A Meta-Analysis

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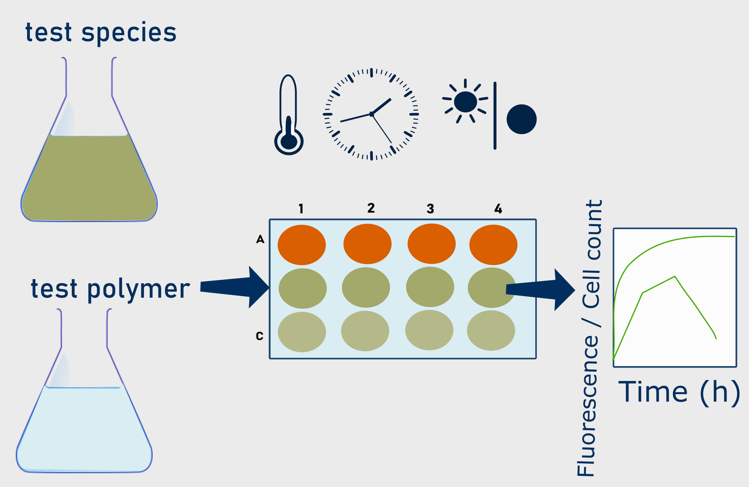
Background

- ecological impacts of nano-and microplastic particles are among the most discussed environmental concerns
- usually hypothesized to reduce growth among aquatic species
- algae form the base of the food web, therefore evaluating their response to the exposure is crucial for the aquatic foodweb
- yet, the the reported outcomes vary from growth inhibition to stimulation of growth using OECD-like standard tests
- this fuels a conflict of information and a data synthesis for risk assessment regarding polymers potential growth inhibition is needed
- using a meta-analysis we aim to synthesis study outcomes to facilitate reliable hazard assessment

OECD - standard test



Meta-analysis

- meta-analysis permits an evaluation of the effect sizes across different studies
  - increased sample size, and analysing the variability between and among study entries
  - the technique allows genealisation of tendencies, identififying predictors
    - outcome new hypothesis and experimental designs can be generated

H1: Exposure to plastic particles causes growth inhibition, which is concentration dependent.

H2: Particle size, shape, and polymer material contribute significantly to the effect size.

H3: The inhibitory effect decreases with increasing exposure duration.

