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Phosphorus limitation of benthic algae in UK rivers

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Background and research drivers

Aim: To use within-river flume mesocosms to determine a phosphorus-limiting threshold for UK rivers.

The last 20 years have seen European-driven legislation result in wide-scale adoption of phosphorus mitigation methods and improvements in sewage treatment works. This has led to large improvements in water quality (in terms of chemical status) but has not always been coupled with the expected ecological improvement (especially in relation to algal biomass).

Phosphorus is often cited as the main nutrient limiting algal growth in rivers meaning tight regulation of concentrations is critical to prevent algal blooms. However, there is limited research to answer the question 'what concentration is the right concentration?' and no definitive threshold has been quantified. The limited ecological improvement observed so far suggests that even after phosphorus mitigation, concentrations in our rivers are still too high and, therefore, greater than the phosphorus-limiting threshold.

Approach and methodology

A series of portable within-river flume mesocosm experiments were run in 3 contrasting rivers, with different ambient soluble reactive phosphorus (SRP) concentrations, across the UK (Figure 1).

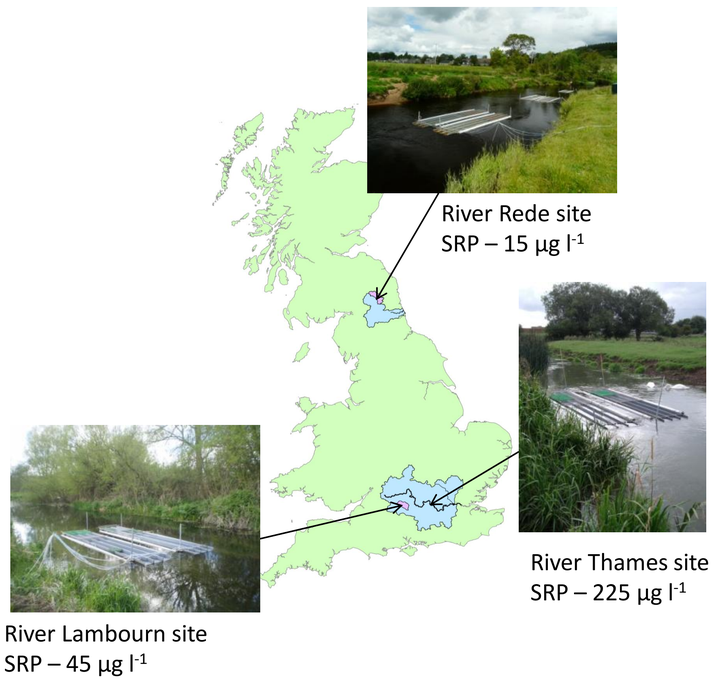

Figure 1: Location of within-river flume experiment sites and the average soluble reactive phosphorus (SRP) concentration of these.

The structures were 5 m long and 0.3 m wide, each containing 3 flumes. Floats on either side meant that a constant water depth (*ca.* 5 cm) was maintained throughout each experiment. Gates at the upstream end of the flume allowed water velocity to be controlled (Figure 2).

A different nutrient treatment was assigned to each flume with each set of 3 having 1 control (unmodified river water) in it. Phosphorus concentrations were increased by the addition of potassium ortho-phosphate (KH_2PO_4) and decreased by the addition of an iron salt solution ($FeSO_4$ or $FeCl_3$) which reacted to form a non-bioavailable phosphorus precipitate. Chemicals were added to the flumes via pipes, with drip rates being controlled by peristaltic pumps. Phosphorus concentrations were monitored at least twice a day during each experiment and quantified by spectrophotometry using the molybdate blue method.

Once the required phosphorus concentrations were achieved and maintained, 49 cm^2 unglazed ceramic tiles were placed at the downstream end of the flume to allow benthic algal growth to be quantified (Figure 2). At the end of each experiment (*ca.* 10 days) tiles were removed and chlorophyll-*a* concentrations were quantified.

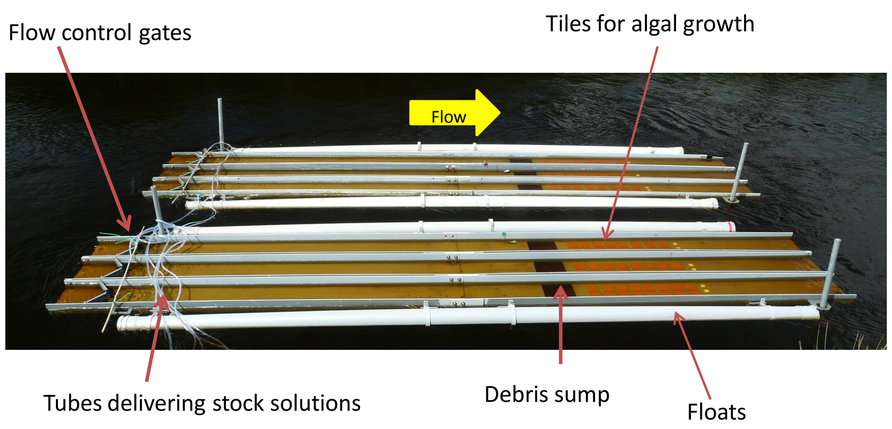

Figure 2: Two sets of within-river flumes.

