MEMORANDUM

To:

From: Paul Scholes **Date:** July 2019
Senior Environmental Scientist

File Ref: Obj Ref

Copy To: Graeme Howard, Andy Bruere, Rob Donald, Heidi Fraser

Subject: **Rotorua Lakes 2018-2019 TLI Update - DRAFT**

Introduction

The Regional Natural Resources Plan (RNRP) includes policies designed to manage the water quality of the 12 the Rotorua Te Arawa lakes. Each of these lakes has an objective Trophic Level Index (TLI) based on past water quality (RL O1 (Objective 11) of the RNRP). The TLI is a numerical index that represents the water quality aspirations of the regional community.

Monitoring programmes have been developed to identify changes in lake water quality and ecology. These include physico-chemical water quality monitoring to generate the TLI, algal monitoring with a focus on cyanobacteria, and macrophyte monitoring using the LakeSPI index.

The objective of this report is to update the annual TLIs for each of the lakes and compare values against the objectives set in the RNRP. The TLI is made up of four measures; Total Phosphorus, Total Nitrogen, Chlorophyll-*a* and Secchi depth (water clarity).

Results

Table 1 summarises the TLI data for the Rotorua Lakes for the period July 2018 to June 2019.

Table 1 *Three-yearly average TLI values, annual TLI, trophic status category and LakeSPI condition for the Rotorua Lakes.*

Lake *Regional Natural Resources Plan Objective* *TLI units*	2014/15 Annual TLI *TLI units*	2015/16 Annual TLI *TLI units*	2016/17 Annual TLI *TLI units*	2017/18 Annual TLI *TLI units*	**2018/19 Annual TLI**	**2018/19 3 yearly annual average TLI**	**Lake Type** *based on Trophic Status*	**LakeSPI Condition** 2018[1]
Ōkaro **5.0**	**4.6**	**4.6**	**4.9**	5.2	5.2	5.1	Super-trophic	Moderate
Rotorua **4.2**	4.4	4.4	**4.1**	4.3	4.4	**4.2**	Eutrophic	Moderate
Rotoehu **3.9**	4.5	4.6	4.6	4.8	5.3	4.9	Eutrophic/ Super-trophic	Poor
Rotomahana **3.9**	4.0	4.0	4.0	4.2	4.0	4.1	Mesotrophic/ Eutrophic	High
Rotoiti **3.5**	3.7	3.8	3.8	3.9	3.8	3.8	Mesotrophic	Poor
Rerewhakaaitu **3.6**	**3.3**	**3.4**	**3.5**	4.0	4.1	3.8	Mesotrophic	Moderate
Okareka **3.0**	3.3	3.2	3.4	3.5	3.4	3.4	Mesotrophic	Moderate
Tikitapu **2.7**	2.9	2.9	**2.6**	2.9	2.9	2.8	Oligotrophic	Moderate
Ōkataina **2.6**	2.8	2.8	2.9	3.0	2.8	2.9	Oligotrophic	Moderate
Tarawera **2.6**	3.1	3.0	3.1	3.1	3.0	3.1	Oligotrophic	Moderate
Rotoma **2.3**	2.5	2.4	**2.3**	2.5	2.6	2.5	Oligotrophic	High
*Rotokakahi** ***3.1***	*4.0*	*3.7*	*3.8*	*3.7*	*3.8*	*3.7*	Mesotrophic	Moderate

*Italicised figures are based on Te Wairoa Stream monitoring and a three-parameter TLI (no Secchi disk).

Lake Ōkaro

Lake Okaro remains just above its target TLI of 5.0. The annual average TLI improved slightly on last year in part due to lower chlorophyll-a concentrations in late spring/early summer. Both total nitrogen (TN) and total phosphorus (TP) annual average concentrations were elevated compared to the last five years, although productivity (as indicated by chlorophyll-a) did not increase compared to the previous year). Lower algal biomass in late summer 2019 saw an improvement in water clarity, and reduced total nitrogen (TN) and total phosphorus (TP) concentrations. Dissolved reactive phosphorus (DRP) in the hypolimnion was elevated compared to the previous five years.

Cyanobacteria were present at red action levels when summer monitoring began in November 2018, continuing into early January. Cyanobacteria biovolumes dropped off after this and remained in green surveillance level for the remainder of the season.

[1] NIWA (2018). Assessment of the Rotorua Te Arawa lakes using LakeSPI – 2018.

