Internal phosphorus loading and remediation in lakes

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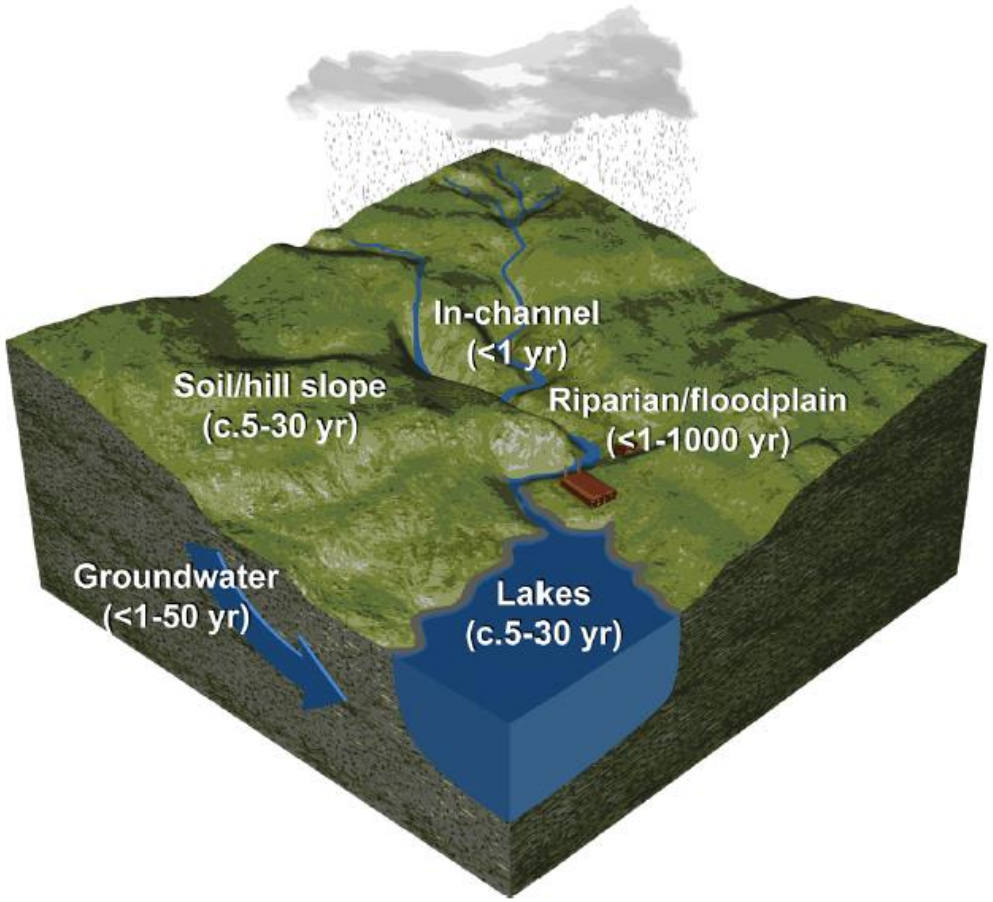
Legacy phosphorus confounds recovery in lakes



Even if we reduce catchment P sources our lakes won't recover by policy deadlines.....

Ecological status of 31,819 km^2 lake surface area needs to be improved to meet EU WFD targets

