School of Earth and Environmental Sciences
Ysgol Gwyddorau'r Ddaear a'r Amgylchedd

Better Water Quality for Wales
27 – 29 June 2023

Rethinking Eutrophication

Dr Rupert Perkins, Cardiff University

Peter Kille, Sophie Watson, Annalise Hooper, Amie Parris, Inge Elfferich, Emily Slavin, Veronica Bell, Charlotte Taylor, Thom Bellamy and others

“**Eutrophication** is the process by which an entire body of water, or parts of it, becomes progressively enriched with minerals and nutrients, particularly nitrogen and phosphorus.”
Wikipedia

“This is when there is too much nutrient in rivers, lakes/reservoirs, estuaries or the sea, causing excessive growth of algae and plants. This adversely affects the quality of the water and our uses of it, as well as damaging the local ecology.”
Environment Agency

"nutrient-induced increase in phytoplankton productivity“
Chapin, 2011

“Eutrophication is the result of excessive enrichment of water with nutrients, which may accelerate the growth of algae (phytoplankton) in the water column.”
OSPAR

“**Eutrophication** is characterized by excessive plant and algal growth due to the increased availability of one or more limiting growth factors needed for **photosynthesis**”
Schindler 2006

Eutrophication and Harmful Algal Blooms

What is an algal bloom?

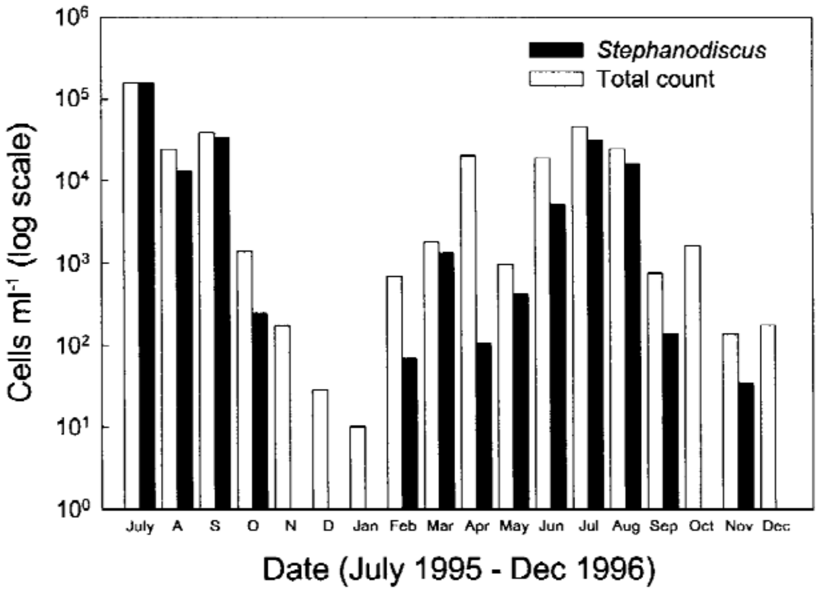
The Phosphorus Mindset

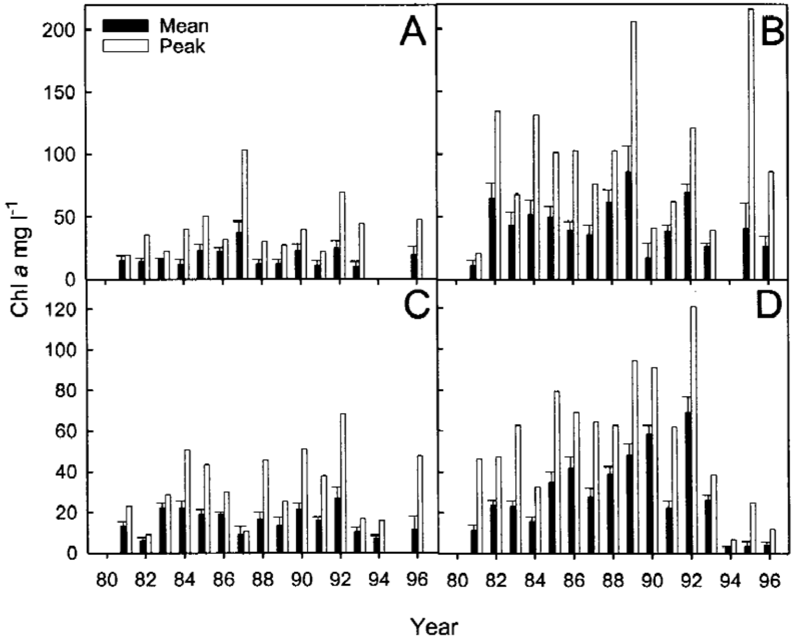
1970s-1990s – phosphate rich discharges driving HABs – high media attention

