# Nutrient analysis for Lake Tarawera

## ⇨ implications for TLI calculations, modelling and management

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**Summary**

The Lake Tarawera catchment is understood to be a priority for BOPRC policy development, and supporting science. Here, we revisit issues with monitoring data for nutrients, particularly phosphorus, identified but not resolved by the Water Quality Technical Advisory Group (TAG). These issues have become somewhat urgent because 1) they determine the degree to which there is a declining trend in Trophic Level Index (TLI) for Lake Tarawera, and 2) they have limited the application of lake modelling for scenario analysis to support policy for the Tarawera catchment under as suggested in the Lake Tarawera Action Plan and National Policy Statement – Freshwater Management.

We have identified and recommend that the continuous monthly measurements taken since 1989 at the Lake Tarawera outflow as part of NIWA's National River Water Quality Network be substituted for the problematic monitoring data. If accepted, this will allow progress on both immediate requirements noted above. An important first step is noting the revised nutrient and TLI trends. A number of related conclusions and recommendations are made for consideration.

NB: This memorandum is a revised version of one provided to BOPRC in April 2019

**Background**

The issues discussed here relate to abrupt increases observed in phosphorus concentrations for Lake Tarawera post-2010 monitoring data. This led Bay of Plenty Regional Council (BoPRC) to undertake interlaboratory comparison for analyses of dissolved and total phosphorus in Lake Tarawera water samples from July 2017 to January 2018, for five separate laboratories. Comparison revealed substantial differences among labs, with BoPRC values tending to be substantially higher than results from labs that deal more frequently in low environmental concentrations (i.e., Hill Laboratories and NIWA; Figure 1).

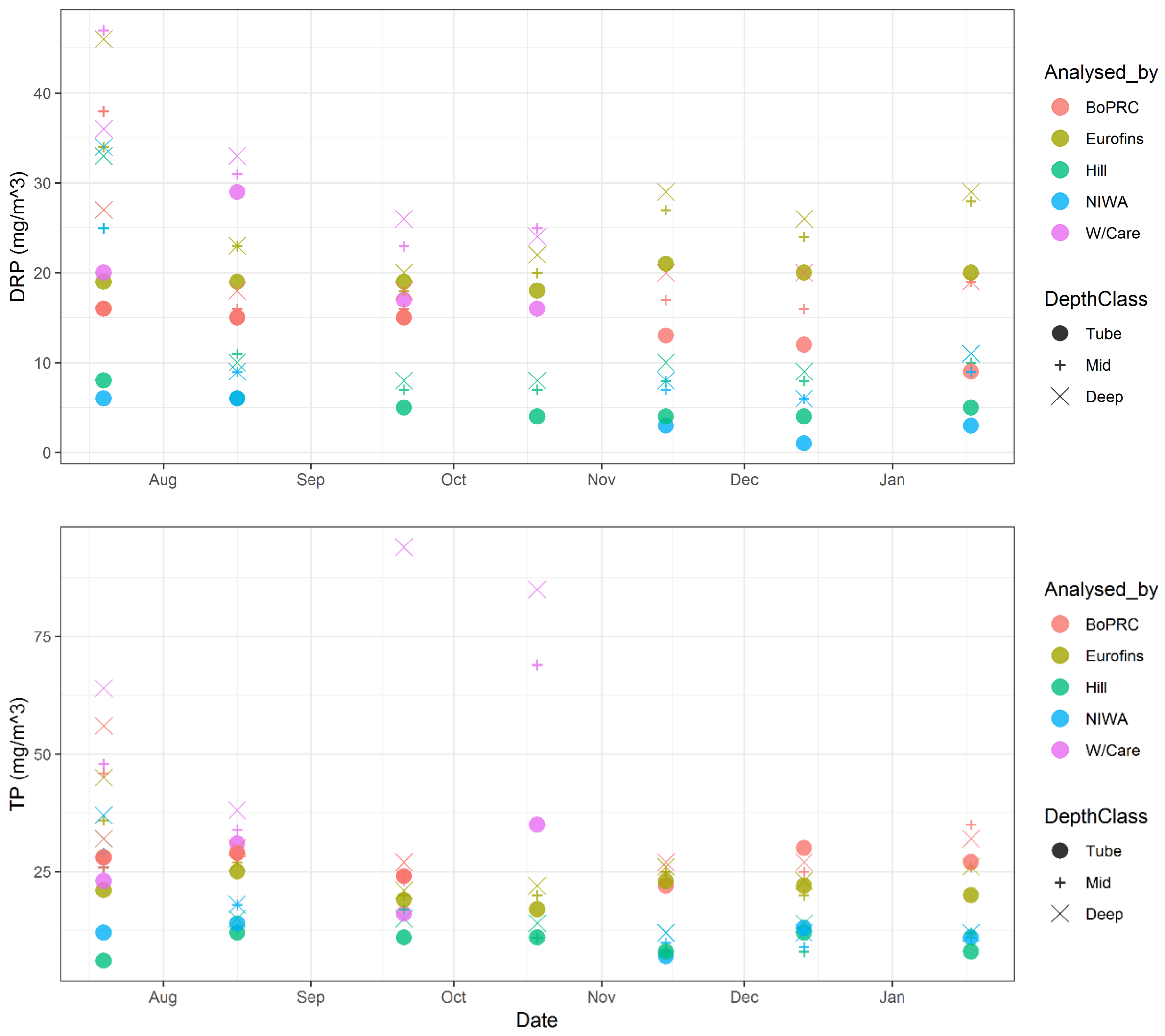



*Figure 1. Results of interlab comparison of phosphorus analyses for top) dissolved, and bottom) total phosphorus.*

The long-term monitoring record shows an abrupt change in P concentrations upon commissioning of the new BoPRC laboratory in late 2010 (Figure 2). These spurious (high) results could be due to susceptibility of recent BoPRC analytical methods to interference by silica and/or arsenate resulting from the geothermal influence on Tarawera.

