P corrections for Lake Tarawera Model & TLI Review
WQTAG 19 May 2020

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THE UNIVERSITY OF WAIKATO
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Te Pūnaha Matatini
Data ▪ Knowledge ▪ Insight

Recap & direction: Lake Tarawera

August 2019 TAG: Memo details use of NRWQN site (outflow) to clarify need to correct BOPRC P data for Lake Tarawera.

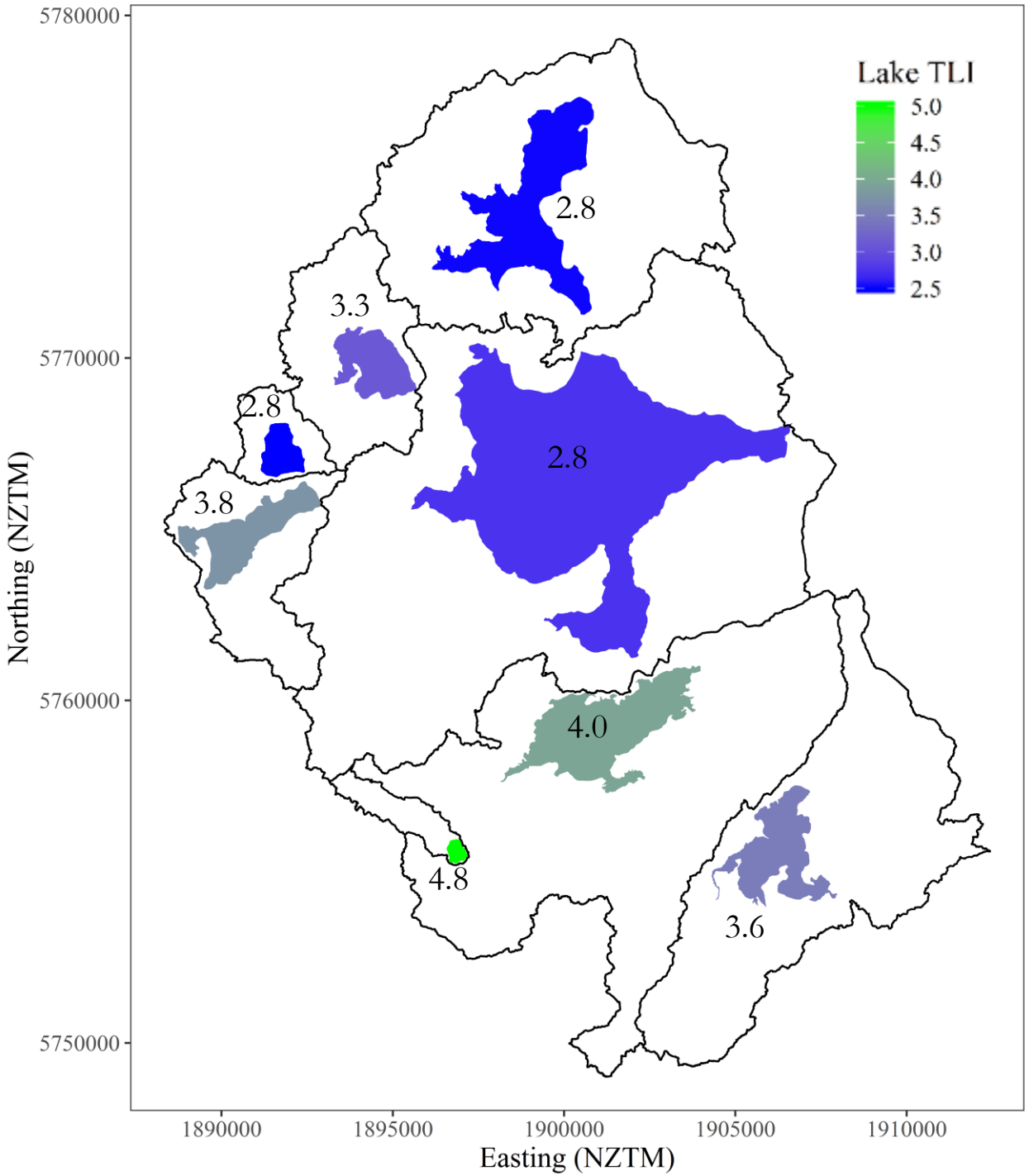
Implications for Lake Modelling (Jon Abell)

- Outflow represents epiliminion; need hypolimnion if possible
- How good is corrected data?

Implications for TLI

- Large corrections in some lakes (Tarawera & Rotomahana?)
- Opportunity for systematic review of TLI data and baselines
  - Confirm little change for most lakes?