Response to enrichment with P required other factors to combine

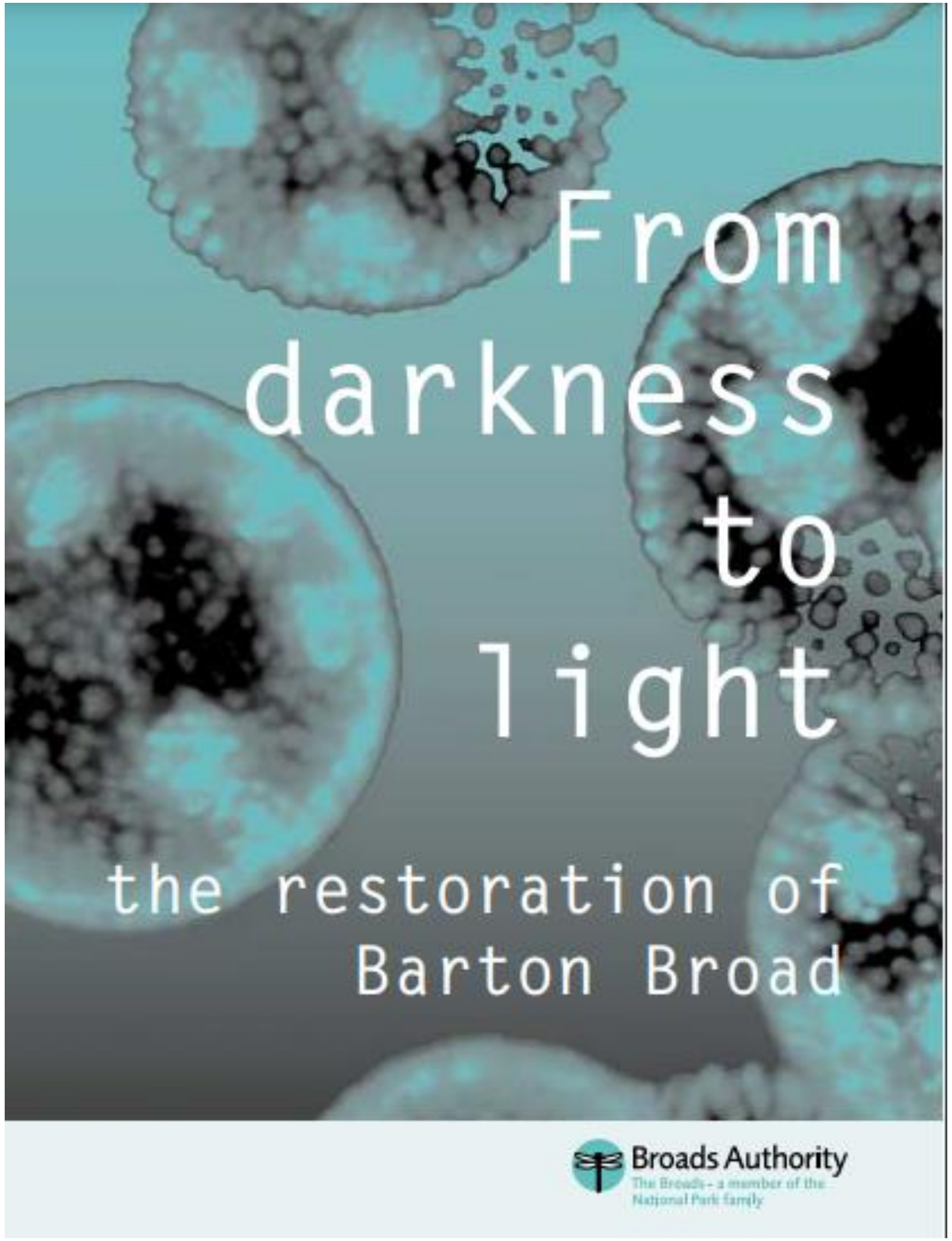
Nutrients and environmental variables – cyanobacterial dominance

Perturbation to switch between bi-stable states (Scheffer et al. 2001; Norfolk Broads etc.)





Figures from Perkins and Underwood, 2001



Catastrophic shifts in ecosystems

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All ecosystems are exposed to gradual changes in climate, nutrient loading, habitat fragmentation or biotic exploitation. Nature is usually assumed to respond to gradual change in a smooth way. However, studies on lakes, coral reefs, oceans, forests and arid lands have shown that smooth change can be interrupted by sudden drastic switches to a contrasting state. Although diverse events can trigger such shifts, recent studies show that a loss of resilience usually paves the way for a switch to an alternative state. This suggests that strategies for sustainable management of such ecosystems should focus on maintaining resilience.