Notably, recent analyses (2017-18) by Hill Labs and NIWA appear consistent with earlier results from 2009 to 2010 when samples were sent to these labs while BoPRC was between labs.


*Figure 2. Long term monitoring record for DRP and TP in Lake Tarawera. Values are coloured by laboratory used, and shape represents the sample depth.*

Although interlaboratory comparison was not undertaken for nitrogen, recent BoP analyses appear very consistent with analyses by Hill Labs and NIWA 2009 to 2010, whereas measurements by BoPRC pre-2009 lack the clear seasonal pattern evident over recent years (i.e., likely indicative of poor precision), and appear to be biased towards higher values (i.e., poor accuracy).

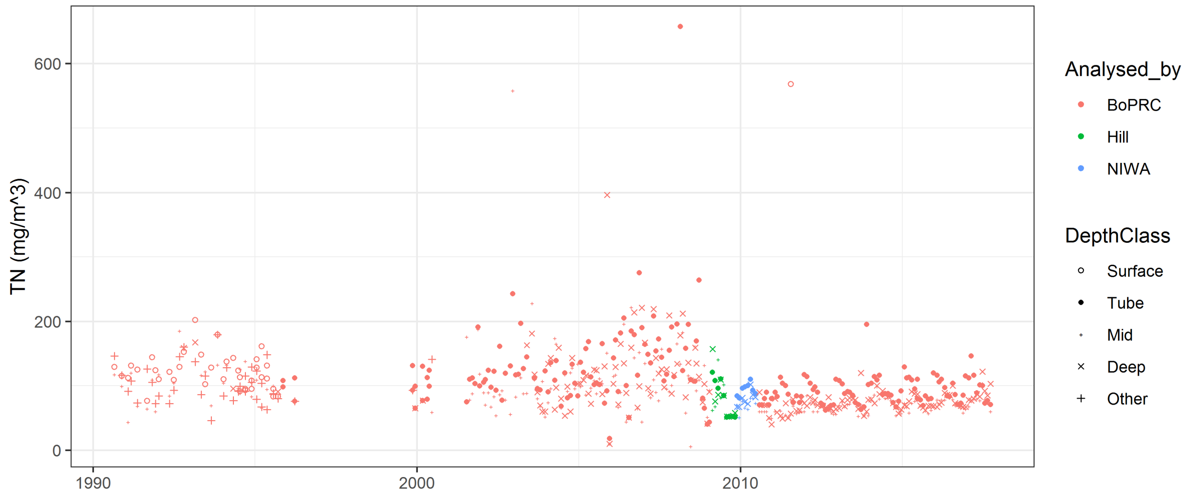



*Figure 3. Long term monitoring record for total nitrogen in Lake Tarawera. Values are coloured by laboratory used, and shape represents the sample depth.*

### Proposed Solution

NIWA has been monitoring water quality at the outflow of Lake Tarawera c. monthly since 1989, as part of the National River Water Quality Network (NRWQN) (Figure 4; yellow dot).

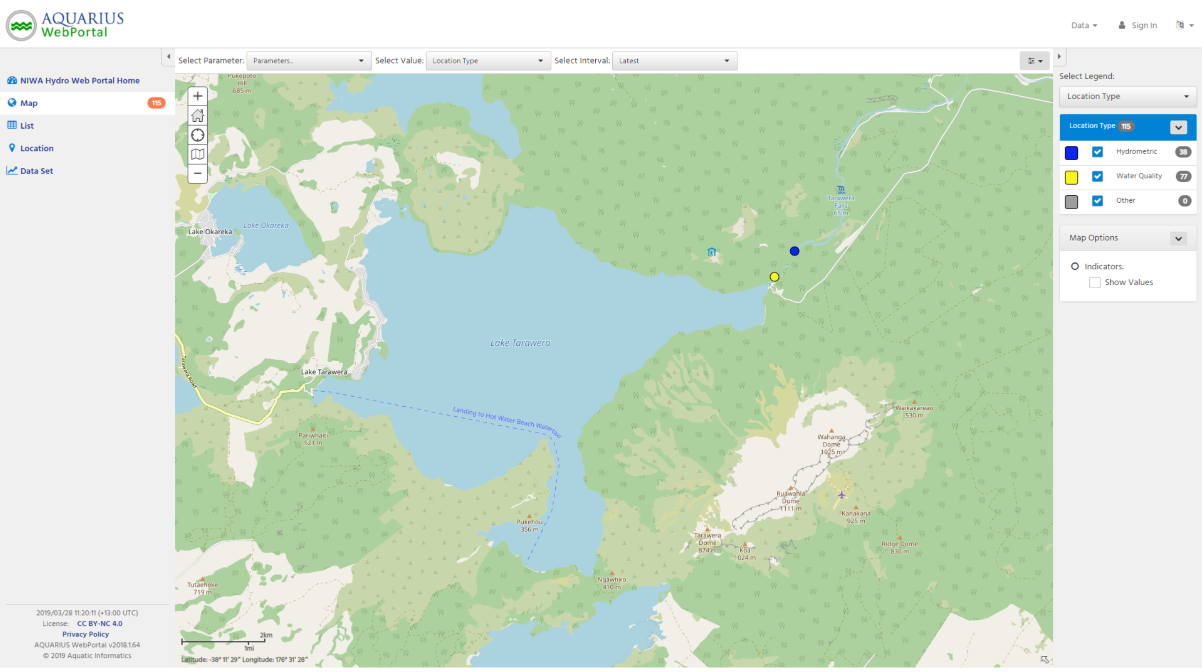



*Figure 4. Location of NRWQN monitoring site for the Tarawera River (source: [https://hydrowebportal.niwa.co.nz/Data/Map/Parameter/NoParameter/Location/Type/Interval/Latest](https://hydrowebportal.niwa.co.nz/Data/Map/Parameter/NoParameter/Location/Type/Interval/Latest) )*

National funding for collection and laboratory analysis in the NRWQN has supported continuous, long-term monitoring data with a quality at a high international standard. Comparison of NRWQN data with the BoPRC monitoring record yields revealing insights. The NRWQN data are very consistent through time, compared with the BoPRC record which is much more variable and shows step changes at the boundary of laboratory changes (Figure 5). The close match in nitrogen concentrations post-2009, including for seasonal patterns, suggest that the outflow measurements are highly representative of the mid-lake monitoring site. Therefore, it is possible to recalculate Tarawera's Trophic Level Index by substituting NRWQN data for TN and TP in place of BoPRC data.

