INTERCALIBRATION OF MACROINVERTEBRATES IN LAKES
NORTHERN GIG EUTROPHICATION & ACIDIFICATION

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Galway, 13 October 2011
Littoral Invertebrates - Overview

- "2-tailed" Perla
- "3-tailed" Baeis
- Chironomus
- Tubificidae
- Gammarus
“owing to significant shortfalls in monitoring and assessment systems….it was currently not possible to use benthic invertebrates to assess the ecological status of lakes” Nixon *et al.* (2003), Cardoso *et al.* (2005) and Nõges *et al.* (2005)

REBECCA 2003 – 2006 Establish relationships between chemical and ecological status in surface waters & Identify knowledge gaps.
19 Academic institutions, 14 Member states (incl. 1000+ lake sites)
→ More robust assessment tools are needed to improve precision in the dose response relationship using benthic invertebrates in lakes

JRC identified the current lack of ecological knowledge regarding the effects of anthropogenic disturbance on lake littoral communities as a major impediment hindering the successful implementation of the WFD (Heiskanen and Solimini, 2005; Solimini *et al.*, 2006).
Under WFD, a legal requirement to incorporate benthic invertebrates into assessment systems for lakes exists.

WFD monitoring programme → littoral invertebrates sampled from exposed stony shorelines in lakes in April and Sept.

EPA funded 2 year research project to develop an assessment system for IE lakes using benthic invertebrates → NS Share project.
Lake littoral invertebrate intercalibration - eutrophication

- Not included in Phase 1 of the IC exercise
- First meeting in February 2008 - All GIGs present
- IE in Northern GIG with SE, UK, NO, FI
  - SE – national method, approved
  - UK – national method, awaiting approval
  - NO – no data, no method (littoral eutrophication)
  - FI – no data, no method (littoral eutrophication)
  - IE – data, method under development
Objective: to develop an ecological classification model based on changes in littoral assemblages along a eutrophication gradient.

WFD compliant: Abundance, Trophic Score, Indicator Taxa

Type specific: alkalinity bands

\[ y = -0.2615x + 1.1321 \]
\[ R^2 = 0.7102 \]

Overall Lake EQR

Log TP (ug/L)

Low alkalinity lakes

\[ y = -0.5039x + 1.5235 \]
\[ R^2 = 0.5526 \]

Mid alkalinity lakes

\[ y = -0.2779x + 1.1803 \]
\[ R^2 = 0.5516 \]

High alkalinity lakes

\[ y = -0.2615x + 1.1321 \]
\[ R^2 = 0.7102 \]

Overall Lake EQR

Log TP (ug/L)
NS Share tool – IE WFD Data (n = 215)

All lakes (n = 215)

Average EQR vs. log(x+1) Total Phosphorus

- High
- Good
- Moderate

R² = 0.131
UK test NS Share method (n = 47)
Chironomid Pupal Exuviae (CPET) – UK Method

- Chironomid exuviae
- X 4 time per year

Classification of nutrient impact on lakes using the chironomid pupal exuvial technique

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ARTICLE INFO

Keywords: Chironomida; Chironomid exuviae; Lake Water Framework Directive; Nutrient impact; Ecological criteria

ABSTRACT

The European Union Water Framework Directive (WFD) aims to achieve Good ecological status of European surface waters by 2015 through the determination of reference state to provide a measure of perturbation by human impacts based on biotic, chemical, and physical descriptors. Chironomids are excellent indicators of nutrient enrichment due to their sensitivity to a wide range of factors, including nutrient enrichment. The classification of nutrient impact on lakes using the chironomid pupal exuvial technique is described in this paper. The method involves the collection of pupal exuviae from the leeward side of lakes and identification to species level. The classification of nutrient impact is based on the ratio of the number of pupal exuviae collected to the number of pupal exuviae collected from reference sites.

