The relationship between bedload transport and periphyton abundance in New Zealand rivers

Jo Hoyle, Murray Hicks, Cathy Kilroy

National Institute of Water and Atmospheric Research (NIWA), New Zealand

1. QUICK INTRO TO PERIPHYTON

- Periphyton (or benthic algae) is the "slime" that coats the surfaces of bed sediments and wood in streams, rivers, lakes and other waterways.
- Periphyton provides a rich food source for the upper trophic levels of stream ecosystems and can also provide an important ecological service by removing dissolved nutrients and contaminants from the flow.
- An over-abundance of periphyton (or the wrong types) can have negative effects on habitat quality, water chemistry and biodiversity, and can reduce recreational and aesthetic values.

2. THE PERIPHYTON PROBLEM

- Intensification of landuse, increasing demand for water for drinking, industry, power generation, and agriculture, and the eutrophication of waterways can all lead to an over-abundance of periphyton (or the wrong types)
- To manage these impacts we need to establish reliable quantitative relationships between periphyton abundance and key driver variables

3. CURRENT KNOWLEDGE

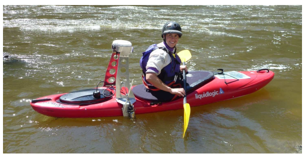
- Periphyton abundance is generally controlled by a balance between
  - Factors that control **Growth** (nutrients, light & temperature)
  - Factors that control **Loss** (hydrological disturbance & invertebrate grazing).
- Nutrient supply and flow are two fundamental drivers, both often affected by human activities, and key when it comes to setting water quality and quantity limits.
- There are three theoretical mechanisms responsible for periphyton removal that relate to flow:
  - Drag (or sloughing)
  - Abrasion (sand blasting)
  - Molar action (being scraped off by the bed rolling over)
- Yet, reliable predictors of periphyton biomass across a range of rivers have proven elusive and we currently have limited ability to predict the effects of changes in flow regime or nutrients on the abundance of periphyton.

4. IDEA & APPROACH

- In this study we suggest that understanding geomorphic differences in rivers may improve understanding of which rivers are most vulnerable to changes in flow or nutrients with respect to algal blooms.
- We explore this idea using the following steps:

1. Select 18 existing monitoring sites that have 5 years of data showing a wide range of typical periphyton abundance (chlorophyll *a*), nutrient levels (soluble inorganic nitrogen, SIN, soluble reactive phosphorus, SRP), flow regime (median flow Q_{50} and peak flow) and varying geomorphology (i.e. alluvial vs threshold channels).

2. Survey cross sections and a long profile at each site using a 'survey kayak' to capture the bathymetry of deep sites, and collect grain size data (D_{50}, D_{90}).

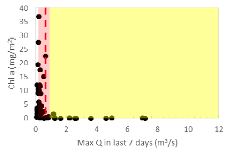


3. Use a 1-D hydraulic model (GRATE) to establish the flows required to initiate the key mechanisms of periphyton removal at each monitoring site based on sediment mobility, i.e.,
   - If no sediment is mobile – drag is the only available mechanism
   - If sand/fine gravel is mobile – abrasion becomes the dominant mechanism
   - If most of the bed is mobile (>D_{50}) – molar action becomes the dominant mechanism.
4. Assess which flows typically cause a threshold reduction in periphyton at each site (see results)
   - Develop a method of establishing this threshold
   - Assess if there is a common mechanism removing periphyton (e.g. is abrasion more important than molar action?).
5. Assess whether understanding the frequency with which these removal mechanisms occur improves our understanding of why some sites have a greater tendency for nuisance periphyton.

5. RESULTS

1. Can we identify flows that typically cause a threshold reduction in periphyton at each site?

We plotted Chl *a* versus maximum discharge in the previous 7 days at each site and defined the 'periphyton removal discharge' (Q_{pr}) as the flow that reduced Chl *a* to 10mg/m² in 95% of cases (red dashed line).

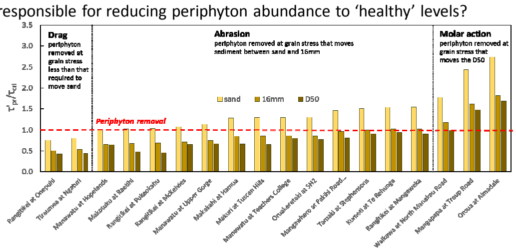


We modelled the flow required to move the D_{50} and move 2mm, 4mm, 8mm & 16mm grains (accounting for hiding) and then over-plotted the zones of abrasion (pink) and molar action (yellow) to relate mechanisms to removal.

2. Which mechanism is typically responsible for reducing periphyton abundance to 'healthy' levels?

We compared the grain stress at the 'periphyton removal discharge' (τ'_{pr}) at each site with the critical stress required to initiate motion of different sized grains (τ_{cri})

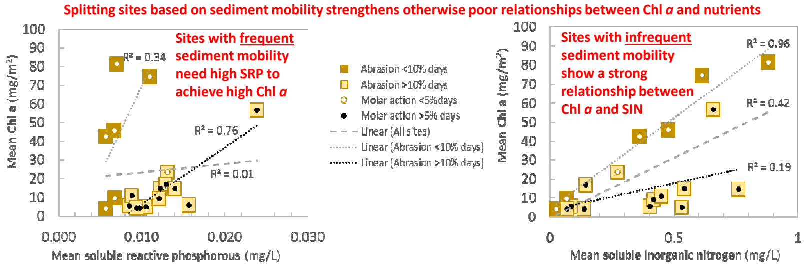
Abrasion is key for periphyton removal at most sites but some sites require molar action.



3. Does frequency of abrasion or molar action explain why some sites have a greater tendency for nuisance periphyton?

If we sort sites into different classes based on frequency of abrasion (sand mobilisation) or molar action (frequency of D_{50} mobilisation) we see a clear difference in the relationship between mean Chl *a* and mean soluble inorganic nitrogen (SIN), or soluble reactive phosphorus (SRP) (two fundamental growth-promoting nutrients).

Splitting sites based on sediment mobility strengthens otherwise poor relationships between Chl *a* and nutrients



6. CONCLUSIONS

- Our results showed that at the majority of sites we can identify a clear threshold flow that reduces periphyton abundance to low levels and that this flow typically corresponds with flows required to move sand to fine gravel (up to 16mm). i.e. abrasion is a key removal mechanism.
- We find that the relationship between mean periphyton abundance and mean nutrient concentration (SIN and DRP) varies depending on the frequency of sediment mobility (both abrasion and molar action).
- This suggests that by partitioning the sites based on frequency of sediment mobility we can predict sites which have potential to grow nuisance levels of periphyton.

7. FURTHER WORK

- There is still considerable work to do when it comes to prediction of periphyton abundance at any point in time within a site.
- There will always be some noise in the relationships within a site as the ease with which periphyton is removed by hydrological disturbance can vary depending on pre-flood biomass, age, health, species or the conditions under which the periphyton grew.
- Also, the reality of whether a flow actually causes abrasion will be inherently spatially and temporally variable due to varying sediment supply and spatially variable sand transport . This will be particularly true in 'threshold' channels (where part of the bed is essentially immobile), as abrasion may be less effective and periphyton is able to find refuge in the lee or high on large immobile clasts.

NIWA

jo.hoyle@niwa.co.nz