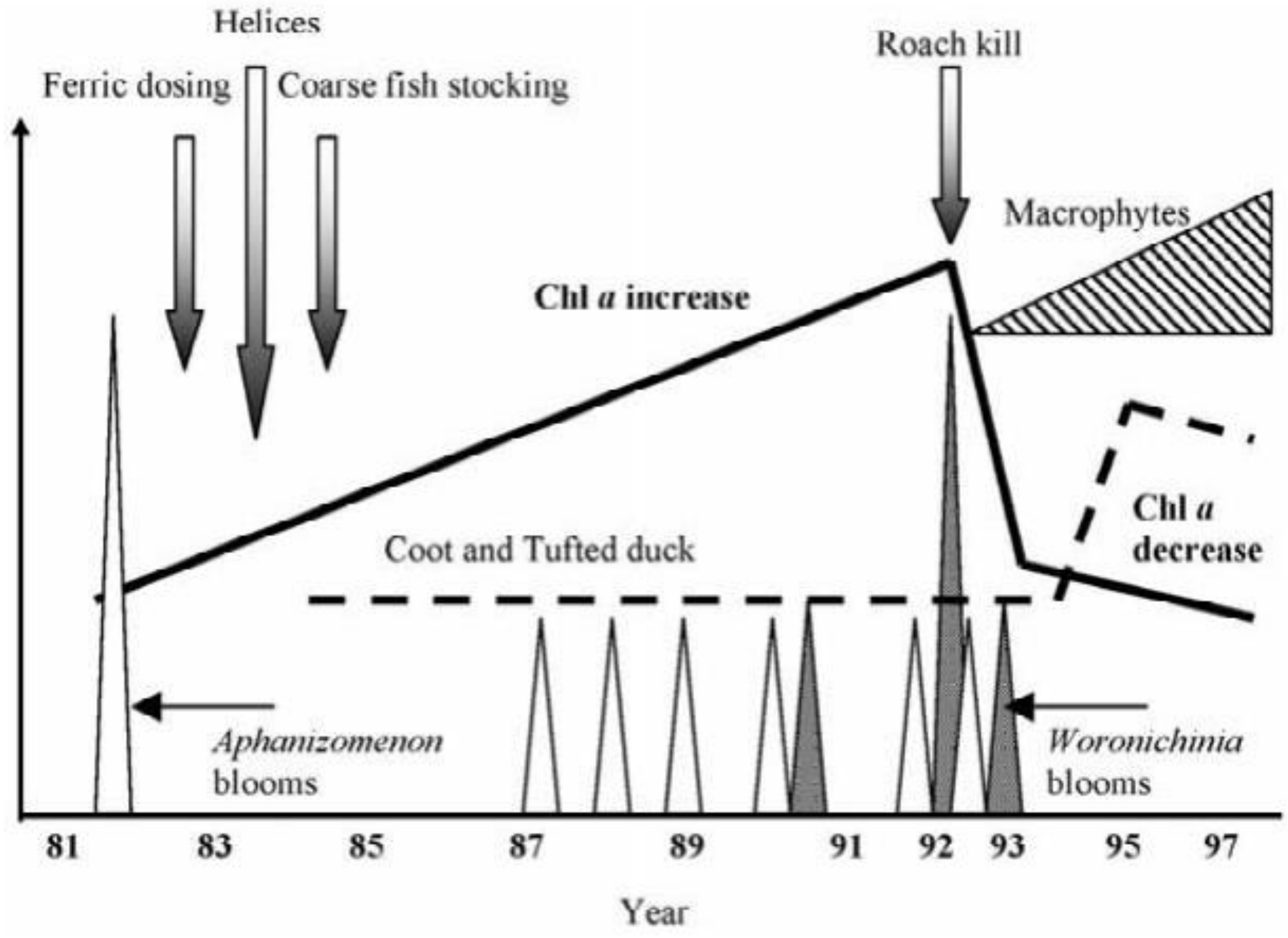
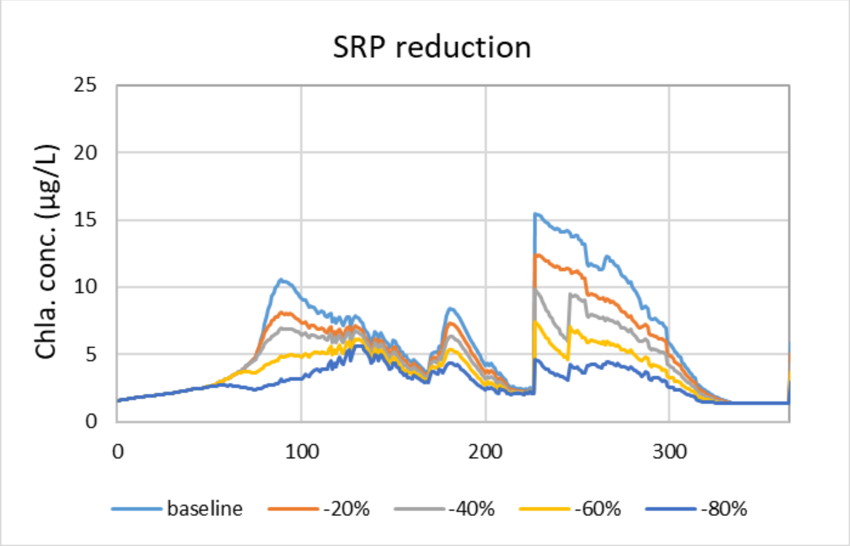
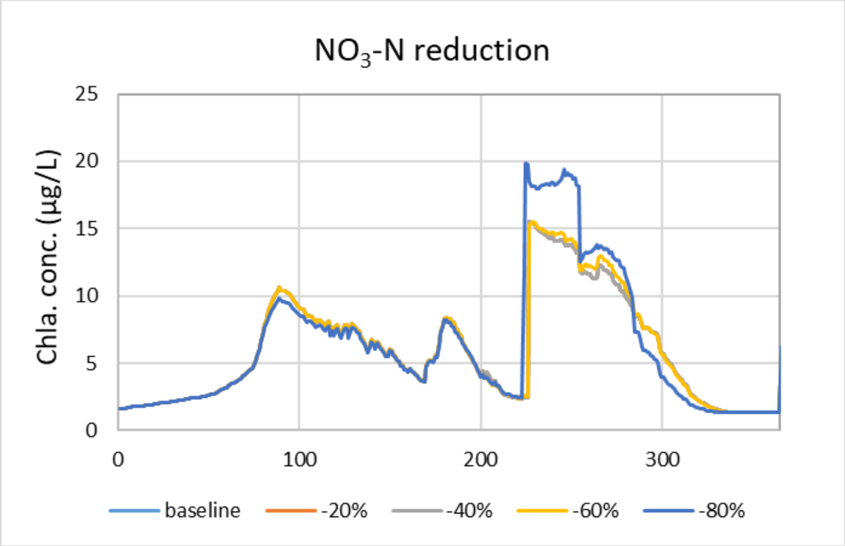
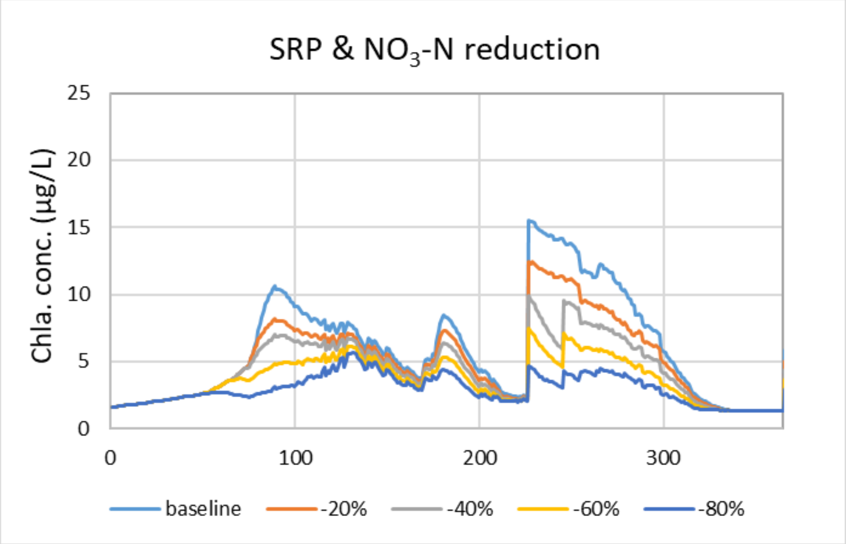


Figure from Perkins and Underwood, 2001

Can we reduce Phosphorus any further and if we do… will it make a difference?