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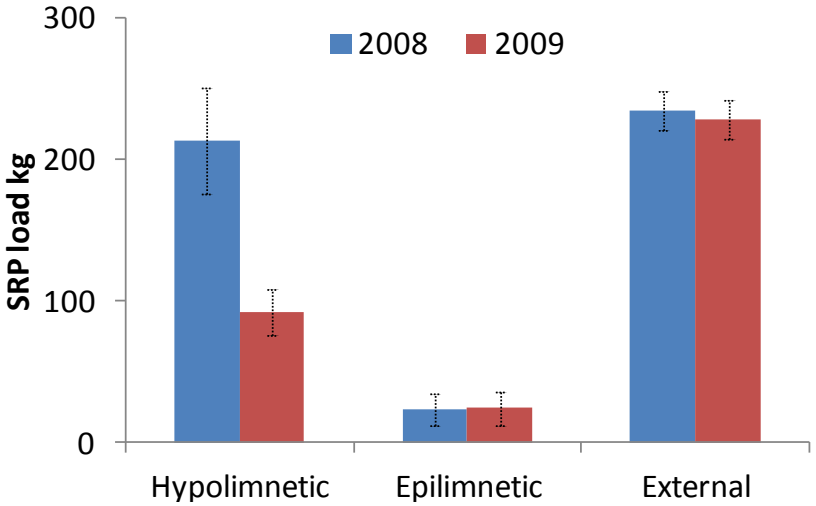
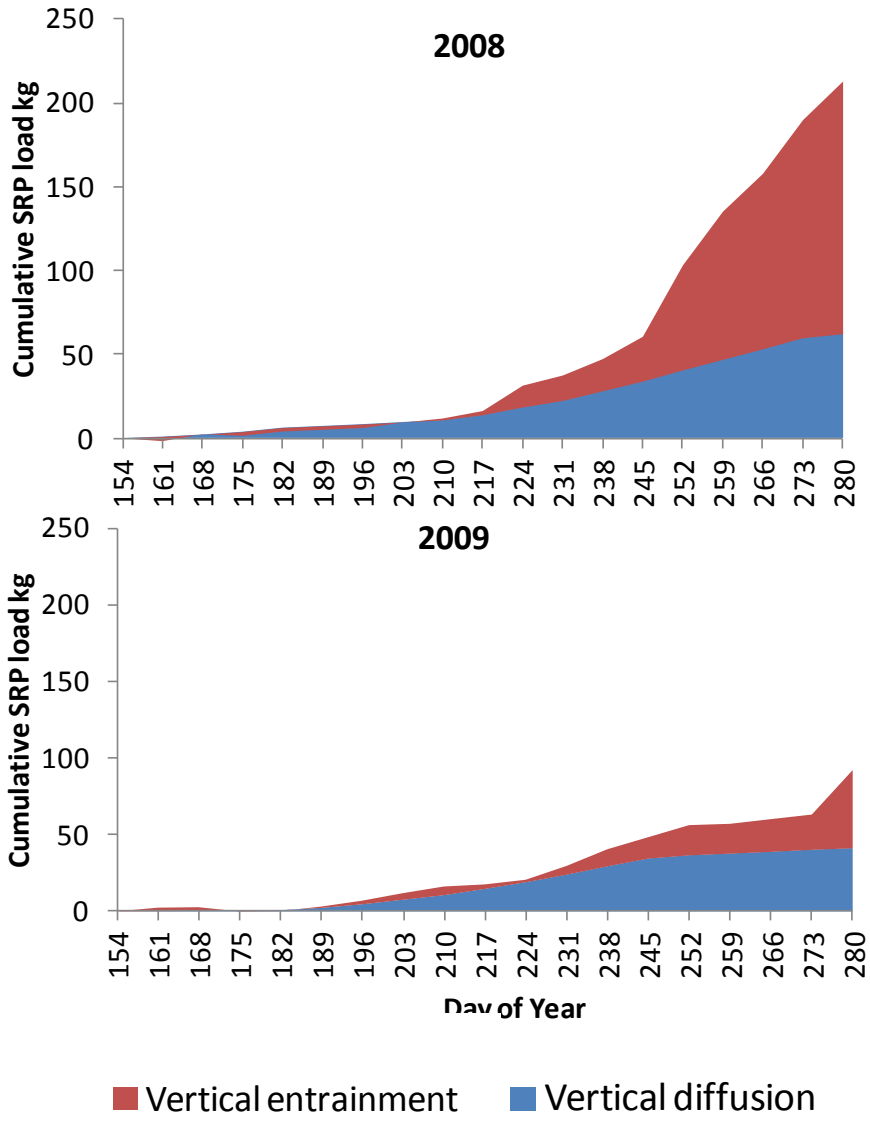
Jarvie et al., 2013. ES&T