1. Introduction

At its implementation the WFD was the most significant piece of European water legislation for some 25 years. The WFD requires member states to protect and enhance all surface waters, including natural and artificial lakes (Council of the European Union, 1995). Reference waterbodies, having no or very minor anthropogenic physical-chemical and hydro-morphological alterations, have to be identified, monitored, protected, and provided a measure of how far other catchments have been perturbed by human-induced impacts. Taxonomic composition and abundance of algal, fish, and macroinvertebrates are often used to measure the anthropogenic impacts of water quality for routine evaluations. These measures have been operational since January 2007 with the aim of achieving at least Good ecological status of waterbodies by December 2015, defined as these biological measures showing low levels of disturbance by human activity compared with the reference condition. Practical considerations required for WFD methods before implementation have been reported for macroinvertebrates by Geddes et al. (2000) and for diatoms by Riby et al. (2005). The chironomid pupal exuvial technique (CPET) is developed here as a tool for defining reference state of lakes so that anthropogenic impacts can be measured and lakes classified by ecological quality. The Chironomidae are a good surrogate for aquatic macroinvertebrates, they are the most species-rich family, with representatives of all major feeding modes (Booth, 1995). and there are numerous studies demonstrating their high secondary productivity in lotic and lentic habitats, a major conduit transferring denitrified energy to fish (Rabalais, 1995). From Britain 102 chironomid species have been identified (Wilson and Race, 2005a; Latham and Race, 2005a,b); more than all other species of non-dipteran aquatic macroinvertebrates found in the British lakes. CPET provides more postlarval species data than CPM (Dawson et al., 2006) and was the only method to have a significant signal to relate ratio among meso-eutrophic Finnish lakes affected by diffuse pollution. The collection of floating chironomid pupal exuviae (skins) at the leeward shore of standing water bodies provides a simple and safe means of obtaining abundant macroinvertebrate data representative of at least a large part of the lake. The sample is passively collected by wind and water currents, integrating adult
CPET Results IE (n = 142)

Reference score = -0.142-0.483 log (surface area)-0.57 log (mean depth) + 0.376 log (retention time) + 0.364 log (catchment area)

$r^2 = 0.768$
CPET UK results

Trophic Score Vs. pressure gradient UK data (n = 32)

CPET EQR Vs. pressure gradient UK data (n = 32)

R² = 0.7486

y = -0.0313x + 0.8913

R² = 0.0638
Average Score Per Taxon (ASPT) - SE

Reference conditions

3.05 Scope of reference conditions: Surface water type-specific
3.06 Key source(s) to derive reference conditions:
Scope of reference conditions: Existing near-natural reference sites

3.07 Reference site characterisation:
Number of sites: ca 300
Geographical coverage: whole of Sweden
Location of sites: whole of Sweden
Data time period: 2000 national survey and Trend Streams (national monitoring programme)
Criteria: Use of pressure filter to identify reference conditions.

3.08 Reference community description: n.a.
3.09 Results expressed as EQR: Yes

Boundary setting

3.10 Setting of ecological status boundaries: Equidistant division of the EQR gradient
3.11 Boundary setting procedure: n.a.
3.12 "Good status" community: n.a.

<table>
<thead>
<tr>
<th>SE</th>
<th>ASPT</th>
<th>EU</th>
<th>TP and NO2+NO3</th>
<th>R²=0.25-0.30, significant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ASPT IE lakes (n = 182)

\[ y = -0.1112x + 1.0539 \]

\[ R^2 = 0.1012 \]

<table>
<thead>
<tr>
<th>SE Ecoregion 14</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref</td>
<td>5.85</td>
</tr>
<tr>
<td>High</td>
<td>&gt; 0.95</td>
</tr>
<tr>
<td>Good</td>
<td>0.70 - 0.95</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.50 - 0.70</td>
</tr>
<tr>
<td>Poor</td>
<td>0.25 - 0.50</td>
</tr>
<tr>
<td>Bad</td>
<td>&lt; 0.25</td>
</tr>
</tbody>
</table>

\[ y = -0.1112x + 1.0539 \]
\[ R^2 = 0.1012 \]
Conclusion – lakes eutrophication

- Deadline for method submission to NGIG: Feb. 2011
- Poor relationships found with
  - NS Share IE tool
  - CPET UK tool
  - SE ASPT tool
  - BE multimetric index
  - Existing metrics available in AQEM database

- CIS Guidance Document 14 states:
  If a metric shows no relation with the pressure gradient then you cannot proceed to set boundaries.
  - Get another metric
  - Get more data
  - Improve the pressure gradient
SE and UK failed to intercalibrate their two approved methods (CPET and ASPT). IE has both types of data, there was no relationship which could be used to develop a common metric to allow IC to proceed.

NGIG concluded it was **currently** not feasible to IC benthic invertebrates for littoral lake eutrophication due to incompatibility of existing metrics.