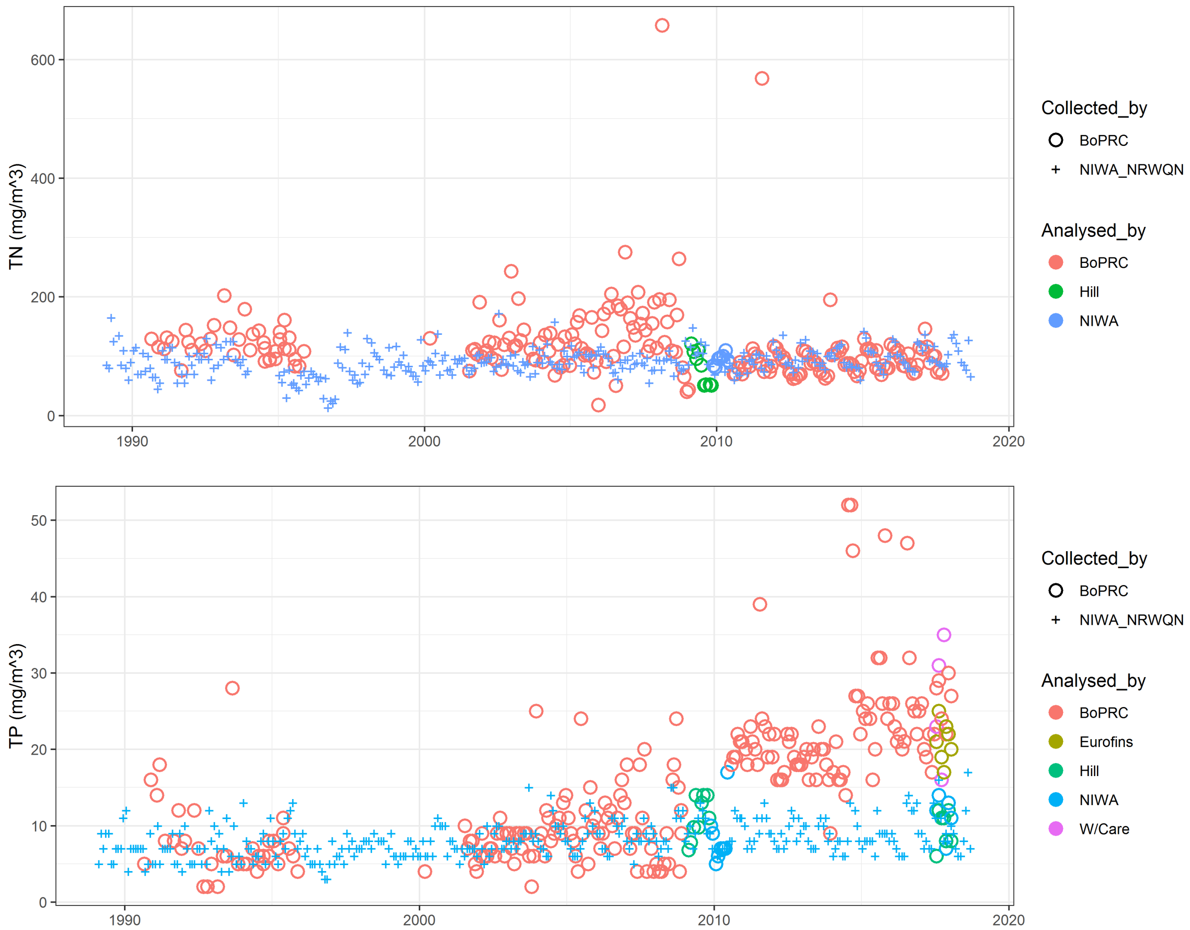



*Figure 5. Comparison of NRWQN measurements of Tarawera outflow (plus symbols) and BoPRCs monitoring record for the mid-lake (circles).*

We undertook comparison of TLI values over time using BoPRC data for TN and TP, versus TLI calculated by substituting the (evidently more accurate) NRWQN data for TN and TP. Source data (following removal of a few obvious outliers) are shown in Figure 6.

