MEMO

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FROM	Mark Heath
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Setting nutrient criteria to achieve desired community periphyton biomass attribute states at Ruamāhanga Whaitua reporting sites

Executive summary

The National Policy Statement for Freshwater Management (NPS-FM, 2017) requires regional councils to set in-stream criteria for nitrogen and phosphorus as a part of their approach to achieving periphyton biomass objectives, the latter being compulsory to set above the numeric bottom line defined in Appendix 2 of the NPS-FM. Nutrient criteria required to meet community periphyton biomass objectives at Ruamāhanga reporting sites are assessed in this technical document using total nitrogen (TN) and dissolved reactive phosphorous (DRP) look-up tables developed by Snelder et al. (2015) and nutrient prediction outputs from the collaborative modelling project. Periphyton biomass attribute states were predicted for the three Ruamāhanga Whaitua CMP scenarios (BAU, Silver and Gold) as well as the baseline. The accuracy of the model predictions was assessed by comparing the actual measured biomass state against those predicted by the TN and DRP look-up tables for the baseline.

There was poor agreement between actual/current periphyton biomass state, and that predicted by Snelder et al. (2015) TN and DRP look-up tables using the baseline data. The look-up tables tended to overestimate periphyton biomass. The results showed large decreases in current TN or DRP are needed to achieve desired community periphyton attribute states, and in some cases these decreases in nutrients may be unattainable. Alternative ways of achieving periphyton biomass objectives such as by shading should be explored further. In the Parkvale Stream shading from willows appears to have been responsible for a two attribute state decrease in periphyton biomass. To improve confidence in the relationship between nutrient criteria and periphyton biomass predictions in the Ruamāhanga Whaitua, and Wellington Region, it is recommended that a region-specific model is developed.

Introduction

The NPS-FM (2014) identified periphyton biomass as a key national ecosystem health value and mandated regional councils to manage periphyton biomass in each freshwater management unit (FMU). In 2017 the NPS-FM was amended, requiring regional councils to additionally set in-stream criteria for dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) concentrations in association with achieving the compulsory periphyton biomass objectives.

The Ruamāhanga Whaitua committee has recently defined their periphyton biomass objectives for each of their proposed monitoring sites within each FMU. However, the instream DIN and DRP concentration criteria for managing periphyton biomass have not yet been set.

In this memo, I present the results of an initial analysis, which utilised a set of TN and DRP concentration look-up tables developed by Snelder et al. (2015) to estimate the periphyton attribute state for each reporting point, under each of the Ruamāhanga collaborative modelling project (CMP) modelled scenarios (Baseline, BAU, Silver and Gold).

The TN and DRP look-up tables developed by Snelder et al, (2015) to predict periphyton biomass attribute state are built on a series of models and assumptions. Each model and assumption has a level of uncertainty associated with it; this uncertainty compounds with every model/assumption added. The model was built based on the relationship between periphyton biomass and several explanatory variables in a national dataset from the National River Water Quality Network[1]. The model's spatial coverage is thus nationally relevant and useful for predicting broad-scale patterns but the authors' express caution about the uncertainty with predictions, particularly at local scales. For example the model performed poorly at predicting periphyton biomass when tested on Environment Canterbury and Horizons Regional Council region-wide datasets. Model outputs, therefore, should be used as a guide and initial step, rather than being a confident basis from which to set sub-regional scale nutrient criteria.

Methods

The TN and DRP concentrations in the look-up tables are grouped based on REC source-of-flow classes, which subdivide NZ's rivers on the basis of differences in catchment climate and topography. Thus, sites (river segments in the case of the model) with the same catchment climate and topography in the REC database have the same TN and DRP thresholds for periphyton attribute state.

Snelder et al, (2015) developed three sets of TN and DRP look-up tables for each REC source-of-flow class; 20, 10 and 5% periphyton state exceedance, respectively. Twenty percent exceedance assumes that 20% of segments (river reaches) in a given source-of-flow class will exceed a given periphyton biomass state. The 20% proportion exceedance threshold, used here, is recommended by Snelder et al. (2015) because of the high model uncertainty at the site scale, which indicated the model predictions for individual segments also have high uncertainty.