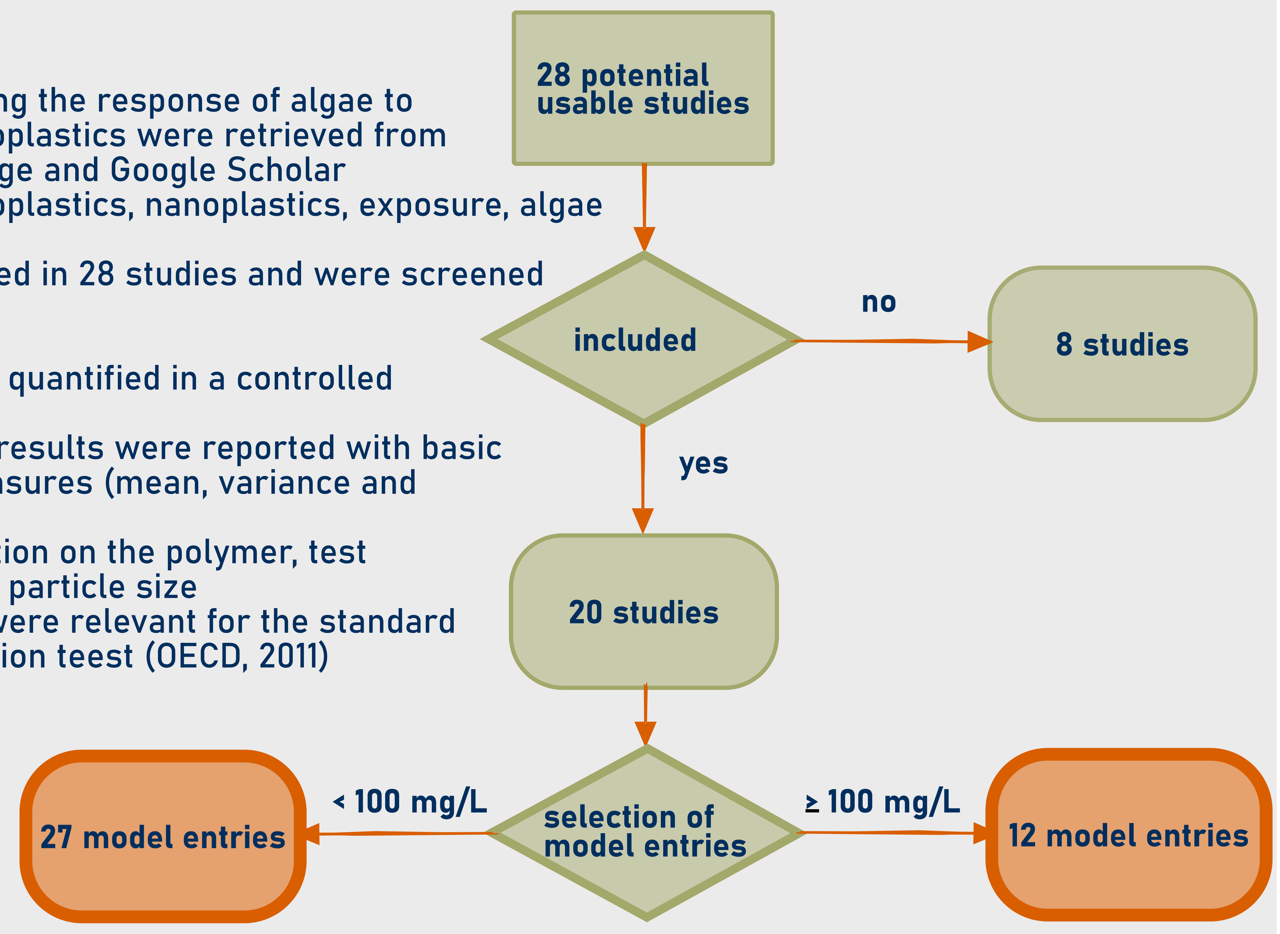
H4: Freshwater and marine species respond similarly to the exposure of micro-and nanoparticles.

Data acquisition

- studies examining the response of algae to nano- and microplastics were retrieved from Web of Knowledge and Google Scholar
- Keywords: microplastics, nanoplastics, exposure, algae

- the search yielded in 28 studies and were screened according:

(i) exposure was quantified in a controlled experiment
(ii) experimental results were reported with basic statistical measures (mean, variance and sample size)
(iii) basic information on the polymer, test concentration, particle size
(iv) the endpoint were relevant for the standard growth inhibition teest (OECD, 2011)



Meta-analysis- Models

- the data was grouped according to the particle concentration tested (100 mg/L)
- (i) Low- concentration model - no-effect expected
- (ii) High- concentration model - growth inhibition expected

Moderators

- Particle shape
- Polymer size
- Particle concentration
- Polymer density
- Algae lifeform
- Polymer-type

