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

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&

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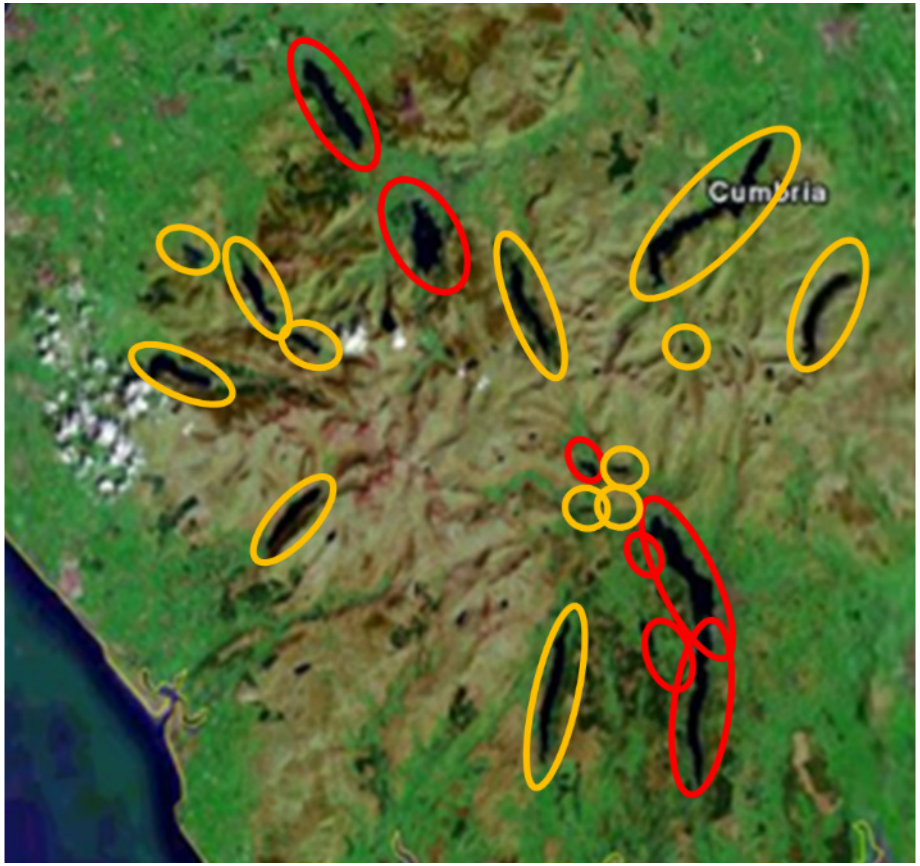
Environment Agency North-West Region, North Area

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 Chl*a* & patchy Secchi depth)
- Subsequent standardised Tours by IFE/CEH/EA in 1991, 1995, 2000, 2005, 2010 and most recently 2015

Seven lakes in the fortnightly CEH long-term monitoring programme

The additional thirteen lakes in the Lakes Tour

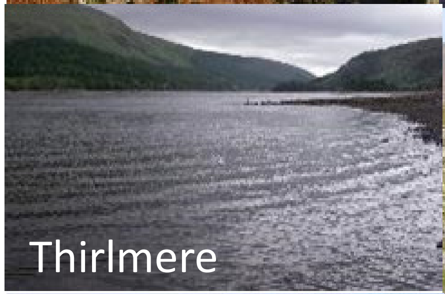
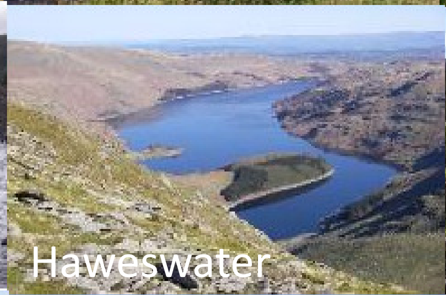
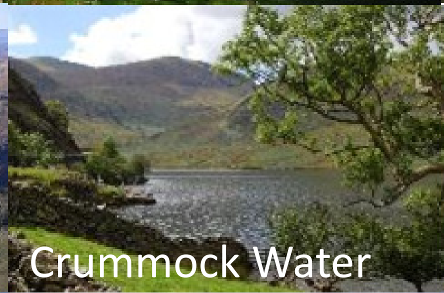
What the tour involves…

- 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


Wastwater

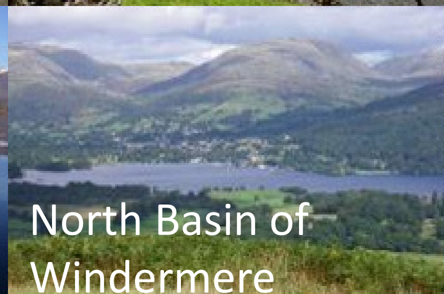
Ennerdale Water

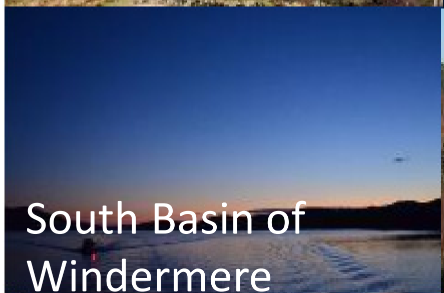
Buttermere

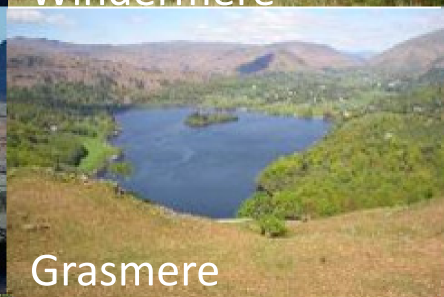
Brothers Water

Thirlmere

Haweswater

Crummock Water

Coniston Water

Ullswater

Derwent Water

North Basin of Windermere

Rydal Water

South Basin of Windermere

Bassenthwaite Lake

Grasmere

Loweswater

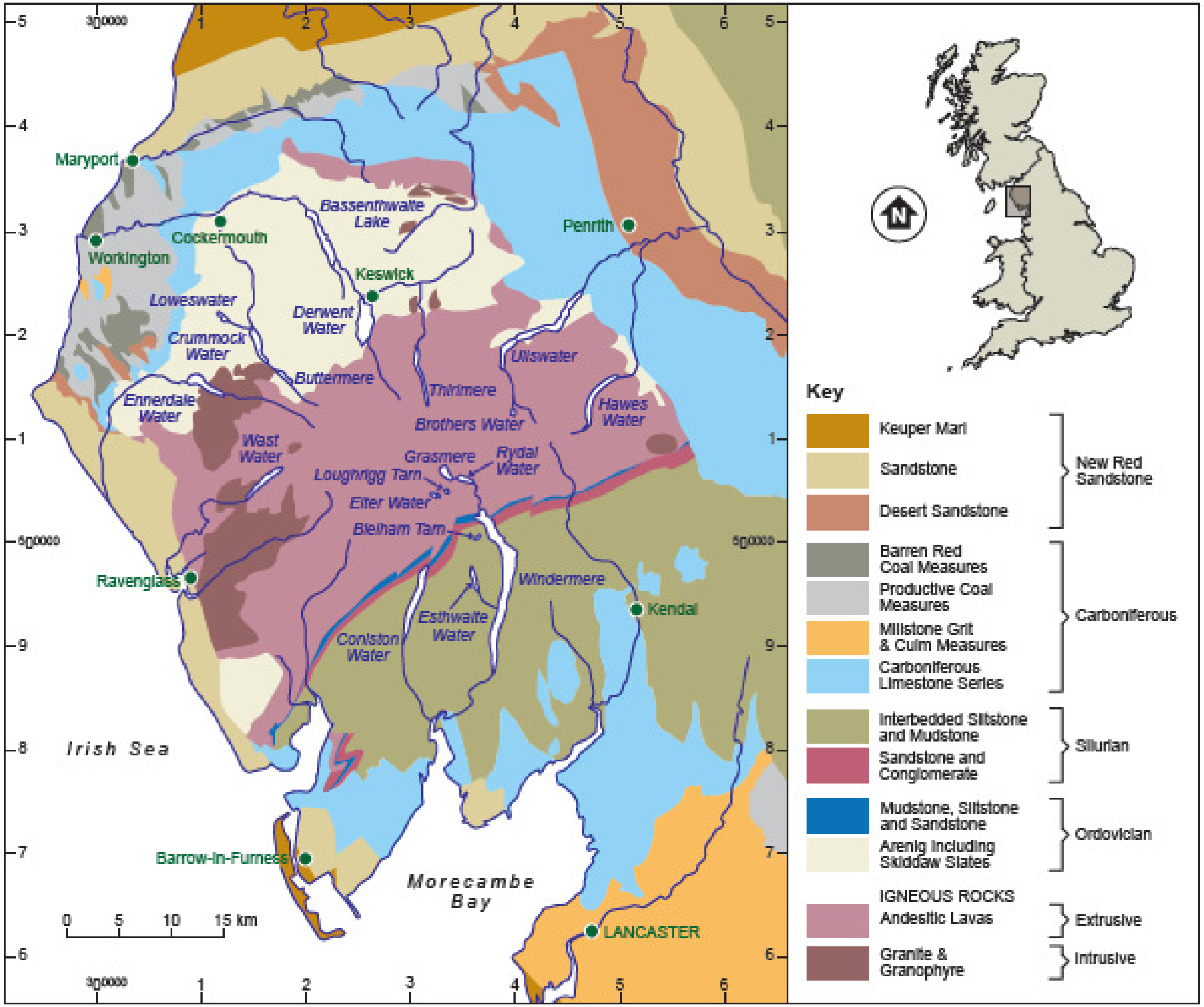
Loughrigg Tarn

Esthwaite Water

Elterwater

Blelham Tarn

Variable geology- variable lakes



Based upon the 1:625 000 scale Geological Map of Great Britain, with the permission of the British Geological Survey.

