Reach-scale biogeochemistry within agricultural streams: interactions with riparian vegetation, channel geomorphology and hydrology.

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Morag Stewart
B.Sc. Hons. (University of Melbourne)

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Abstract

Biogeochemical processes represent the mass-balance and cycling of key elements (carbon, nitrogen and phosphorus) in aquatic systems, providing basal resources to aquatic foodwebs, as well as being an important indicator of ecosystem function. The rate at which autotrophic and heterotrophic processes occur and the carbon:nutrient stoichiometry within reaches can be influenced by abiotic parameters linked to channel geomorphology and hydrology. In agricultural streams, the removal of riparian vegetation has led to a decline in nutrient retention through reduced geomorphic complexity. Stream restoration projects commonly use riparian revegetation techniques at a reach scale to reinstate structural complexity with the aim of restoring biogeochemical processes such as organic matter and nutrient retention. However, there has been little research into the success and outcomes of these projects, particularly at spatial scales relevant to restoration. This thesis examines in-stream biogeochemical processes in vegetated and non-vegetated reaches within intermittent streams in an agricultural setting, located within the Gwydir River catchment, NSW, Australia. I predicted that there would be an increase in geomorphic complexity at vegetated reaches compared to non-vegetated reaches, which would lead to an increase in nutrient and organic matter retention within the vegetated reaches. I also predicted that enhanced nutrient and organic matter retention would be linked to increased rates of ecosystem respiration at vegetated reaches compared to non-vegetated reaches. To explore the interaction of hydrology on biogeochemical processes in intermittent streams, the study took place during four different magnitudes of discharge including a cease-to-flow period.

On-ground surveying techniques were employed to develop high-resolution digital elevation models (DEMs), and spatially explicit habitat maps that identified channel morphology and key geomorphic features. There was no difference in the number of geomorphic features present between vegetated and non-vegetated reaches. However, there were differences in the types of geomorphic features present with flood debris accumulation points only found at vegetated reaches and a larger number of macrophyte beds present within non-vegetated reaches. Non-

vegetated reaches also had a larger wetted areas compared to vegetated reaches, which led to lower surface area:volume ratios and surface water velocities.

Nutrient stoichiometry and retention within vegetated and non-vegetated reaches was explored through mass-balance techniques. There were no significant differences in nutrient stoichiometry and retention between vegetated and non-vegetated reaches during any of the four different sampling periods. There was an increase in nutrient loads imported to each reach during high-flow periods, however, this was not always related to an increase in nutrient retention. Correlation analyses showed that only retention of soluble reactive phosphorus was correlated to hydro-geomorphic variables including surface area:volume ratio and wetted area in the non-vegetated reaches. Nutrient retention was not correlated with any hydro-geomorphic parameters within the vegetated reaches.

Benthic organic matter surveys showed that there were no significant differences in organic matter mass or composition between vegetated and non-vegetated reaches during the four different sampling periods. Exploration of organic matter retention using mass-balance techniques and experimental organic matter releases showed that all reaches could retain organic matter, but the mechanism of retention differed between vegetated and non-vegetated reaches. At vegetated reaches, flood debris accumulation points and bank edges were the main geomorphic features responsible for organic matter retention, while pools and macrophytes were the features responsible for retention in the non-vegetated reaches. Litterbag experiments were used to explore the fate of retained organic matter, again showing no significant difference in organic matter breakdown between treatments, however, there was a significant negative effect of discharge on mass loss within vegetated reaches.

The dominant sources of dissolved organic carbon (DOC) within vegetated and non-vegetated reaches across the different sampling periods were investigated using extracellular enzyme techniques. The analyses showed that during the low and no-flow periods the main sources of DOC available to heterotrophs were high-quality low-molecular weight DOC from allochthonous and autochthonous sources, while during the high-flow periods the DOC pool was dominated by low-quality high-molecular weight substrates from allochthonous sources.

As the quality of DOC can alter rates of ecosystem respiration (ER), the shift to low-quality DOC during the high-flow periods suggested an increase in the rates of ER within reaches. During the low and no-flow periods, the majority of DOC was derived from algal sources in vegetated reaches, while within the non-vegetated reaches, the majority of DOC was derived from both algal and macrophyte sources. These results suggest that different pathways are contributing to ecosystem gross primary productivity (GPP) between vegetated and non-vegetated reaches during the low and no-flow periods.

Whole-reach rates of GPP and ER were not significantly different between vegetated and non-vegetated reaches. However, macrophyte biomass, but not chlorophyll *a* concentration, was significantly greater within non-vegetated reaches. This suggests that although the overall metabolic rates were not significantly different, the dominant pathways contributing to metabolism were different between vegetated and non-vegetated reaches. Both vegetated and non-vegetated reaches were predominantly net autotrophic during the no-flow period but shifted to a heterotrophic state during the high-flow periods. There was a significant decrease in rates of GPP and ER, as well as chlorophyll *a* concentration with increased discharge. These significant relationships and the shift in trophic state highlight the importance of hydrology in controlling ecosystem metabolism in these streams.

The findings of this study show that reach-scale riparian vegetation did alter the types of geomorphic features present, but there was no overall difference in the quantity of organic matter retained within reaches. In addition, the process of organic matter retention was further complicated by the interaction of hydrology. In contrast to the predictions, the quantity and quality of organic matter was not important in controlling nutrient retention or rates of metabolism, which would suggest that riparian vegetation did not have a dominant effect on these biogeochemical processes. However, although there was no overall effect of riparian vegetation on rates of metabolism, there was a significant negative effect on macrophyte biomass. Therefore, the presence of riparian vegetation in intermittent upland streams in agricultural landscapes do not impact rates of dominant biogeochemical processes, but will alter the mechanisms that regulate reach-scale processing of nutrients and organic matter.

Table of Contents

Chapter 3: Nutrient dynamics within vegetated and non-vegetated reaches.

Chapter 4: Organic matter dynamics within vegetated and non-vegetated reaches.

List of figures

List of Tables

List of Plates