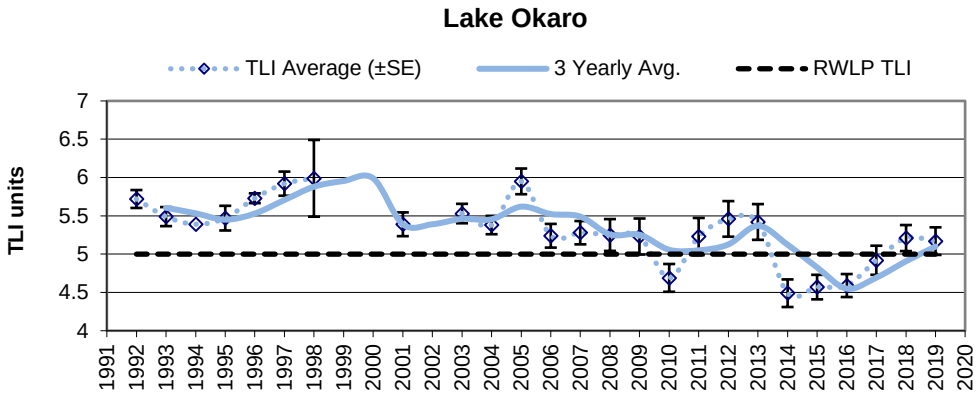

Figure 1: Lake Ōkaro annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Rotorua

The three year average TLI sits at the objective TLI (4.2 TLI units), although the annual average TLI remains above the objective, at 4.4 TLI units. Chlorophyll-*a* and TN concentrations remain steady, but TP concentrations were the highest in five years. This is in part explained by DRP increases in late summer/autumn coinciding with stratification events.

Two strong stratification events occurred, one in January and another on March. The most significant seems to have been over late March, lasting around a week.

Cyanobacteria levels remained relatively low, similar to the previous summer. All of the sites within Lake Rotorua remained in the green surveillance level during the course of this season.

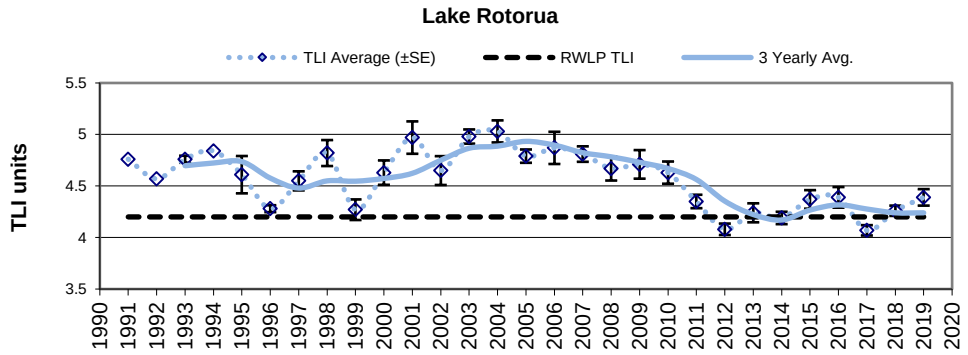

Figure 2: Lake Rotorua annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Rotoehu

Lake Rotoheu's year has been marked by persistent cyanobacteria blooms for most of the year. This has seen the TLI annual and three yearly average rise to 5.3 and 4.9 respectively. TN and TP concentrations have spiked over the summer with the onset of stratification. Chlorophyll-a concentrations are some of the highest in recorded history which has led to an ongoing recent decline in water clarity.

There has been strong nitrate concentrations over the past few winters. While this may in part be explained as conversion of ammonia released from sediment during stratification, there may be also additional input released form soils due to recent forest harvesting.

Both sites in Lake Rotoetu started and ended the monitoring season in an alert status. On the 21st of November 2018 Kennedy Bay was in amber alert level and Ōtautū Bay was in the red action mode. Kennedy Bay joined Otautu Bay in the red action level on the 5th of December 2018 and for the majority of the season they were both in red action level with intermittent decreases to amber and green level biovolumes on occasion. These occasional drops in biovolume did not remain low for long enough to remove the red alert status, until Kennedy Bay reached an amber alert status in the middle of May 2019. A health warning remains for the lake due to ongoing cyanobacterial blooms.

