CLUES Nutrient Load Predictions for the Ashburton Basin Lakes – 2021 Cawthron report – Supplementary Memorandum

By Tina Bayer, Adrian Meredith, Tom Drinan & Hugh Robertson June 2021

Introduction

The purpose of this supplementary memorandum is to:

i) Provide a simplified summary of the findings of the CLUES Cawthron report.
ii) Outline the implications of the report to lake management.
iii) Supply additional technical information to help interpretation of the report including the most recent lake water quality data.

Summary of Cawthron report

The purpose of the modelling report (Kelly et al 2021[i]) was to:

(i) Update previous (2014[ii]) catchment nutrient load modeling.
(ii) Estimate the catchment load reductions (for Total Nitrogen and Total Phosphorus) needed to meet the Canterbury Land and Water Regional Plan (LWRP) objectives for lakes in the Ō Tū Wharekai (OTW, Ashburton Lakes) basin and Upper Waimakariri catchment.
(iii) Provide updated bird contributions to total nutrient loads in the Ashburton Lakes basin.

Key findings:

The Cawthron report provides an estimated reduction in **both in-lake nutrient concentrations and catchment nutrient loads** (detailed in Table 5 of Kelly et al 2021). In-lake nutrient concentrations reflect current conditions in the lakes and can be assessed against LWRP objectives. External catchment loads of nutrients contribute to in-lake nutrient concentrations, but do not translate 1:1 to in-lake concentrations due to nutrient attenuation (i.e., the reduction of nutrients by processes other than dilution – e.g., plant/algal uptake) and processing. The load reductions were determined from both monitoring data and the relationship between lake water quality and catchment loads from the CLUES model[1]:

All monitored lakes in the **Ashburton Lakes basin** need **reductions in algal biomass** and in-lake **Total Nitrogen concentrations** to meet the LWRP objectives (outcomes) and limits. Four out of 8 lakes need reductions in in-lake **Total Phosphorus concentrations** to meet the plan limits.

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[1] Loads were calculated from the reductions in in-lake concentrations required to meet plan limits which were then translated into an estimated load reduction via the regression models built with CLUES catchment loads estimates and the monitoring data (Vollenweider model). Load reductions estimates are not a direct output of the CLUES model.

Most of the Ashburton Lakes require major reductions in **catchment nutrient loads to** meet the LWRP plan objectives and limits. Of the lakes evaluated[2]

- 80% of lakes require large **Nitrogen load** reductions.
- 33% of lakes require large or moderate **Phosphorus load** reductions.
- 100% of lakes need **significant reductions in nutrient loads to meet algal biomass** (chlorophyll a) plan objectives.

Similarly, many of the **Waimakariri lakes** also require moderate or large nutrient load reductions to meet plan objectives. Lake nutrient load reductions are therefore not unique to the Ashburton lakes, and may be needed in many high-country lakes across Canterbury.

The **nutrient load reductions are described for entire lake catchments** (catchment-scale), and not for individual farms or sub-catchments, and do not account for fine-scale land cover (e.g. location of winter fodder crops, location of high production areas [e.g. legumes such as lucerne], or other small scale, high-impact activities or areas).

Lakes Emily and Emma have the highest contribution of **bird sources to total nutrient loads**. All other lakes have low bird contributions to total nutrient loads, accounting for less than 9% (of total lake loads) for Total Phosphorus and less than 2% for Total Nitrogen.

Implications for lake management

The Cawthron report provides additional evidence that **significant catchment nutrient load reductions** are needed in all monitored lakes in the Ō Tū Wharekai area and for many of the Waimakariri Lakes. The report also provides an estimate of the magnitude of load reductions required for each lake.

The need for significant nutrient load reductions in the Ashburton Lakes basin is also evident from the Department of Conservation's and Environment Canterbury's stream and lake monitoring data. These monitoring data show:

- increasing trends of total nutrient concentrations and algal biomass in many lakes in the basin (Table 1) along with increasing nutrient concentrations in streams.
- that LWRP objectives are consistently not being met for nutrient concentrations and algal biomass outcomes in the lakes.

As both Nitrogen and Phosphorus availability is likely to control algae, **both Total Nitrogen and Total Phosphorus catchment loads** will need to be co-managed to avoid further increases in algal biomass and failure to achieve the overall algal biomass outcome.