Actual measured periphyton biomass attribute state, up to January 2018, was calculated for all of the Ruamāhanga Whaitua reporting sites currently monitored as part of the GWRC periphyton biomass monitoring programme. The performance of the TN and TP look-up tables in predicting periphyton biomass attribute state was assessed by comparing the baseline modelled attribute state estimates against the actual measured attribute state. Because three years of data (or 36 data points) had not been collected for any of the 10 monitored Ruamāhanga sites, as required by the NPS-FM to determine periphyton biomass state, available data was extrapolated to represent 36 data points.

[1] Managed by NIWA

Results

Model performance

There was poor agreement between actual periphyton biomass state and that predicted by Snelder et al. (2015) TN and DRP look-up tables (Table 1). Of the ten sites currently monitored in the Ruamāhanga Whaitua, three were correctly assigned, two underestimated and five overestimated. Two of the sites, Parkvale Stream at weir and Ruamāhanga at Te Ore Ore, were overestimated by two attribute states. Possible reasons for this are explored further in the discussion section.

Table 1: Actual periphyton biomass attribute state for those Ruamāhanga Whaitua sites where periphyton biomass is currently monitored. *n* = sample size. Note, samples cannot always be collected due to high flows and site access.

Site	*n*	A band count	B band count	C band count	D band count	Current state#	Predicted state*	
							TN	DRP
Huangarua R at Ponatahi Br	*15*	6	4	3	2	**D**	**D**	**C**
Kopuaranga R at Stuarts	*27*	5	6	9	7	**D**	**D**	**C**
Mangatarere S at SH2	*29*	18	5	4	2	**D**	**D**	**D**
Parkvale S at weir	*21*	16	4	0	1	**B**	**D**	**D**
Ruamāhanga R at Gladstone	*26*	21	4	1	0	**B**	**C**	**C**
Ruamāhanga R at Waihenga	*17*	15	1	0	0	**B**	**C**	**C**
Waipoua R at Colombo Rd Br	*6*	4	2	0	0	**B**	**D**	**B**
Ruamāhanga R at Te Ore Ore	*11*	11	0	0	0	**A**	**C**	**C**
Waingawa R at South Rd	*12*	12	0	0	0	**A**	**A**	**A**
Waiohine R at Bicknells	*15*	15	0	0	0	**A**	**B**	**B**

Current state extrapolated to represent 36 data points, * Predicted periphyton attribute state based on Snelder et al. (2015) look-up tables

Modelled attribute state

For each of the three modelled scenarios (BAU, Silver and Gold) there was little or no change in periphyton biomass attribute state from the modelled baseline for any of the reporting sites as predicted by both the TN and DRP look-up tables (Table 2 and 3).

Total Nitrogen

When assessing the three scenarios for the year 2040 against the baseline, only the Huangarua and Waipoua rivers segments were predicted to degrade an attribute state when using the TN look-up tables. Both of these sites moved from a D to C attribute state under the silver and gold 2040 scenarios. Under the Gold 2080 scenario, 10 sites were modelled to drop one attribute state and two sites two attribute states from the baseline state.

Table 2: Estimated periphyton biomass attribute state based on modelled total nitrogen concentrations at each proposed monitoring site