Results

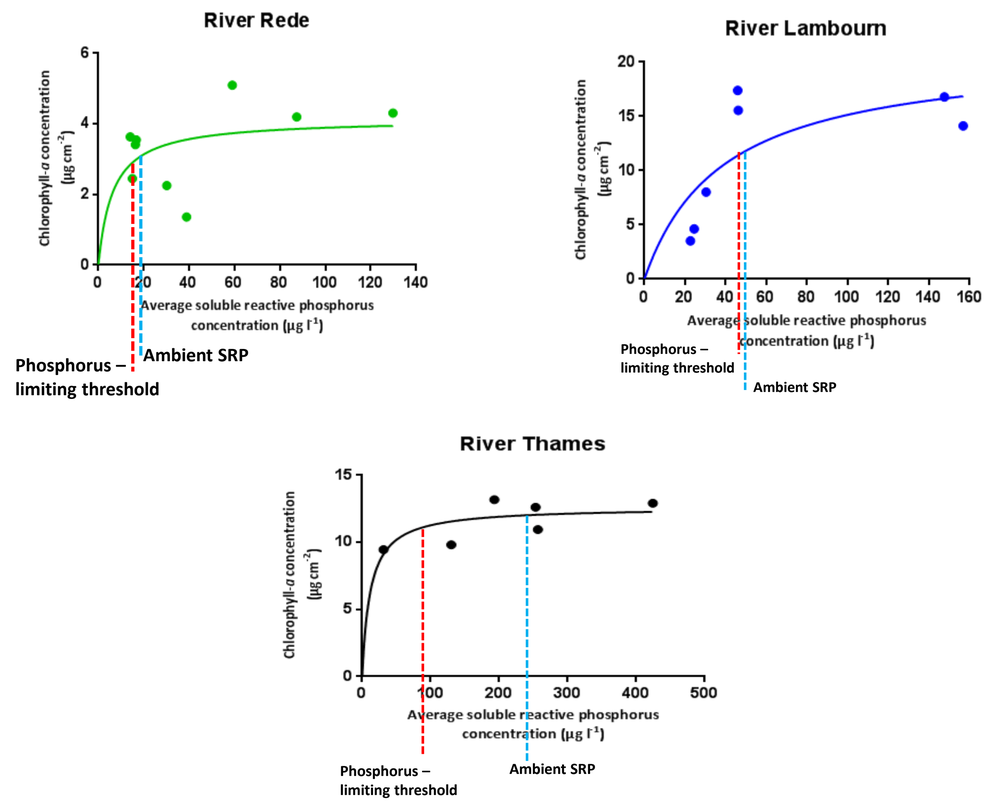

Figure 3: Relationship between phosphorus and chlorophyll-*a* concentration in the 3 rivers examined.

Despite ambient nutrient concentrations being different, adding phosphorus did not increase total periphyton biomass (as measured by chlorophyll-*a* concentration) in any of the three rivers investigated (Figure 3). The River Rede and River Lambourn were at the phosphorus-limiting threshold while ambient phosphorus concentrations in the River Thames were greater than the threshold. The experiments showed the phosphorus-limiting threshold to be 15, 45 and 100 µg l^{-1} for the River Rede, River Lambourn and River Thames respectively.

Although total periphyton biomass did not change with phosphorus addition (Figure 3), the proportions of different functional groups and species within them (community composition of the biofilm) did. Figure 4 shows the results from flow cytometry analysis of the biofilms accrued in different flumes over the course of the 11 day experiment on the River Lambourn. Flow cytometry is a laser based analytical technique that discriminates particles within the algal biofilm based on size, shape, cell structure and their constituent photosynthetic pigments.

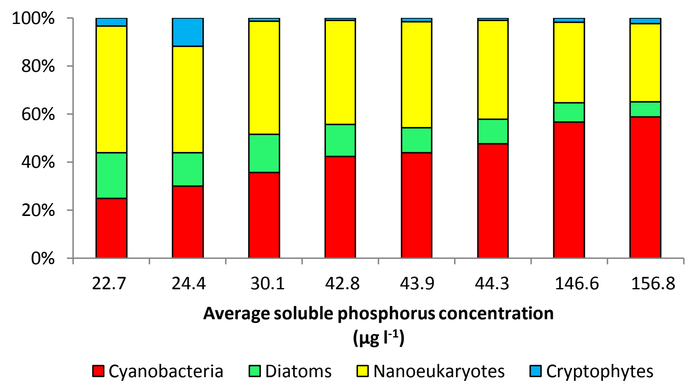

Figure 4: Change in the proportion of functional groups within the biofilm as phosphorus concentration increases.

Adding phosphorus resulted in a decrease in the proportion of nanoeukaryotes and diatoms in the biofilm and an increase in the proportion of cyanobacteria. Due to the toxicity of some cyanobacterial species this could have important implications for ecosystem health. Changes in community composition were observed below the 45 µg l^{-1} phosphorus-limiting threshold identified by analysis of total biomass. This suggests traditional methods of analysis do not provide the full picture. Further analysis of diatom communities (data not shown) has also suggested that a shift in species occurs at SRP concentrations of *ca.* 30 µg l^{-1}.

Conclusions

This work suggests that phosphorus concentrations must be reduced to **below 30 µg l^{-1}** in UK rivers if the aim of phosphorus mitigation schemes is to result in an improved ecological status (the phosphorus-limiting threshold).

The results from the River Rede suggest that even at SRP concentrations of *ca.* 15 µg l^{-1}, SRP concentrations are in excess for benthic algal growth. However, the lower concentrations of chlorophyll-*a* accrued in the River Rede (4 µg cm^{-2} compared to 12 to 15 µg cm^{-2} in the River Lambourn and River Thames) indicates that benthic algae are being limited by a secondary factor in this system.

WHY: Are reduced phosphorus concentrations not limiting benthic algae in UK rivers?

BECAUSE: Resulting phosphorus concentrations are still not below the phosphorus-limiting threshold.

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