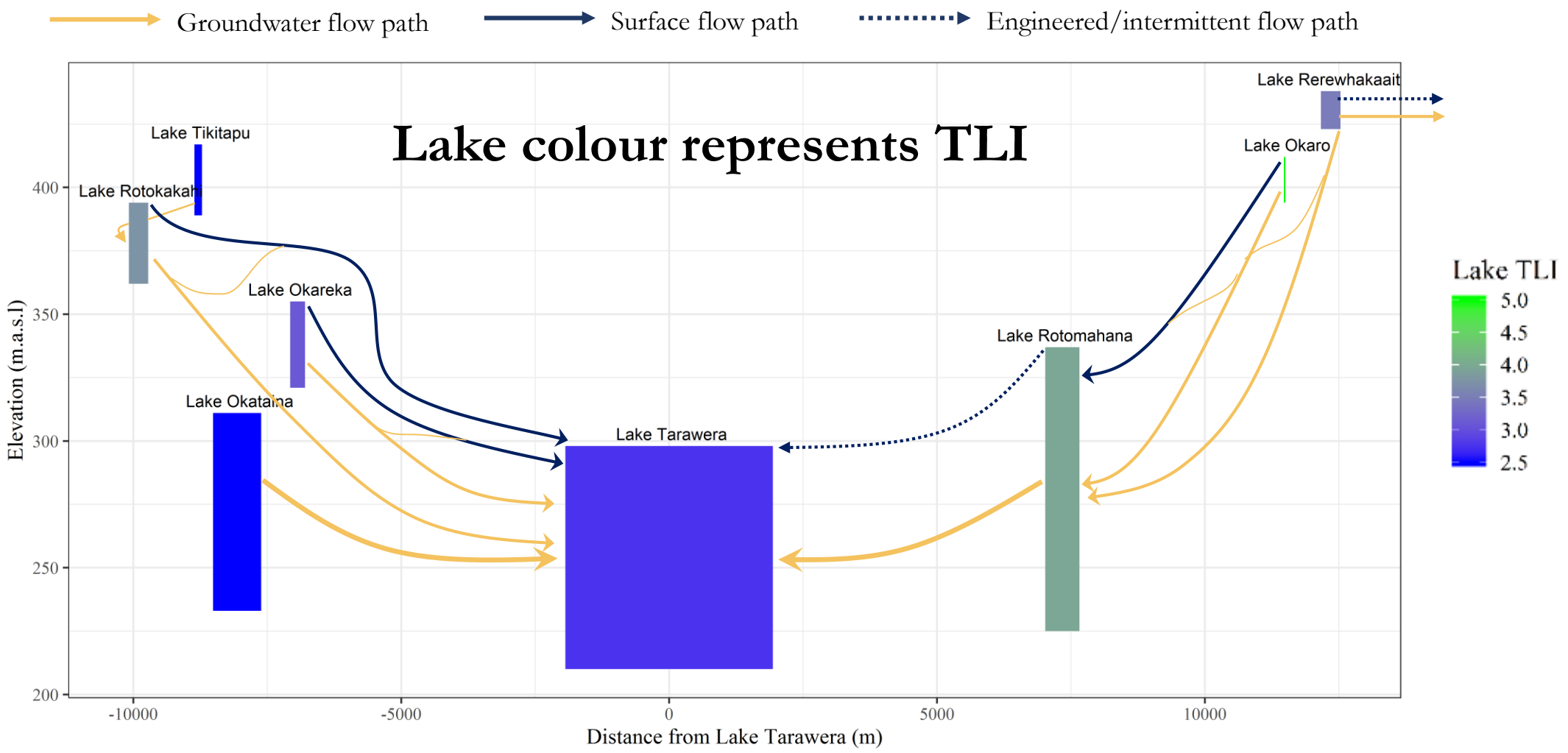
Water quality of ‘connected’ lakes



Trophic Level Index	Lake Type
Less than 2	Very good water quality (microtrophic)
2 – 3	Good water quality (oligotrophic)
3 – 4	Average water quality (mesotrophic)
4 – 5	Poor water quality (eutrophic)
Greater than 5	Very poor water quality (supertrophic)

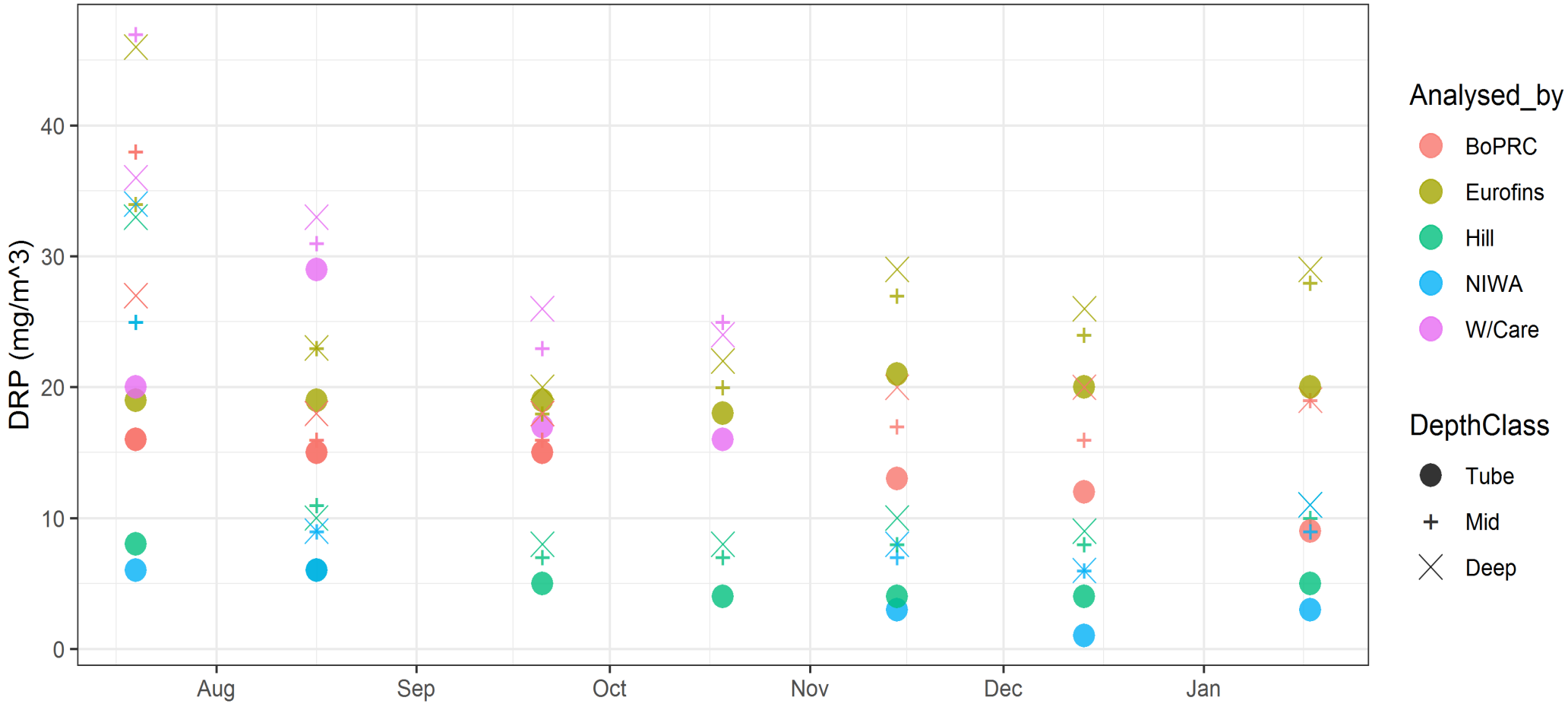
Tarawera conceptual model

Arrows show flow paths between lakes and into Tarawera



More information on hydrological connections: White et al. 2016 (GNS report)