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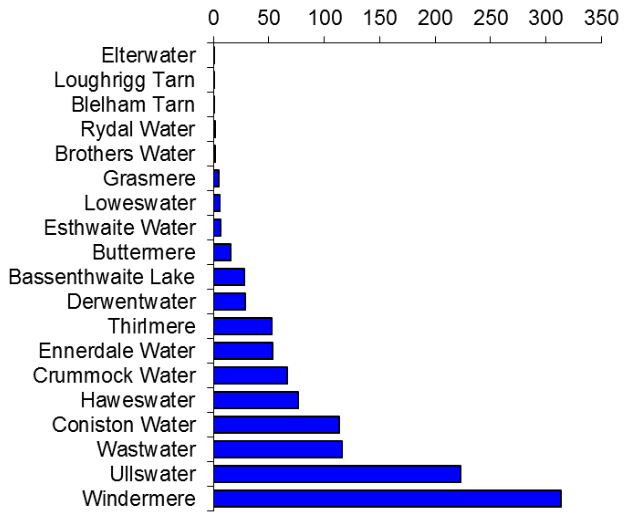
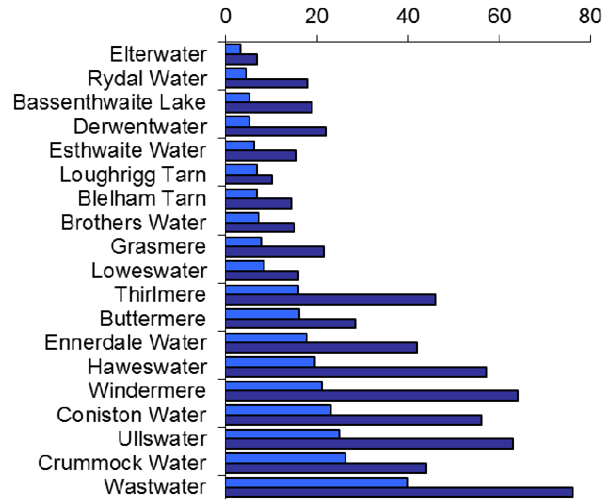
Variable lake morphometry & chemistry

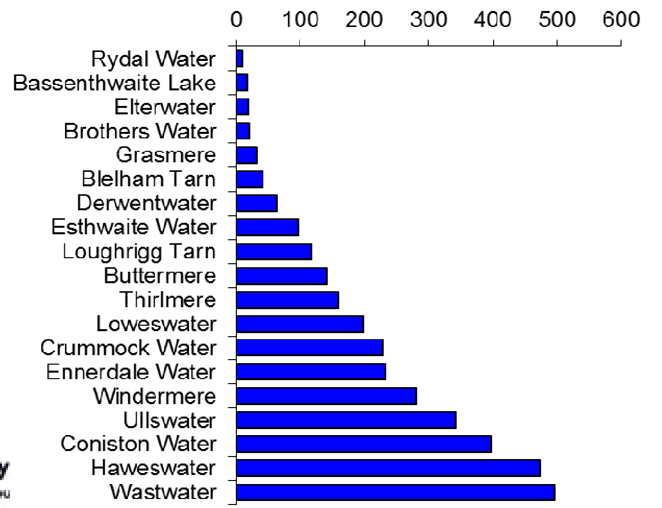
Lake volume (Mm^3)



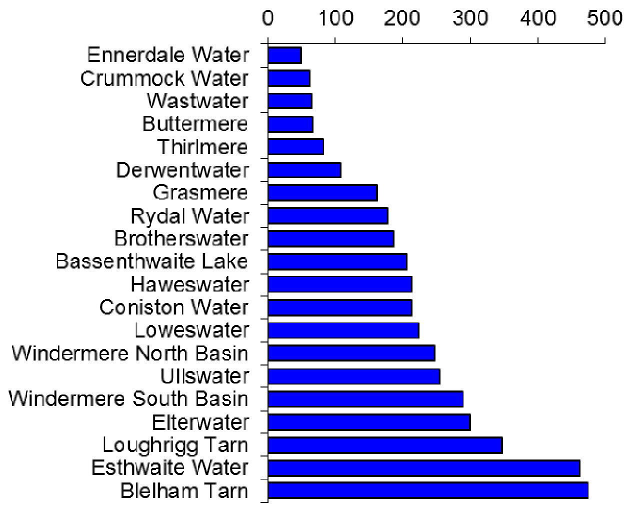
Max or mean depth (m)



Mean retention time (day)



Alkalinity (mequiv m^3)



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Exploiting the spatial patterns across lakes for science

Photo I.J. Winfield

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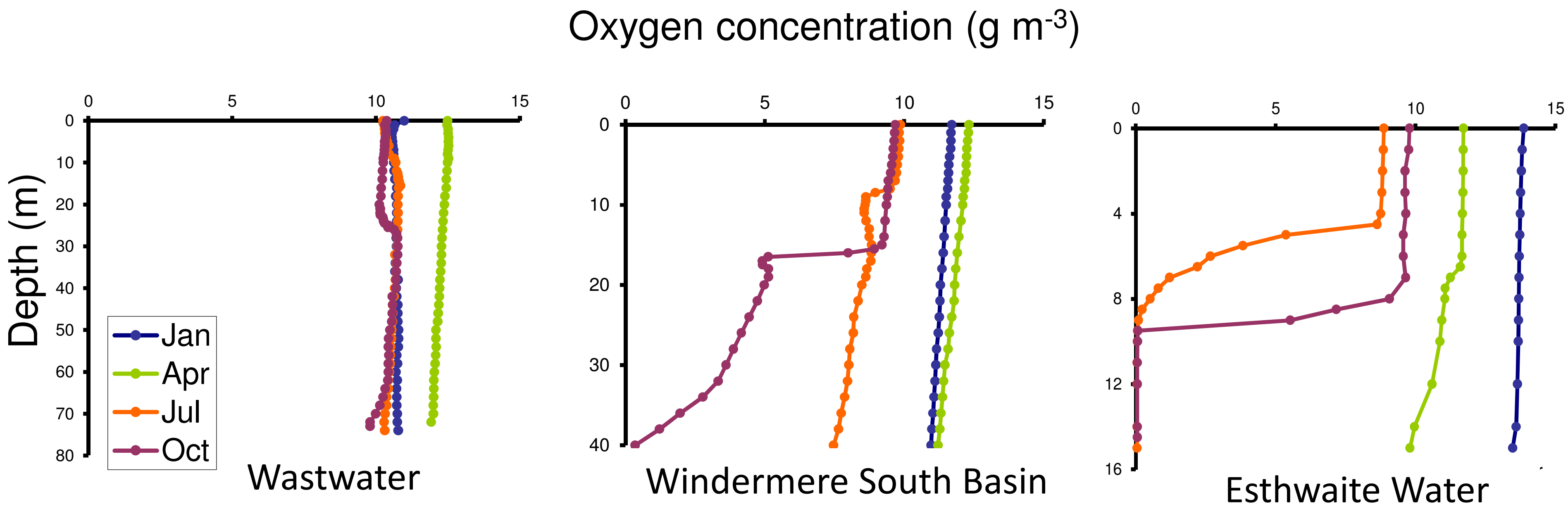
Seasonal oxygen concentration profiles