Site	Baseline	Objective	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua R Ponatahi B	D	**B**	D	D	D	C	C	C	C	C	C
Kopuaranga R at Stuarts	D	**C**	D	D	D	D	D	D	D	D	B*
Mangatarere R at SH2	D	**A**	D	D	D	D	D	D	D	D	C
Parkvale S at Renalls Weir	D	**B**	D	D	D	D	D	D	D	D	C
Ruamāhanga R at Gladstone B	C	**B**	C	C	C	C	C	C	C	C	B*
Ruamāhanga R at Pukio	C	**B**	C	C	C	C	C	C	C	C	B*
Ruamāhanga R at Te Ore Ore	C	**B**	C	C	C	C	C	C	C	C	B*
Ruamāhanga R at Waihenga B	C	**B**	C	C	C	C	C	C	C	C	B*
Taueru R at Gladstone	D	**C**	D	D	D	D	D	D	D	D	C*
Tauherenikau R at Websters	B	**A**	B	B	B	B	B	B	B	B	B
Waingawa Rr at South Rd	A*	**A**	A*	A*	A*	A*	A*	A*	A*	A*	A*
Waiohine Rat Bicknells	B*	**B**	B*	B*	B*	B*	B*	B*	B*	B*	B*
Waipoua R at Colombo B	D	**A**	D	D	D	C	C	C	C	C	B
Whangaehu R at 250m from Conf	B*	**C**	B*	B*	B*	B*	B*	B*	B*	B*	B*
Makahakaha S Mouth	D	**C**	D	D	D	D	D	D	D	D	B*
Otukura S Mouth	C	**B**	C	C	C	C	C	C	C	C	B*
Rua US Lwai Outlet	B*	**B**	B*	B*	B*	B*	B*	B*	B*	B*	B*
Ruamāhanga Wardells	C	**B**	C	C	C	C	C	C	C	C	B*
Tauanui R Mouth	B	**A**	B	B	B	B	B	B	B	B	B
Turanganui R Mouth	B	**A**	B	B	B	B	B	B	B	B	B

*meets community periphyton biomass objective

Table 3: Estimated periphyton biomass attribute state based on modelled dissolved reactive phosphorus concentration at each proposed monitoring site

Site	Baseline	Objective	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua R Ponatahi B	C	**B**	C	C	C	C	C	C	C	C	C
Kopuaranga R at Stuarts	C*	**C**	C*	C*	C*	C*	C*	C*	C*	C*	C*
Mangatarere R at SH2	D	**A**	D	D	D	D	D	C	D	C	C
Parkvale S at Renalls Weir	D	**B**	D	D	D	D	D	D	D	D	D
Ruamāhanga R at Gladstone B	C	**B**	C	C	C	C	C	C	C	C	C
Ruamāhanga R at Pukio	C	**B**	C	C	C	C	C	C	C	C	C
Ruamāhanga R at Te Ore Ore	C	**B**	C	C	C	C	C	C	C	C	C
Ruamāhanga R at Waihenga B	C	**B**	C	C	C	C	C	C	C	C	C
Taueru R at Gladstone	D	**C**	D	D	D	C*	C*	C*	C*	C*	C*
Tauherenikau R at Websters	B	**A**	B	B	B	B	B	B	B	B	B
Waingawa R at South Rd	A*	**A**	A*	A*	A*	A*	A*	A*	A*	A*	A*
Waiohine R at Bicknells	B*	**B**	B*	B*	B*	B*	B*	B*	B*	B*	B*
Waipoua R at Colombo B	B	**A**	B	B	B	B	B	B	B	B	B
Whangaehu R at 250m from Conf	C*	**C**	C*	C*	C*	C*	C*	C*	C*	C*	C*
Makahakaha S Mouth	D	**C**	D	D	D	C*	C*	C*	C*	C*	C*
Otukura S Mouth	C	**B**	C	C	C	C	C	C	C	C	C
Rua US Lwai Outlet	C	**B**	C	C	C	C	C	C	C	C	C
Ruamāhanga Wardells	C	**B**	C	C	C	C	C	C	C	C	C
Tauanui R Mouth	B	**A**	B	B	B	B	B	B	B	B	B
Turanganui R Mouth	B	**A**	B	B	B	B	B	B	B	B	B

*meets community periphyton biomass objective

Dissolved Reactive Phosphorus

Using the DRP look-up tables three sites the Mangatarere, Taueru and Makahakaha were predicted to improve an attribute state when assessing the three different modelled scenarios for the year 2040 against the baseline. The Taueru and Makahakaha moved from a D to C attribute state under the silver and gold 2040 scenarios, while the Mangatarere moved from a D to C under the gold 2040 scenario only. No additional attribute state changes, other than the aforementioned, were predicted under the Gold 2080 scenario using the DRP look-up tables.

National bottom line

Under the Silver 2040 Ruamāhanga CMP scenario periphyton biomass was estimated to fail the bottom line (attribute state D) at the Mangatarere River and Parkvale Stream sites. The Parkvale Stream monitoring site was also predicted to fail the bottom line under the Gold 2040 scenario. No sites failed the bottom line under the Gold 2080 scenario.