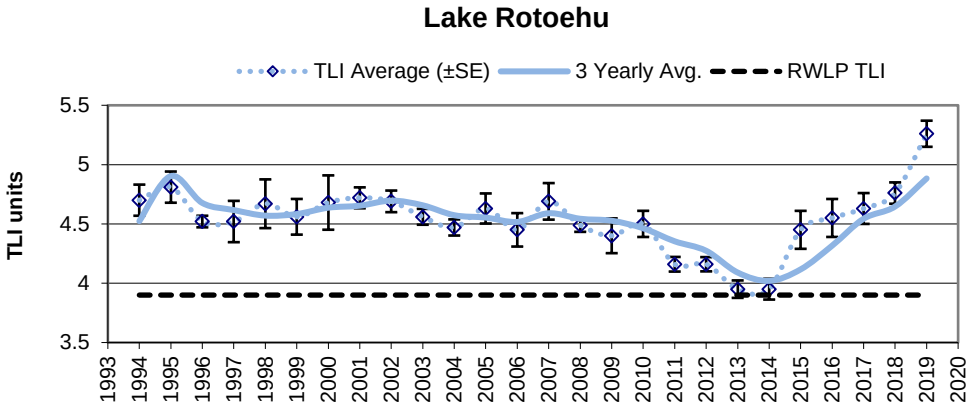

Figure 3: Lake Rotoehu annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Rotomahana

Lake Rotomahana's annual average TLI dropped back down after an increase last year, moving from 4.2 to 4.0. The annual average TLI remains above the RNRP objective of 3.9, and the three yearly average remains relatively steady at 4.1.

There was an improvement in water clarity and chlorophyll-a concentrations compared to last year. TN concentrations have increased in the past two years, with TP reasonably stable over the past five years.

Dissolved reactive phosphorus (DRP) concentrations showed a slight increase as did ammoniacal nitrogen. There was a more sustained increase in nitrate-nitrite-nitrogen concentrations over the 2018/2019 winter making for the the highest annual average observed for this lake since observations begun. This has impacted total nitrogen with the highest total nitrogen in ten years observed.

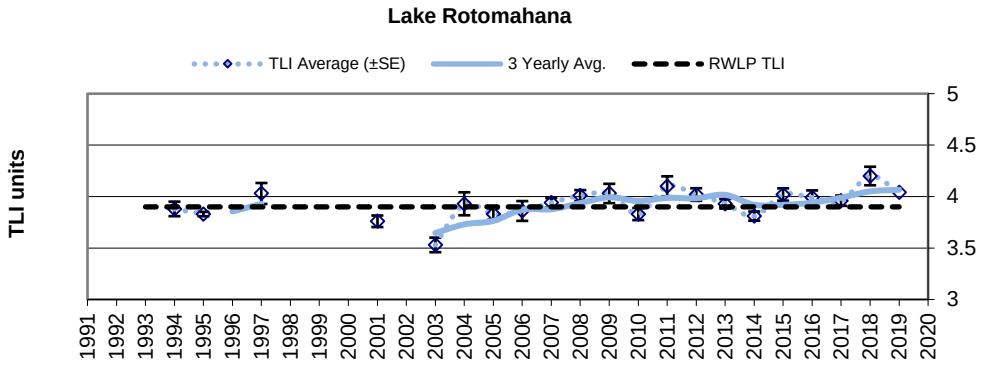

Figure 4: Lake Rotomahana annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Rotoiti

Lake Rotoiti's annual average TLI decreased slightly compared to last year at 3.8, but remains above its objective TLI of 3.5. The three-year average TLI is 3.8. Annual average TP concentration was the lowest in the last five years, while TN remains steady. An elevated spike in chlorophyll-a concentration occurred in autumn probably due to lake turnover.

Dissolved nutrients remain stable, as does hypolimnetic oxygen demand.

Cyanobacteria biovolumes were relatively low, with the exception of Okawa Bay. Here, orange alert levels were reached in mid-January for one week and again in March for the entire month. Red alert levels were reached in May resulting a health warning being imposed.