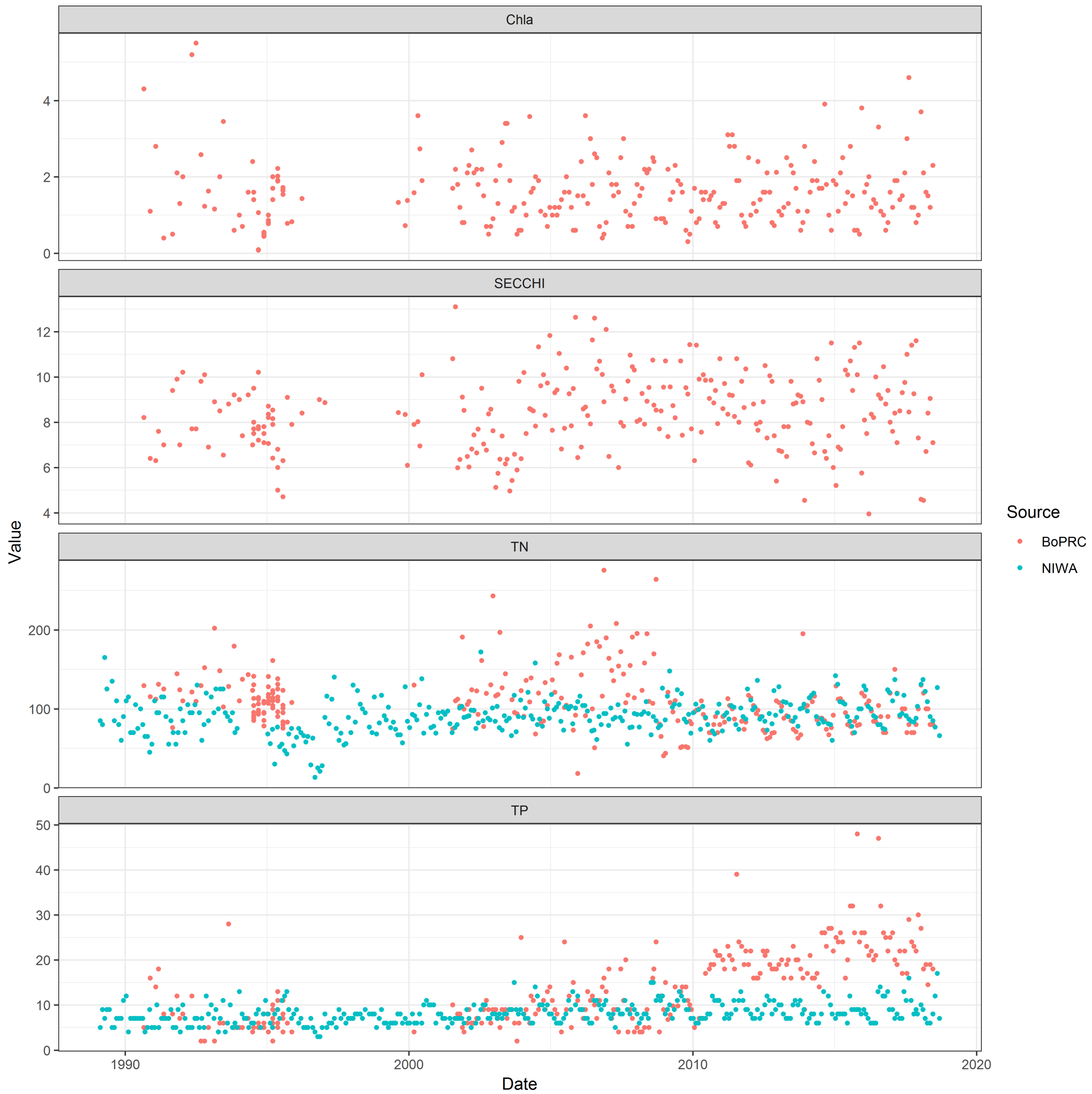



*Figure 6. Source data for TLI calculations using BoP data for TN and TP (red circles) or NRWQN data (blue circles).*

We calculated annual TLI values for both datasets (Appendix 1 and 2) by adopting the approach of McBride et al. (2019). Briefly, annual averages for the four constituent TLI variables were calculated by taking the average of seasonal averages for surface water quality measurements (in order to reduce seasonal sampling bias). These were then converted to TLI values (Figure 7).