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



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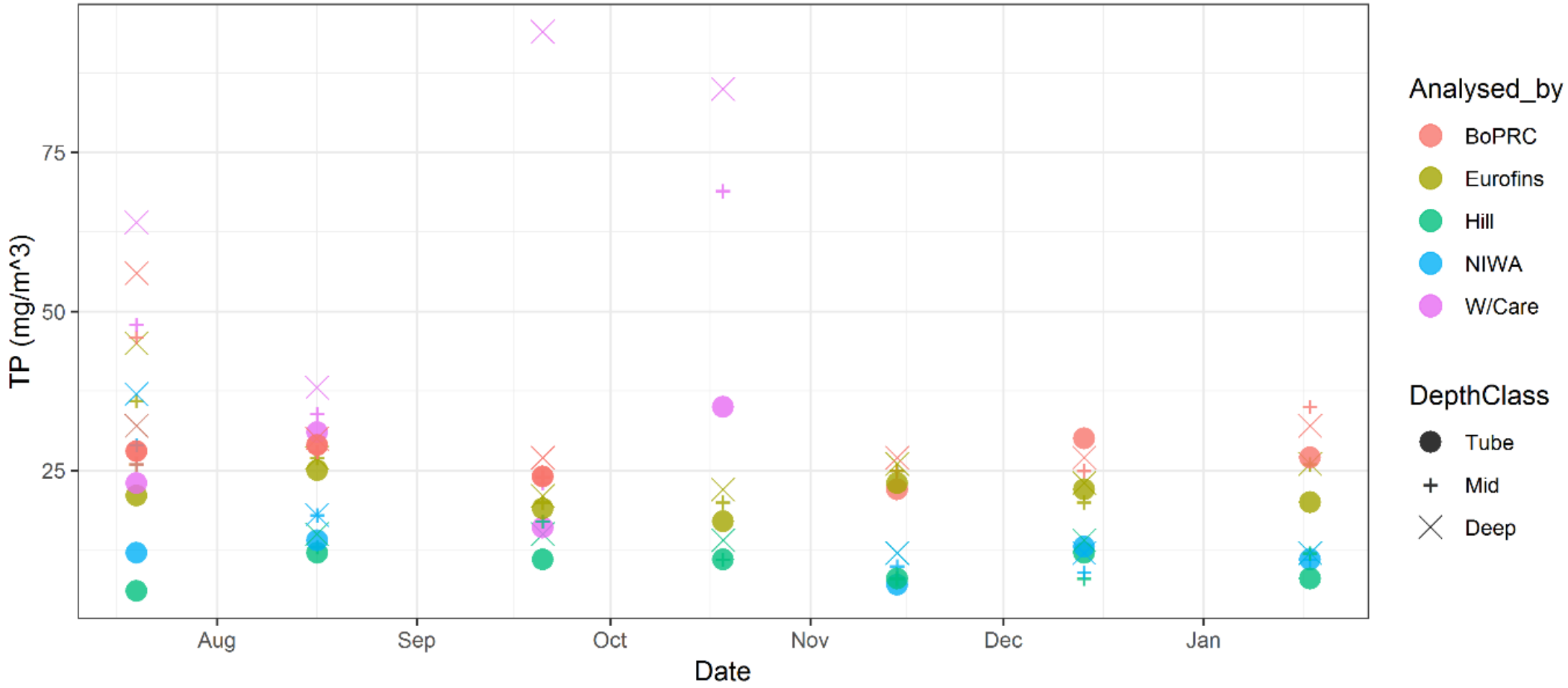
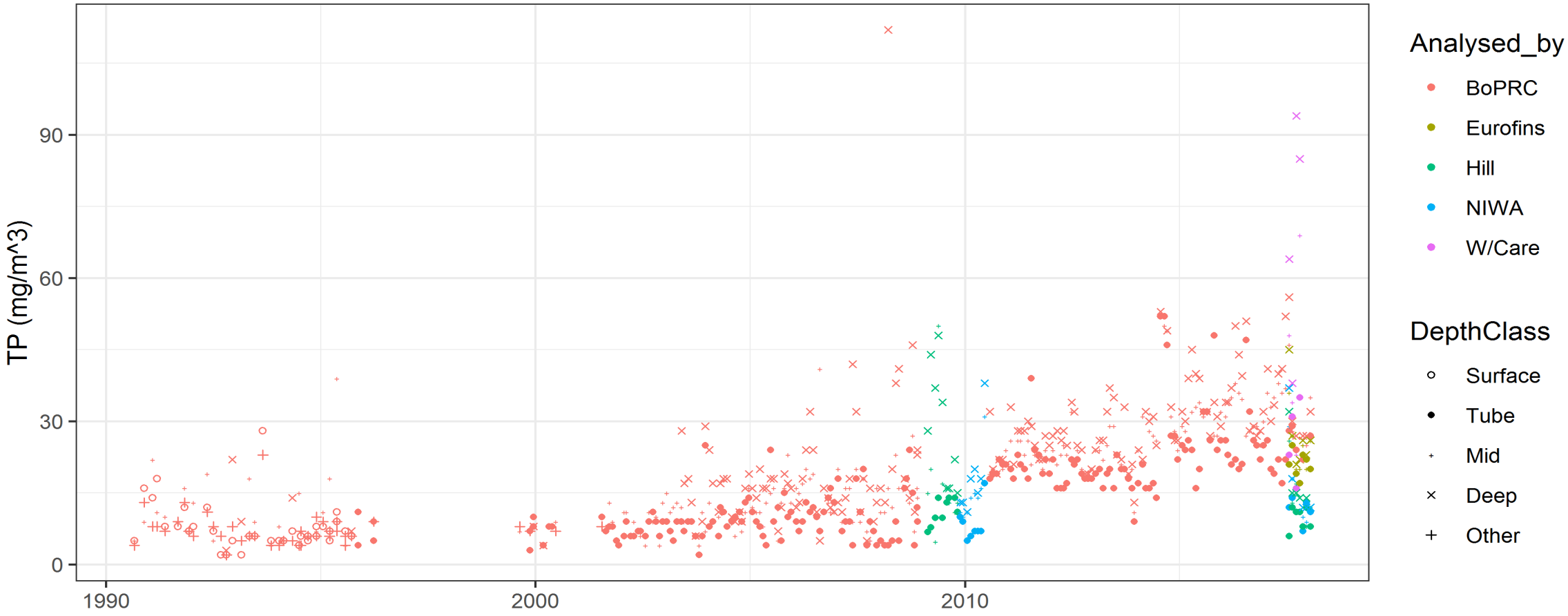
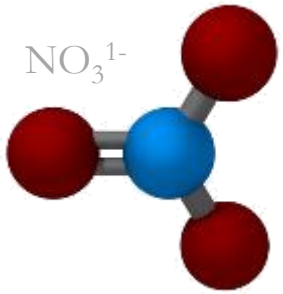
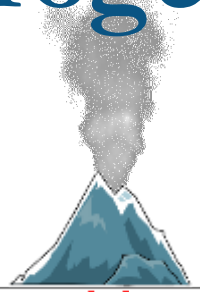


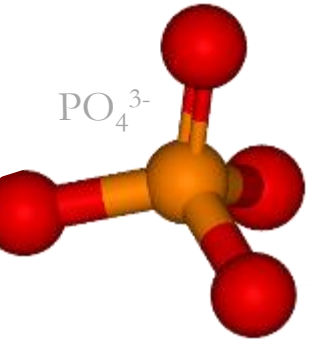
Figure 2. Long term monitoring record for DRP and TP in Lake Tarawera. Values are coloured by laboratory used, and shape represents the sample depth