Lakes are often accumulators of nutrients and legacy issues can persist for years after external nutrient loads are reduced. Degradation is not readily reversible; especially once lakes have

[2] Some lakes were excluded from the load assessment based on poor catchment model fit. These lakes are likely to have additional factors driving nutrient dynamics and algal biomass (beside catchment land cover, soil type, land topography and climate) that were difficult to model. These additional factors may include internal loading processes within a lake and unquantified additional external nutrient sources. The following lakes were removed from load reduction estimates: Lakes Emma, Denny, Clearwater, and Hawdon. **Their removal does not indicate they do not also require significant nutrient load reductions.**

reached their 'tipping points'. Climate change is likely to further increase the lakes vulnerability. These considerations highlight the need for substantial and urgent action to prevent the Ashburton lakes from entering into (or remaining in) persistent, degraded states.

Supplementary technical information and updated lake water quality data

The Cawthron report does not include the 2020/2021 seasons data or recent (post 2018) land use mapping. As nutrient and chlorophyll a concentrations are continuing to increase in most lakes, even higher nutrient load reductions than indicated in the CLUES modelling report will be required to meet the LWRP objectives and targets.

Table 2 presents an overview of required reductions of in-lake nutrient concentrations and catchment loads needed to meet the LWRP objectives. The data presented in this table uses the load reduction estimates from the Cawthron report, but in-lake concentration reductions are based on 2017-2021 monitoring information and are therefore more up to date than what is shown in the Cawthron report (2015-2020). Updated Trophic Level Index and NPS-FM attribute grades are shown in Table 3.

Specifically, recent monitoring highlighted:

- None of the lakes monitored in the Ashburton basin now meet the plan objectives for the Trophic Level Index in the period between 2017 and 2021 (based on 5-year averages, Table 3).
- Most lakes in the Ashburton basin continue to have increasing trends in in-lake Total Nitrogen concentrations and/or algal biomass (Table 1), and the frequency and magnitude of exceedance of LWRP objectives is increasing.
- There have been recent large increases in algal biomass in Lakes Clearwater and Heron alongside increasing nutrient trends (Figure 1 and 2, Table 1):
    - Lake Heron no longer meets the LWRP Total Nitrogen concentration limit based on the latest 5-year averages (2017-2021)
    - The Lake Heron Total Phosphorus concentration limit was exceeded in the past 2 years, and the Total Nitrogen concentration limit exceeded in the past 4 years.
    - **Lake Heron and Lake Clearwater did not meet the NPS-FM national bottom line for algal biomass in 2020/2021.**
    - Conditions below the national bottom line indicate that lake ecosystems have undergone, or are at high risk of, a shift to a persistent, degraded state.
- Urgent action is needed for Lake Clearwater in particular as there are indications that the lake may be 'tipping' (i.e. transitioning from a clear macrophyte dominated state to a turbid algae dominated state).

In terms of land use:

- The report used land use data available from LCDB5 that is based on land use data up until to 2018; therefore, it may not detect more recent land use changes. It also uses broad categories and does not account for differences in farming practices.

Additional information for interpretation:

Overall, the catchment model performed reasonably well in predicting lake water quality from catchment land uses for most lakes. However, the Cawthron report clearly states that given the complexity of models and lake ecosystems there are some areas of uncertainty.

The report and our memo have considered land use responses from a water quality limits approach, and have not directly considered the relevance or appropriateness of these (plan) targets and limits to cultural values and Mātauranga measures of the lakes.

Below are notes to assist in interpretation of the report's findings:

- The relationship between in-lake nutrient concentrations and catchment nutrient loads is not linear, so catchment **load** reductions needed are higher % reductions than measured in-lake total nutrient concentrations.
- For the lakes that could not be effectively modelled, significant nutrient load reductions are still likely to be required given their currently degraded water quality status.
- The community of algae present can vary from lake to lake and over time, which can influence lake trophic status and nutrient sensitivity. These relationships may need to be considered when developing individual lake catchment management strategies.
- Investigations into different forms of nutrients (dissolved organic, dissolved inorganic, and particulate) are ongoing for the monitored Ashburton lakes. Preliminary results indicate that the proportion of nutrients that are immediately bioavailable varies markedly between the lakes. This variability could help explain some differences in algal biomass responses to total nutrient concentrations and loads, and poor model fit for some lakes.
- For Lake Heron where a large proportion of Total Nitrogen load is delivered as bioavailable nitrate in some areas, having catchment load limits for Total Phosphorus, Total Nitrogen **and nitrate** may be a more effective management strategy than relying on total nutrient load limits alone.
- While nutrient concentrations are useful indicators of eutrophication, algal biomass indicates the overall ecosystem response. It is the increase in algal biomass above reference conditions that compromises the ecological, cultural, recreation and amenity values. All Ashburton Lakes need higher reductions of algal biomass than nutrient concentrations (both based on current in-lake concentrations and modelling results), which suggests that the current limits for Total Nitrogen and Total Phosphorus are not necessarily conservative enough to achieve the chlorophyll a objectives.
- Because the contribution of birds was excluded from the load reductions, the estimates of Total Phosphorus load reduction required from some lakes (Emma, Emily) may be lower than what is currently estimated, given the recent management of bird populations.
- There is a mismatch between LWRP Schedule 8 and Table 1a in terms of TLI objectives vs. plan limits for Lake Emily and the Maori Lakes. In the report this was resolved by using the plan objectives (TLI of 4 and chlorophyll a of 5 µg/L), and the TP and TN concentrations (350 µg/L TN and 20 µg/L of TP) that correspond to a TLI of 4. This mismatch needs to be resolved in future plan changes.

