Inland Water Quality Monitoring Programmes

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Freshwater Needs are Universal

Photos of
1. Drinking water supply
2. Food - Inland Fisheries & irrigation for crops/livestock
3. Hydropower
4. Tourism & recreation
Freshwater Quality is Not

Photos of
1. Developed nation: Drinking water reservoir & tap
2. Less developed nation: poor quality water source where drinking water is mixed with other uses - livestock watering and washing
3. Developed nation: child drinking mineral water from bottle
4. Less developed nation: child drinking muddy water from bottle
Benefits provided by freshwaters can only be maintained if they are protected from deterioration. Need suitable methods to monitor and assess impacts.
Purpose of Inland Water Monitoring

LTER high frequency

Research purposes - impacts of climate change on water quality
- GLEON: Global Lake Ecological Observatory Network
- NETLAKE: Networking Lake Observatories in Europe

Large-scale

Regulatory purposes – to protect water quality and freshwater biodiversity
- EU: Water Framework Directive (WFD)
- USA: Clean Water Act
- Australia & NZ: ANZECC
- South Africa: National Water Act

EO potential for both long-term, high-frequency and large scale (in-lake and global)
Carlson (1977) Limnology and Oceanography. 22:2 361-369
A trophic state index for lakes.
EU Water Framework Directive (WFD)

**General Aim**

To promote sustainable water use and protect and enhance aquatic environments

**Technical Aim**

To achieve “good status” in all surface waters by 2027 at the latest

Widespread surveillance and operational monitoring of rivers, lakes and coastal waters implemented.
WFD Monitoring: Indicators of Ecological Health

- Phytoplankton
- Macrophytes & Phytobenthos
- Benthic Invertebrates
- Fish

Biology integrates multiple stressors over range of timescales

- Supporting water quality
  (nutrients, temperature, oxygen, turbidity)
Water Bodies in Europe: Integrative Systems to assess Ecological status and Recovery

<table>
<thead>
<tr>
<th>MS</th>
<th>Abundance</th>
<th>Taxonomic composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>CHL-A, TBV</td>
<td>%CYA</td>
</tr>
<tr>
<td>Belgium</td>
<td>CHL-A</td>
<td>%CYA, %CHRY</td>
</tr>
<tr>
<td>Cyprus</td>
<td>CHL-A, TBV</td>
<td>BV-CYA</td>
</tr>
<tr>
<td>Denmark</td>
<td>CHL-A</td>
<td>%CYA, %CHRY</td>
</tr>
<tr>
<td>Estonia</td>
<td>CHL-A &lt;sub&gt;surf&lt;/sub&gt;, CHL-A &lt;sub&gt;tot&lt;/sub&gt;</td>
<td>Phytoplankton community description</td>
</tr>
<tr>
<td>Finland</td>
<td>CHL-A, TBV</td>
<td>%CYA (impact taxa)</td>
</tr>
<tr>
<td>Germany</td>
<td>CHL-A, CHL-A &lt;sub&gt;max&lt;/sub&gt;, TBV</td>
<td>Algal class metrics</td>
</tr>
<tr>
<td>Ireland</td>
<td>CHL-A</td>
<td>BV-CYA</td>
</tr>
<tr>
<td>Italy-lakes</td>
<td>CHL-A, TBV</td>
<td>%CYA</td>
</tr>
<tr>
<td>Italy-reservoirs</td>
<td>CHL-A, TBV</td>
<td>BV-CYA</td>
</tr>
<tr>
<td>Netherlands</td>
<td>CHL-A</td>
<td>BV-CYA</td>
</tr>
<tr>
<td>Norway</td>
<td>CHL-A, TBV</td>
<td>BV-CYA &lt;sub&gt;max&lt;/sub&gt;</td>
</tr>
<tr>
<td>Poland</td>
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<td>BV-CYA</td>
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<td>Portugal</td>
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<td>Slovenia</td>
<td>CHL-A, TBV</td>
<td>BV-CYA</td>
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<td>Spain</td>
<td>CHL-A, TBV</td>
<td>%CYA</td>
</tr>
<tr>
<td>Sweden</td>
<td>CHL-A, TBV</td>
<td>%CYA</td>
</tr>
<tr>
<td>UK</td>
<td>CHL-A, TBV</td>
<td>BV-CYA</td>
</tr>
</tbody>
</table>


*Hydrobiologia* (2013) 704 (1)
WFD Phytoplankton Indicators

Sensitive indicators of *impact* of nutrient pollution

**Composition**
- Functional response
  - Chlorophyll-a
  - Total Biovolume
  - [Water clarity]

- Structural response
  - Community Index (e.g. PTI)

**Abundance**
- Algal Blooms

**Algal Blooms**
- Sustainable water use
  - Cyanobacteria Biovolume
  - % Cyanobacteria

**ECOLOGICAL STATUS**
- HIGH
- GOOD
- MODERATE
- POOR
- BAD

comparable ecological thresholds

uncertainty in classification

deviation from reference state

frequency & intensity
Cyanobacteria: Indicator of ecological health and ecosystem services (water supply & recreation)
WFD Indicator: Algal Bloom Intensity

Sustaining recreational quality of European lakes: minimising the health risks from algal blooms through phosphorus control.