CIS guidance 14 states if assessment methods differ so much the data cannot be compared then the member states must:
- Find an alternative intercalibration approach or
- Carry out an on-site comparative field exercise on selected sites.

JRC: stated IC was a legal requirement under WFD, and even if IC Phase 2 was over, that **requirement remained**, and the onus was on member states to meet it.

Phase 3?
Phase 1 acidification intercalibration unsuccessful
- Restricted database (five sites on each boundary)
- Impractical lake typology (mean depth, surface area)
- Lack of compliant national methods

Phase 2 intercalibration (new personnel)
- Expanded Database - full gradient
- New Typology (clear and humic types only)
- Development of new acid metrics
Benthic Invertebrates – Acidification - Lakes

- IE in Northern GIG with SE, NO, UK & FI (observer status)

<table>
<thead>
<tr>
<th>Country</th>
<th>National Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>MILA 😊</td>
</tr>
<tr>
<td>NO</td>
<td>Raddum 😞</td>
</tr>
<tr>
<td>UK</td>
<td>AWIC 😊</td>
</tr>
<tr>
<td>IE</td>
<td>Raddum 😞</td>
</tr>
<tr>
<td>FI</td>
<td>Did not participate</td>
</tr>
</tbody>
</table>

- SE compliant method for lakes
- Raddum index not compliant (continuous scale and EQR required)
- AWIC developed for stream and not suitable for lakes
<table>
<thead>
<tr>
<th>Type</th>
<th>Characterisation</th>
<th>Altitude m.a.s.l</th>
<th>Mean Depth meters</th>
<th>Alkalinity meq</th>
<th>Lake Area Km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-N1</td>
<td>Lowland, shallow, siliceous, moderate alkalinity, large.</td>
<td>&lt; 200 m</td>
<td>3-15</td>
<td>0.2 - 1</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>L-N2a</td>
<td>Lowland, shallow, siliceous, low alkalinity, large.</td>
<td>&lt; 200 m</td>
<td>3-15</td>
<td>&lt; 0.2</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>L-N2b</td>
<td>Lowland, deep, siliceous, low alkalinity, large.</td>
<td>&lt; 200 m</td>
<td>&gt;15</td>
<td>&lt; 0.2</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>L-N3</td>
<td>Lowland, shallow, peat, large</td>
<td>&lt; 200 m</td>
<td>3-15</td>
<td>&gt; 30 mg Pt/l &lt; 0.2 alk</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>L-N5</td>
<td>Boreal, shallow, siliceous, low alkalinity, large</td>
<td>Between lowland and highland</td>
<td>3-15</td>
<td>&lt; 0.2</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>L-N6</td>
<td>Boreal, shallow, peat, large</td>
<td>Between lowland and highland</td>
<td>3-15</td>
<td>&gt; 30 mg Pt/l &lt; 0.2 alk</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>L-N7</td>
<td>Highland, shallow, siliceous, low alkalinity, large</td>
<td>Above treeline</td>
<td>3-15</td>
<td>&lt; 0.2</td>
<td>&gt; 0.5</td>
</tr>
</tbody>
</table>
IC Database construction – acceptance criteria

- a rule based system for matching chemistry and biological data: 4 chemistry samples in 365 days preceding the biological sample. Obligatory rule.
  → IE data excluded!

Metric development

- existing metrics Raddum, NIVA, Medin and AWIC
- species sensitivity, indicator weight, tolerance
- range of potential metrics tested against MS
3. **Procedure for deriving the ecological quality ratio for the parameters**

3.1 **Calculation of the observed value of LAMM**

The observed value of the parameter, LAMM, should be calculated using the equation:

\[
\text{Observed value for LAMM} = \frac{\sum_{k=1}^{n} S_{hk} \times W_{hk} \times H_{hk}}{\sum_{k=1}^{n} W_{hk} \times H_{hk}}
\]

where:
- "\( S_{hk} \)" is the acid sensitivity score for taxon "k" given in Column 2 of Table 2
- "\( k \)" represents a taxon listed in Column 1 of Table 2 and present in the sample.
- "\( W_{hk} \)" is the corresponding weighting score for taxon "k" given in Column 3 of Table 2; and
- "\( H_{hk} \)" is the relative abundance score in Column 2 of Table 3 corresponding to the range in Column 1 of that Table which describes the proportion of the number of individuals of taxon "k" in the sample to the total number of individuals of the taxa listed in Column 1 of Table 2 and present in the sample.
Lake Acidification Macroinvertebrate Metric (LAMM)

- LAMM = acid sensitivity * indicator weight * abundance rating

**Graph:**
- Linear regression of LAMM versus LAMM vs. ANC
- S = 0.740
- Rsq = 64
- Data points indicating correlation between LAMM and ANC.