Community objectives

Only six sites were predicted to meet community periphyton biomass objectives by 2040 under the both the Silver and Gold scenarios (table 2 and 3). Under the Gold 2080 scenario 13 of the 20 reporting sites are predicted to meet the Ruamāhanga Whaitua Committees periphyton biomass objectives.

Discussion

The results of this analysis demonstrate that if periphyton biomass is going to be managed by only nitrogen and phosphorus criteria, then substantial reductions are needed to meet community periphyton biomass objectives at a number of sites. For example, to meet the desired ‘A’ attribute state at the Mangatarere River at SH2 a 99.51% reduction in TN and/or a 99.56% reduction in DRP is needed from the current baseline. That is a reduction from 1.229 mg/L to 0.006mg/L for TN and/or a reduction in DRP from 0.091 to 0.0004 mg/L. These target TN and DRP concentrations, needed to achieve an ‘A’ attribute state, are likely to be lower than the actual natural/reference state concentrations[2] for the Mangatarere Stream and; thus, unattainable. Similar nutrient concentration reductions would be needed at a number of other sites to achieve the Whaitua committee’s desired periphyton biomass attribute states if the approach was to try and achieve them using nutrient reductions alone.

The Mangatarere Stream example demonstrates, assuming the look-up table used to generate the predictions is accurate, that managing periphyton biomass by nutrient (TN and DRP) limitation only is going to be extremely difficult, if not unreachable. In Snelder et al. (2015) other factors, such as water temperature, photosynthetic active radiation (PAR) and frequency of flushing flows were also identified as significant variables regulating periphyton biomass. In small streams such as the Mangatarere where large reductions in nutrients are needed to achieve periphyton biomass objectives, regulation of these other factors, in particular water temperature and PAR, may be more effective in reducing periphyton biomass. Reductions in water temperature and PAR can be achieved through riparian planting.

At the Parkvale Stream reporting site recent willow planting has resulted in a marked decrease in periphyton biomass (Figure 1). The site is currently projected to have a ‘B’ attribute state following two years of monthly sampling. However, directly up and downstream of the monitoring site, where there is no willow planting, periphyton biomass is more reflective of ‘D’ biomass attribute state as was predicted by TN and DRP look-up tables. Similarly, annual biomass sampling at this site from 2004 to 2013 indicated the site would have a ‘D’ attribute state. The Parkvale site illustrates how mitigation options other than nutrient management will be important in achieving periphyton biomass attribute state objectives. Moreover, it highlights the limitation of the TN and DRP look-up tables to account for site and river segment variability.

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2 For comparison, the median DRP concentration for reference sites Ruamahanga River at McLays and Waiohine River at Gorge for the 2016/2017 year was 0.002 and 0.003, respectively. During annual summer biomass sampling between 2003 and 2013, the Ruamahanga River at McLays and Waiohine River at Gorge had a maximum chlorophyll *a* concentration of 5.59 and 3.65 mg m^2, respectively. This is well below the periphyton biomass A band threshold of 50 mg m^2 (NPS-FM 2014).

Figure 1: Left, Parkvale Stream before willow planting. Right, Parkvale Stream after willow planting

A limitation of the Snelder et al. (2015) TN and DRP look-up tables is that they do not account for any positive changes in land-use and/or environmental factors, other than predicted changes in TN and DRP. Factors such as land retirement, which may result in increased riparian planting and therefore reductions in water temperature and PAR, are not factored into the look up tables. Thus, periphyton biomass attribute state for the various reporting sites is likely to be overestimated, this was the case in this investigation where five out of the 10 sites currently monitored by GWRC were over predicted by the TN and DRP look-up tables. It is possible that the models used by Snelder et al. (2015) to estimate periphyton biomass attribute state could be manipulated to look at the effect land retirement and riparian planting have on periphyton biomass by altering model inputs PAR and water temperature for each reporting site. This model manipulation could also be used as a rough guide to assess the effect shading has on periphyton biomass at each reporting site, and whether nutrient management or shading (or a combination of both) is a more appropriate periphyton biomass management tool for a given location.