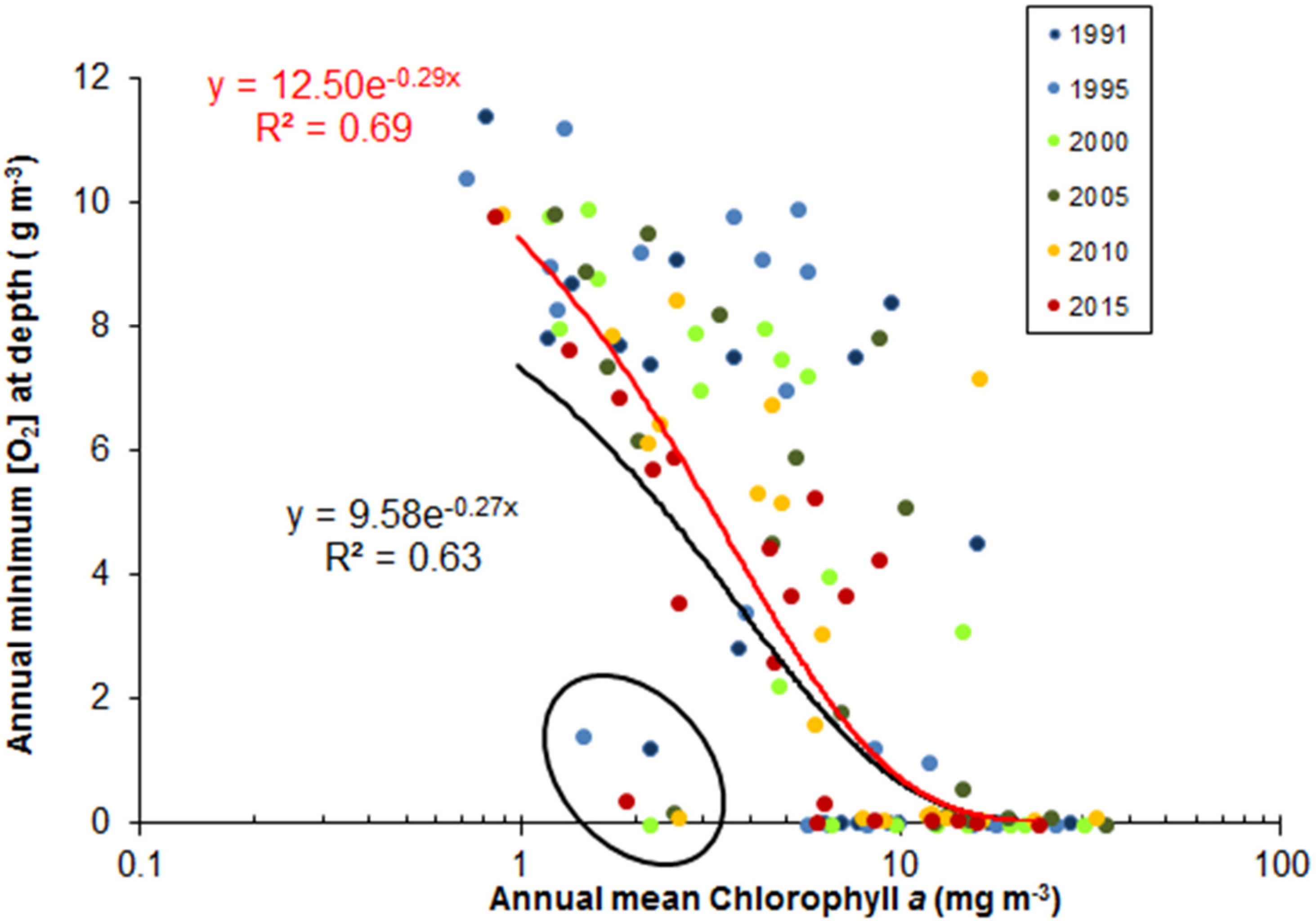


No oxygen depletion

Oxygen depletion above sediment

Oxygen depletion in hypolimnion

Oxygen minima are controlled by phytoplankton chlorophyll *a*



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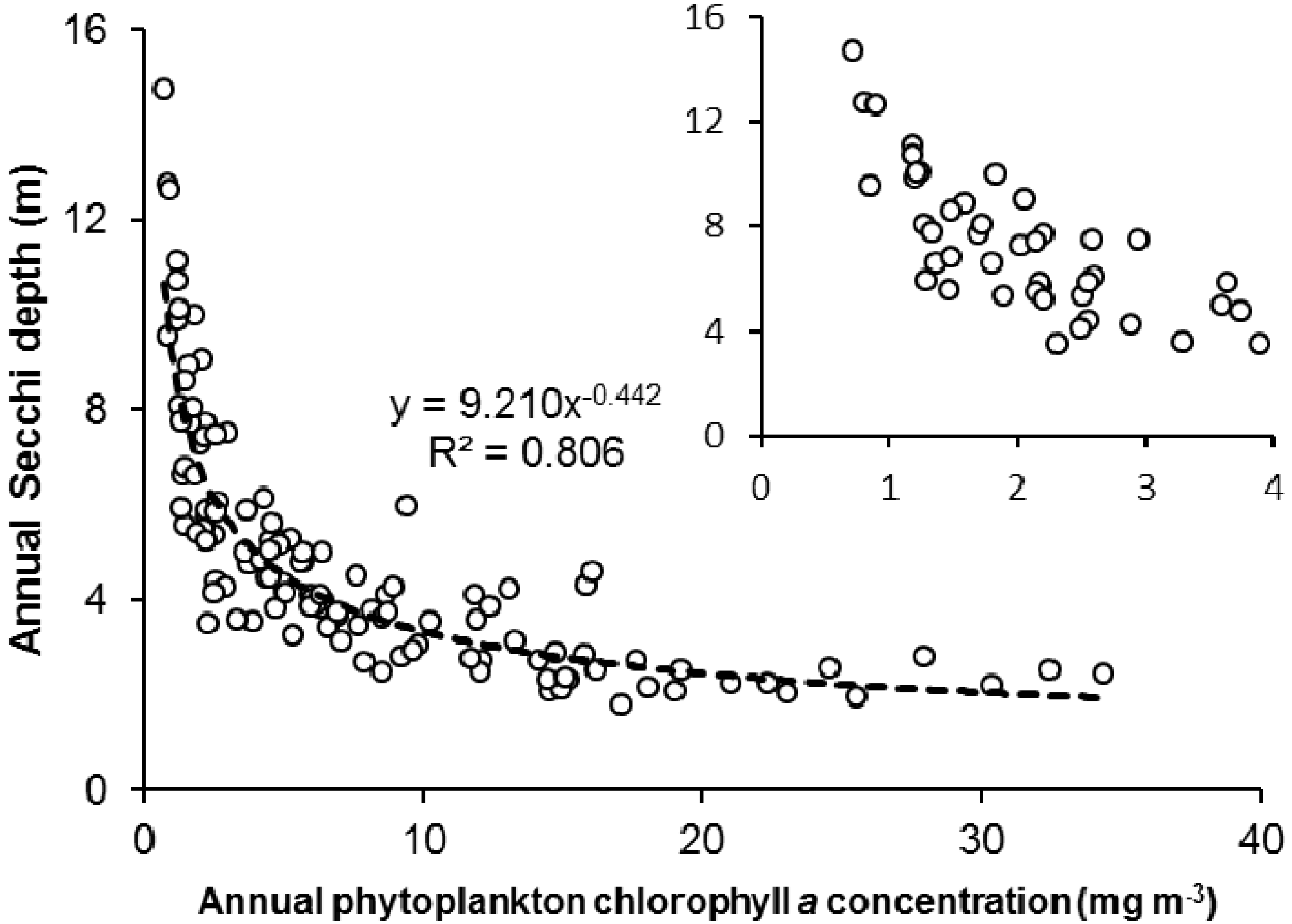
Lakes Tour data from 1991, 1995, 2000, 2005, 2010 & 2015