Inter-annual variation and changes in the weather



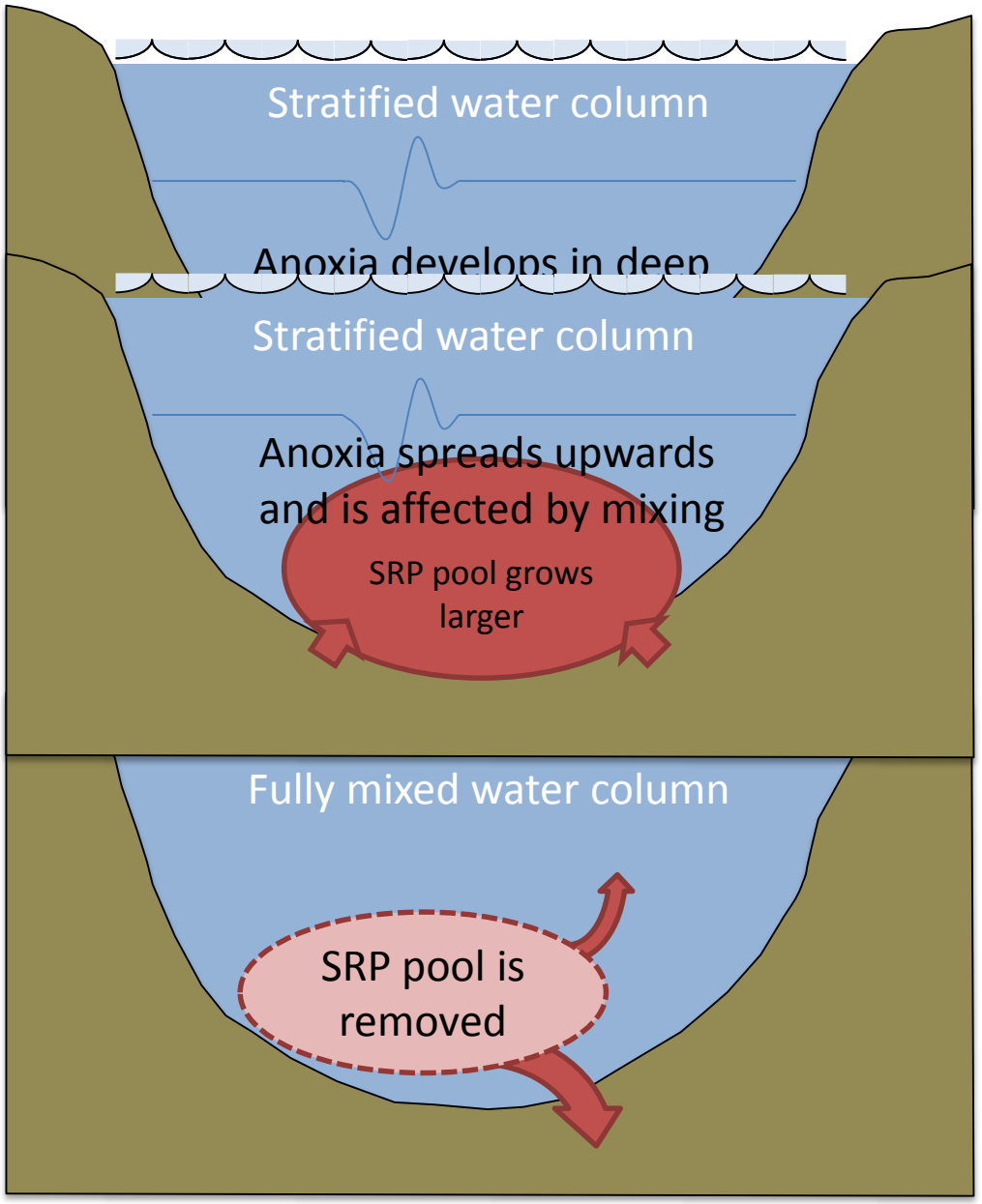


- What was different?
- Increase in wind speed of 0.8 m s^{-1} resulted in a doubling of mid-summer wind energy between 2008 and 2009
- Combined with an 8 W m^{-2} difference in solar radiation resulted in lake cooling in 2009 opposed to warming in 2008