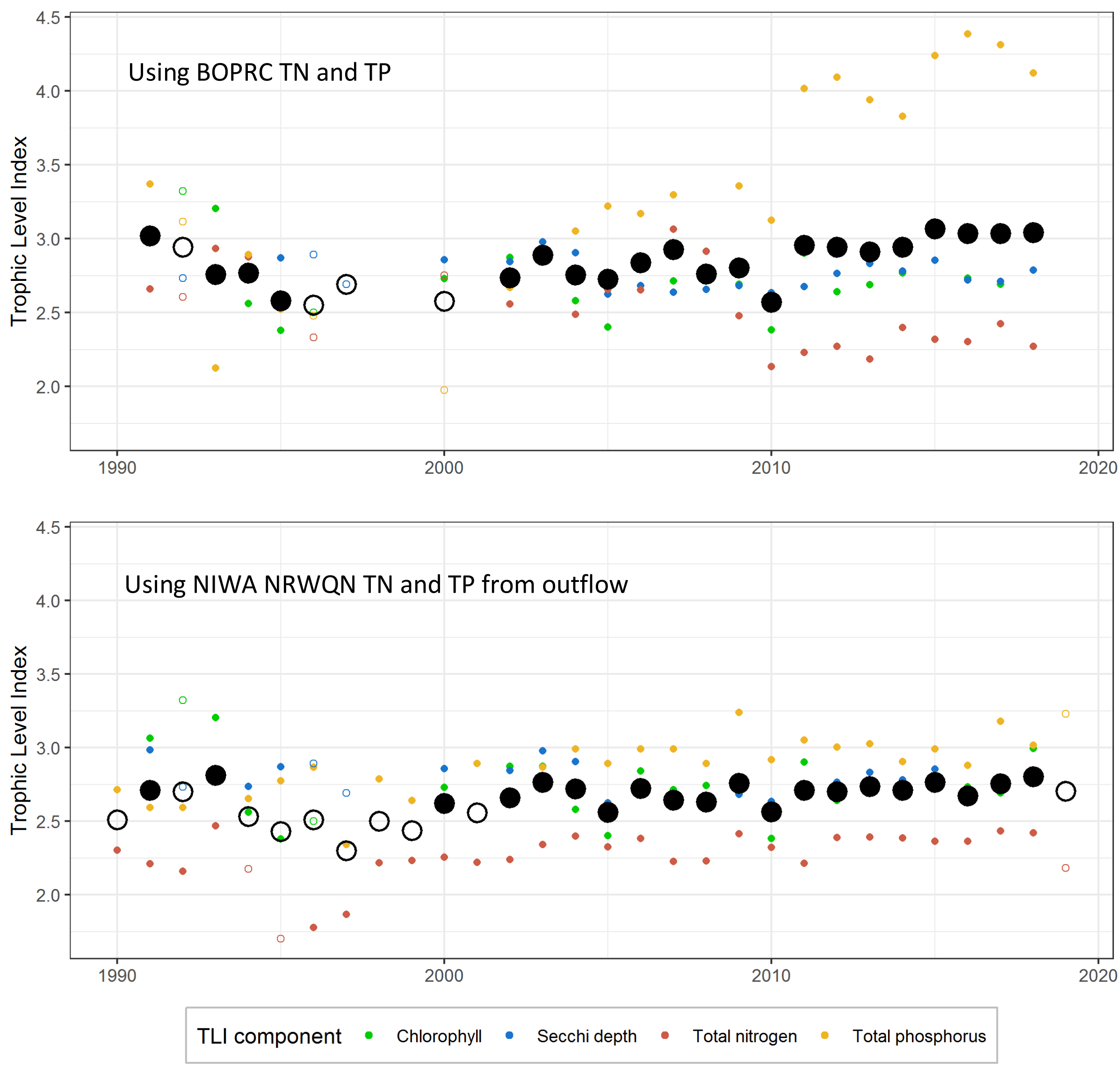



*Figure 7. Comparison of TLI calculated using BoPRC data for TN and TP (top) and NRWQN data for TN and TP (bottom). Completeness of the monitoring record is indicated by solid (all seasons represented) or hollow (incomplete) circles. Overall TLI is shown by the large black circles, whereby solid circles represent years for which there was at least one measurement for all four seasons and for all four TLI variables. Due to methodological differences, values reported here may differ slightly from those given in BoPRC reports (see McBride et al. 2019 for details).*

Direct comparison of TLI calculated by the two methods (BoPRC versus NRWQN for TN and TP data) is shown in Figure 8, where Tarawera's target TLI of 2.6 is shown by the red dashed line. Using BoPRC data (grey dots), TLI (hydrological year) since 2011 has exceeded the target value by as much as 0.45 TLI units, whereas TLI calculated with the (more accurate) NRWQN data (blue dots) exceeds the target TLI by just 0.08 to 0.2 TLI units. Clearly this has large potential implications for lake management going forward. In addition, it may have implications for the estimation of a TLI baseline, given that years with full data from the early 1990s do not appear to be consistent with the TLI target of 2.6.

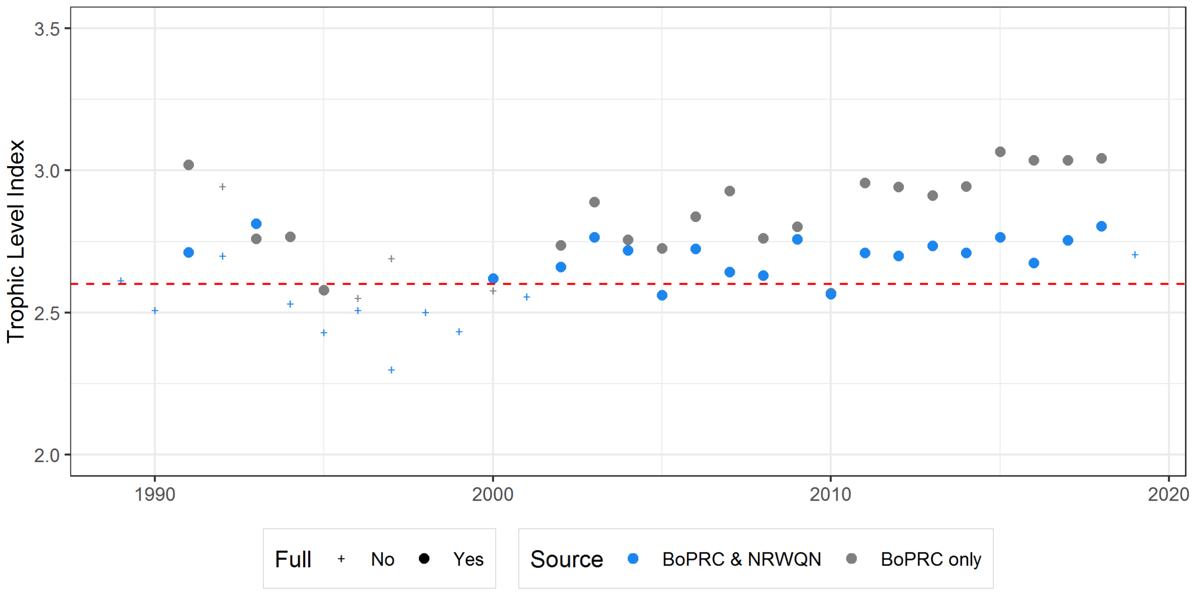



*Figure 8. Comparison of TLI calculated using BoPRC data for TN and TP (grey) versus NRWQN data for TN and TP (blue). Years with incomplete temporal coverage are shown as small plus symbols.*

Any revisions to the action plan for Lake Tarawera should be based to some degree on a technical assessment of the baseline and trends in best available TLI and nutrient datasets. As drivers of TLI, the trends in the TN and TP components therefore deserve focus.

A basic view of the entire NIWA NRWQN dataset is provided in Figure 9. An important feature of the dataset is the nutrient response, most strongly observed as a depression in TP, to the 1996 and 1997 eruptions of Mt Ruapehu, which were known to deposit ash in the Tarawera catchment.