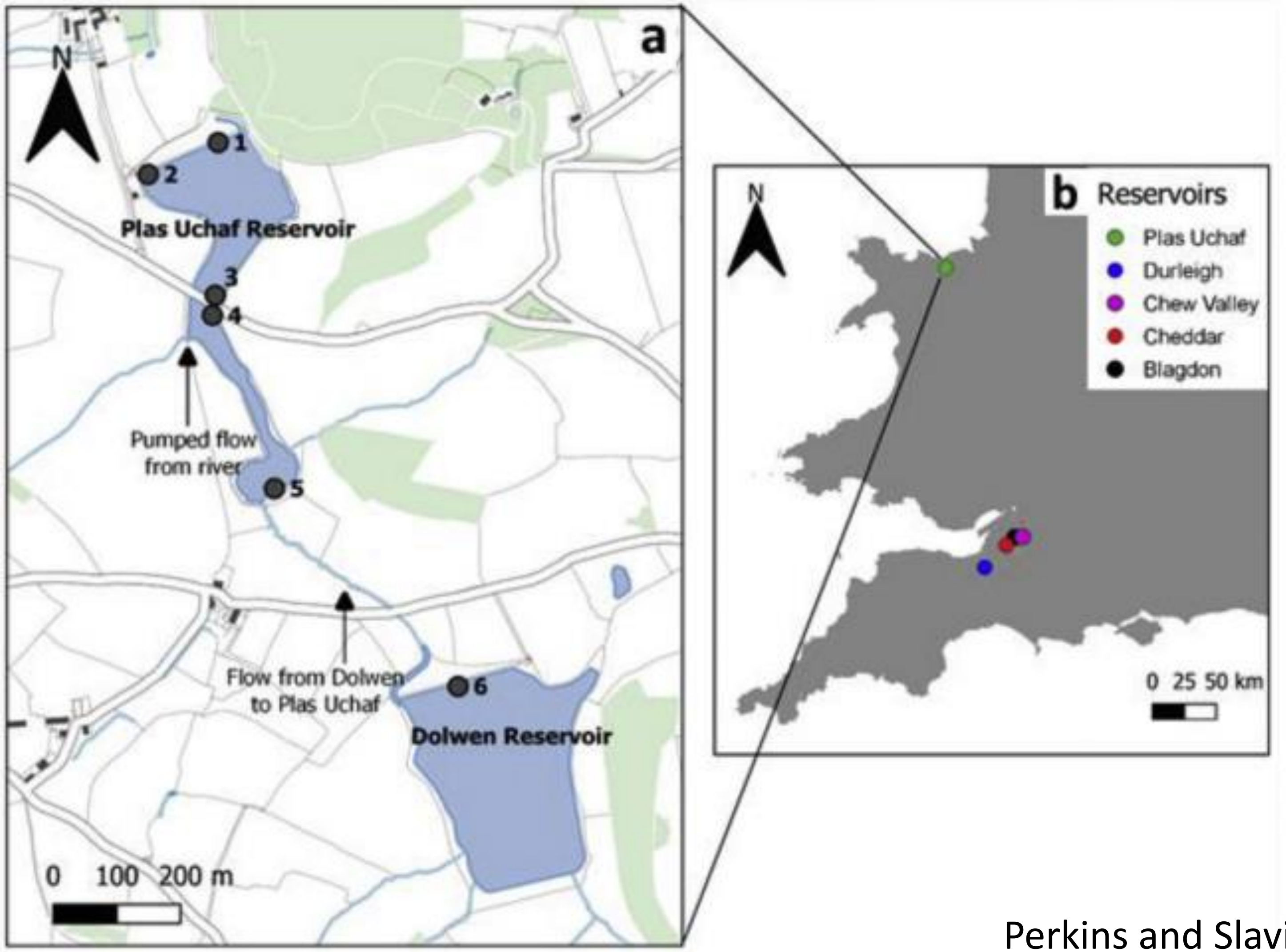




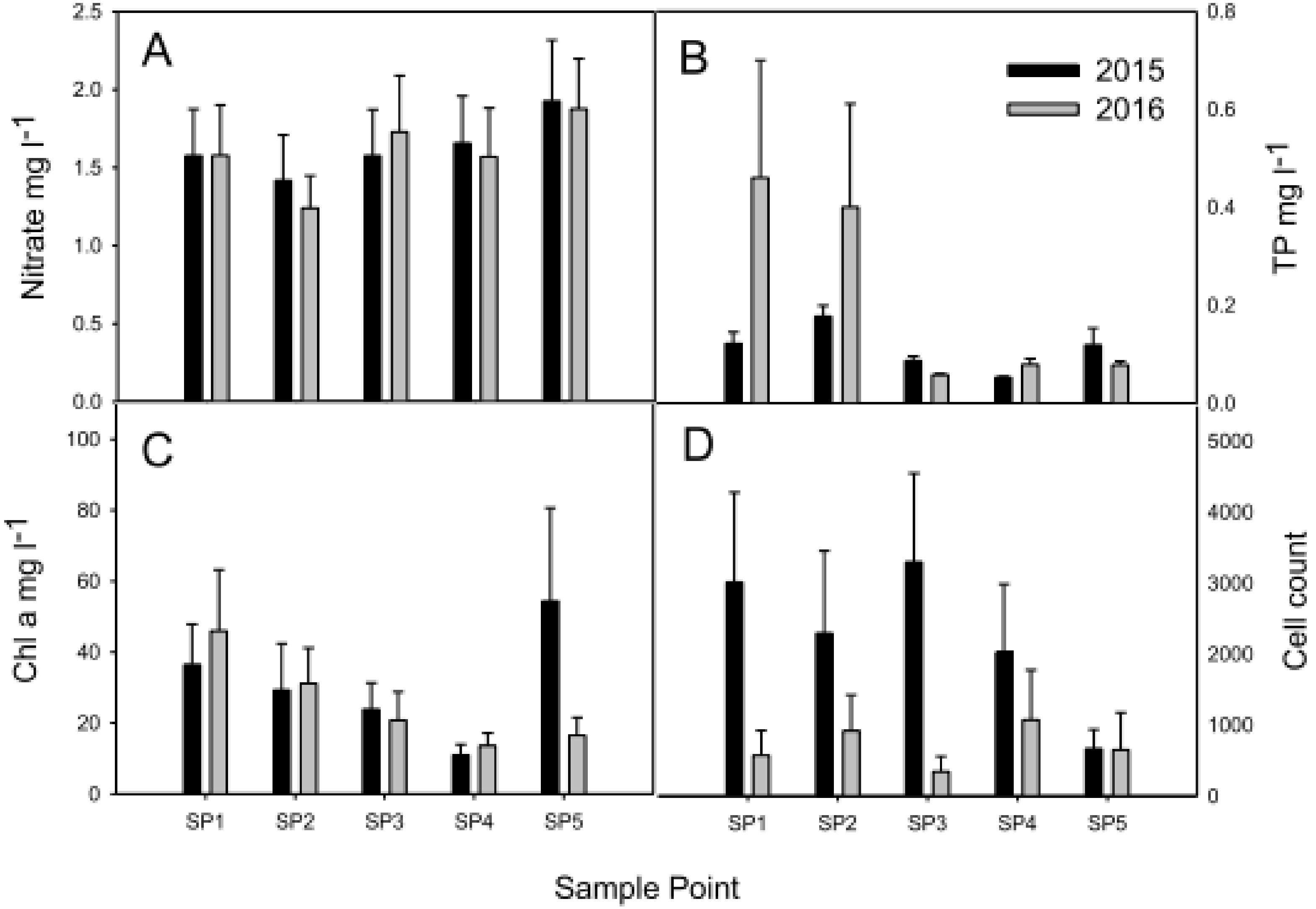


Water Company Internal report reproduced with permission