Mackay et al. 2014 Freshwater Biology

Internal loading in deep stratified lakes

- Early summer – SRP in hypolimnion low and little affected by mixing
- Late summer – some hypolimnetic SRP is mixed up into epilimnion during overturn
- Mid summer – weather conditions determine potential supply of SRP from hypolimnion through mixing changes to anoxic area and volume



Mackay et al. 2014 Freshwater Biology

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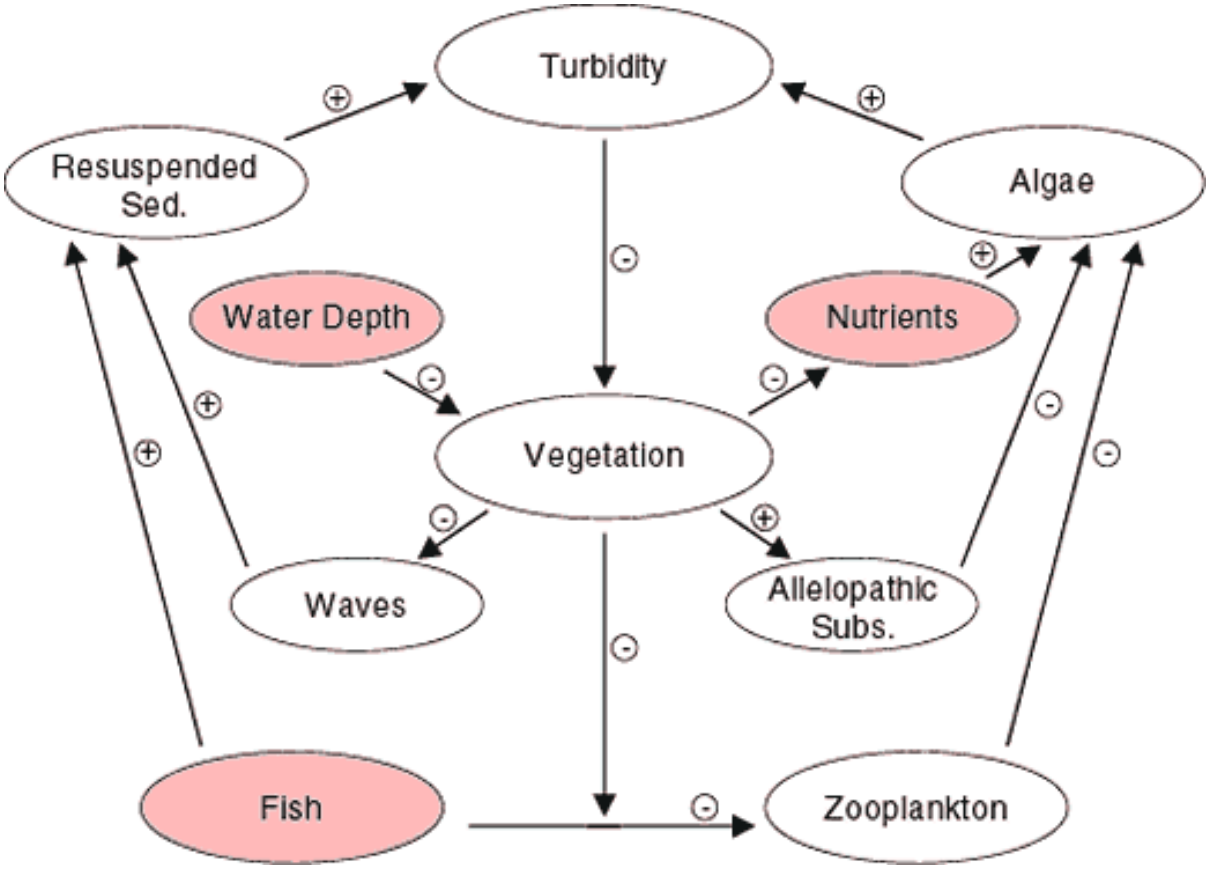
Internal loading in shallow lakes