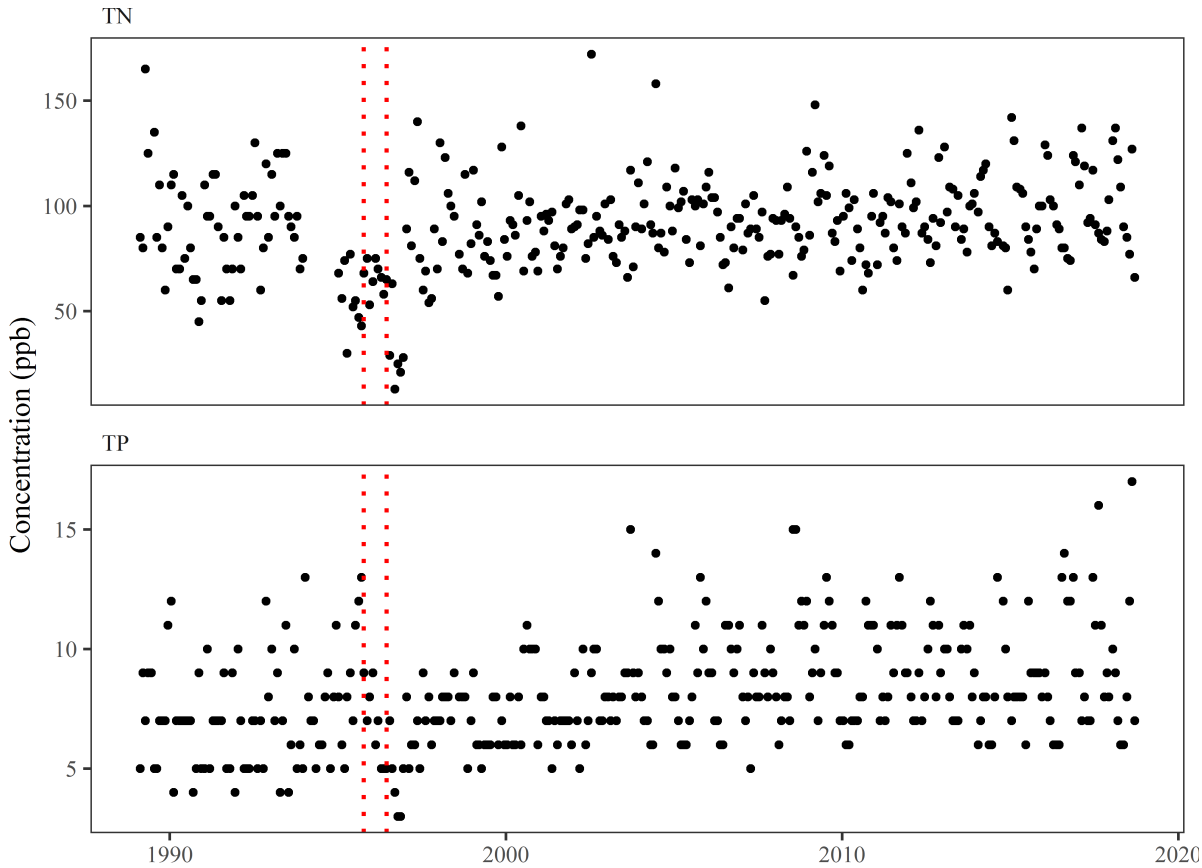



*Figure 9. The NIWA NRWQN dataset from the Tarawera Outflow for TN (above) and TP (below). Ruapehu eruptions generating ashfalls are shown as red lines.*

Figure 10 shows preliminary trend analysis performed in JMP v14.3, after removing the seasonal cycle. A "robust" trend analysis removing outliers shows little differentiation from a simple linear trend analysis. However, a local smoother (loess) fit does show reasons for both caution and additional enquiry. As expected, such an analysis shows effects from the 1996-7 eruptions. The apparent trends increasing TN since circa 2006, and no change or a slight decrease in TP since circa 2010, both deserve further investigation as to their significance and possible drivers.

