Is Agricultural Pesticide Pressure of Prime Relevance for the Composition of Macroinvertebrate Communities in Small Agricultural Streams?

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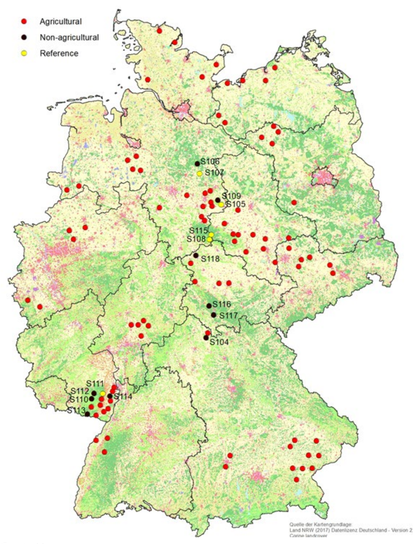
The project ‚Kleingewässer Monitoring'

- Two-year pilot study (2018-2019) by the Helmholtz Centre for Environmental Research (UFZ) on behalf of the German Federal Environment Agency (UBA) to record the chemical and biological status of small agricultural watercourses ([1], [2], [3], [4])
- Focus on effects of plant protection products on macroinvertebrates



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KgM Kleingewässer Monitoring

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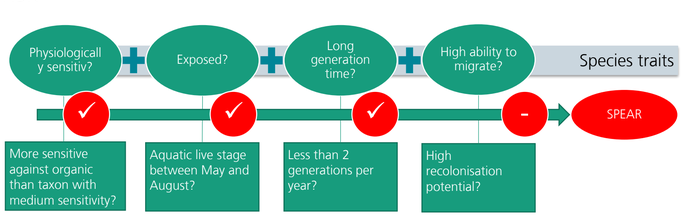
The SPEAR concept [5]

- Macroinvertebrate taxa classified as Species at Risk or not at risk



$$SPEAR_{pesticides} = \frac{\sum_{i=1}^{n} \log(4x_i + 1) \times y_i}{\sum_{i=1}^{n} \log(4x_i + 1)}$$

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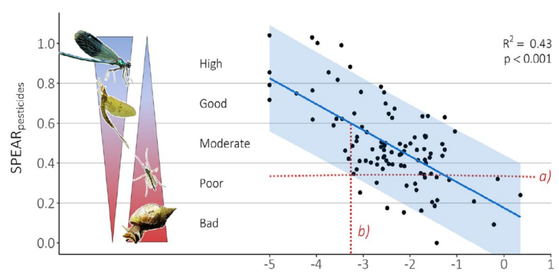
n = number of taxa; x_i = abundance of taxon i; y = 1, if taxon i is classified as SPEAR, y = 0, if taxon i is classified as not at risk

- Standardisation to median SPEAR index value of 5 reference sites
- Definition of 5 SPEAR quality classes of equal width
- Regression of SPEAR on maximum Toxic Unit per site as indicator for pesticide stress



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Conclusions by Liess et al. [1]

- *'we revealed for the first time the prime relevance of agricultural pesticide pressure for the composition of invertebrate communities'*
- *'current authorisation of pesticides underestimates the actual ecological risk, as measured pesticide concentrations exceeded current regulatory threshold levels in most of the agricultural streams. In addition existing thresholds were not protective for invertebrates'*
- *'we identified pesticide threshold concentrations that will ensure an appropriate protection of the invertebrate stream community'* (AC_{field})

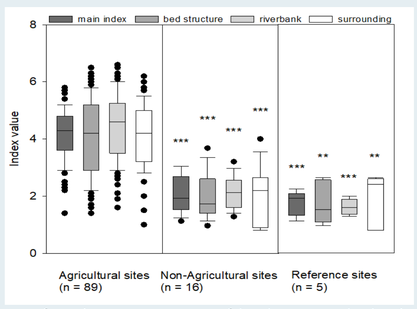
Concerns related to SPEAR evaluation

- The basic idea is simple, but the details of the calculation are difficult to reproduces and seem to have been modified for each data set
- $SPEAR_{pesticides}$ is optimised to indicate PPP effects, but PPPs are not the only stressor in the field
- Other macroinvertebrate indices are best explained by other factors, for example, the proportion of mayflies, stoneflies and caddisflies (%EPT index) has a similarly good multiple regression as SPEAR (R^2 = 0.60)compared to 0.61), but is best explained by structural deficits of the streams [1]
- The aim of the project was therefore to analyse the macroinvertebrate data without prior assessment of the taxa:
  1. *Do agricultural and non-agricultural sites differ in terms of their environmental factors?*
  2. *What is the influence of the factors on the biocoenosis?*
  3. *How great is the influence of the PPP contamination?*