- Resuspension of sediment nutrients occurs due to waves and fish activity
- Direct impact on light climate and provision of nutrients for algal growth
- Negative impact on macrophytes
- Shift from macrophyte-dominated to phytoplankton-dominated state



Scheffer et al. 1993 Trends in Ecology and Evolution

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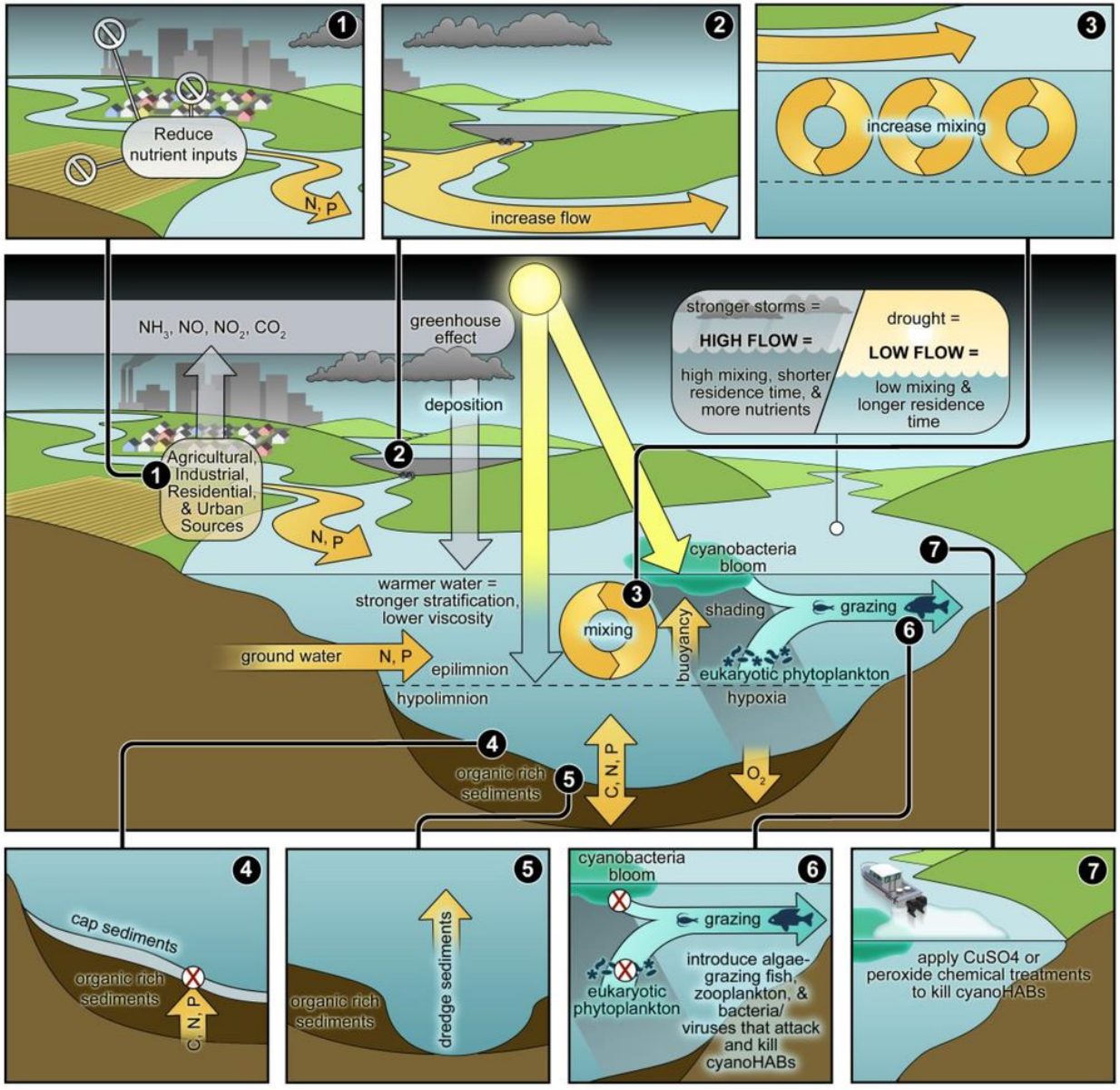
Remediation of harmful algal blooms