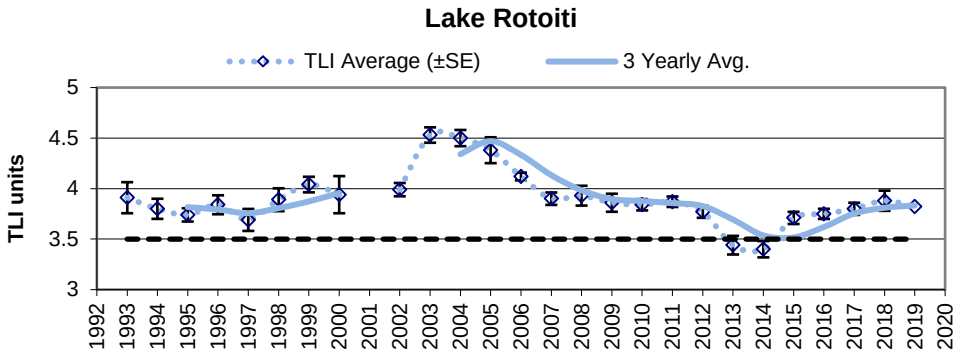

Figure 5: Lake Rotoiti annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Rerewhakaaitu

Lake Rerewhakaaitu's annual average TLI continues to rise above the RNRP objective of 3.6, at 4.1 for 2018/2019. The three year average increased to 3.8 TLI units. Strong stratification events and high lake levels, a result of intensive rainfall events, have led to increased TN and TP concentrations. Chlorophyll-*a* concentrations have been increasing over the past couple of years, and correspondingly Secchi depth (water clarity) has been decreasing. Secchi depth has shown some improvement in 2019.

Nitrate-nitrite-nitrogen levels remain elevated explaining the increase in TN. Concentrations peaked over the past two winters as did lake levels. Ammoniacal nitrogen increased over the stratification period as a result of oxygen depletion leading to nutrient sediment release. Ammoniacal nitrogen is converted to nitrate-nitrite-nitrogen under conditions right for denitrification explaining the increase in nitrate-nitrite-nitrogen. However, there may have been additional inputs from sub-surface leaching from surrounding lands.

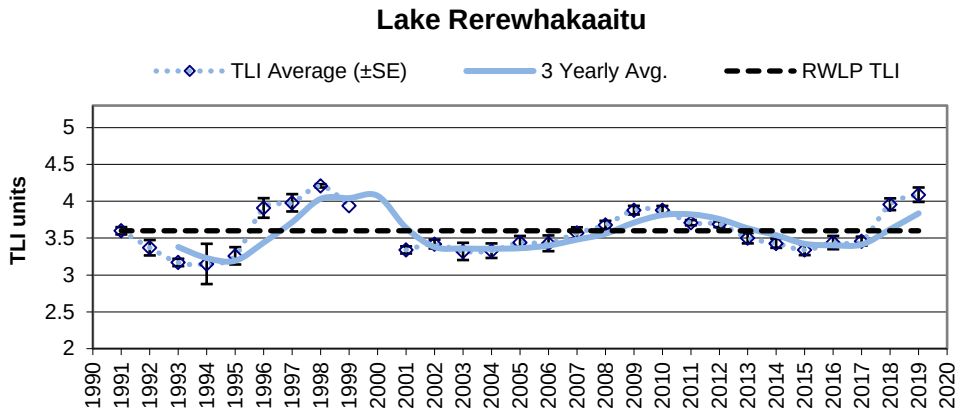

Figure 6: Lake Rerewhakaaitu annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Okareka

Lake Ōkāreka's annual average TLI decreased slightly from 3.5 last year to 3.4 for 2018/2019. The three year annual average remains steady at 3.4 TLI units. TN has remained stable over the past 10 years decreased on average compared to last year, and the annual average TP showed a reduction compared to last year but displays a longer term increasing trend.

Hypolimnetic oxygen levels remain similar to the last two years; however ammoniacal-nitrogen concentrations did increase in the hypoliminion over the stratification period for the last two years. Dissolved reactive phosphorus and nitrate-nitrite-nitrogen remain relatively unchanged. Increased lake level two years ago had some influence on nutrient concentrations, and may still have some legacy effect.