Severe & chronic health effects widespread: Brazil, China, Serbia, USA...
Sampling Frequency & Uncertainty

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Sampling Frequency</th>
<th>Minimum Samplings</th>
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</thead>
<tbody>
<tr>
<td>Chlorophyll a</td>
<td>3 months for 3 years</td>
<td>9</td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td>1 month for 6 years</td>
<td>6</td>
</tr>
</tbody>
</table>

$\approx €1$ million for 400 lakes

Strength and uncertainty of phytoplankton metrics for assessing eutrophication impacts in lakes.
WFD Success: National WQ Information Systems

RBMP Data Download

Welcome

Download Using Map tab
To retrieve data, click on the Draw and Extract Data icon and click and drag a diagonal line across the area of interest to create a bounding box on the map. Water body information within the drawn extent would be displayed in a grid below the map. This information can be downloaded to an appropriate file format from the Export Options panel.

Download Using Query tab
Water body information can be obtained from one or a combination of two or more values from the available categories. Click Search once the search criterion is formed. The resultant information can be downloaded to an appropriate file format from the Export Options panel.

Export Options Panel
Clicking on the Export Option panel expands the panel and reveals the data export options available. Select the required export file format and either click the Export Displayed Grid button to export the resultant grid displayed at the bottom of the Export Options panel or Check the required fields within the Export Option panel and click on the Export Checked Fields button to Export the selected/checked fields.

www.environment.scotland.gov.uk/get-interactive/data/water-body-classification/
WFD Success: WISE

Water Information System for Europe

Source: European Environment Agency

Percent of classified water bodies in less than good ecological status or potential

Widespread surveillance and operational monitoring implemented

Robust state-changed assessments of ecological quality with quantified uncertainty

Availability of monitoring data in centralised information systems

Better consistency of methods and data standards
South Africa: Eutrophication Monitoring

Eutrophication data, summer 2014 - 2015

- Eutrophication potential (mostly rivers)
  - Negligible
  - Moderate
  - Significant
  - Serious

- Trophic status (mostly dams)
  - Oligotrophic
  - Mesotrophic
  - Eutrophic
  - Hypertrophic

260 major reservoirs
≈ 50% hypertrophic
(>30 µg L⁻¹ Chl-a)

www.dwaf.gov.za/iwqs
Resource Quality Information Services
water quality data exploration tool
Cyanotoxin concentrations exceed WHO (1999) TDI limit for more than 80% of the time in five South African reservoirs.

Eutrophication: present reality and future challenges for South Africa
Monitoring Gap: bloom development

Exceedance of cyanobacterial health thresholds in Loch Leven, Scotland

WFD monitoring “bloom frequency” is too expensive
Monitoring Gap: spatial extent of bloom

Airborne RS: Phycocyanin

Opportunity: Citizen Monitoring

Validation of EO products
Diversity II (inland waters)
www.diversity2.info

GloboLakes
www.globolakes.ac.uk

Earth2Observe
www.earth2observe.eu

Global Lakes Sentinel Services
www.glass-project.eu
GloboLakes

Assess the sensitivity, coherence and causes of lake WQ responses to environmental change at a global scale (1000 lakes)

Led by University of Stirling (Andrew Tyler)
Involving PML (Steve Groom), CEH & Universities of Dundee, Glasgow and Reading

- chlorophyll a
- phycocyanin
- water temperature
- coloured DOM
- total suspended solids
- (primary production)
Chlorophyll in Lake Turkana, Kenya

MPH Algorithm
(Matthews et al., 2012. Remote Sensing of Environment, 114, 2705-2718)

- Chlorophyll-a
- Cyanobacteria bloom flag
- Cyanobacteria surface scum coverage

Source: Emma Tebbs (CEH) & Ruth O'Donnell (University of Glasgow)

We acknowledge the ESA DUE DIVERSITY II project for providing ENVISAT data and derived indicator products.
EO Summary: Strengths & Weaknesses

**Strengths**
- High-frequency monitoring
- Whole-lake surface coverage – Chl-a, TDS, Temp.
- Global coverage – less developed & inaccessible regions
- Centralised information systems
- Cost effective?
- Consistent methods? [see threats]

**Weaknesses**
- Limited parameters
- Small and shallow water-bodies
- Shoreline & cloud cover interference
EO Wrap-up: Thoughts for Discussion

Opportunities
• EO offers a paradigm shift in understanding of water quality trends and drivers
• Early warning of algal bloom development
• Synergies with citizen monitoring
• Synergies between WQ & biodiversity monitoring

Threats
• Satellite changes – dealing with gaps & differences
• Algorithm diversity – chl-a, cyanobacteria
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