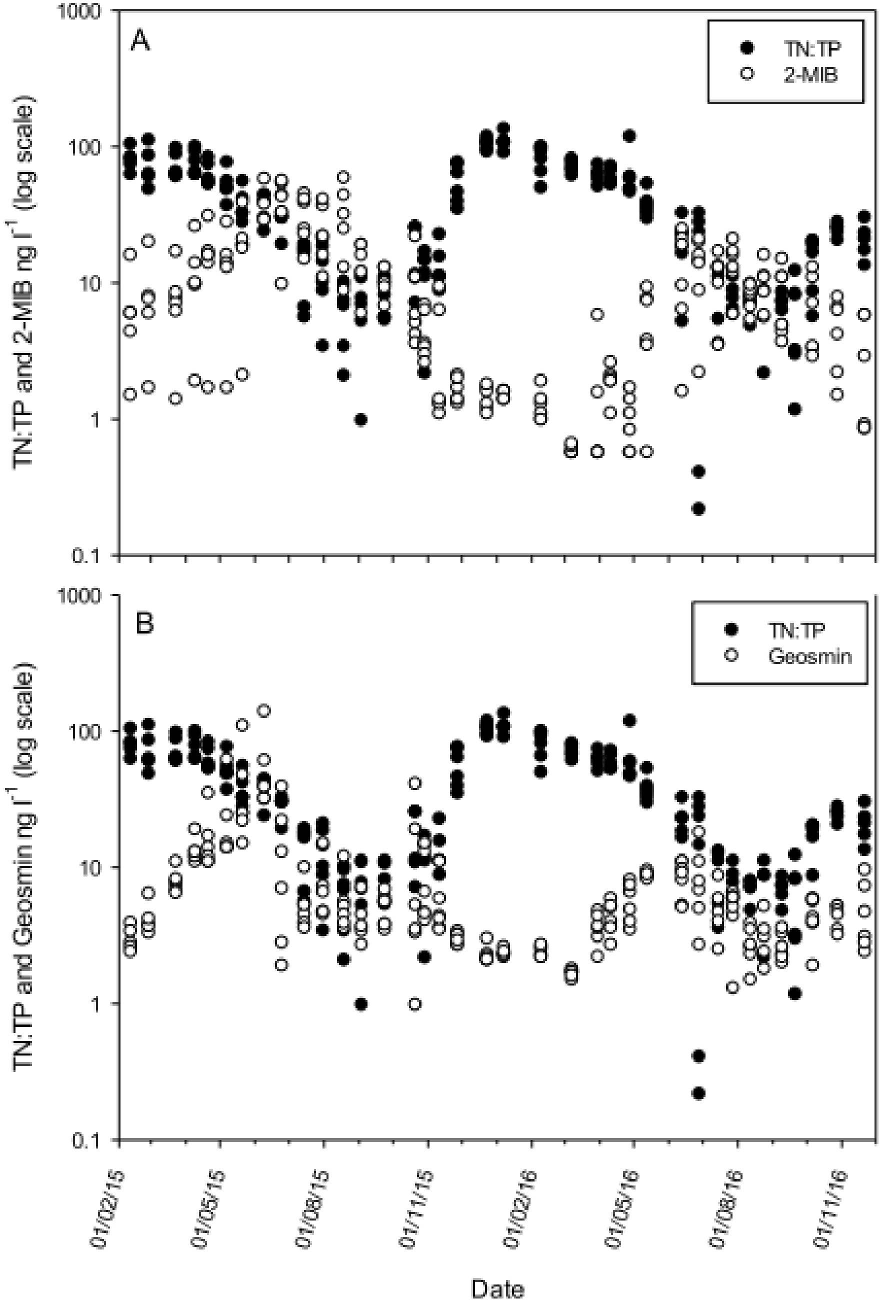
Relative changes in nutrients are key



Perkins and Slavin et al. 2019



Perkins and Slavin et al. 2019