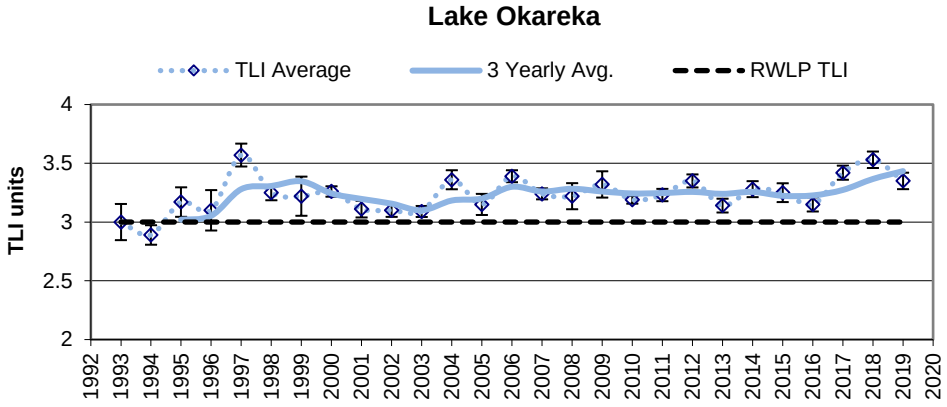

Figure 7: Lake Okareka annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Tikitapu

Lake Tipitapu's annual average TLI remains at 2.9 above the 2.6 TLi objective. The three-year average TLI also remains at 2.8 for 2018/2019 year.

Chlorophyll-*a* average annual concentrations decreased compared to a high level in the previous year, but did have a sustained winter/spring peak after winter turnover. TN has remained at steady

concentrations, and phosphorus decreased to lowest levels in over ten years, similar to those experienced in 2011/2012 (also a time of increased lake level). Water clarity (Secchi depth) did show a significant decrease over winter/spring leading to an annual average drop over 1 metre.

Ammoniacal-nitrogen concentrations increased in the hypoliminion over the stratification period, although no observable change to dissolved reactive phosphorus and nitrate-nitrite-nitrogen.

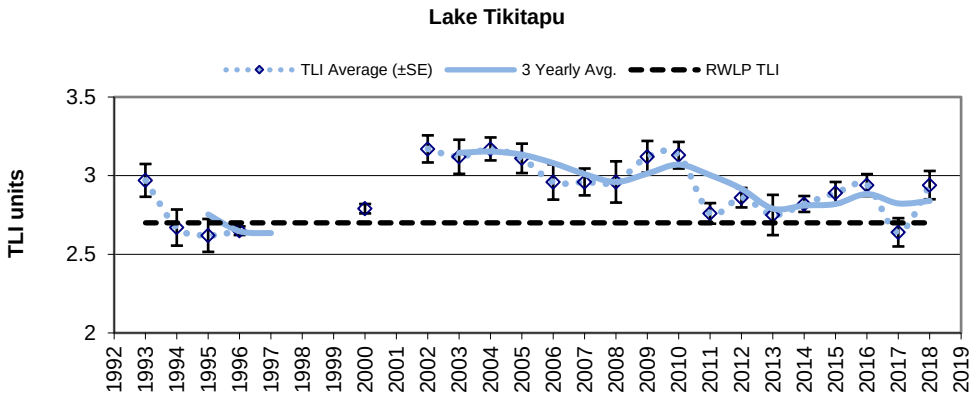

Figure 8: Lake Tikitapu annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Ōkataina

Lake Ōkataina's annual average TLI decreased from the previous two years sitting at 2.8 compared with 3.0 last year. The three-yearly average TLI remained at 2.9.

Average annual chlorophyll-*a* concentrations dropped compared to the last three years, but continues to display strong seasonal patterns (winter high, summer low). Both TP and TN remain relatively stable. A low water Secchi depth reading was taken in early summer holding the annual average value down.

The oxygen depletion rate decreased compared to the previous five years. Nitrate-nitrite-nitrogen did show an increase in the hypolimnion, which may be an artefact of ammonical nitrogen build up during stratification.

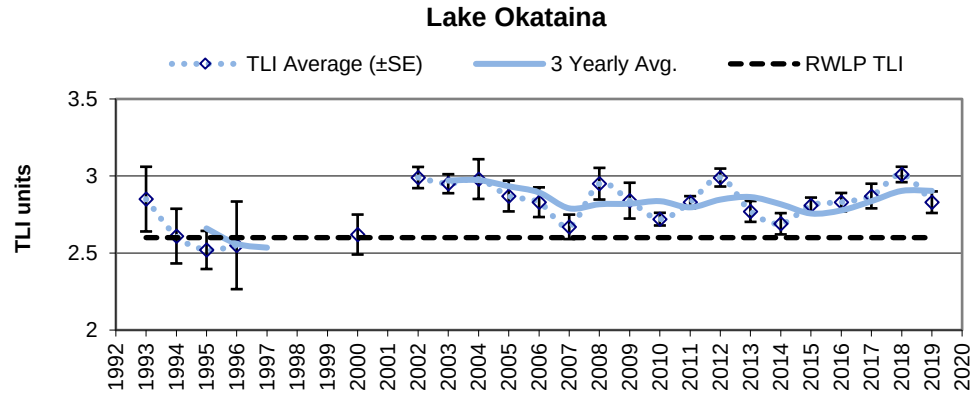

Figure 9: Lake Ōkataina annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Tarawera

The annual average TLI in Lake Tarawera remains similar to last year at 3.0. The TLI remains almost 0.5 above the RNRP objective of 2.6, with the three year average steady at 3.1.