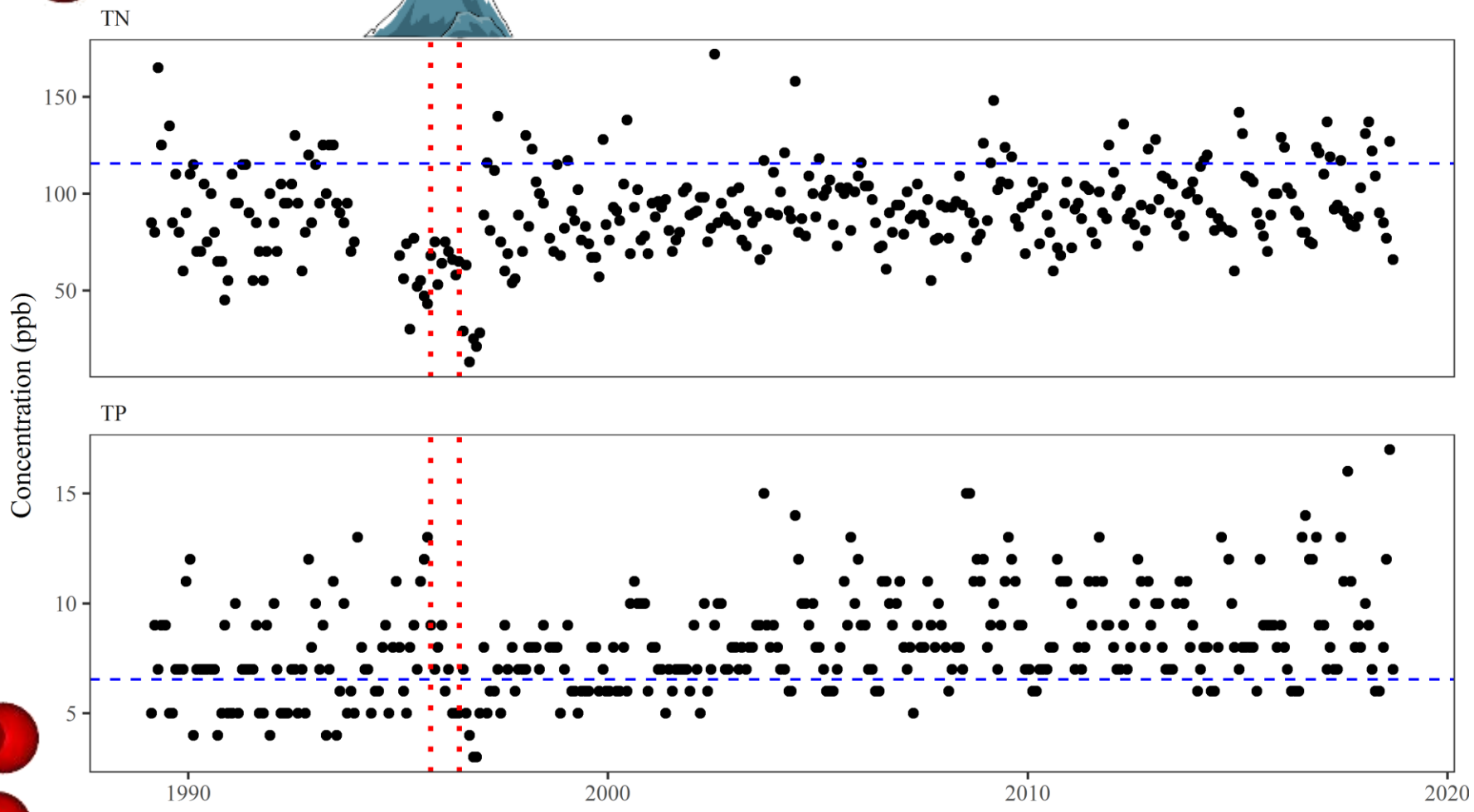


Nitrogen and phosphorus (total)









TLI (TN) = 2.6

TLI (TP) = 2.6

Data: NIWA NRWQN at Lake Tarawera outlet

Figure 5: Comparison to NRWQN - TP

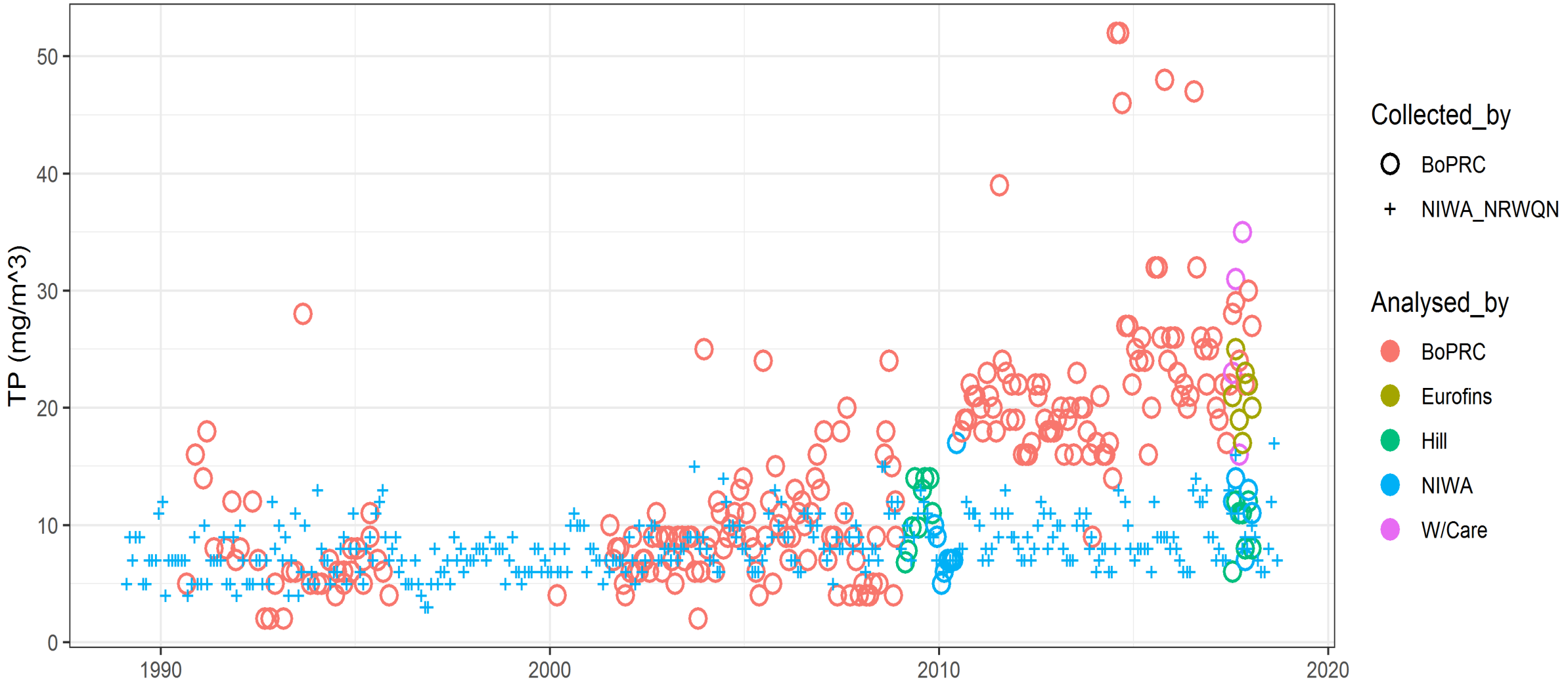


Figure 3. Long term monitoring record for total nitrogen in Lake Tarawera.