Calculation of effect sizes

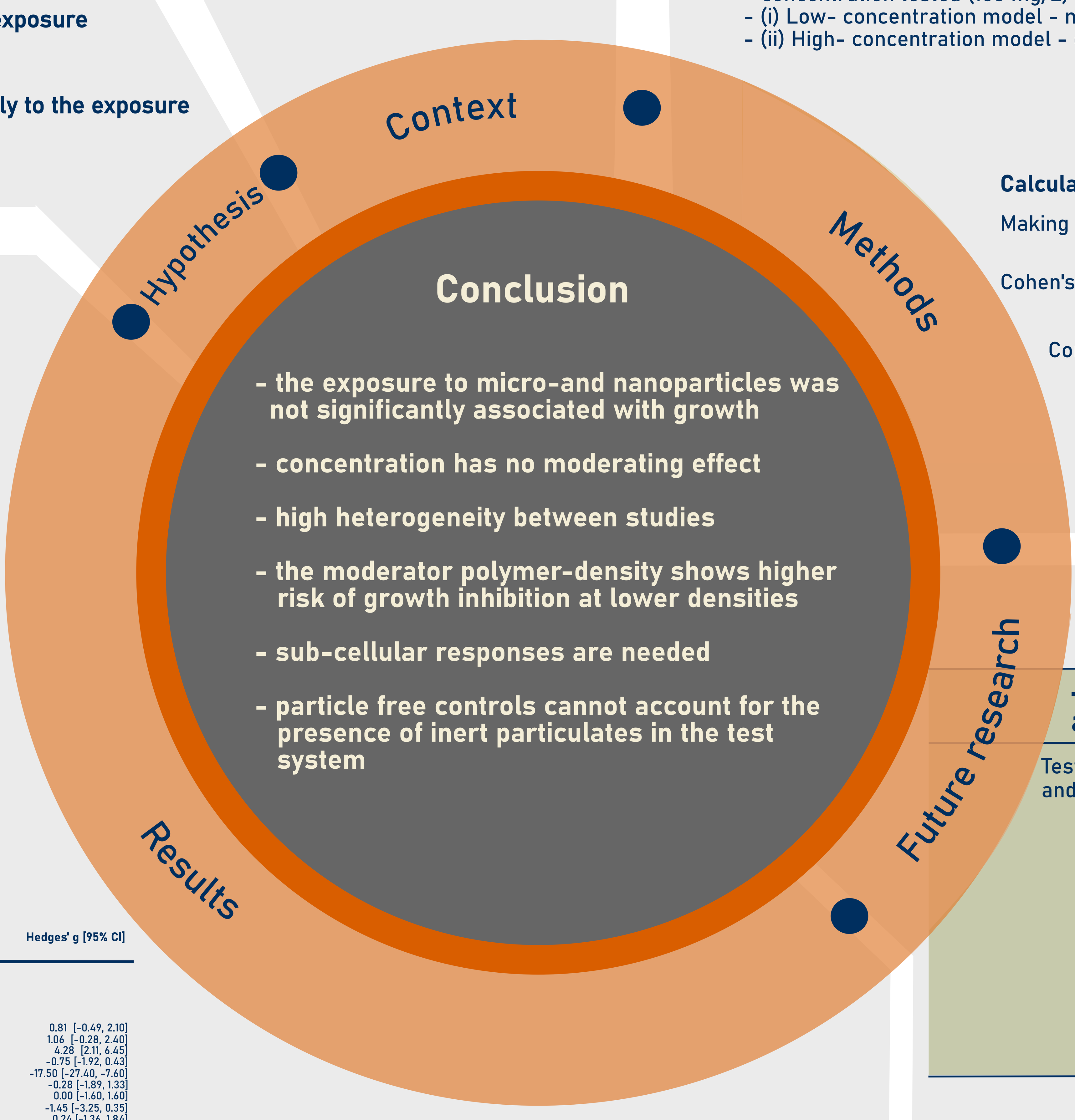
Making effects comparable

Cohen's d : $d = (Mean_T - Mean_C) / \sqrt{\frac{n_T - 1 \cdot SD_T^2 + n_C - 1 \cdot SD_C^2}{n_T - n_C - 2}}$

Correction factor J: $J = 1 - \frac{3}{4 \cdot (df - 1)}$

Hedge's g : $g = J \cdot d$

Sampling Variance V : $V = \frac{(n_T + n_C)}{(n_T \cdot n_C)} + \frac{g^2}{2 \cdot (n_T + n_C)}$