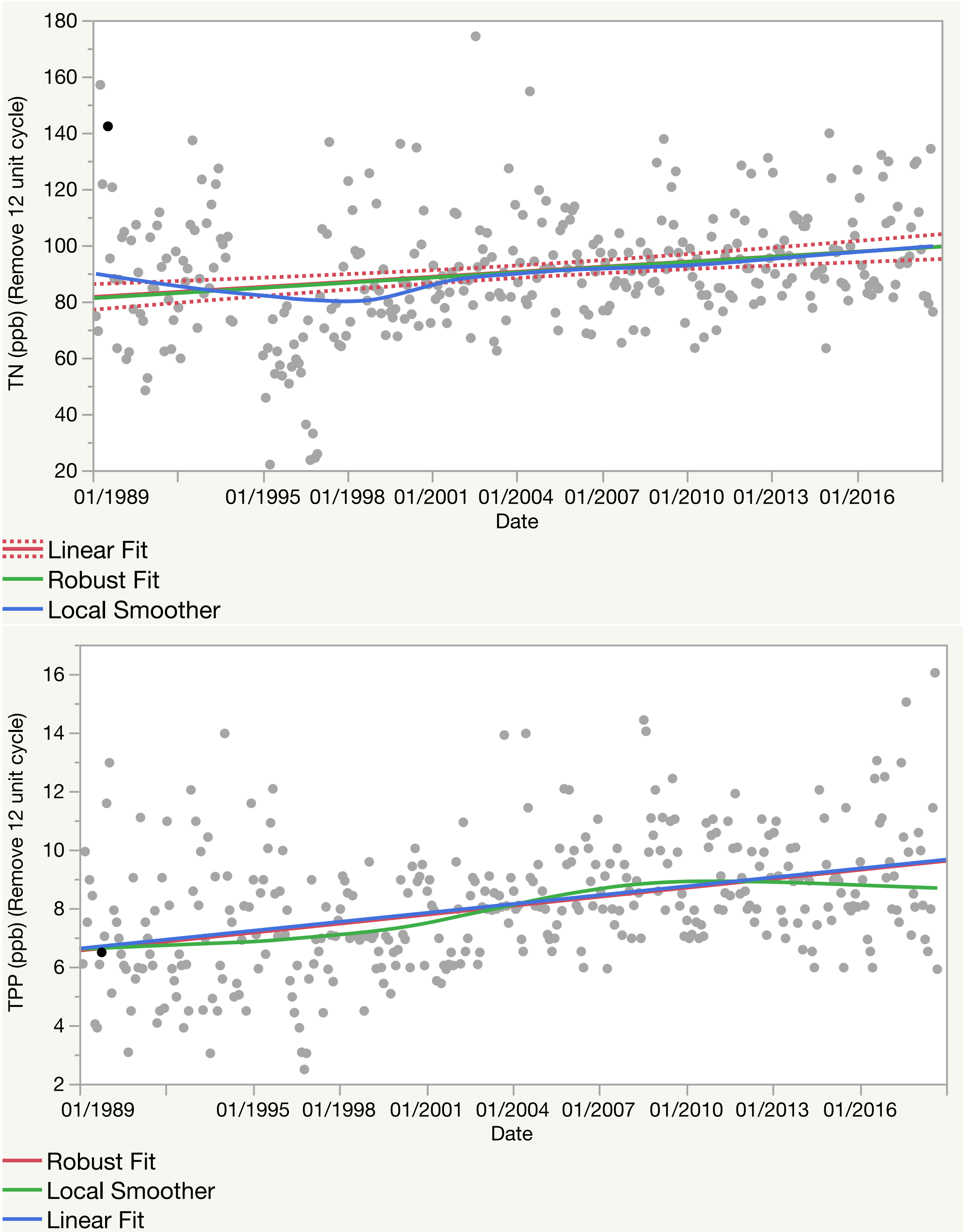



*Figure 10. Preliminary trend analyses of the NIWA NRWQN TN (above) and TP (below).*

**Conclusions & *recommendations***

The following conclusions and recommendations (in *italics*) are provided for direct consideration by BOPRC or the TAG. The recommendations most immediately addressing the two issues highlighted in the summary are in boldface italic.

1. The above analysis highlights the tremendous importance of consistency over time in analytical methods. Interlab comparisons and periods of overlap during method changes play an important role in assessment of analytical methods for environmental concentrations, and careful consideration of potential interferences or issues.

2. BoPRC methods for nitrogen analysis post-2010 appear to have substantially improved accuracy and precision of nitrogen measurements.

3. BoPRC methods for phosphorus analysis post-2010 appear highly prone to inaccuracy and/or interference by the unusual chemistry of Lake Tarawera (high silica and/or arsenate are known issues with the analysis method employed).

4. *Identification of the cause for the inaccuracy of recent BoPRC phosphorus measurements is essential, as is careful consideration of the extent to which this problem is common to other BoPRC monitoring sites, particularly those that may be geothermally influenced.*

5. ***For Tarawera, nitrogen analyses prior to 2009, and phosphorus analyses post-2010 undertaken by BoPRC appear to be unsuitable for calculating TLI in Tarawera with respect to targets. For Tarawera, NRWQN data appear highly suitable to calculate accurate TLI and trends, and we therefore propose that this be carried out.***

6. The NRWQN data are not applicable to any other BOPRC lakes, so this will not be possible for other lakes or streams. Data needs to be assessed for similar issues.

7. Adjustment of data pre- and post-2010 (e.g., Scholes & Hamill 2016 Appendix 1 and 2) for analytical offsets should consider the causes of inaccuracy, which may vary among sites (e.g., because of varying geothermal influence). The imprecision of some periods of analysis (i.e., not just inaccuracy) should also be considered when assessing the appropriateness of measurement adjustment.

8. ***The NRWQN TN and TP measurements <u>provide a proposed solution</u> for the solving the issues with process-based lake modelling carried out for Tarawera, where concerns have been raised about calibration to BoPRC post-2010 TP measurements. These data should be substituted***

9. *Investigation of the long-term monitoring records (following from Figures 2, 3, and 5) should be undertaken for other lake (and possibly streams/inflows), to identify any analytical issues including suspicious step changes at the boundary of laboratory changes. These could have consequences for management of other lakes or catchments, particularly where any biases in pre-2010 laboratory measurements (particularly TN) can be confirmed.*

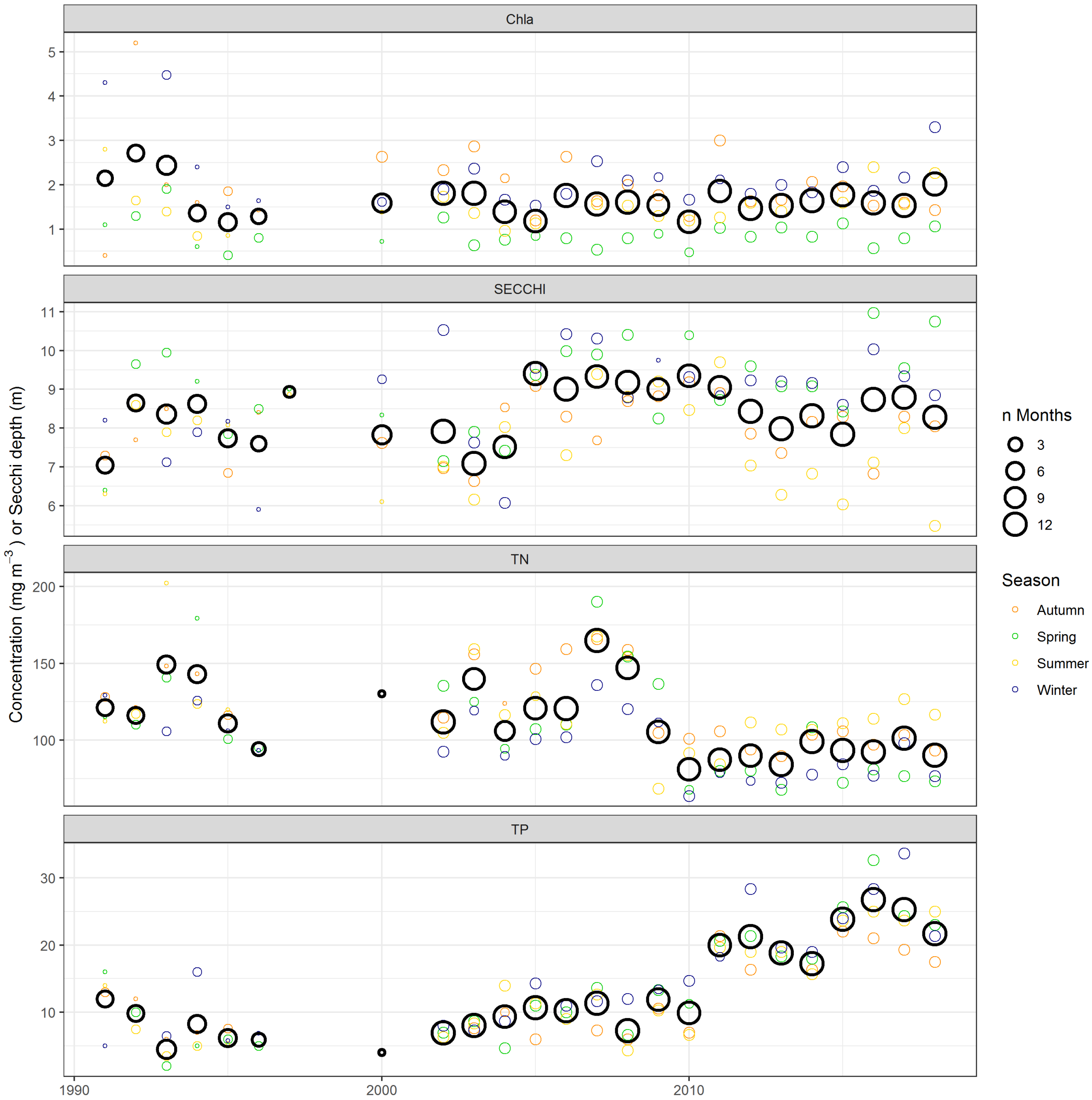
10. ***It may be worthwhile reassessing the TLI target for Tarawera, and considering trends relevant to the a revised action plan for the lake.***