An additional limitation of the TN and DRP look-up tables is that the models they are developed from are based on the relationship between periphyton and explanatory variables from the National River Water Quality Network. The NIWA network is biased towards bigger/larger rivers, under representing smaller river and stream orders. It also does not separate individual periphyton taxa. Some taxa such as *Phormidium* (toxic algae) and *Didymosphenia* (Didymo, not currently present in the North Island) are well adapted to bloom in low nutrient environments (Heath and Greenfield 2016). In reduced nutrient environments (in particular DRP) *Phormidium* may become more prevalent.

Setting nutrient criteria

Changes in 2017 to the NPS-FM now require regional councils to set in-stream concentrations and exceedance criteria (‘nutrient criteria’) for nitrogen and phosphorus as a part of their approach to achieving periphyton biomass objectives, the latter being compulsory to set above the numeric bottom line defined in Appendix 2 of the NPS-FM. Nutrient criteria to meet the Ruamāhanga Whaitua periphyton biomass objectives, and national bottom lines, were assessed in this technical document using total nitrogen (TN) and dissolved reactive phosphorous (DRP) look-up tables developed by Snelder et al. (2015).

There was poor agreement between actual periphyton biomass state and that predicted by Snelder et al. (2015) TN and DRP look-up tables. Seven of the ten reporting sites currently monitored by GWRC were incorrectly assigned. Snelder et al. (2015) TN and DRP look-up tables are not considered to provide an accurate prediction of periphyton biomass attribute state for the Ruamāhanga Whaitua reporting sites and are therefore not considered suitable to use in setting nutrient criteria for meeting periphyton objectives. One of the key limitations of the Snelder et al. (2015) TN and DRP look-up tables is that they do not account for the other factors that regulate periphyton biomass, such as reduced PAR through riparian planting.

In the absence of a fit for purpose periphyton biomass model from which nutrient criteria can be set, it is recommended that nutrient criteria for meeting the Ruamāhanga Whaitua periphyton objectives are based on the modelled DIN and DRP concentrations derived from the CMP scenario (BAU, Silver or Gold) suitable for meeting the other freshwater objectives in each freshwater management unit. Depending on the scenario identified for freshwater management unit, it is not likely that nutrient criteria will achieve periphyton objectives at all sites by nutrient reductions alone. Additional mitigations will likely be required alongside nutrient reductions to achieve the Ruamāhanga Whaitua periphyton biomass objectives at some locations. These additional mitigations should form part of the plan to achieve periphyton objectives.

It is also recognised that there is a lack of fit for purpose data on periphyton growth and understanding of its drivers in the Ruamāhanga whaitua. It is recommended that a monitoring framework is developed to assess the multiple drivers of periphyton growth. Such monitoring would need to sit alongside monitoring of the achievement of the Ruamāhanga Whaitua periphyton objectives. The results from this monitoring programme should be used to build a fit for purpose regional, or Whaitua, periphyton model to inform future objective setting and the identification of more accurate nutrient criteria.

Recommendations

- In the absence of a fit for purpose periphyton biomass model from which nutrient criteria can be set, it is recommended that nutrient criteria for meeting the Ruamāhanga Whaitua periphyton objectives are based on the modelled DIN and DRP concentrations derived from the CMP scenario (BAU, Silver or Gold) suitable for meeting the other freshwater objectives in each freshwater management unit.

- Alongside nutrient reductions, additional mitigations will be required to achieve the Ruamāhanga Whaitua periphyton biomass objectives at some locations. These additional mitigations should form part of the plan to achieve periphyton objectives.

- It is recommended that a monitoring framework is developed to assess the multiple drivers of periphyton growth. Such monitoring would need to sit alongside monitoring of the achievement of the Ruamāhanga Whaitua periphyton objectives.

- The results from this monitoring programme should be used to build a fit for purpose regional, or Whaitua, periphyton model to inform future objective setting and the identification of more accurate nutrient criteria.

- In order to assess the effectiveness of shading as a periphyton mitigation option in the Wellington region, undertake an investigation comparing periphyton biomass at shaded and non-shaded reaches.

References

- Snelder T, Greenwood M, Quinn J and Elliott S. 2015. *Nutrient concentration thresholds to achieve periphyton objectives across climate source of flow classes.* Appendix B in Analysis of Water Quality in New Zealand Lakes and Rivers (Larned et al. 2015).