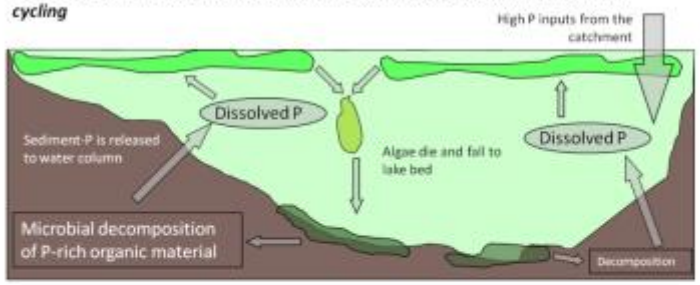
1. External loading
2. Increased flushing
3. Increased mixing
4. Sediment capping
5. Sediment dredging
6. Trophic cascade
7. Chemical treatment

Paerl 2014 Life

Using sediment ‘capping’ to reduce internal loading

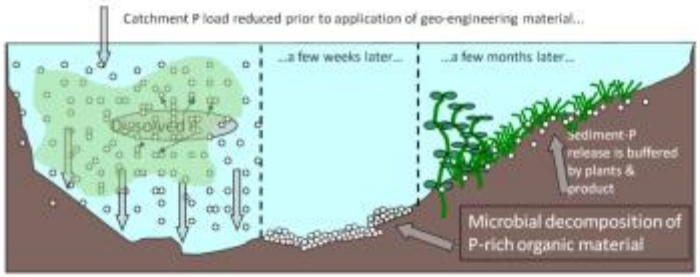
ALGAL DOMINATED STATE

Resilience to change maintained through high algal production and internal P cycling



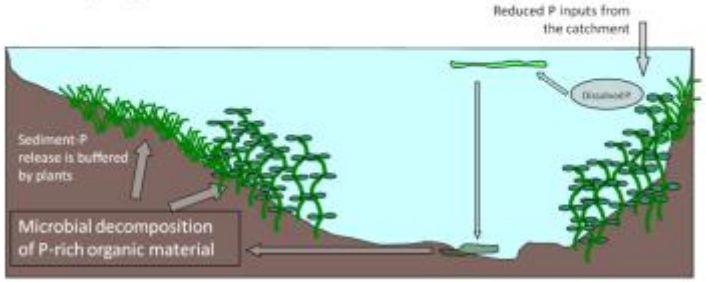
FORCING A CHANGE OF STATE

Following successful reduction of catchment P inputs, internal loading feedback mechanism is disrupted using geo-engineering products providing an opportunity for aquatic macrophytes to re-establish lake bed sediments



PLANT DOMINATED STATE

Resilience to change maintained through high plant production and regulation of internal P cycling