Secchi depth is largely controlled by phytoplankton chlorophyll



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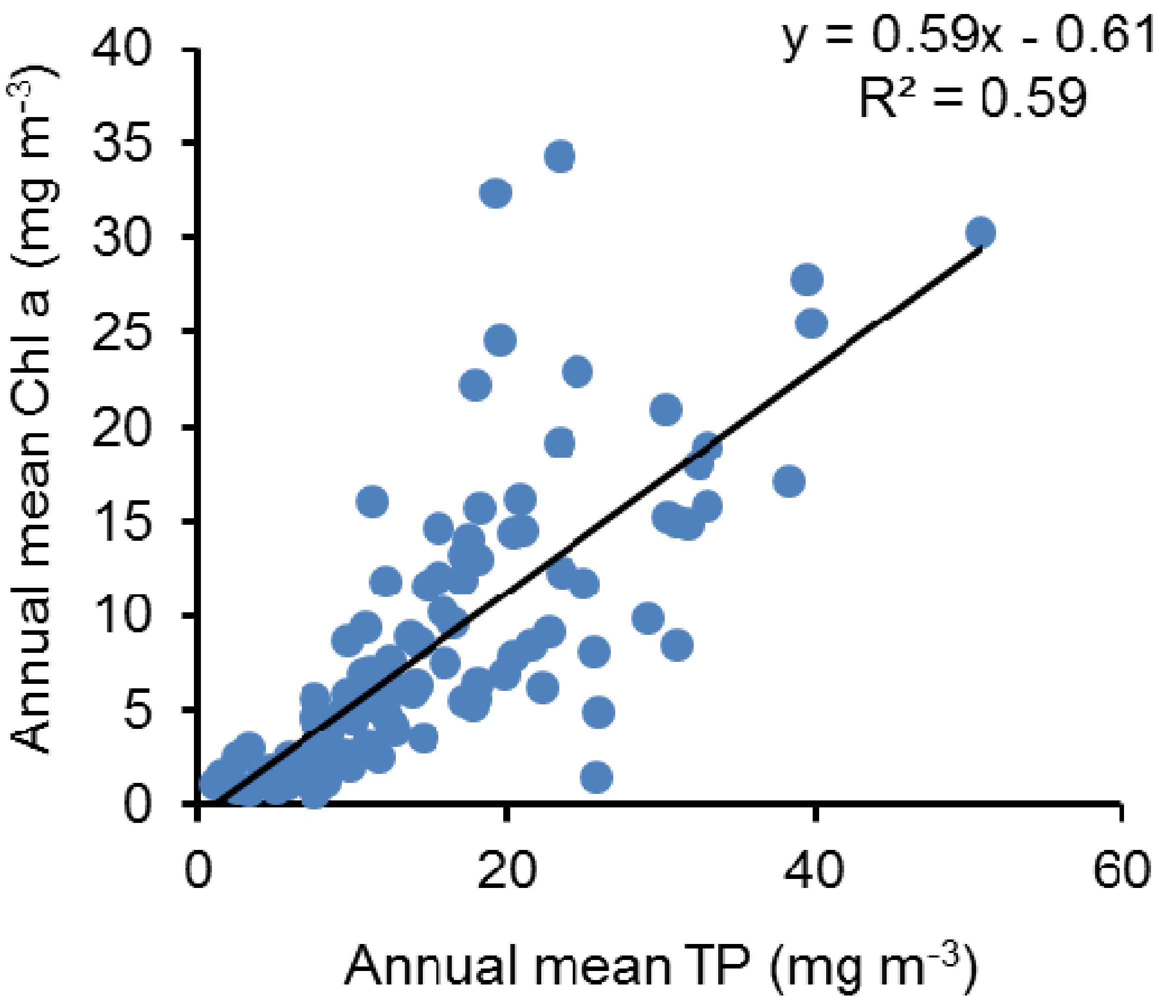
Lakes Tour data from 1991, 1995, 2000, 2005, 2010 & 2015

Chl *a* is largely controlled by phosphorus

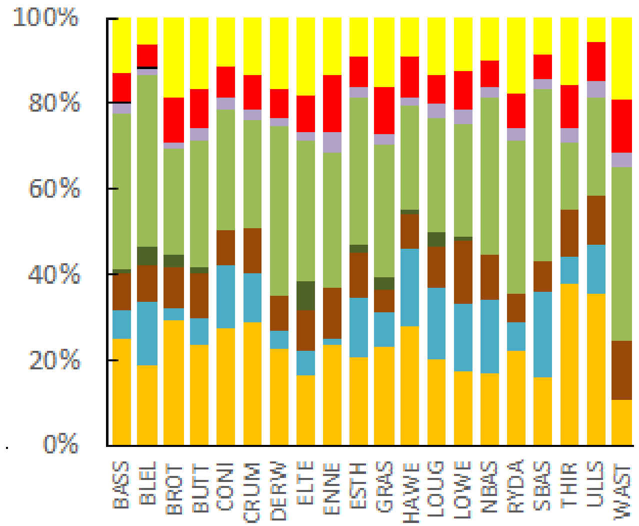


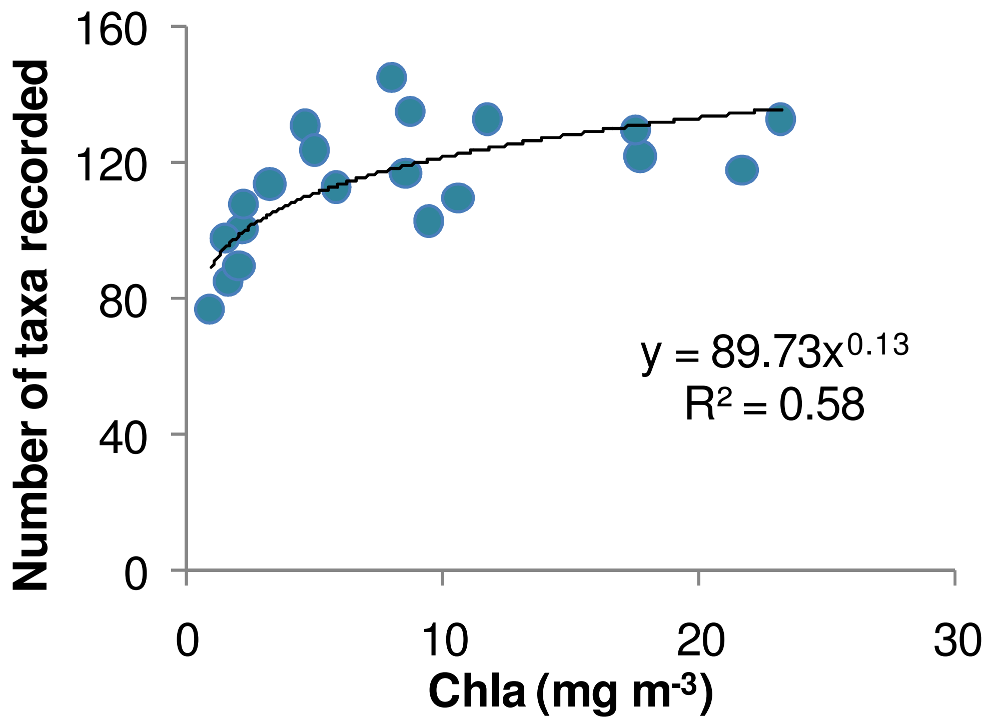
Lakes Tour data: Annual average from 1991, 1995, 2000, 2005, 2010 & 2015

Phytoplankton species richness & composition

diatoms
cyanobacteria
dinoflagellates
euglenophyted
chlorophytes
haptophytes
cryptophytes
chrysophytes

Percent of total biovolume





Multiple regression:

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

Adj R^2 = 71.9%, P<0.001

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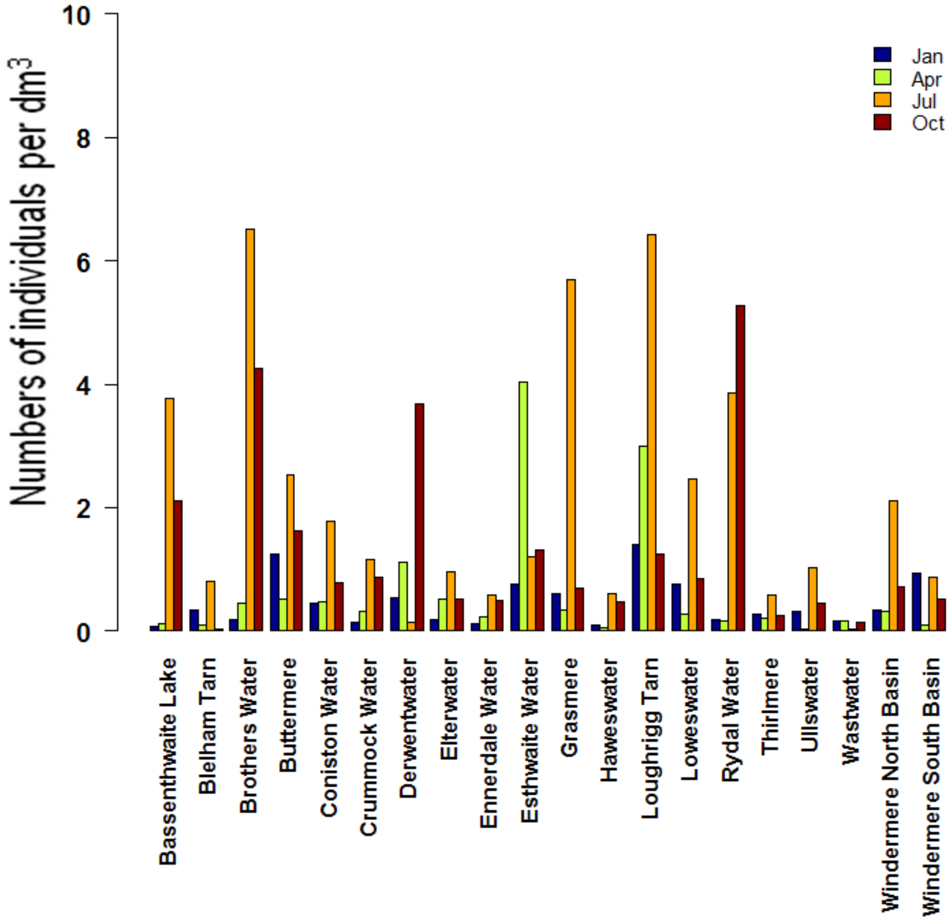
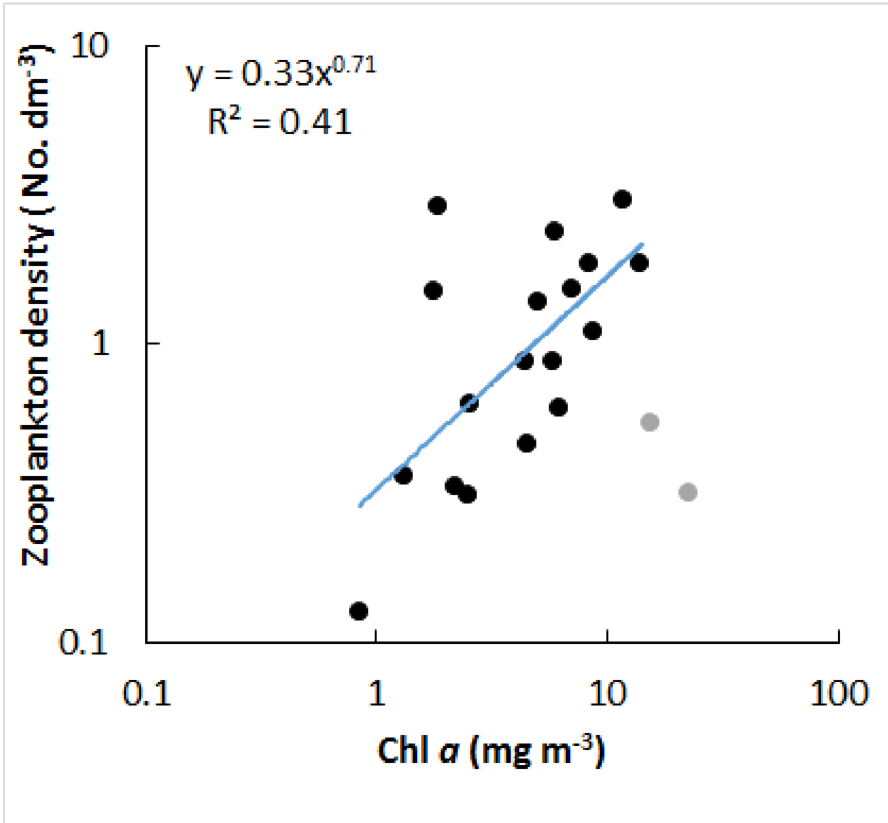
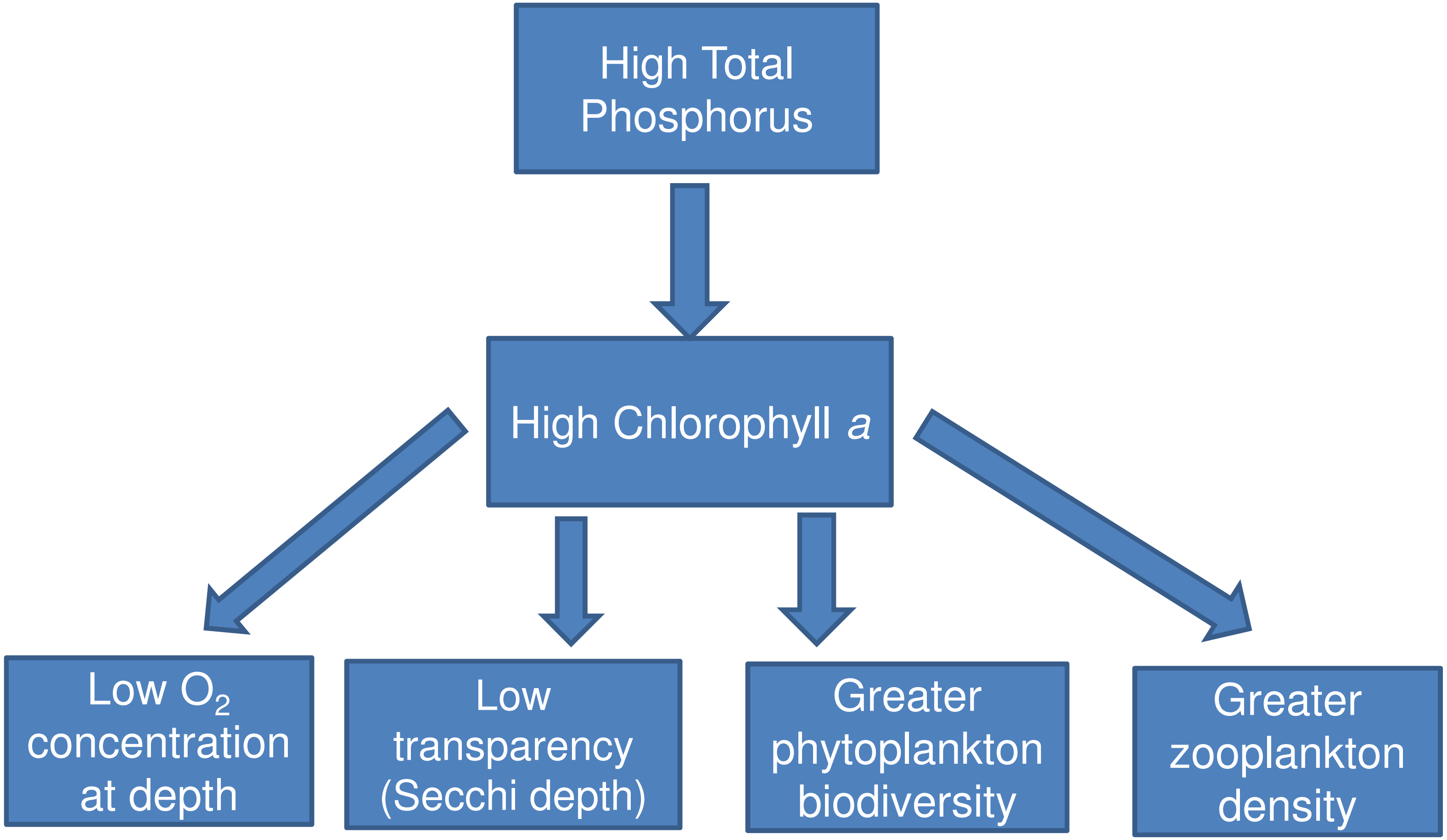
Zooplankton