**Article:**
- Littoral macroinvertebrates as indicators of lake acidification within the UK
- Ben McFarland, Fiona Carse, Leonard Sandin
- Abstract:
  - The Water Framework Directive (WFD) requires the assessment of acidification in sensitive water bodies.
  - Chemical and macroinvertebrate samples were collected to assess acidification of clear and humic lakes in the UK.
  - Three acid-sensitive metrics that were assessed against acid-neutralizing capacity (ANC) and pH, highly significant relationships were detected using the Lake Acidification Macroinvertebrate Metric (LAMM).
  - The metric was used to assign high, moderate, poor, and bad status classes, as required by the WFD.
  - In clear-water lakes, macroinvertebrates changed with increasing acidification, which did not indicate any discontinuities, so a chemical model was used to define boundaries. In humic lakes, biological data were able to indicate a distinct, good/moderate boundary between classes.
  - Humic lakes had significantly lower pH than clear lakes in the same class, not only at the good/moderate boundary where different methods were used to set boundaries, but also at the high-good boundary, where the same chemical modeling was used for both lake types. These findings support the hypothesis that toxic effects are reduced at waters rich in dissolved organic carbon (DOC).
  - A typology is needed that splits humic and clear lakes to avoid naturally acidic lakes from being inappropriately labeled as acidified.

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LAMM - IE WFD lake data Alk < 0.2 meq; TP < 20μg/l

Clear lakes (colour < 30) n = 27

Humic lakes (colour >30) n = 20

\[ y = 0.0912x + 0.4006 \]
\[ R^2 = 0.1751 \]

\[ y = -0.001x + 1.1105 \]
\[ R^2 = 2E-05 \]
If a metric shows no relationship with the pressure gradient then you cannot proceed to set boundaries.
- get another metric
- get more data
- improve the pressure gradient

FI did not participate in any acidification IC as they do consider anthropogenic acidification a pressure.

JRC “Acidification: although this pressure is declining, acidification effects are still important in parts of Europe. It is therefore proposed to include acidification for relevant types.

- Does IE have the relevant types?
Lake Acidification - Benthic invertebrates

- SE, UK, NO proceeded to IC → option 3
- Good correlation between 3 national metrics and PCM
- UK and SE complied with IC boundaries but NO method biased at the GM boundary and was revised upwards.
- IC boundary fitted with national types so no adjustments necessary.

<table>
<thead>
<tr>
<th>MS</th>
<th>Method</th>
<th>$R^2$</th>
<th>n</th>
<th>HG</th>
<th>GM</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>MILA</td>
<td>0.424</td>
<td>27</td>
<td>0.85</td>
<td>0.6</td>
</tr>
<tr>
<td>UK</td>
<td>LAMM</td>
<td>0.626</td>
<td>76</td>
<td>0.86</td>
<td>0.7</td>
</tr>
<tr>
<td>NO</td>
<td>Multiclear</td>
<td>0.770</td>
<td>15</td>
<td>0.95</td>
<td>0.745</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MS</th>
<th>Method</th>
<th>Pre- IC</th>
<th>Post- IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>MILA</td>
<td>😊</td>
<td>😊</td>
</tr>
<tr>
<td>NO</td>
<td>Raddum</td>
<td>😞</td>
<td>MultiClear 😊</td>
</tr>
<tr>
<td>UK</td>
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<td>😊</td>
<td>LAMM 😊</td>
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</tr>
<tr>
<td>FI</td>
<td>Did not participate</td>
<td>Did not participate</td>
<td></td>
</tr>
</tbody>
</table>
Consequences of setting boundaries

- Boundaries set in December 2011 will be formally agreed by Ecostat in February 2012 and will later become a legal Official Decision.

- Boundaries are binding for next 6 year cycle of RBMP and could be used by EC for compliance checking of the 2\textsuperscript{nd} RBMP.

- Non-compliance risks legal infringement processes