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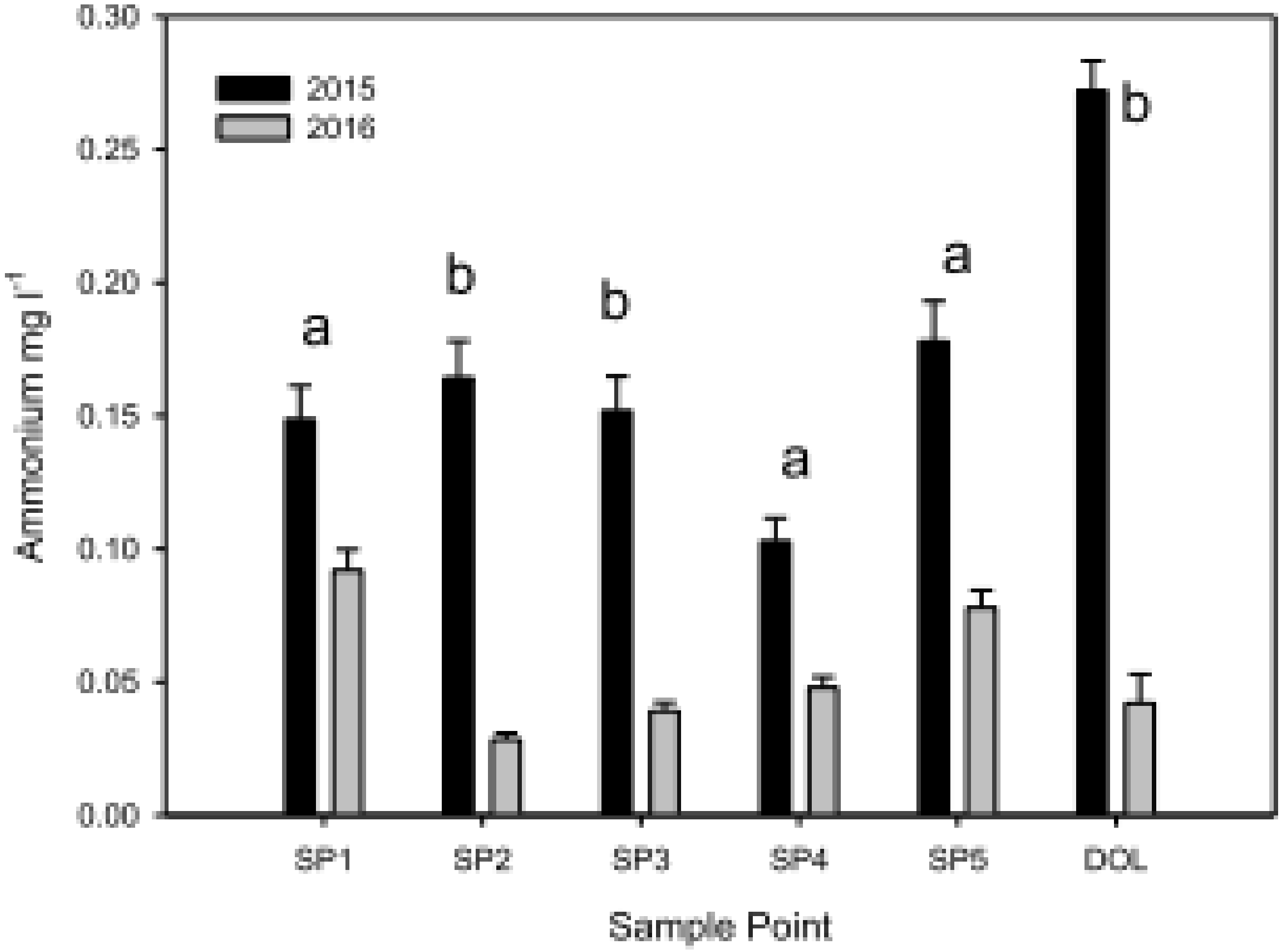
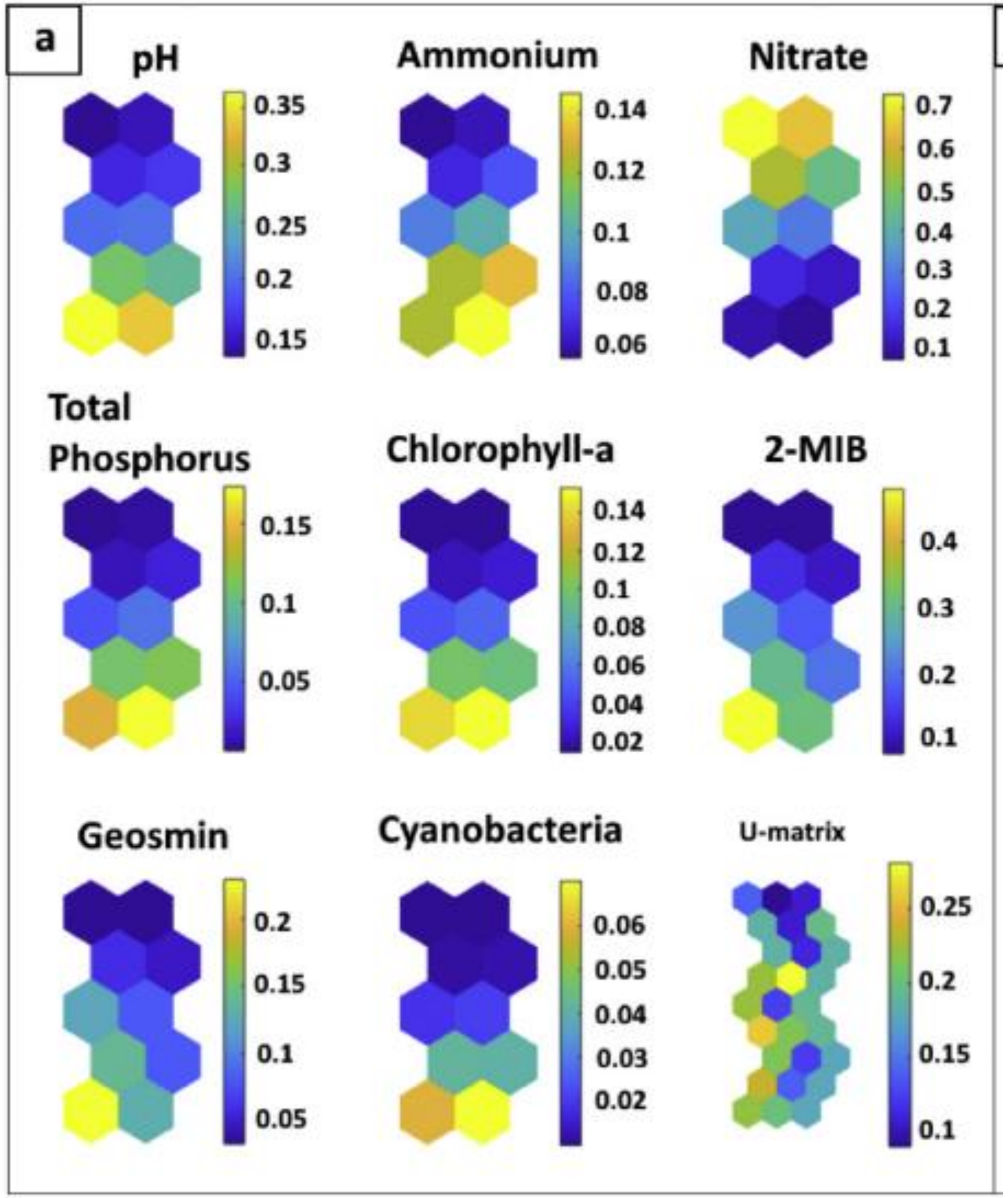


