Is the pressure-specific invertebrate index PSI an ecologically relevant tool for determining water quality sedimentation targets?

Miriam Glendell, Richard Brazier, Chris Extence and Richard Chadd
• WFD target of 80% of freshwaters in GES by 2015 has been missed
• Only 17% of waterbodies in England in Good or High condition in 2015! (4% in Netherlands, 42% in France)
• Agriculture is a No. 1 reason for failure to meet the WFD standards in the UK, responsible for about 30% of failures
Multiple pressures

- Climate change

- Diffuse water pollution

- Urbanisation

- Over-abstraction

- Agriculture intensification

- Invasive species

- Habitat modification

- Climate change

Complex interactions

- pH
- Nutrients

- Biological community

- Dissolved oxygen

- Low flow

- Temperature regime

Tools to identify the causes of impairment and inform land management decisions
Research aims

Sedimentation is a significant cause of river impairment worldwide, however until recently, a macro-invertebrate sedimentation index was lacking¹.

- First empirical study to test a novel pressure-specific macro-invertebrate index to act as a tool for determining ecologically relevant water quality sedimentation targets²

What is PSI?

- Over 400 species and families of British benthic macro-invertebrates assigned to one of four Fine Sediment Sensitivity Ratings (A–D) from highly sensitive to highly insensitive – based on the ecological understanding of species anatomical, physiological and behavioural traits.

- Weighted relative abundance of FSSR groups is used to calculate a PSI score; 0 being completely sedimented and 100 being unsedimented.

\[
PSI = \frac{\sum \text{Scores for Sediment Sensitivity Groups A&B}}{\sum \text{Scores for all Sediment Sensitivity Groups A – D}}
\]

\[
EQI = \frac{\text{observed PSI}}{\text{expected PSI}}
\]

using the reference condition model RIVPACS/RICT.
Two contrasting study catchments

**Horner Water:** 22km² upland catchment with extensive semi-natural habitats on organo-mineral soils, dominated by Western Sessile Oak woodland and heather moorland.

**Aller:** 14.8km² lower lying catchment dominated by mineral soils, intensive arable / short-term ley farming and livestock rearing.
Methods

- Invertebrate sampling spring & autumn 2010 and 2011 – 51 samples, 65 families, 25 093 individuals
- PSI, LIFE, ASPT, NTAXA and % EPT abundance calculated + O:E EQIs
- Sedimentation quantified as:
  - average base flow TSS conc. for 6-months preceding the sampling
  - % exceedance – time for which the 25 mg L$^{-1}$ threshold has not been exceeded (> 1,000 base flow and storm flow WQ samples)
  - % fine bed sediment cover - visual
  - suspendable bed sediment concentration
- Environmental gradients examined using PCA
- Multi-level hierarchical mixed models used to examine the relationship between PSI and sedimentation
Environmental gradients

Glendell et al. 2014 Freshwater Biology
PSI & sedimentation variables

- No significant difference in PSI and O:E PSI between seasons
- PSI significantly higher in 2010 while % fine bed sed. cover higher in 2011 (P < 0.05)
- % fine bed sediment correlated with suspendable bed sed. (R=0.8, P<0.001)
- PSI significantly related to % fine bed sediment cover (fine silt & clay) and altitude

P = 0.002
% deviance = 10.7%
Other indices

<table>
<thead>
<tr>
<th>Macro-invertebrate indices</th>
<th>P-value</th>
<th>% deviance</th>
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</thead>
<tbody>
<tr>
<td>PSI</td>
<td>0.002</td>
<td>10.7</td>
</tr>
<tr>
<td>O:E PSI</td>
<td>0.014</td>
<td>6.8</td>
</tr>
<tr>
<td>O:E LIFE</td>
<td>0.034</td>
<td>5.2</td>
</tr>
<tr>
<td>LIFE</td>
<td>0.014</td>
<td>7.0</td>
</tr>
<tr>
<td>EPT % abundance</td>
<td>0.014</td>
<td>6.1</td>
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</table>
## Correlation of PSI with other indices

<table>
<thead>
<tr>
<th>Season</th>
<th>LIFE</th>
<th>ASPT</th>
<th>NTAXA</th>
<th>EPT % abundance</th>
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<tbody>
<tr>
<td>PSI</td>
<td></td>
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</tr>
<tr>
<td>Spring 2010</td>
<td>0.630*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Autumn 2010</td>
<td>0.771**</td>
<td>0.744**</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Spring 2011</td>
<td>0.799**</td>
<td>0.731**</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Autumn 2011</td>
<td>0.899**</td>
<td>0.843**</td>
<td>ns</td>
<td>ns</td>
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</table>

<table>
<thead>
<tr>
<th>O:E PSI</th>
<th>O:E LIFE</th>
<th>O:E ASPT</th>
<th>O:E NTAXA</th>
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<tbody>
<tr>
<td>Spring 2010</td>
<td>0.578*</td>
<td>ns</td>
<td>ns</td>
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<tr>
<td>Autumn 2010</td>
<td>0.781**</td>
<td>0.664*</td>
<td>ns</td>
</tr>
<tr>
<td>Spring 2011</td>
<td>0.822**</td>
<td>0.646*</td>
<td>ns</td>
</tr>
<tr>
<td>Autumn 2011</td>
<td>0.911**</td>
<td>0.840**</td>
<td>ns</td>
</tr>
</tbody>
</table>
Conclusions

- PSI not the only invertebrate metric related to a physical measure of sedimentation.
- However, the relationship between % fine bed sediment cover and PSI was statistically more significant and provided a better fit than for other metrics.
- PSI and % fine bed sediment proposed as ‘twin targets’ for the monitoring of sedimentation impacts and the achievement of ‘Good ecological status’ under WFD.
- PSI should be subjected to further testing along a pronounced environmental gradient of powerful stressors.
Finetuning the PSI index

- Improved correlation between % fine sediment (<2mm) and E-PSI (rs=-0.74, p<0.01) - higher than the median correlation coefficient (0.64) of invertebrate-based indices (in relation to their respective pressures) that have been reviewed in Europe (Birk et al. 2012)
- Reduced correlation between E-PSI and other biological indices (LIFE, ASPT, EPT)
- Increased discrimination between % fine sediment values among PSI groups, especially at the very high and very low end of the impact spectrum
Future research needs

- More robust assessments directly comparable with the WFD river invertebrate status classification
- Improving our knowledge of the sensitivity and behaviour of PSI and other sedimentation metrics
- Improve our ability to predict reference values independently of hydro-morphological variables such as width, depth and substrate composition, which are affected by anthropogenic pressures
Acknowledgements

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Thank you for your attention!

m.glendell@exeter.ac.uk