Table 1: Long-term trends for the Ashburton Lakes (2007-2021)

Lake	Total Nitrogen	Total Phosphorus	Chlorophyll a
Heron	Very likely increasing		Very likely increasing
Maori-Front	Very likely increasing	Likely decreasing	
Maori-Back	Likely increasing		Very likely increasing
Emily		Very likely increasing	Likely increasing
Clearwater	Very likely increasing	Very likely increasing	Very likely increasing
Camp	Very likely increasing		Very likely increasing
Emma	Likely increasing	Likely increasing	Very likely increasing
Denny	Likely decreasing		

Very likely >90% likelihood; likely 67-90%

Table 2: Reductions of in-lake concentrations (based on 2017-2021 averages) and catchment loads needed to meet LWRP objectives

Lake	TN in-lake reduction needed	TP in-lake reduction needed	Chla in-lake reduction needed	Estimated TN Load reduction*	Estimated TP Load reduction*
Heron	9%		81%	0-33%*	
Maori Front	45%		54%	>66%*	
Maori Back	34%	13%	63%	>66%*	
Emily	25%	29%	40%	>66%*	33-66%*
Clearwater	74%	55%	80%	ND* likely >66%**	>66%*
Camp	52%		37%	>66%*	
Emma	76%	70%	87%	ND*	
Denny	75%	91%	83%	ND* likely >66%**	

Kelly et al 2021, ND = not determined as outside regression model

** estimated based on 2017-2021 in-lake data only. Lakes Clearwater, Emma and Denny fall outside the regression model. Lake Emma is likely to be affected by internal loading processes. Lakes Clearwater and Denny likely have additional sources of nutrients in their catchments.

Table 3: Updated lake water quality assessments of the Ashburton lakes

Lake	TLI 2020/ 2021	LWRP assessment (ø 2017-2021)			NPS-FM Attribute State (2017-2021) (in µg/L)				Frequency of NPS-FM D-bands in all years 2017-2021			
		TLI (ø2017-2021)	Grade	LWRP met?	TN - MED	TP - MED	Chla - MED	Chla - MAX	TN	TP	Chla - MED	Chla - MAX
Heron	3.9	3.6	mesotrophic	NO	150	7	6.1	38			1	
Maori-Front	3.8	4.3	eutrophic	NO	620	8	1.8	137				2
Maori-Back	4.8	4.5	eutrophic	NO	410	16	4.3	80			1	1
Emily	4.1	4.4	eutrophic	NO	410	23	3.5	50				
Clearwater	5.4	4.3	eutrophic	NO	510	14	4.3	40	1		1	
Camp	3.6	3.4	mesotrophic	NO	330	7	2.8	6.6				
Emma	5.3	4.8	eutrophic	NO	620	26	10.8	48	1		3	
Denny	4.5	5.0	supertrophic	NO	530	49	8	140		3		

TLI = Trophic Level Index, TP = Total Phosphorus, TN = Total Nitrogen, Chla = chlorophyll a, MED = median, MAX = maximum. NPS band colour coding: Blue = A-band, Green = B-band, Orange = C-band, Red = D-band.