Perkins and Slavin et al. 2019



Perkins and Slavin et al. 2019

Nutrients and functional control

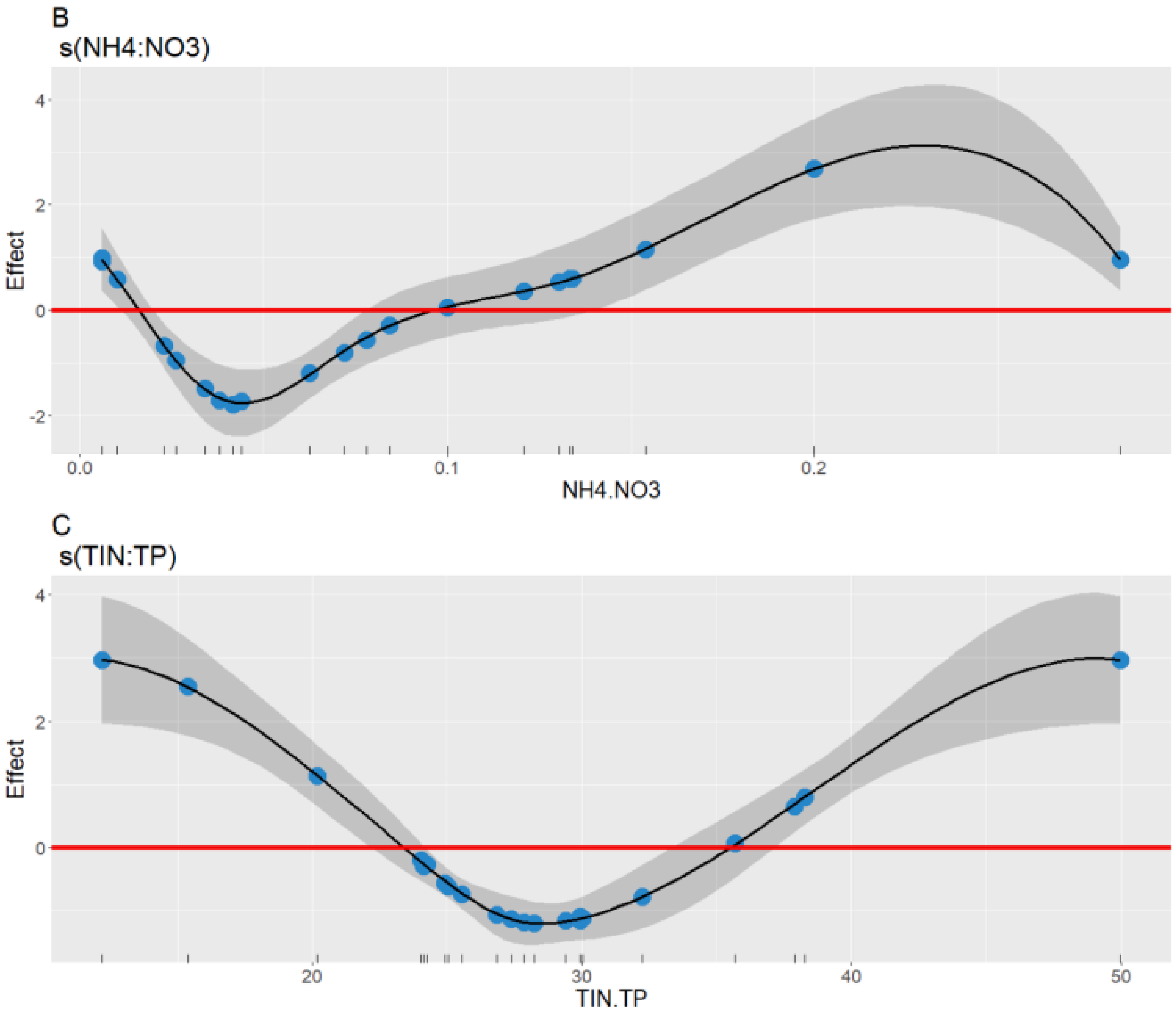
GAM model results for reservoir 1 with *geoA*:16S copy numbers mL^{-1} as the response variable. Using summer 2019 as the reference level for seasonal comparison.