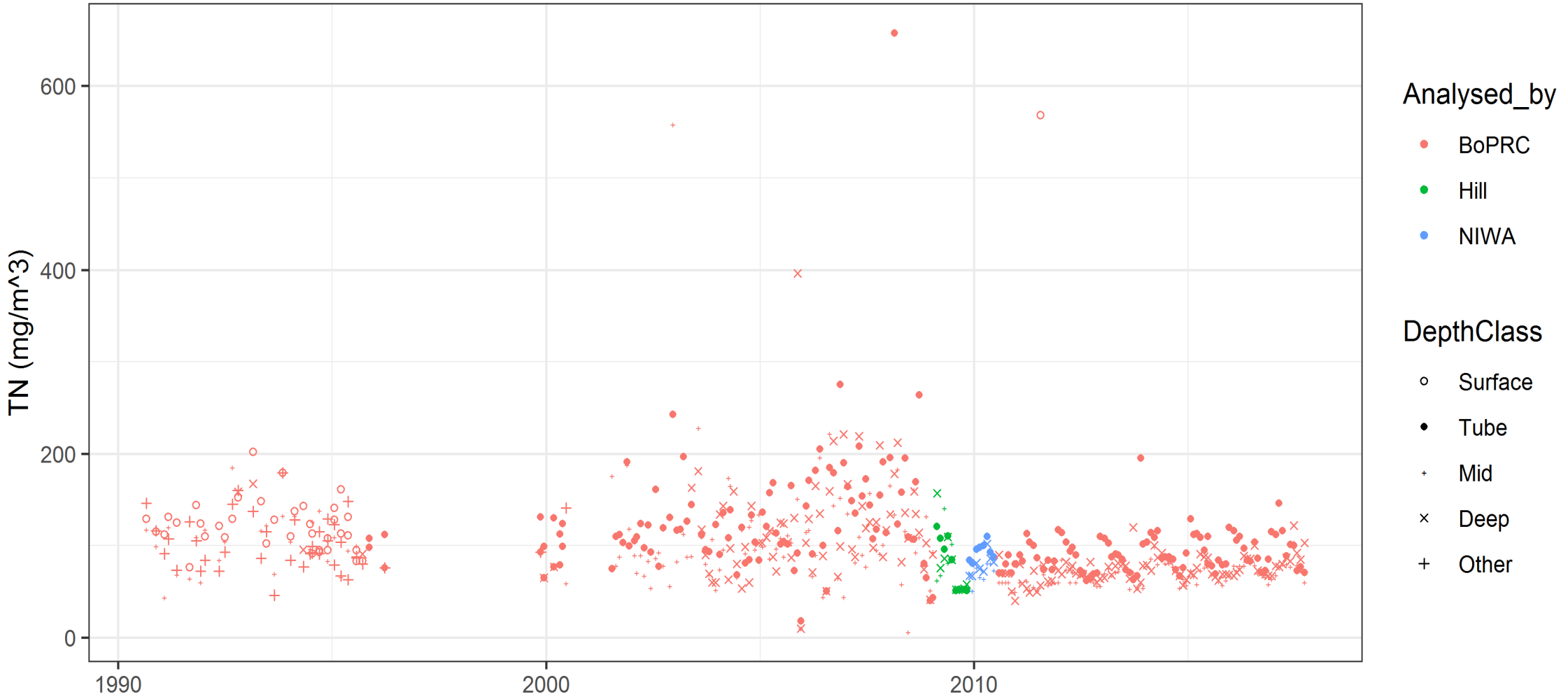
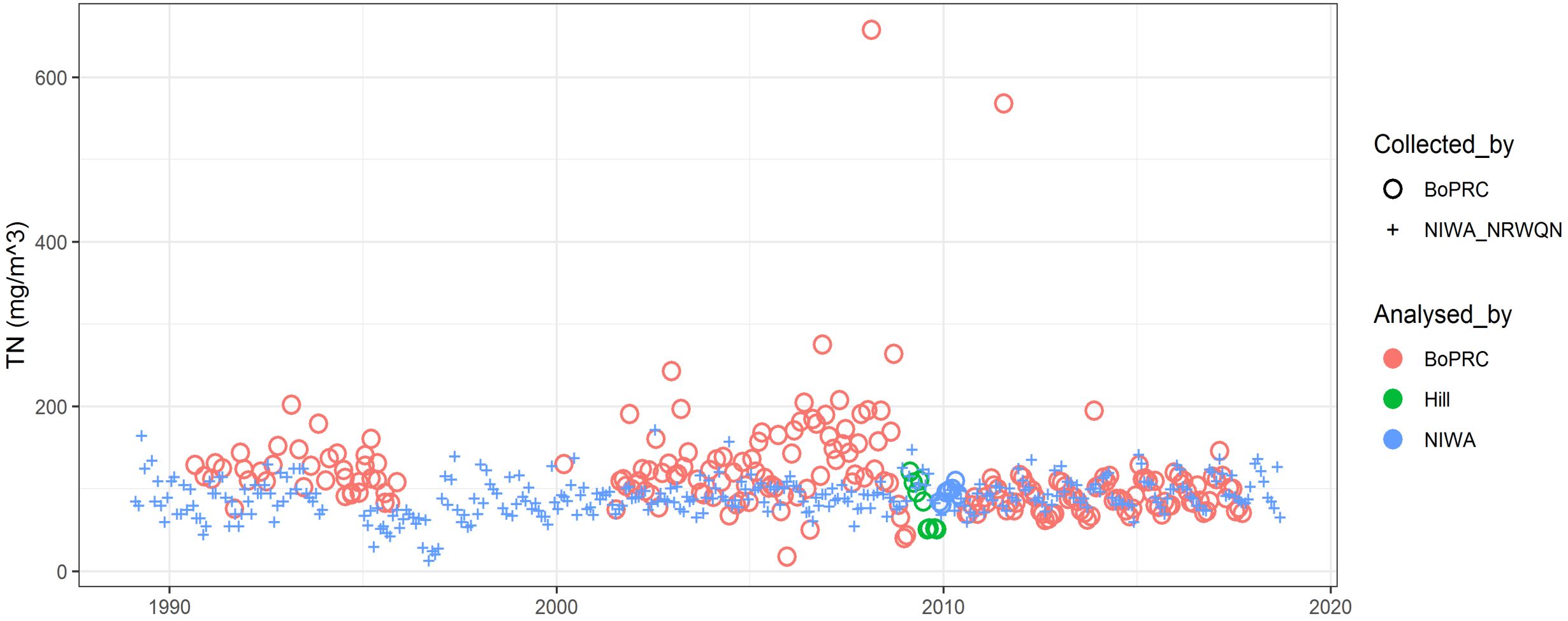


