Waikato Regional Council Technical Report 2018/43

Assessment of Waikato River nutrient limitation: Peer reviewed key findings of WRC and DairyNZ studies

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

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This report was commissioned by the Technical Leaders Group for the Healthy Rivers Wai Ora Project
Report No. HR/TLG/2015-2016/3.3

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19 March 2015

Document #: 3306846

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Draft for discussion purposes

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The Technical Leaders Group approves the release of this report to Project Partners and the Collaborative Stakeholder Group for the Healthy Rivers Wai Ora Project.

Signed by:

Date: 10 May 2016

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Reports

Waikato River Bioassay Study 2013-14. Assessment of nutrient limitation prepared for Waikato Regional Council by Gibbs et al., NIWA Client Report No. HAM2014-072

Factors influencing chlorophyll a concentrations in the Waikato River. Retention time and thermal stratification in the hydro lakes prepared for DairyNZ by Gibbs et al., NIWA Client Report No. HAM2014-059.

This statement of findings reflects a caucusing session, held on 26 February 2015, involving Bill Vant (WRC), David Burger (DairyNZ) and Max Gibbs (NIWA) who prepared a draft statement of findings, and David Hamilton, Marc Schallenberg and Ian Hawes who peer reviewed the draft statement. The session was chaired by John Quinn and attended in part by Bryce Cooper.

19 March 2015

Agreed statement of findings

Background:

1. Water quality monitoring data from the Waikato River typically show short-term (daily to monthly) variation in relation to factors such as season and flow. Long-term (10 and 25 yr) chlorophyll-*a* concentrations (indicating phytoplankton biomass) show a significant decreasing trend at all sites downstream of Lake Ohakuri. Long-term trends also show a statistically significant increase in total nitrogen concentration and no change or a decrease in total phosphorus concentration (Vant, 2013).
2. Chlorophyll-*a* concentration is generally low in winter and increases rapidly in September with concentrations attaining a maximum value between October to March.
3. The lack of long-term increase in chlorophyll-*a* concentration despite increase in total nitrogen concentration in trend data indicates controls of phytoplankton biomass are more complex than only nitrogen concentration, as previously assumed in many studies.
4. Two separate studies have recently been completed to better understand nutrient limitation and drivers of phytoplankton biomass in the hydro lakes and main stem of the River.
5. WRC commissioned NIWA to undertake monthly nutrient bioassay and zooplankton grazing experiments at four river monitoring locations (Ohakuri, Karapiro, Ngaruawahia and Rangiriri) from November 2013 to April 2014.
6. DairyNZ commissioned NIWA to measure primary production rates under four different flow regimes in Lake Karapiro between December 2013 and March 2014, and to understand stratification and mixing processes, dissolved oxygen dynamics, and in-lake nutrient limitation on one sampling occasion.
7. The interpretation of the data from each study was based only on the data measured during that study, although several of the research team members worked on both studies.
8. The long-term monitoring data and trend analyses are used to support the key findings of the two studies summarised below.

Key findings both studies:

9. The results of the two studies are complementary and together provide useful data supporting interpretations on the potential drivers of phytoplankton growth in the River.
10. In summer, total N and P concentrations increase downstream from Lake Ohakuri, with the majority of the N increase generally between Lake Ohakuri and Lake Karapiro. The dissolved inorganic component of total N and P is lower in summer than winter, and chlorophyll-*a* concentration higher.
11. Phytoplankton biomass in the Waikato River is likely to be influenced by a number of factors including nutrients, light, mixing, dilution, water flow, water column stratification and zooplankton grazing. The studies addressed many of these factors to provide complementary data to the long-term trend analysis.
12. The role of nutrients in limiting phytoplankton biomass was addressed by examining trends in field data over 25 years and conducting short-term bioassay experiments where nutrients were added in the laboratory or field under conditions where other factors were controlled. Within the constraints of the bioassay studies (including that pre-filtration (40 µm) to control zooplankton grazers may have also removed large algal species), there was no clear indication that a single nutrient promoted phytoplankton growth at all sites and all times. The bioassay results showed spatial and temporal variations in chlorophyll-*a* responses to nutrients. Five-day laboratory bioassays showed that phytoplankton biomass most often increased with additions of both N and P, particularly below Lake Ohakuri, while a single 24 hour field bioassay in Lake Karapiro showed that chlorophyll-*a* increased in response to N alone. Reductions in phytoplankton are therefore expected to result from reductions of N or P. This expectation is consistent with observed temporal trends in chlorophyll *a* and nutrients along the river – i.e. N has increased, but P has declined, apparently causing chlorophyll-*a* concentration to decline as well.

13. Water quality in the Waikato River is affected by processes occurring in the hydro lakes, in particular from residence time of sufficient duration to allow phytoplankton biomass to increase during passage through the lakes, with flow-on effects downstream of Lake Karapiro. For example, the phytoplankton biomass below Karapiro is higher than would occur without the hydro lake, allowing biomass to reach higher levels than would otherwise be attained during passage between Karapiro and Port Waikato.

Key findings River main stem:

14. Within the constraints of the studies, there were indications that phytoplankton growth was enhanced with the addition of N and P, and to a lesser extent, with P alone. The long duration (5 days) of these experiments increased the likelihood of finding a response to N and P together because the phytoplankton may have been running out of both nutrients. There were no apparent increases to N addition on its own. This suggests the potential for co-limitation of phytoplankton under these conditions.
15. Zooplankton grazing is likely to influence phytoplankton biomass in the Waikato River at times.