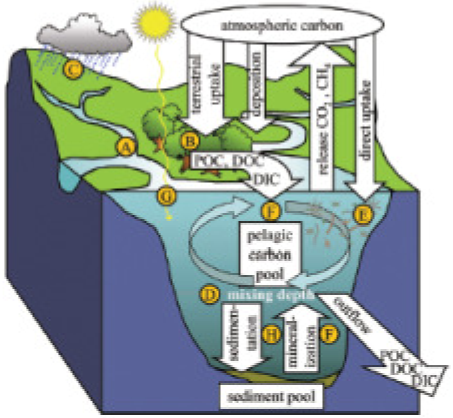


Consequences of nutrient availability

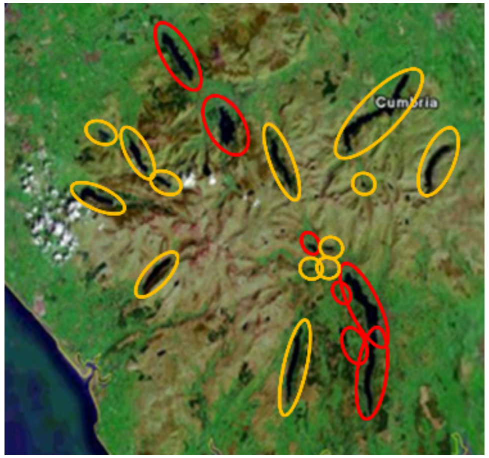


Catchments, lakes & global C-cycling

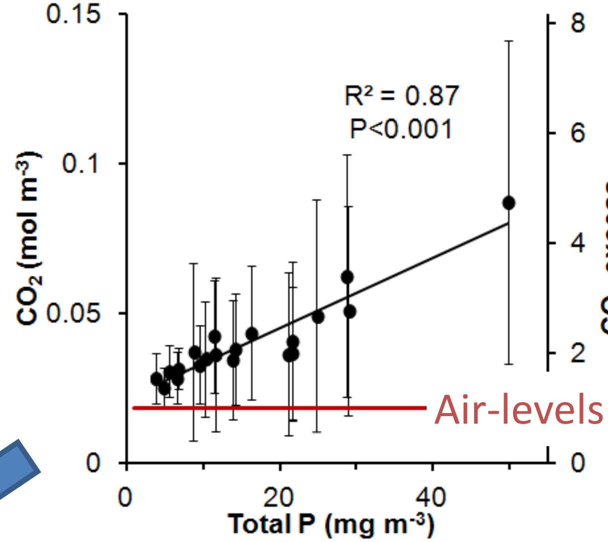
Lakes are important in global C-cycle

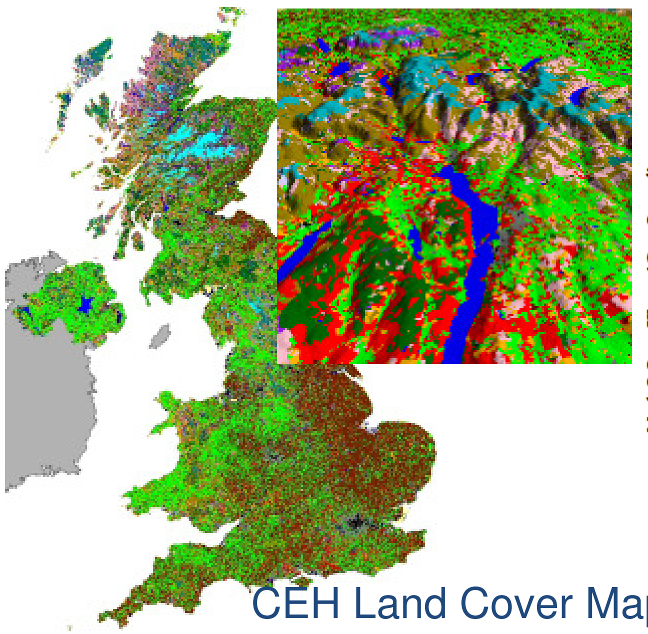


Lakes Tour data on Cumbrian lakes

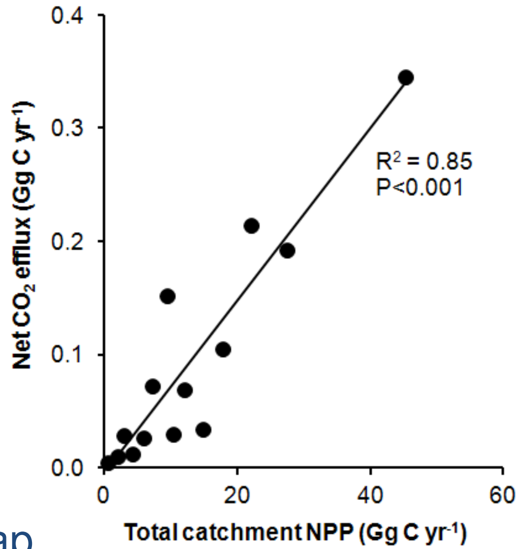


Paradox: mean [CO_2] greatest in most productive lakes



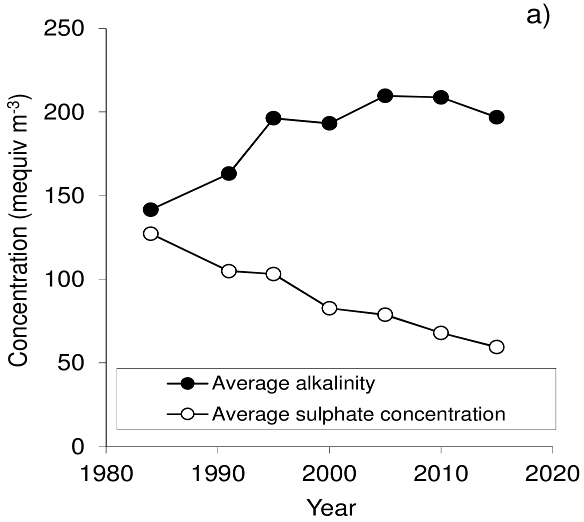


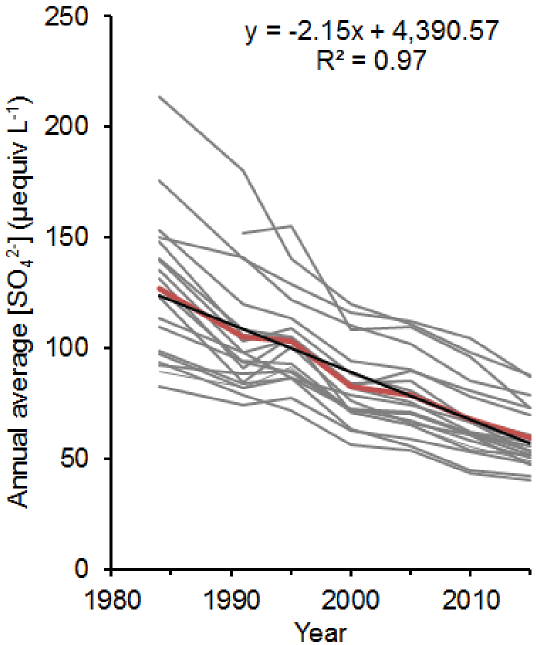
CEH Land Cover Map

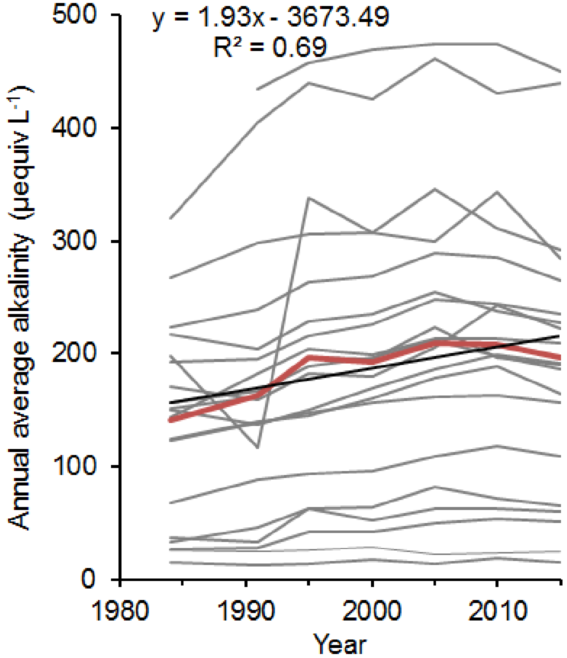


Maberly *et al.* (2013). *Nature Climate Change* 3: 391-394.