## References

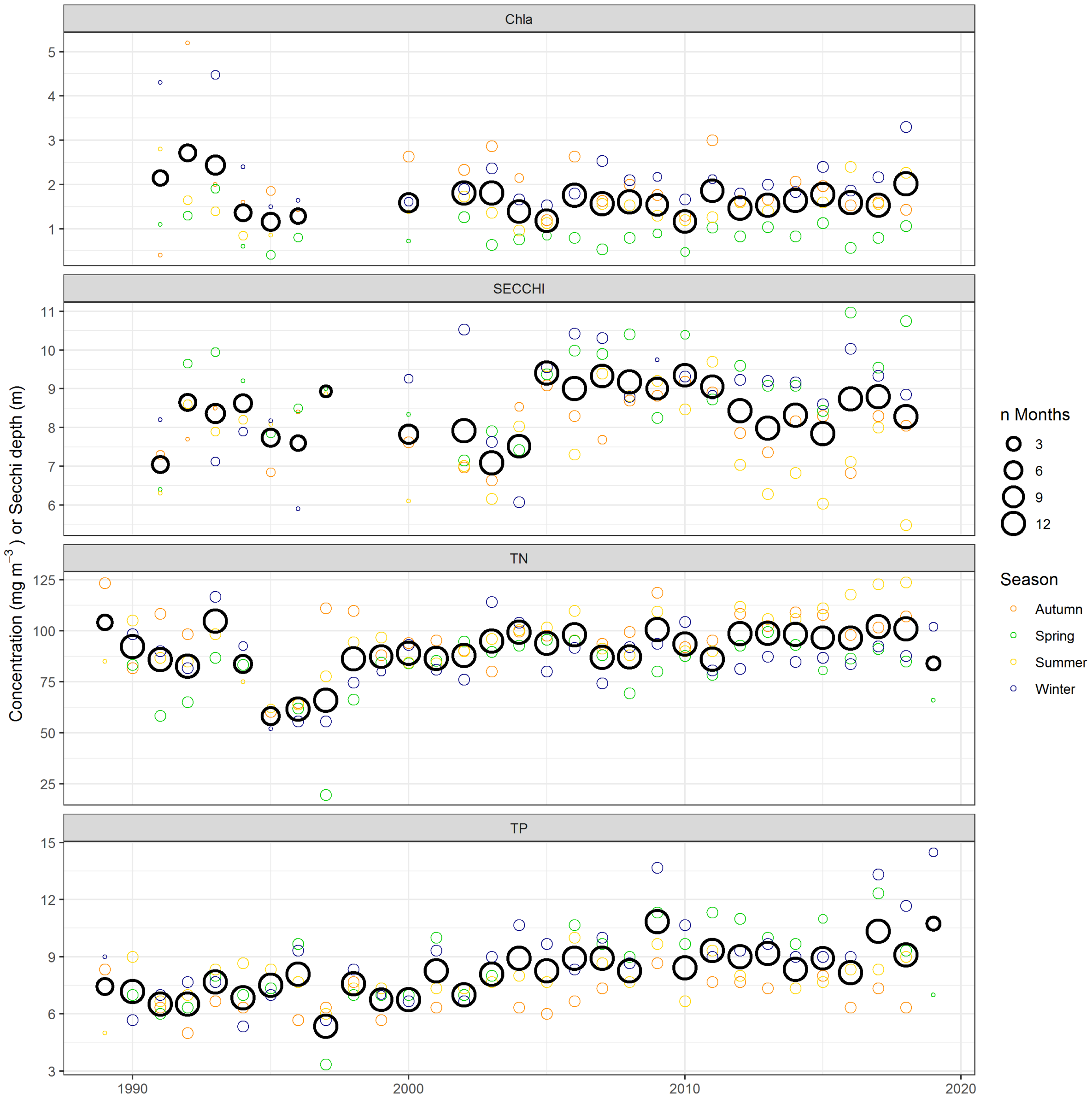
McBride, C.G., Abell, J.M., and Hamilton, D.P. (2018). Long-term nutrient loads and water quality for Lake Rotorua: 1965 to 2017. ERI report 123. Environmental Research Institute, The University of Waikato, Hamilton, New Zealand. 71 pp.

Scholes, P., & Hamill, K. (2016). Rotorua Lakes Water Quality Report 2014/2015. Bay of Plenty Regional Council.

## Appendices




*Appendix 1: Annual and seasonal summary of TLI data using BoPRC measurements of TN and TP.*




*Appendix 2: Annual and seasonal summary of TLI data using NRWQN measurements of TN and TP.*