Figure 5: Comparison to NRWQN - TN

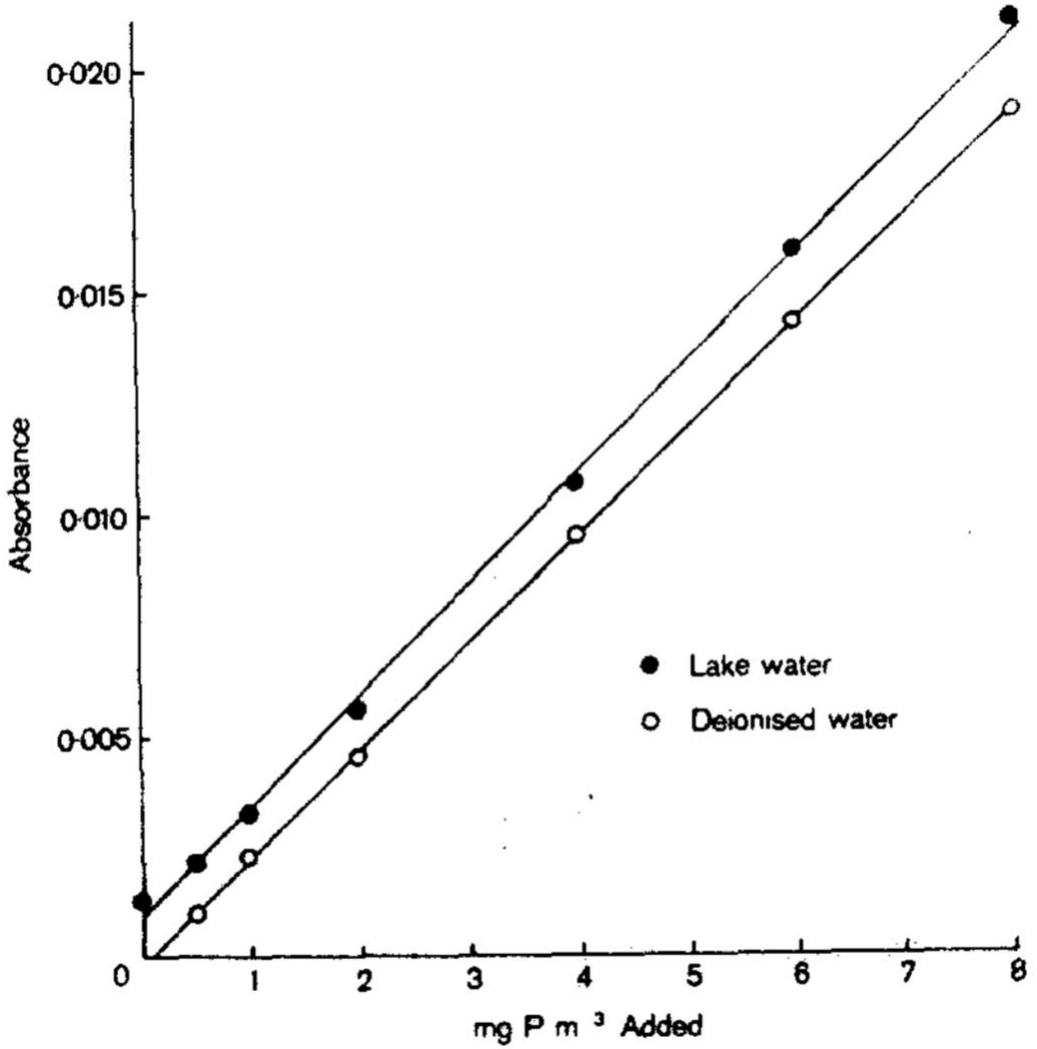


Revealed at the last TAG: NIWA's method …

- Downes 1978
- also matches NWASCO 1981

Table 1. A comparison of PO_4-P analyses with and without reductant

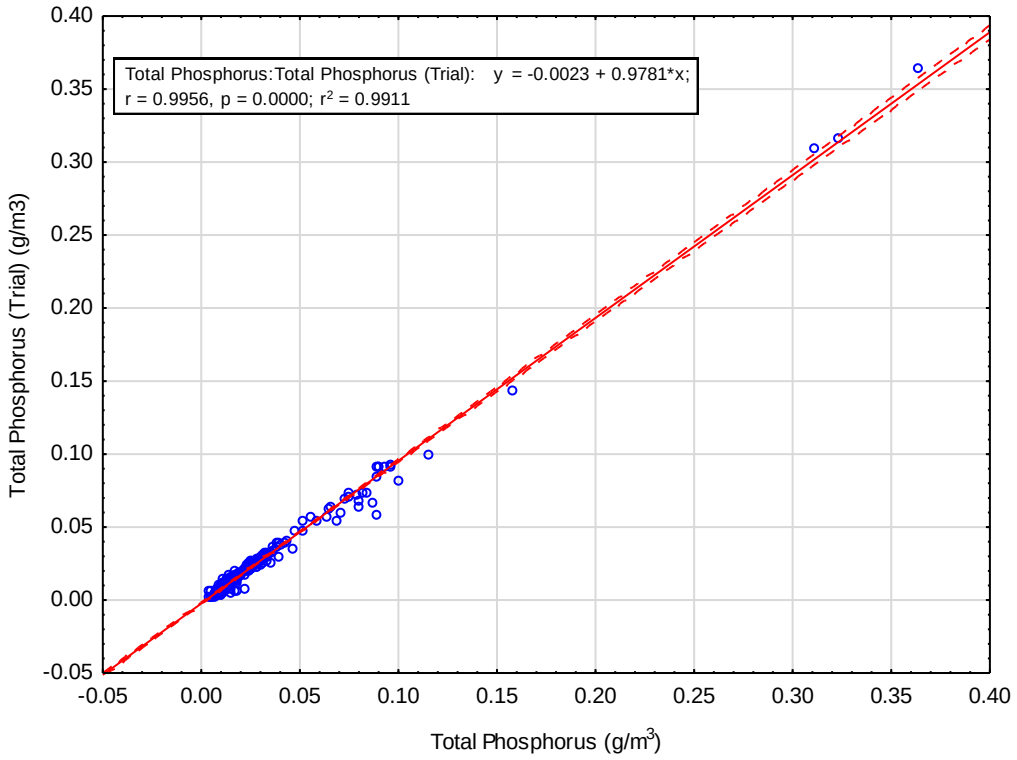
Sample	Without reductant (mg P m^{-3})	With reductant (mg P m^{-3})
Lake water	1.2	0.2
Lake water + 100 mg AsO_4^{2-}-As m^{-3}	7.8	0.4
Lake water + 60 g m^{-3} $HgCl_2$	1.4	0.2
Lake water + 4 mg P m^{-3}	5.3	4.4
Lake water + 4 mg P m^{-3} + 100 mg AsO_4^{2-}-As m^{-3}	13.0	4.3
Lake water + 4 mg P m^{-3} + 60 g m^{-3} $HgCl_2$	5.4	4.3

