A survey of the status of the lakes of the English Lake District: The Lakes Tour 2015


Lake Ecosystems Group and Analytical Chemistry Centre for Ecology & Hydrology, Lancaster UK

&

K. Bell, R. Clark, A. Jackson, J. Muir, P. Ramsden, J. Thompson, H. Titterington, P. Webb

Environment Agency North-West Region, North Area
History & geography of the Lakes Tour

- Started by FBA in an *ad hoc* way: some data from 1950s, 1960s & 1970s
- FBA 1984 ‘Tour’ first nearly-standardised tour (but no data on Chla & patchy Secchi depth)

Seven lakes in the fortnightly CEH long-term monitoring programme
The additional thirteen lakes in the Lakes Tour
What the tour involves...

- 20 lake basins
- Four visits per year (Jan, Apr, Jul and Oct)
- Standardised measurements:
  - Profiles of temperature and oxygen
  - Secchi depth
  - pH, alkalinity and major anions and cations
  - Plant nutrients (TP, SRP, nitrate, ammonium, silicate)
  - Phytoplankton chlorophyll a, abundance & species composition
  - Zooplankton abundance and species composition
- Since 2010
  - heavy metals
  - micro-organics (pesticides & herbicides)
  - review of fish populations
Variable geology - variable lakes
Exploiting the spatial patterns across lakes for science

Photo I.J. Winfield
Seasonal oxygen concentration profiles

Oxygen concentration (g m\(^{-3}\))

<table>
<thead>
<tr>
<th></th>
<th>Depth (m)</th>
<th>Wastwater</th>
<th>Windermere South Basin</th>
<th>Esthwaite Water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No oxygen depletion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oxygen depletion above sediment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oxygen depletion in hypolimnion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Oxygen minima are controlled by phytoplankton chlorophyll a

Secchi depth is largely controlled by phytoplankton chlorophyll

\[ y = 9.210x^{-0.442} \]

\[ R^2 = 0.806 \]

Chl a is largely controlled by phosphorus


\[ y = 0.59x - 0.61 \]

\[ R^2 = 0.59 \]
**Phytoplankton species richness & composition**

- diatoms
- cyanobacteria
- dinoflagellates
- euglenophytes
- chlorophytes
- haptophytes
- cryptophytes
- chrysophytes

Multiple regression:
Total number of taxa = 113 + 3.34 * Lake area + 1.02 * Chla – 3.4 * Secchi depth;

\[ y = 89.73x^{0.13} \]
\[ R^2 = 0.58 \]

**Percent of total biovolume**

Adj \( R^2 = 71.9\%, \ P<0.001 \)
Zooplankton

![Graph showing zooplankton density and Chl a correlation]

- **Graph Details**: The graph shows zooplankton density (No. dm³) against Chl a (mg m⁻³). The data is color-coded by month: Jan, Apr, Jul, and Oct.
- **Equation and R²**: The fitted line has the equation $y = 0.33x^{0.71}$ with an $R^2$ value of 0.41.
Consequences of nutrient availability

High Total Phosphorus

High Chlorophyll a

- Low $O_2$ concentration at depth
- Low transparency (Secchi depth)
- Greater phytoplankton biodiversity
- Greater zooplankton density
Catchments, lakes & global C-cycling

Lakes are important in global C-cycle

Lakes Tour data on Cumbrian lakes

Paradox: mean [CO$_2$] greatest in most productive lakes

Coherent changes caused by acid-deposition

a) Concentration (meq/L) vs Time (1980-2020)

Average alkalinity
Average sulphate concentration

Regression equations:

- For sulphate concentration:
y = -2.15x + 4390.57
R² = 0.97

- For alkalinity:
y = 1.93x - 3673.49
R² = 0.69
Figure 4.7. Long-term change in overall annual mean concentrations of nutrients (mg m$^{-3}$), major ions (mequiv m$^{-3}$), Secchi depth (m) and pH (unitless) in the 20 lakes of the Lakes Tour. The very high values of TP recorded in Elterwater in 2005 have been excluded.
Focus on five lakes

Wastwater
Crummock Water
Esthwaite Water
Loweswater
Elterwater
Wastwater

- ‘Premier’ (ultra-) oligotrophic lake in England at High or Ref ecological status (WFD)
- Worrying signs of declining Secchi depth

Possible causes:
- Slight signs of increasing productivity (min $O_2$) but not apparent in Chl $a$ - could be linked to climate and stratification (could be checked)
- Secchi decline could also result from input of soil material and/or coloured DOC - no data but could be checked
Crummock Water

- Oligotrophic lake but declining $O_2$ at depth from 9.2 g m$^{-3}$ in 1995 to 3.6 g m$^{-3}$ in 2015 at High or Good ecological status (WFD)

Possible causes:
- Chl $a$ increase from 2.1 to 2.6 mg m$^{-3}$ over same period can only explain 0.7 of the 5.6 g m$^{-3}$ decline
- Stronger stratification - could check
- Increase in DOC – few data but could check
At mesotrophic-eutrophic boundary and at Moderate ecological status (WFD)

Series of upgrades by UU to WwTW and by NE in buying out fish farm

On mesotrophic-eutrophic boundary, although still substantial $O_2$ depletion at depth

Encouraging improvement in TP and Secchi depth and general downward trend in Chl $a$

2015 Chl $a$ increase- CEH fortnightly long-term data could be analysed to give more perspective on recent changes
Loweswater

At mesotrophic-eutrophic boundary and at Moderate ecological status (WFD)

Encouraging signs of improvement following CEH/LU RELU project and community Defra funded project - now part of WCRT

More years of data needed to confirm improvement within envelope of variation caused by weather
A eutrophic lake at Moderate ecological status (WFD)
The shallowest and one of the most rapidly flushed lakes in the Lakes Tour set
Suffered extreme nutrient enrichment with a peak in 1995 for TP and 2005 for Chl a
Encouraging subsequent signs of recovery in TP, Chl a and Secchi depth - but still one of the most enriched lakes in the ‘Tour’
Next talk will give more detail on recent management intervention
Conclusions

The Lakes Tour:

• provides scientific information on how the structure and function of lakes is affected by *local* (e.g. nutrient load), *regional* (e.g. atmospheric deposition) and *global* (e.g. climate change) stressors and how lakes and their catchment interact with the global C cycle

• identifies lakes with poor quality that require more research to understand the causes and suggest remedies

• quantifies the rate and extent of recovery of lakes where management has been undertaken.
• United Utilities is thanked for providing the additional funds to carry out the work

• The Environment Agency is thanked for their collaboration with the field and lab work

• Natural England is thanked for providing funds for the fish component (review plus additional surveys at Brothers Water, Buttermere and Wastwater)

You are thanked for your attention