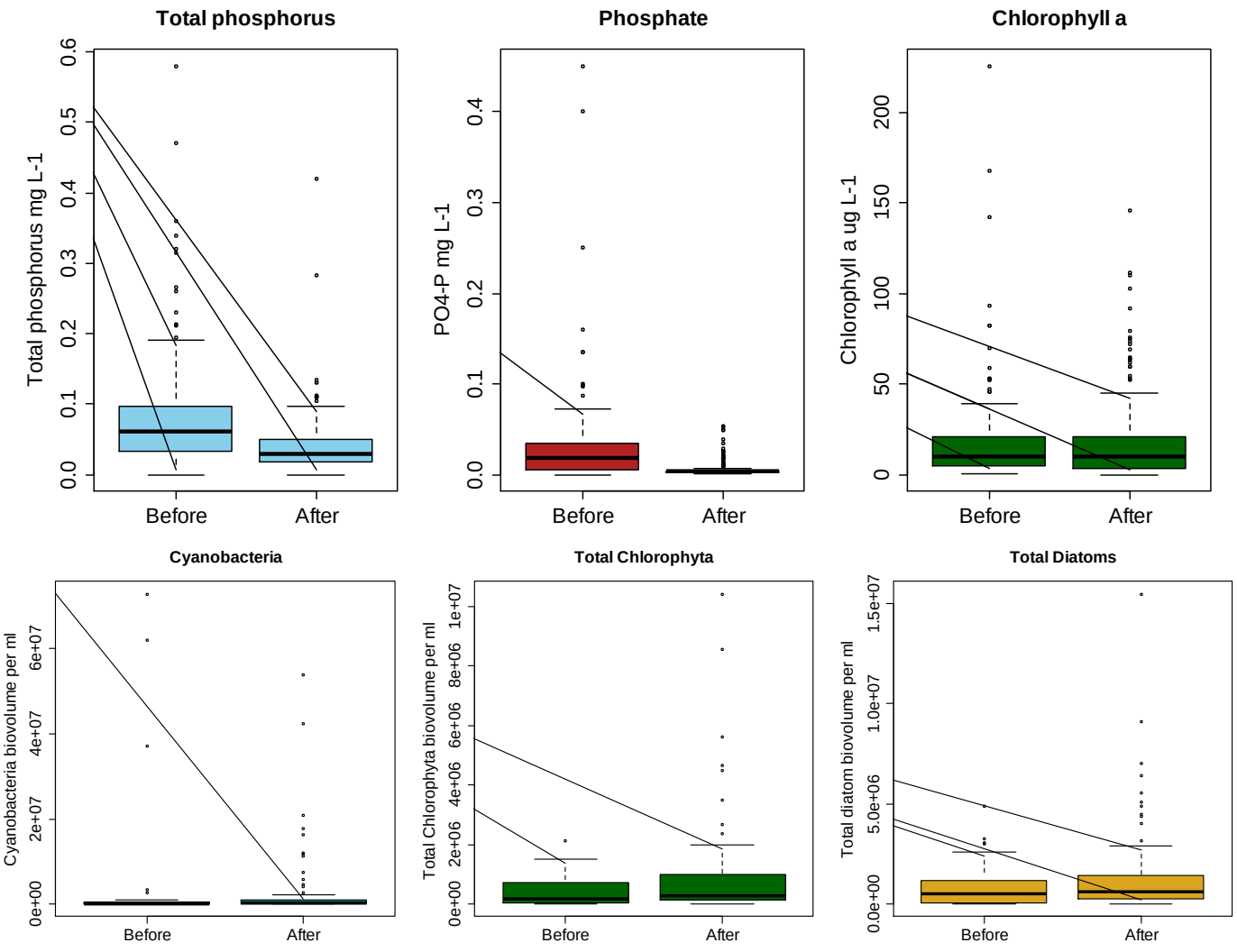


[P = phosphorus]

Mackay et al. 2014 Inland Waters

Results from 15 lakes comparing +/- 24 months

- Significant reduction in TP and PO_4-P
- Only a small reduction in phytoplankton biomass
- Change in community with increases in green algae and diatoms relative to cyanobacteria