Conclusion

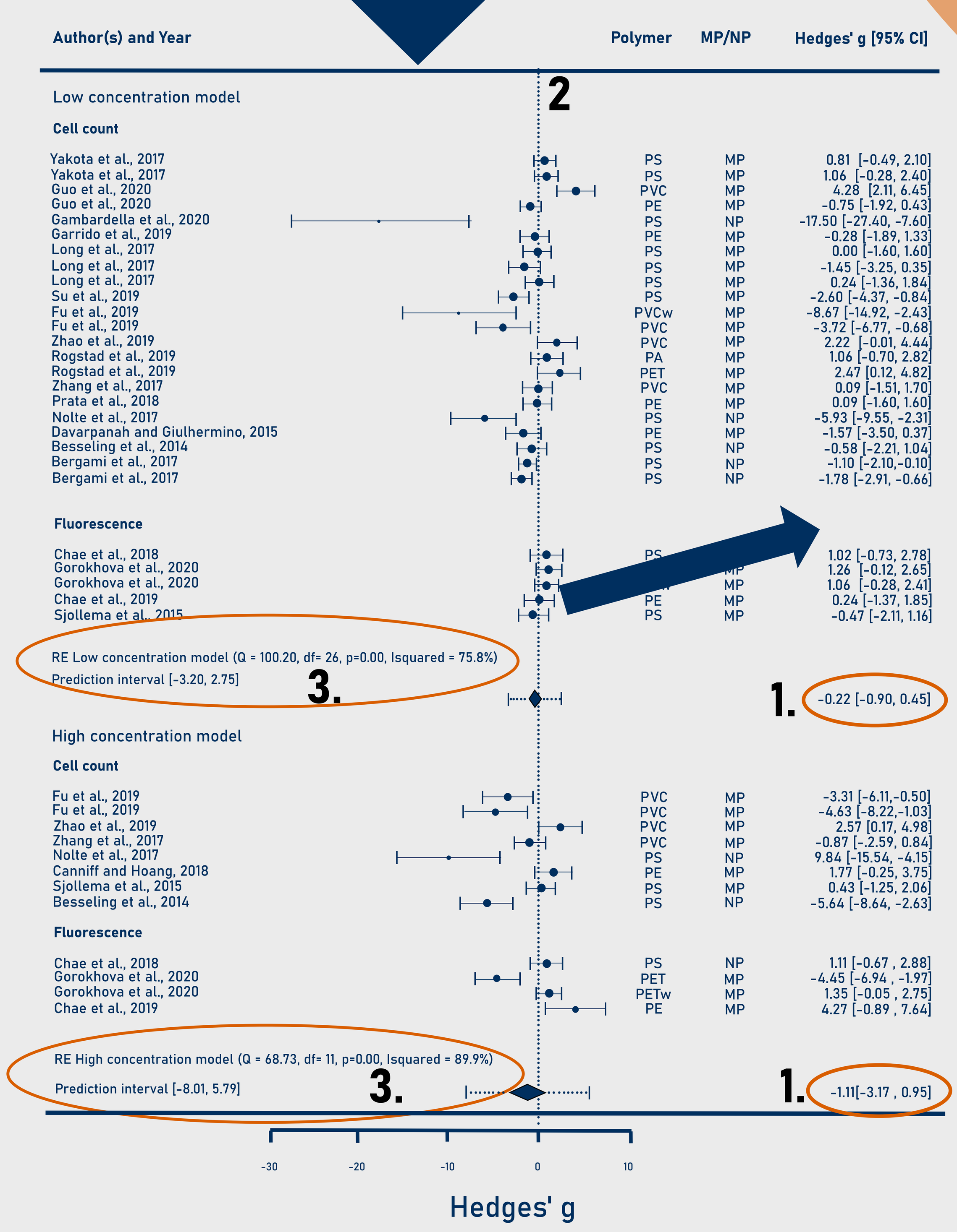
- the exposure to micro-and nanoparticles was not significantly associated with growth
- concentration has no moderating effect
- high heterogeneity between studies
- the moderator polymer-density shows higher risk of growth inhibition at lower densities
- sub-cellular responses are needed
- particle free controls cannot account for the presence of inert particulates in the test system

Outcomes

1. both models don't show significant effects
2. outcomes range from 12-57% inhibition to neutral effects or even stimulated growth (56%)
3. strong heterogeneity only partially explained by moderators
4. strong publication yet, does not alter model outcome

H1: No clear indication that exposure effect is related to MNP concentration.
H2: The Low-concentration model showed a significant stimulating effects on growth (N=6). Yet, particle size nor polymer-type do not have a significant effect.
H3: Growth inhibition effect did not decreased with increasing exposure duration.
H4: Fresh-and saltwater algae react similar to the exposure.