Chlorophyll-*a* annual average concentration decreased compared to last year, consistent with other annual average TLI parameters. Both TN and TP were at their lowest concentrations in five years, but Secchi depth was slightly lower than the previous four years.

Nitrate-nitrite-nitrogen remains stable in the hypolimnion but decreased in the eplimnion compared to previous two years. DRP has decreased compared to the previous five years, consistent with TP.

No reported cyanobacteria blooms occurred over the 2018/2019 season.

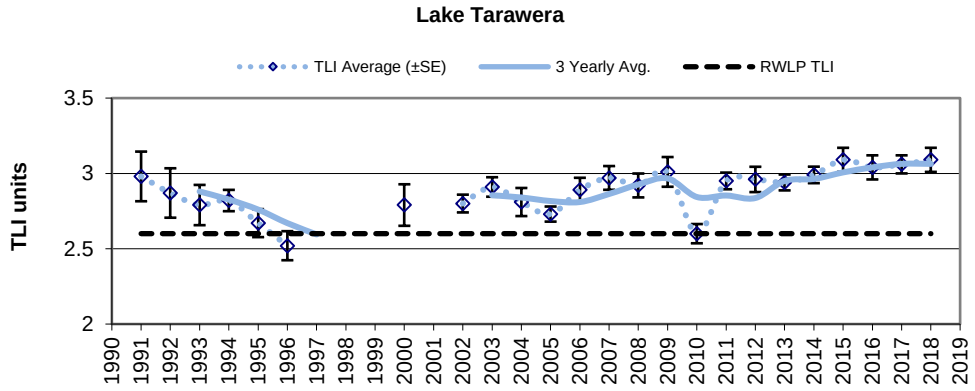

Figure 11: Lake Tarawera annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Rotomā

Lake Rotomā's annual average TLI increased compared to last year to be 0.3 TLI units above its RNRP objective of 2.3, sitting at 2.6. The three-year average TLI for 2018/2019 is 2.5.

The increase in TLI was driven by primarily by some low Secchi results (water clarity) and a small increase in annual average TN concentration. Low water clarity readings are not well supported by measure of eutrophic depth. Phosphorus and chlorophyll-*a* levels remain stable.

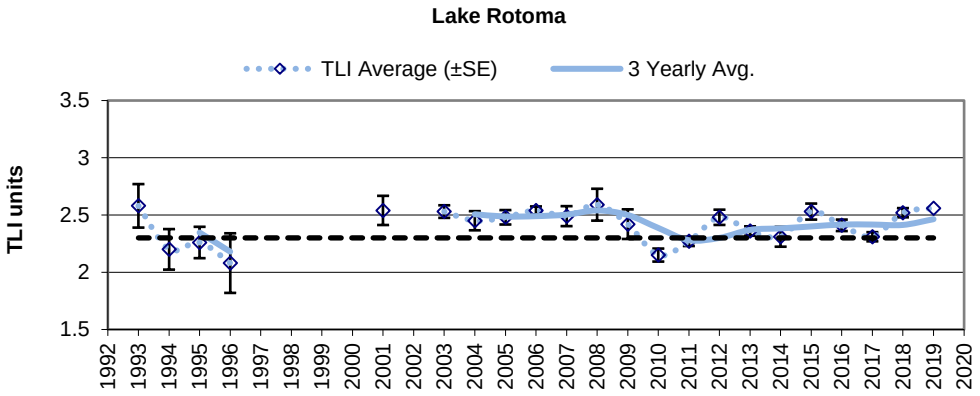

Figure 11: Lake Rotoma annual average and three year average TLI results, compared to the RNRP Objective TLI.

Lake Rotokakahi

The 2018/2019 TLI measured at Lake Rotokakahi (at the outflow) remains steady at 3.8, slightly increased from last year's result of 3.7. The TLI still remains well above its RNRP objective of 3.1. The three year average TLI for 2018/2019 (as measured by TP, TN and chlorophyll-a) remains at 3.7.