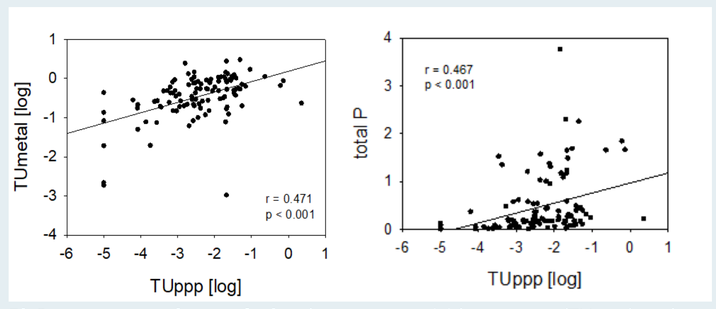
Additional evaluations

- Compare site groups with different land use: 'agricultural' sites vs forest sites using box plots and t- or U-test. The 5 reference sites are a subgroup of the forest sites.
- Correlation between environmental stressors (Spearman rank correlation)
- Principal component analysis of environmental stressors
- Ordination analysis of the macroinvertebrate data seta
  - Pooling overlapping and rare taxa
  - Correspondence analysis to ordinate sites just based on the macroinvertebrate data
  - Canonical correspondence analysis to ordinate sites using information of environmental stressors
  - Rank environmental factors based on the proportion of variance in the macroinvertebrate data set they can explain

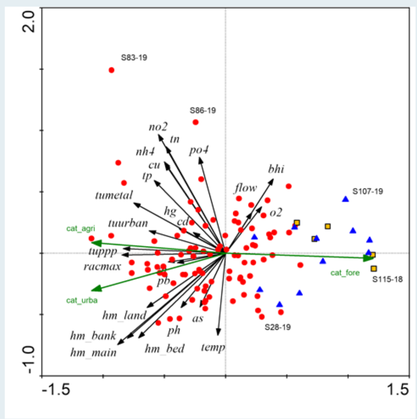
Results



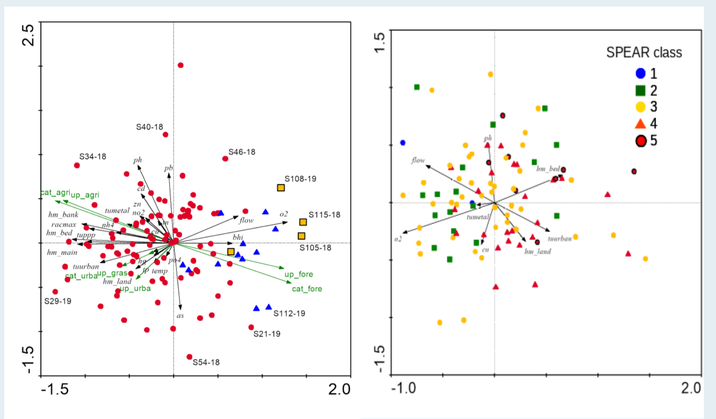
A) Box plots of main parameters of hydro-morphological mapping. Low index values indicate good status (Student's t-test, ***: p < 0.001, **: p < 0.01)



B) Spearman rank correlation between pesticide pressure (TUppp) and metal concentration (left) respectively total phosphorus concentration TU = Toxic Unit = measured concentration / EC50, max. TU was used here



C) Principal Component Analysis (PCA) of sites based on environmental factors: red circles = agricultural, blue triangles = forest, yellow squares = reference (forest) sites. Land use as supplementary variables (green arrows)



D) Canonical Correspondence Analysis (CCA) of macroinvertebrate communities per site. Left: All sites without selection of variables, colours indicate land use as in PCA. Right: Agricultural sites only with automatic forward selection of factors, colours indicate SPEAR classes

Summary

1. *Do agricultural and non-agricultural sites differ in terms of their environmental factors*?
   Yes, PPP contamination differs significantly between agricultural and forest sites (C), but also oxygen content, metal concentrations, nutrient content and hydromorphology (A). PPP contamination ('TUppp') correlates with other stressors (B, C).
2. *What influence do environmental factors have on the community of macroinvertebrates?*
   The structure of the biocoenosis is best explained by oxygen content ('o2'), waterbed quality ('hm_bed'), pH ('pH'), and flow velocity ('flow'). However, only 12 % of the total variance is explained by the first 8 factors automatically selected (D, right CCA).
3. *How big is the influence of pesticide pollution?*
   Pesticide pressure explains a non-significant part of the total variance in the agricultural sites (1.3 %, D, left CCA).

Conclusions

- Analyses with $SPEAR_{pesticides}$ cannot be used to conclude that PPPs are the primary stressor for the entire biotic community. The choice of index influences the result.
- Ordination analysis reveals that only a small part of the observed total variance in the composition of the macroinvertebrate community can be explained by pesticides. Other parameters have higher (but also relatively low) explanatory power.
- As pesticide pressure is not the only stressor, lowering pesticide pressure alone or lowering regulatory thresholds do not automatically lead to higher ecological quality of water bodies. Factors such as habitat quality must not be overlooked when it comes to improving ecological status.
- Monitoring is necessary to assess the current chemical and ecological quality of water bodies. Monitoring data thoroughly analysed can be useful regarding the review of current risk assessments and risk mitigation measures.

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References
[1] Liess et al. (2021): doi.org/10.1016/j.watres.2021.117262 **[2]** Liess et al. (2021): doi.org/10.1594/PANGAEA.931673 **[3]** Liess et al. (2021): www.umweltbundesamt.de/publikationen/belastung-von-kleinen-gewaessern-in-der-0Report **[4]** www.ufz.de/kgm/index.php?en=44480 **[5]** www.ufz.de/index.php?en=38122