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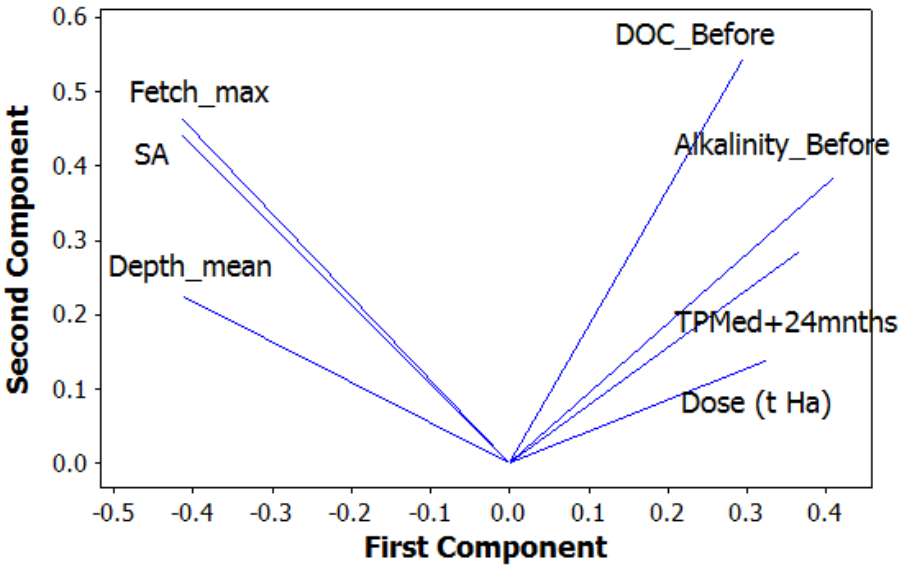
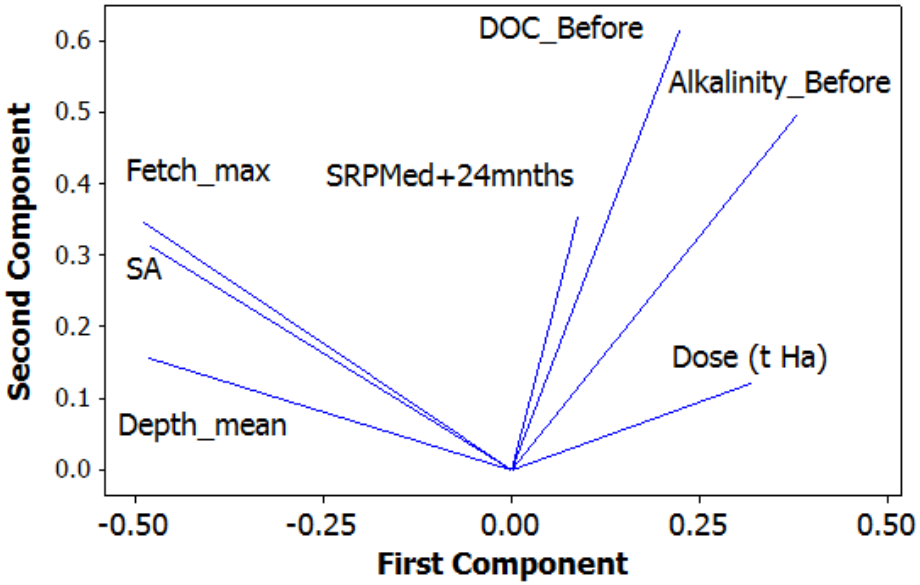
Spears et al. 2015 Water Research

Factors potentially confounding chemical responses





Interactions between DOC and other chemical components of the receiving water may retard operational performance of the product

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Spears et al. 2015 Water Research

Conclusions

- Internal phosphorus loading can be a problem in both shallow and deep lakes
- Variability in the weather can influence how important it is from year to year
- A number of remediation strategies exist for addressing water quality problems like algal blooms
- A meta-analysis of a sediment ‘capping’ material suggest that phosphorus concentrations can be strongly affected, while impacts on phytoplankton are more subtle
- A thorough understanding the lake ‘system’ is required before this approach should be considered, to reduce confounding effects

Acknowledgements

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