Chlorophyll-a and nitrogen concentrations remain stable, however phosphorus concentrations increased marginally compared to last year.

No cyanobacteria blooms were observed over the summer months.

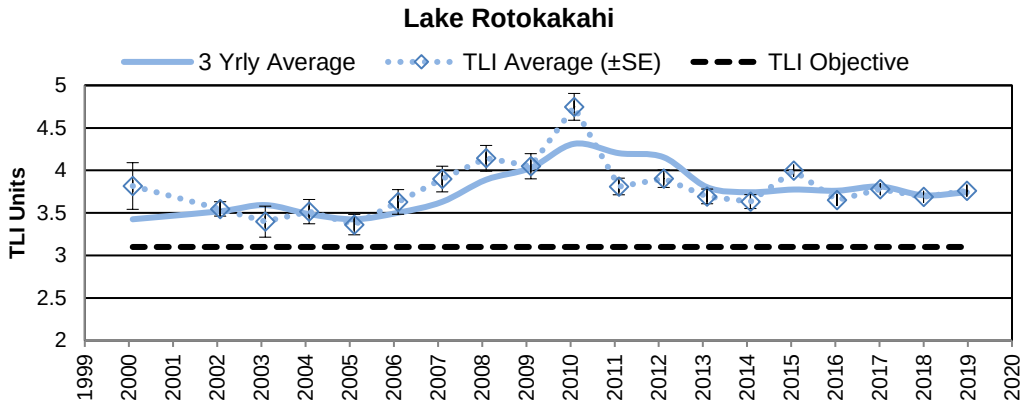

Figure 12: Lake Rotokakahi annual average and three year average TLI results, compared to the RNRP Objective TLI.

Summary

For the second year none of twelve Rotorua-Te Arawa Lakes met their RNRP TLI objective when compared to the annual average TLI for 2018/2019. Comparison of the three yearly annual average with the RNRP TLI objective showed only Lake Rotorua to match their objective TLI.

Trophic status has been impacted by climate, with record increases in lake level occurring in the previous year which may help explain a rise in annual average TLI for many lakes.

Blue-green algae (cyanobacteria) blooms resulted in health warnings being issued by Toi Te Ora for Lakes Rotoehu and Ōkaro. Lakes Rotoiti at Okawa Bay experienced blooms in late autumn resulting in a health warning. Tarawera and Rotorua remained in green surveillance level over the 2018/2019 season.

Monitoring of the of the 12 Rotorua lakes shows that:

- Lake Ōkaro remained above its target TLI for the second year, due to increased TP and TN.
- The TLI for Lake Rotorua remains just above its RNRP objective; however cyanobacteria activity remained at a low level.
- Lake Rotoehu experienced prolonged and severe cyanobacteria blooms exacerbated by sustained stratification. Its annual average TLI moved into super-trophic classification (TLI of 5.3), the first time since the early 1990s.
- Lake Rotoiti TLI remains stable but still exceeds its target TLI by 0.3 TLI units. Okawa Bay did however experience cyanobacteria bloom in late autumn resulting in a health warning. The lake has remained resilient to further degradation since the installation of the Ohau

Channel diversion wall, as indicated by stable hypolimnetic oxygen concentrations and dissolved nutrients.

- After the multiple rain events of the previous year resulted in increased phosphorus levels and rising lake levels, Lake Ōkāreka's annual average TLI decreased compared to last years (three year annual average remained the same). Nitrogen remains stable but there is an increasing phosphorus trend.
- Lake Rerewhakaaitu's annual average TLI has risen over the past two years, driven by sustained stratification events due to climatic conditions.
- Lake Tikitapu remains at a TLI of 2.9, 0.3 TLI units above its objective. Although phosphorus levels decreased there was a significant decline in water clarity, which may be an artefact of the previous year intensive rainfall events and a rise in lake level.
- Lake Rotomahana displayed a decrease in annual average TLI. Nitrate-nitrite-nitrogen is observed to have increased in the past two years.
- Lakes Ōkataina and Tarawera's TLI have been stable over the last five years, but has increased relative to TLI results prior to 2014. This is due to an increase in phosphorus levels.
- After a rapid decline until 2010, Lake Rotokakahi has shown improvement TLI results being stable over the past few years, but exceeding its TLI target.