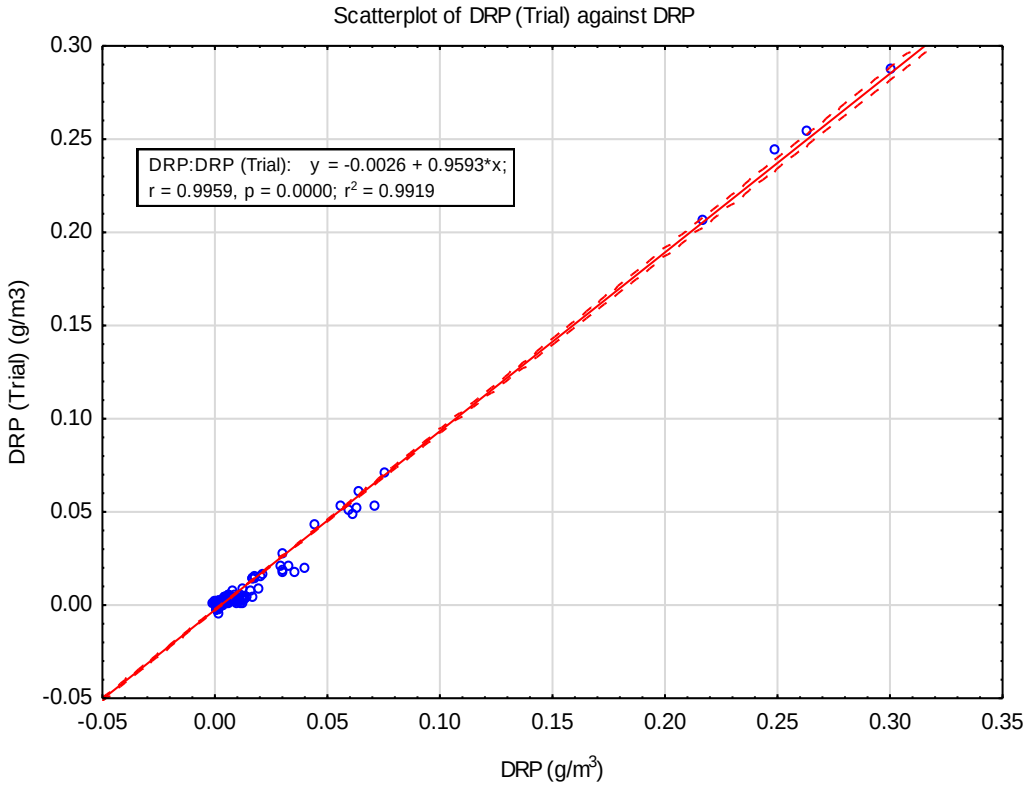


Revealed at the last TAG: BOPRC lab activity

- BOPRC had initiated a new FIA channel
- Silica correction

March 2019 BOPRC File Note – Paul Scholes





Correctable… but how to correct?

Assumptions required for regression models:

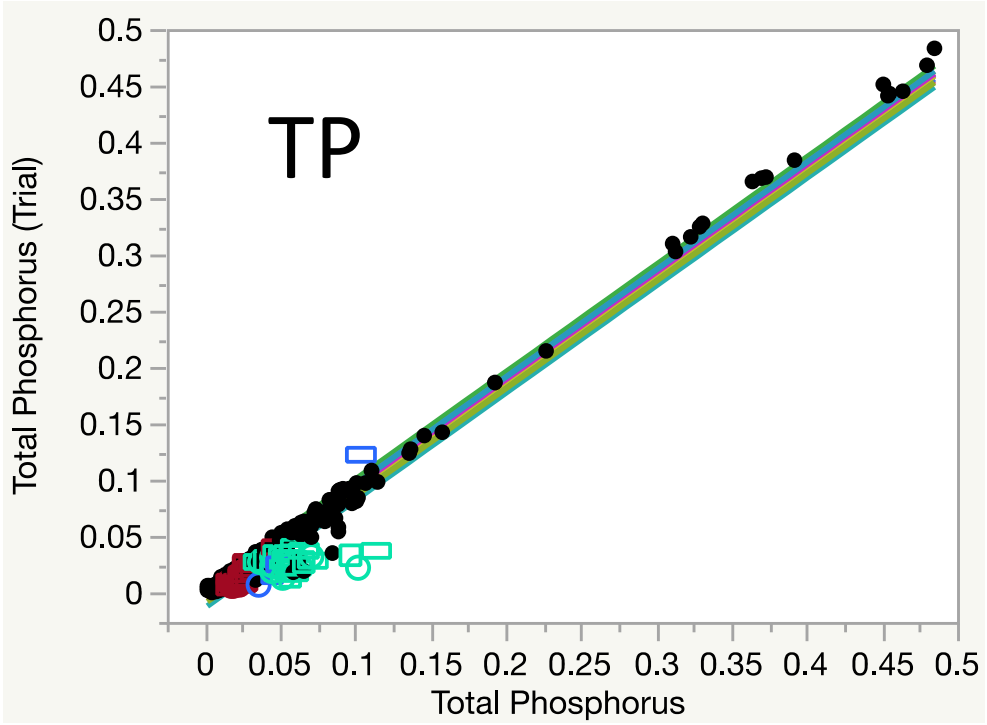
1. Relationship is linear, and an additive combination of independent variables
2. Errors are independent
3. Homoskedasticity (variance isn't bigger on on side)
4. Variance has a normal distribution

Great news: we were good on #4.

1. Relationship is linear, and an additive combination of independent variables

A curve was fitted, but the lakes are different.