Coherent changes caused by acid-deposition







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Long-term trends

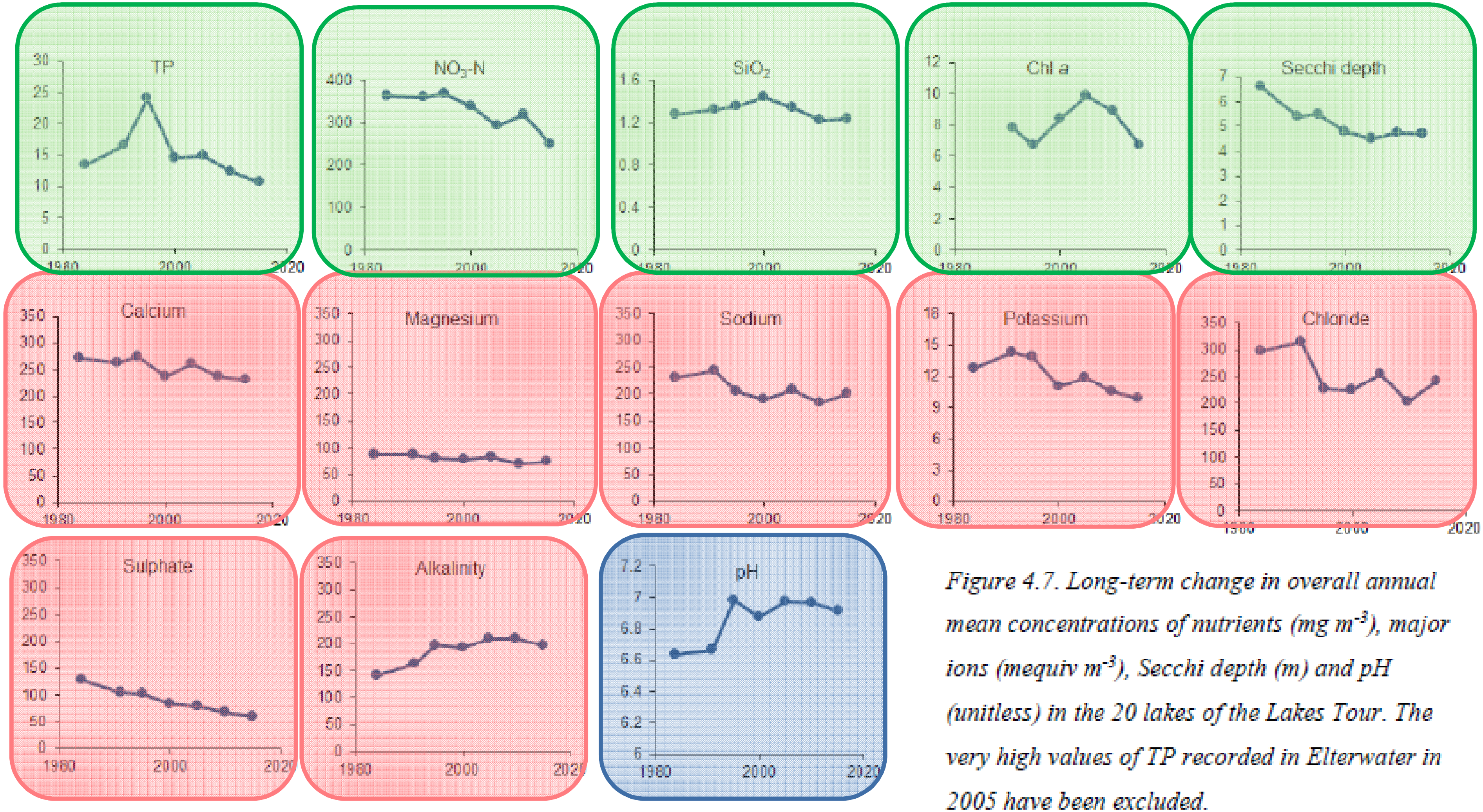

Figure 4.7. Long-term change in overall annual mean concentrations of nutrients (mg m^{-3}), major ions (mequiv m^{-3}), Secchi depth (m) and pH (unitless) in the 20 lakes of the Lakes Tour. The very high values of TP recorded in Elterwater in 2005 have been excluded.

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Focus on five lakes

Wastwater

Crummock Water

Esthwaite Water

Loweswater

Elterwater

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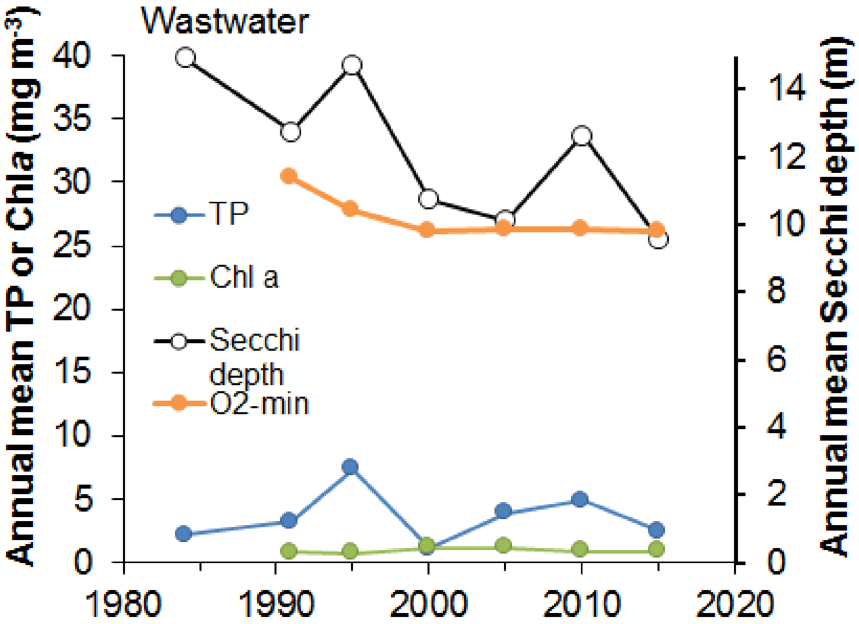
Wastwater

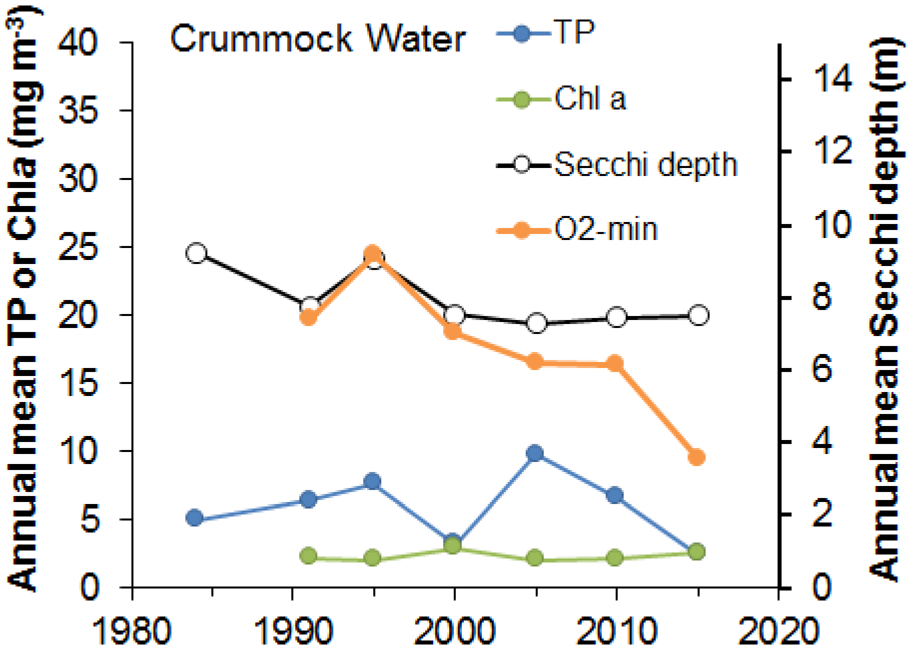


- ‘Premier’ (ultra-) oligotrophic lake in England at High or Ref ecological status (WFD)
- Worrying signs of declining Secchi depth

<u>Possible causes:</u>

- 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

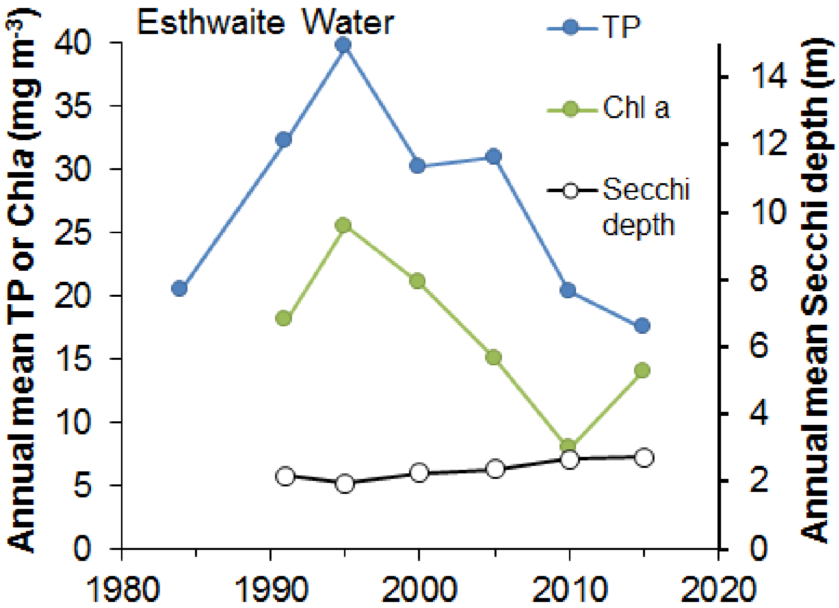


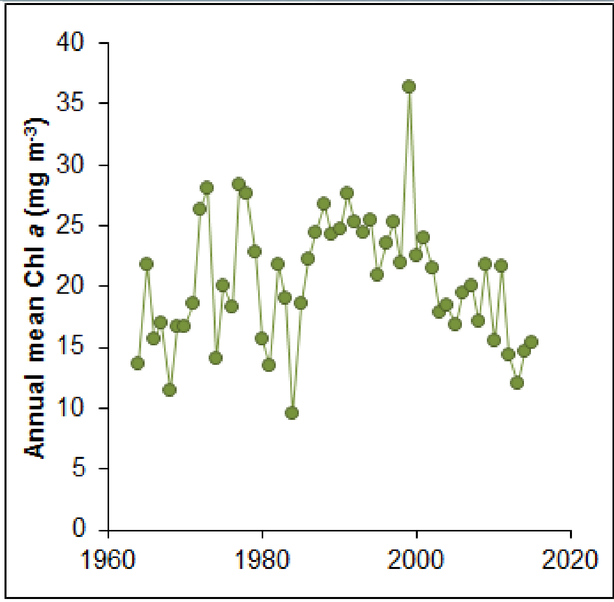
- Oligotrophic lake but declining O_2 at depth from 9.2 g m^{-3} in 1995 to 3.6 g m^{-3} in 2015 at High or Good ecological status (WFD)

<u>Possible causes</u>:

- 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

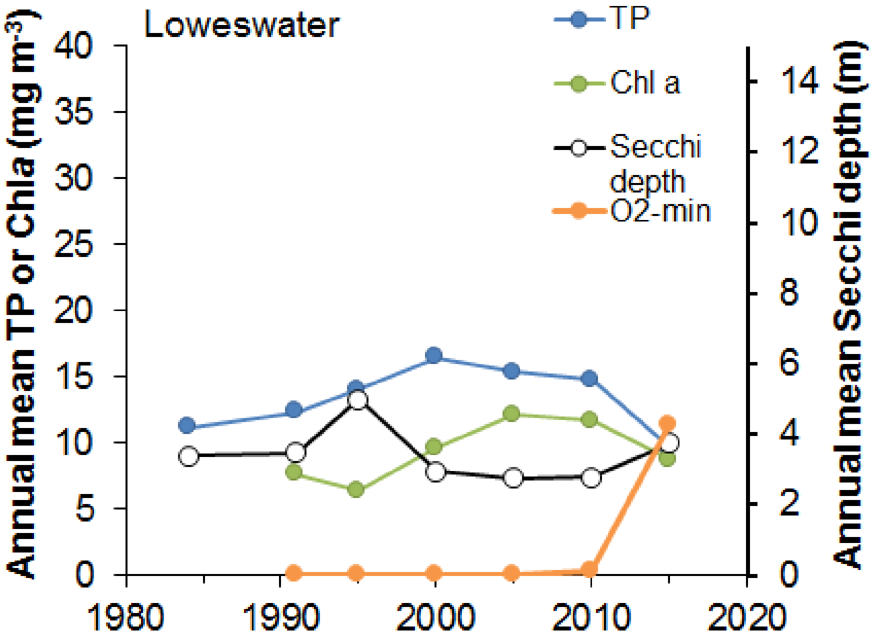
Esthwaite Water





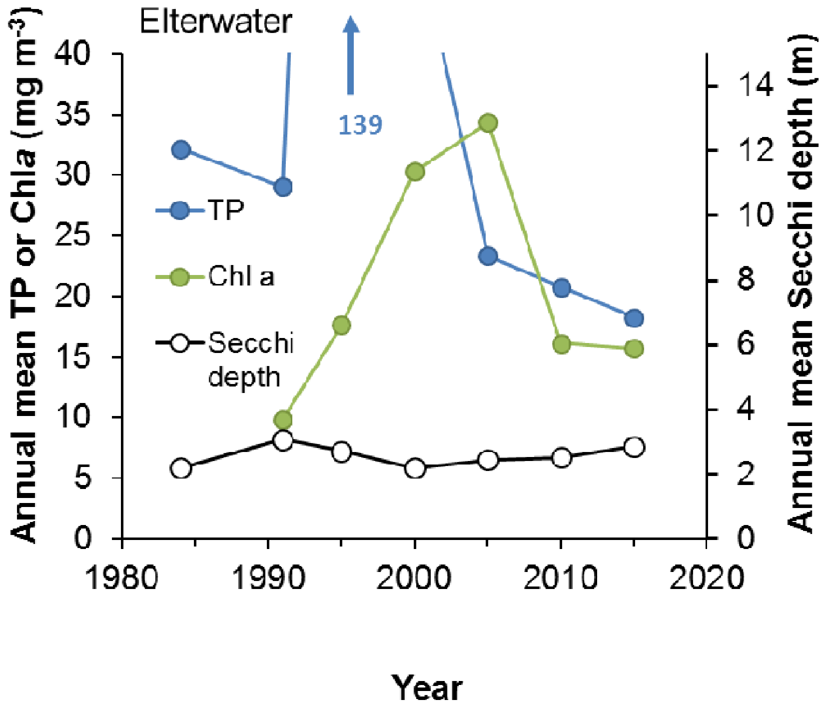
- At mesotrophic-eutrophic boundary and at Moderate ecological status (WFD)
- Series of upgrades by UU to WwTW and by NE in buying out fish farm
- On mesotrophic-eutrophic boundary, although still substantial O_2 depletion at depth
- Encouraging improvement in TP and Secchi depth and general downward trend in Chl *a*
- 2015 Chl *a* increase- CEH fortnightly long-term data could be analysed to give more perspective on recent changes

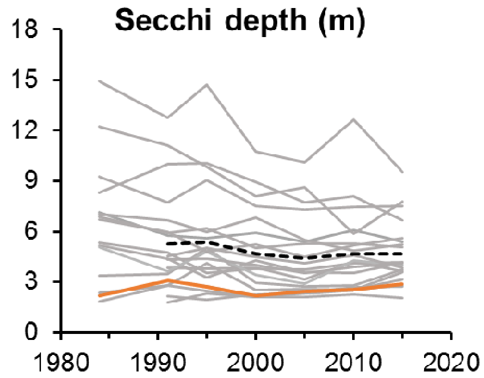
Loweswater

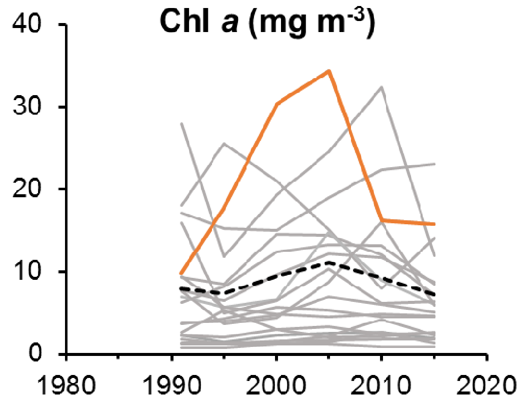


- At mesotrophic-eutrophic boundary and at Moderate ecological status (WFD)
- Encouraging signs of improvement following CEH/ LU RELU project and community Defra funded project- now part of WCRT
- More years of data needed to confirm improvement within envelope of variation caused by weather

Elterwater (Inner basin)





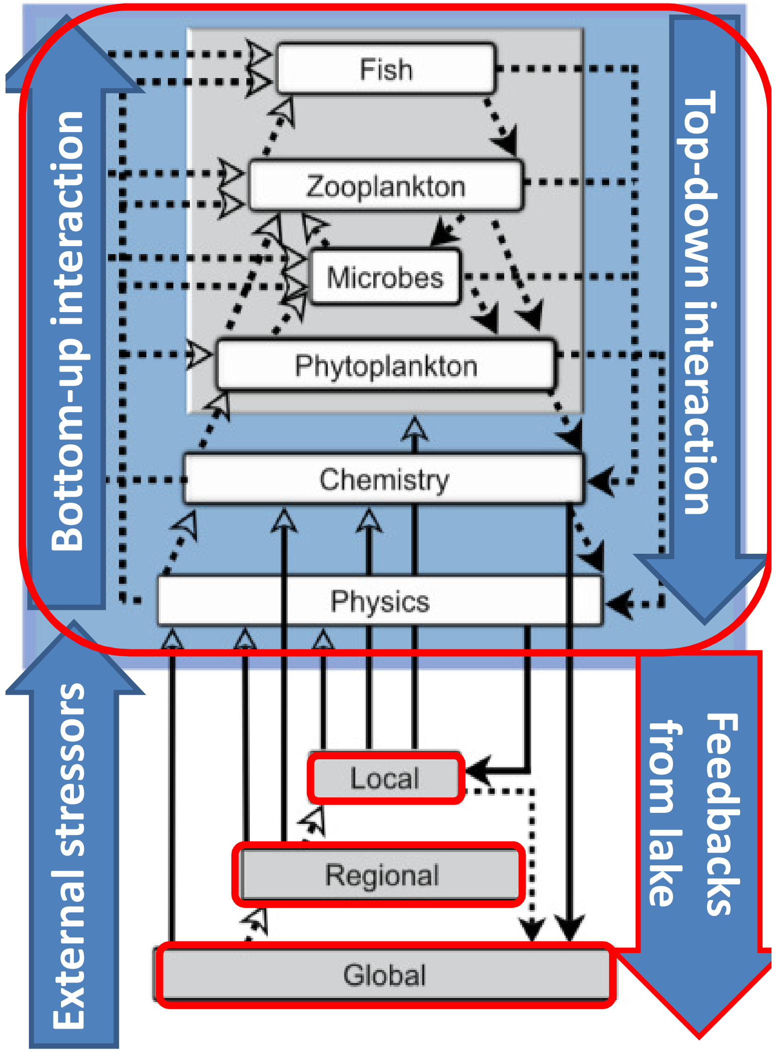


- A eutrophic lake at Moderate ecological status (WFD)
- The shallowest and one of the most rapidly flushed lakes in the Lakes Tour set
- Suffered extreme nutrient enrichment with a peak in 1995 for TP and 2005 for Chla
- Encouraging subsequent signs of recovery in TP, Chl*a* and Secchi depth- but still 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.



Hierarchy of external stressors

Acknowledgements

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- 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

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