Parametric coefficients	Estimate	standard error	p value
Autumn 2019	0.000	0.499	0.999
Winter 2019	−3.733	0.960	< 0.001 ***
Summer 2020	2.073	0.461	< 0.001 ***
Winter 2020	0.732	0.687	0.297
Mean Temperature	−0.405	0.093	< 0.001 ***
Sulphate	1.338	0.162	< 0.001 ***
Dissolved Reactive Silicate	−1.465	3.128	< 0.001 ***
Dissolved Iron	19.325	3.128	< 0.001 ***
Smooth terms	edf	F	p value
Geosmin	2.009	39.040	< 0.001 ***
NH_4^+:NO_3^-	3.000	11.240	< 0.001 ***
TIN:TP	2.315	22.140	< 0.001 ***

Note: Variables with significant influences are indicated by: . $p < 0.1$,. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

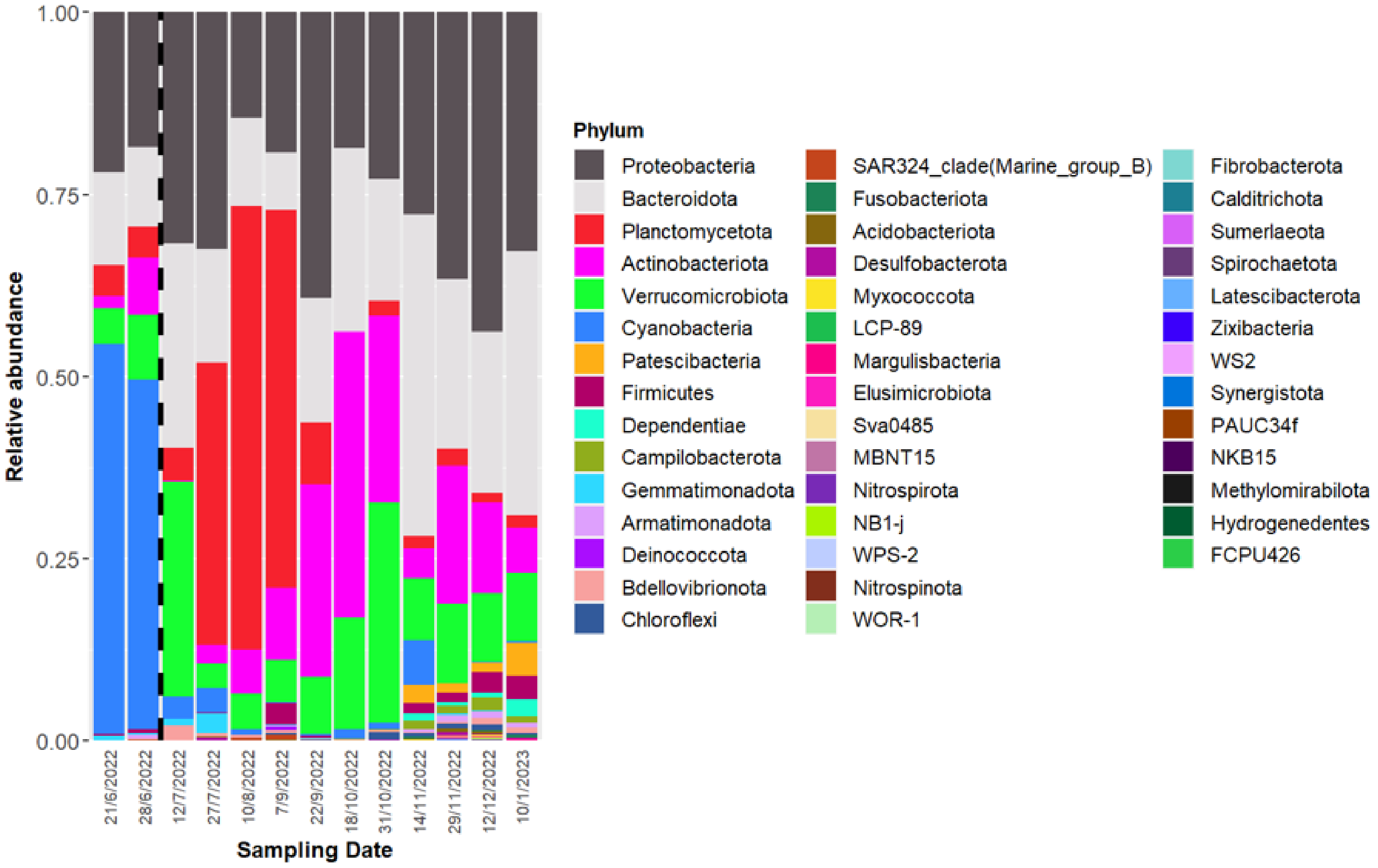
Hooper et al. 2023

Nutrient ratios and GeoA gene copy level
(GeoA gene for synthesis of T&O metabolite of Geosmin)



Hooper et al. 2023

Nutrient ratios change community structure and cyanobacteria dominance/productivity



Watson et al., in prep

Eutrophication story isn’t just phosphorus and HABs

- Need to think of holistic eutrophication, relative abundance of nutrients, proportional changes in nutrients

- This leads to questions on how / when / what to monitor as well as how to analyse and interpret data.

- This has consequences for regulatory nutrient levels and permissive levels in discharges etc.


Thank you!