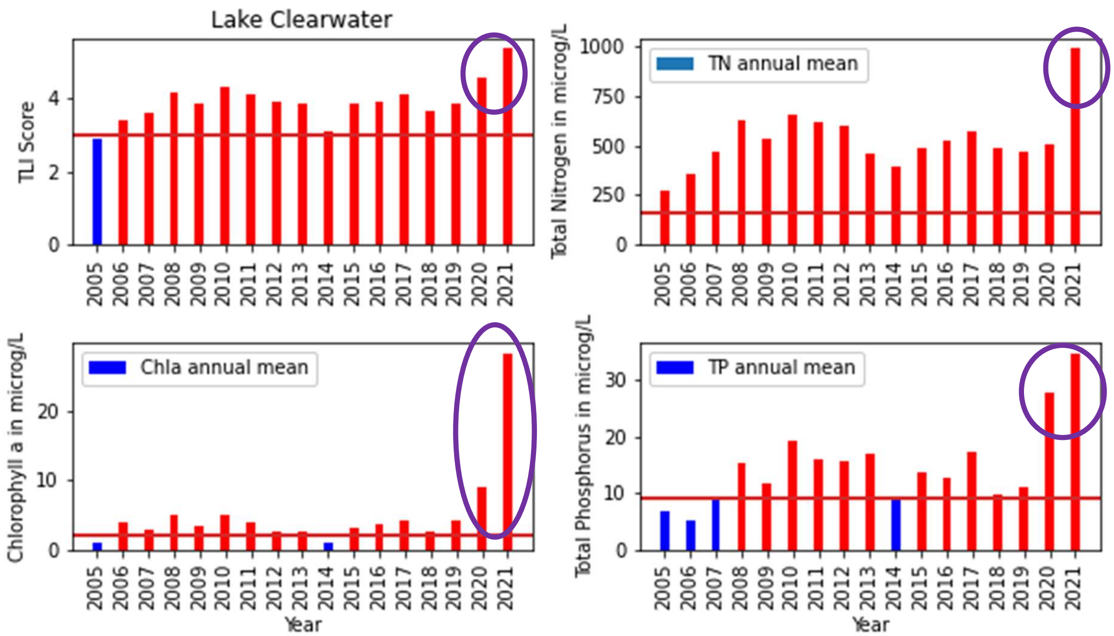

Figure 1: Trophic Level Index, Total Nitrogen, Total Phosphorus and chlorophyll a annual means in Lake Clearwater, 2005-2021. Red line is the LWRP objective/limit. Circle highlights notable recent (2020 2021) increases.

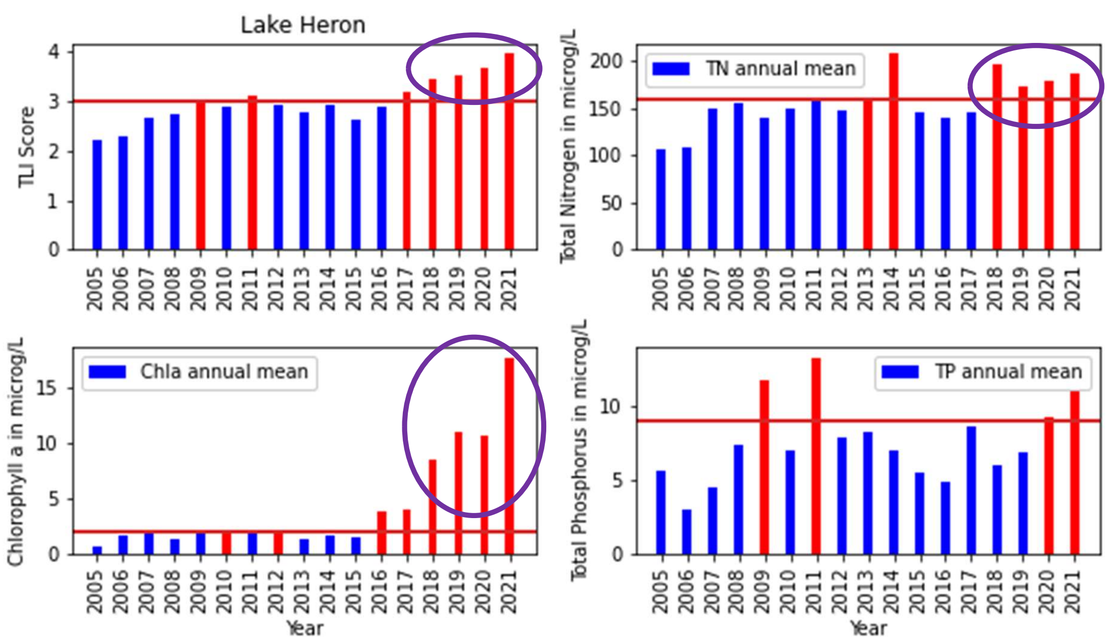

Figure 2: Trophic Level Index, Total Nitrogen, Total Phosphorus and chlorophyll a annual means in Lake Heron, 2005-2021. Red line is the LWRP objective/limit. Circle highlights notable recent (2018 to 2021) increases.

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[i] Kelly, D, Floerl, L, & P Cassanovas (2021). Updating CLUES nutrient load predictions for Ashburton Basin and Waimakariri high-country lakes. Prepared for Department of Conservation & Environment Canterbury. Cawthron Report NO 3589

[ii] Kelly, D, Robertson, H, & C Allen (2014). Nutrient loading to Canterbury high- country lakes for sustaining ecological values. Prepared for Department of Conservation and Environment Canterbury. Cawthron Report NO. 2557