Key findings Lake Karapiro:

16. Surface chlorophyll-*a* concentration increased with distance downstream from Lake Arapuni during periods of thermal stratification. Stratification coincided with periods of increased water residence times associated with low to medium flow rates though Karapiro dam.
17. Thermal stratification depends on solar heating of the upper water and may be enhanced by the high-level outflow to the power station and long water residence time.
18. In a 24-h duration, in-lake bioassay in March, Lake Karapiro chlorophyll-*a* concentration increased in response to added N, and this increase was not enhanced if P was also added.
19. Nutrient limitation may become important during periods of thermal stratification, low flow and long water residence times in hydro lakes, when the shallow mixing depth reduces light limitation, net phytoplankton growth rates are higher and nutrient depletion in the surface waters occurs, particularly at downstream locations.
20. Increases in nutrient availability over the summer growth period may lead to increases in phytoplankton biomass particularly under stratified and low-flow conditions.
21. Increases in nutrient availability during winter are not likely to impact phytoplankton biomass.
22. Zooplankton grazing is suggested to impact phytoplankton production at upstream lake locations during periods when assimilable phytoplankton species are abundant and zooplankton biomass is high.
23. The impact of macrophyte (hornwort, *Ceratophyllum demersum*) and associated epiphytes on nutrient assimilation, recycling and availability to phytoplankton is currently unclear but could be significant given the extensive macrophyte beds present in the lake. Further work would be needed to assess this.

Points of disagreement

Point 1

- The findings in statement 1 are not from the two reports but from supplementary material provided by Bill. There were no statistical analyses of trends presented in the two reports. Bill's excel file shows sign 10y chlorophyll-*a* trend only from the Narrows site down. In the final sentence the relevant sites and time periods have not been specified. As worded, the sentence suggests that at all sites and at both time scales the TN and TP trends are statistically significant. Clearly from the graphs, that isn't the case.

  There are substantial inter-annual variations in these data and these are not mentioned in this statement. For example, the chlorophyll-*a* data (Fig. 8 in Bill's supplementary report) show a sizable decline in chlorophyll-*a* in the river during the late 1990s super El Nino. Recent trends could also reflect drier conditions. Such cyclical, interannual variations in the data indicate to me that other factors (e.g., climate) are important in this system. Thus, attributing the chlorophyll-*a* patterns to nutrient variations is premature. (Marc)

Point 2

- The data in Bill's supplementary report show that chlorophyll-*a* starts increasing between July and August at both Ohakuri and the Narrows and between August and September at Tuakau. These times can be interpreted as the onset of the growing season and therefore increased nutrient availability after these onset periods could result in enhanced phytoplankton growth.(Marc)

Point 12

- "Reductions in phytoplankton are therefore expected to result from reductions of N or P." It's not clear, but from the context, this interpretation appears to refer to the bioassay results. If so, then I disagree with it because 5–day nutrient enhancement bioassays don't provide strong inferences on phytoplankton responses to nutrient reductions in the river. These experiments give an idea of what to expect if you add nutrients and then allow them to be depleted. On the other hand, if the statement represents an extrapolation of the results to the larger river context, then I also disagree with it because the observed responses were after 5 days of isolation from nutrient recycling and other nutrient inputs. (Marc)
- I think that this is the single most contentious area. It is obviously a key one as far as management implications go. As Marc says, there is no real evidence that a reduction in N or P would reduce c chlorophyll-*a*. If N is limiting (as in the Karapiro bioassays) then this is NOT consistent with N increasing and chlorophyll-*a* and P declining. If neither is immediately limiting, then it is reasonable that a sufficient reduction in both would eventually reduce biomass. How would a change of tack statement like "in the absence of a clear indicator of a most limiting nutrient, the precautionary principle would suggest that management to reduce chlorophyll-*a* should target both N and P. "appear. This is an area where both Marc and I have struggled, and have talked outside of the caucus, and I am happy to let him have final sign-off. (Ian)
- The final statement in this point, namely "... P has declined, apparently causing chlorophyll-*a* concentration to decline as well", risks oversimplifying the situation. As noted in point 15, zooplankton grazing is likely to influence phytoplankton biomass at times. And we know that a large, exotic species (*Daphnia galeata*) has been present in NZ in recent years. This species was observed in the Waikato River, especially in the hydrolake samples. So some of the observed decline in chlorophyll-*a* could be due to increased zooplankton grazing. I therefore prefer to conclude point 12 by saying, "... P has declined, apparently contributing to the observed decline in chlorophyll-*a* concentration." (Bill)

Point 21

- We don't really have information to confirm the link in winter. If we regard winter as Jun-Aug and we consider Fig. 4 in WRC document 3286756 (Nitrogen phosphorus and chlorophyll in the Waikato River), there does appear to be quite a high rate of growth (rate of increases in chlorophyll-*a*) in August – at least at Ohakuri and possibly also Karapiro. I suspect this may be partly related to processes identified in Vincent's excellent Ecology paper (1983) which showed how increased nutrients stimulated major increases in biomass and productivity in Taupo in winter. (David H)
  I agree with David's comments (see my comments on Point 2, above) and we should also account for residence time of the river when considering that nutrient loads in the upper river link to potential responses in the lower river (Marc)