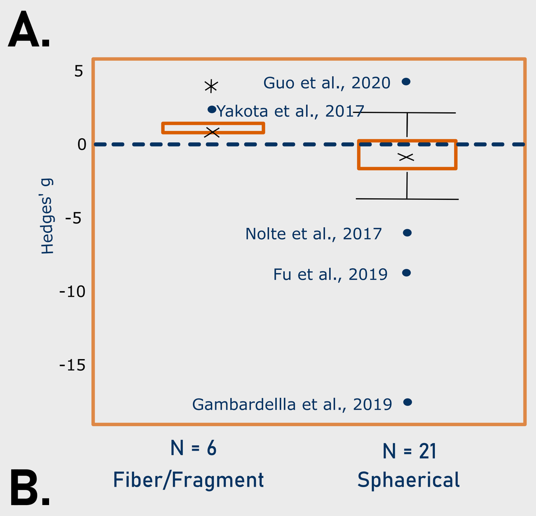
Forest plot



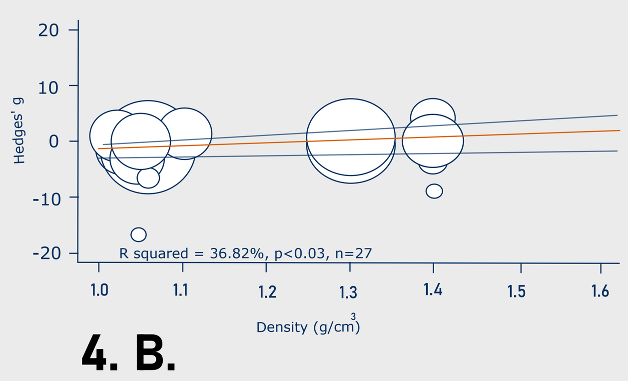
3. Moderator

- particle shape: fiber/fragments stimulate growth
- polymer density: lower density higher toxicity
- other moderator did not account for the heterogeneity of the model outcomes

3. A.



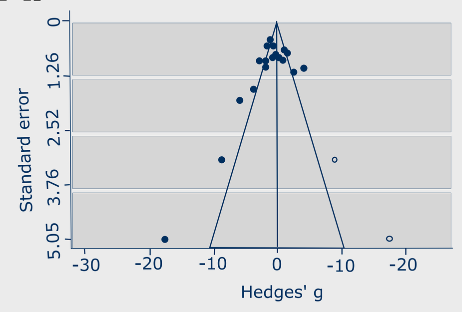
3. B.



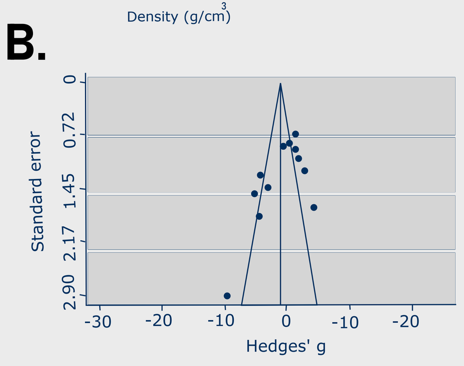
4. Publication bias

- Trim and Fill- method showed missing studies with stimulating effects.
- the model results did not change

4. A.



4. B.



Test aspects	Recommendations
Test material and test species	- well-characterized test material in terms of the poly-mer and particle size distribution; - more studies on non-spaerical and weathered plastic particles are needed; - non-virgin plastics need to be used representatively; - phylogenetically diverse taxa, both marine and freshwater; - experimental endpoints should include parametersgrowth and subcellular mechanisms;
Equipment considerations and exposureconditions	- controls should include both particle-free and particle controls, with natural particles or benchmark plastics particles; - keep the exposure vessels in suspension; to provide constant exposure over time; - levels of nutrient and lightintensity must be sufficient for during the exposurein the highest concentration of the test material; - exposure duration should be adjusted to the growth curve of the algae 72-96 h are in most cases optimal for detectin growth limitation in the exponential phase
Reported parameters	- all test results, both positive and negative, regardless of the statistical significance of the outcome must be reported; - the primary data must be made available for use in meta-analysis and data synthesis

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