$R^2 = 0.98$; RMSE = 0.009 ppm or 9 ppb



Term	Estimate	Std Error	Prob>|t|
Intercept	-0.003158	0.000632	<.0001*
[Okareka]	-0.004261	0.001374	0.0020*
[Okaro]	0.008919	0.002257	<.0001*
[Okataina]	-0.002521	0.001676	0.1332
[Rerewhakaaitu]	0.004095	0.001919	0.0334*
[Rotoehu]	0.001913	0.000946	0.0438*
[Rotokakahi]	0.000626	0.002649	0.8132
[Rotoma]	0.000129	0.001686	0.9392
[Rotomahana]	-0.009689	0.001119	<.0001*
[Rotorua]	0.002181	0.00108	0.0440*
[Tarawera]	-0.005762	0.001662	0.0006*
Total Phosphorus	0.951747	0.008602	<.0001*

Are they parallel?

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Lake	10	10	0.0111467	13.5923	<.0001*
Total Phosphorus	1	1	1.0039713	12242.46	<.0001*

2. Errors are independent (and they're additive?)

Three big things:

1. P → P
2. Silica → P
3. Arsenate → P

Initial test found no As effect; strong Si effect → new FIA channel

Old P channel found to be highly sensitive to silica

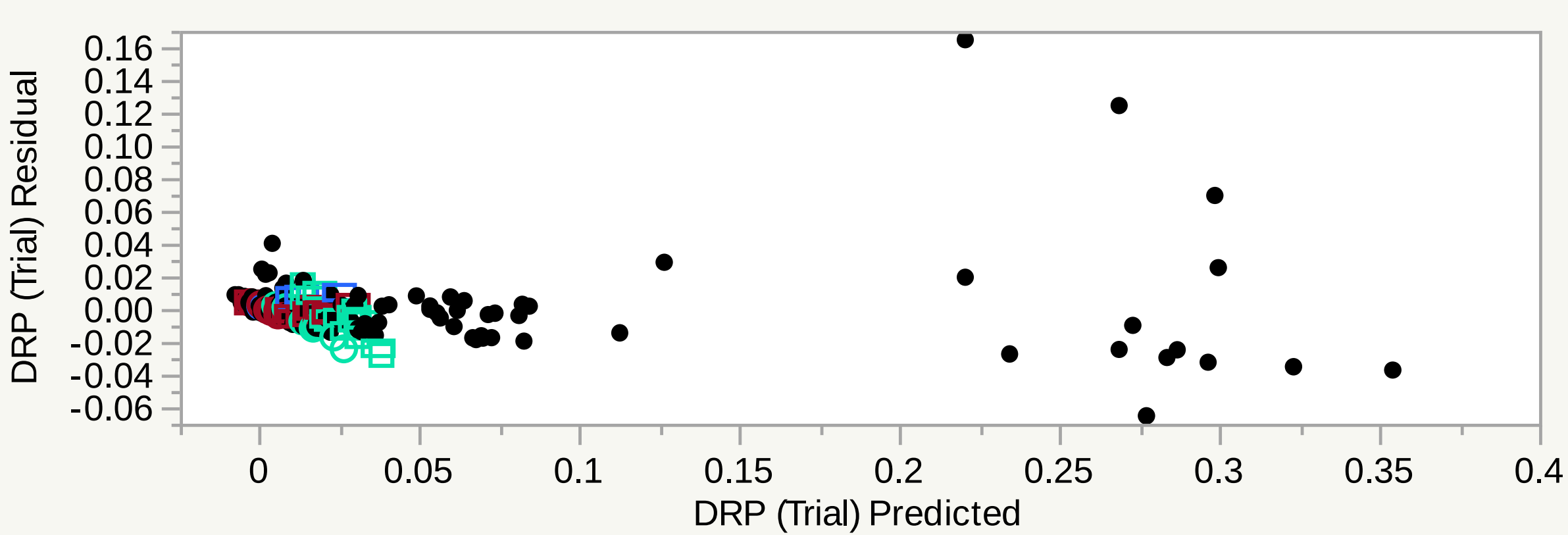
Arsenic testing problematic. Can't confirm parallel, independent effects.

New channel eliminates large silica interference.

Arsenate? Not bad.

3. Heteroskesticity? (Uh oh)

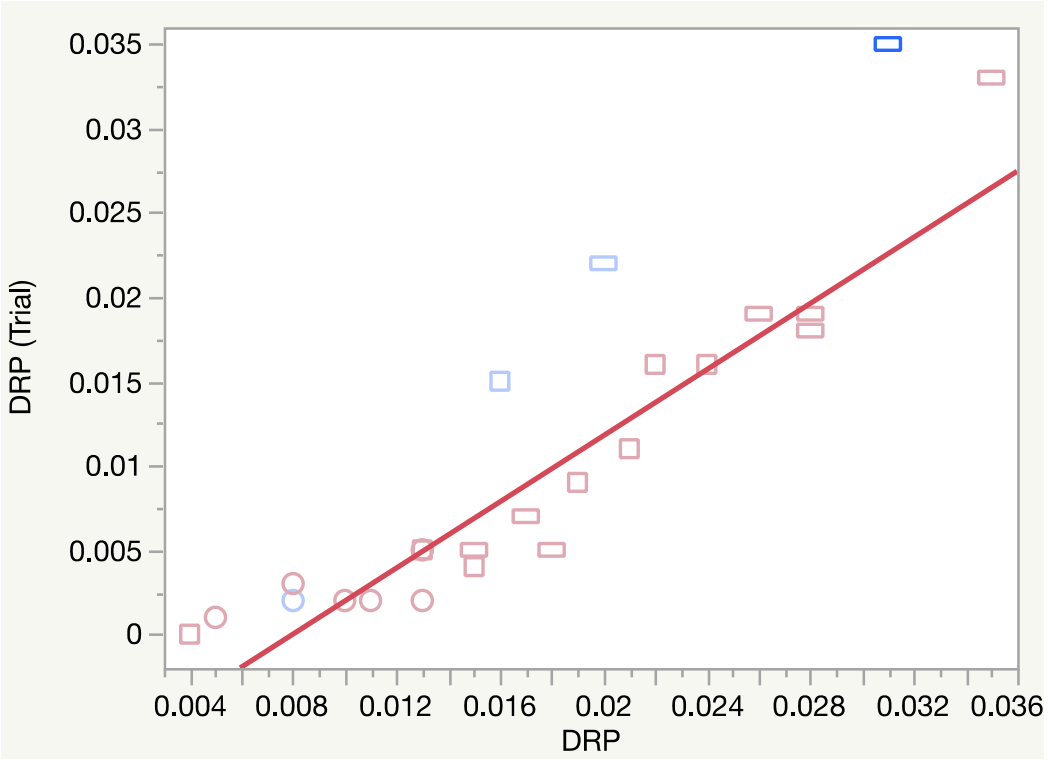
Residual by Predicted Plot



A relatively easy solution to all three problems: fit each lake (or group of similar lakes separately)

Fit Lake Tarawera Data only: example

DRP (Trial) = -0.007834 + 0.9800363*DRP



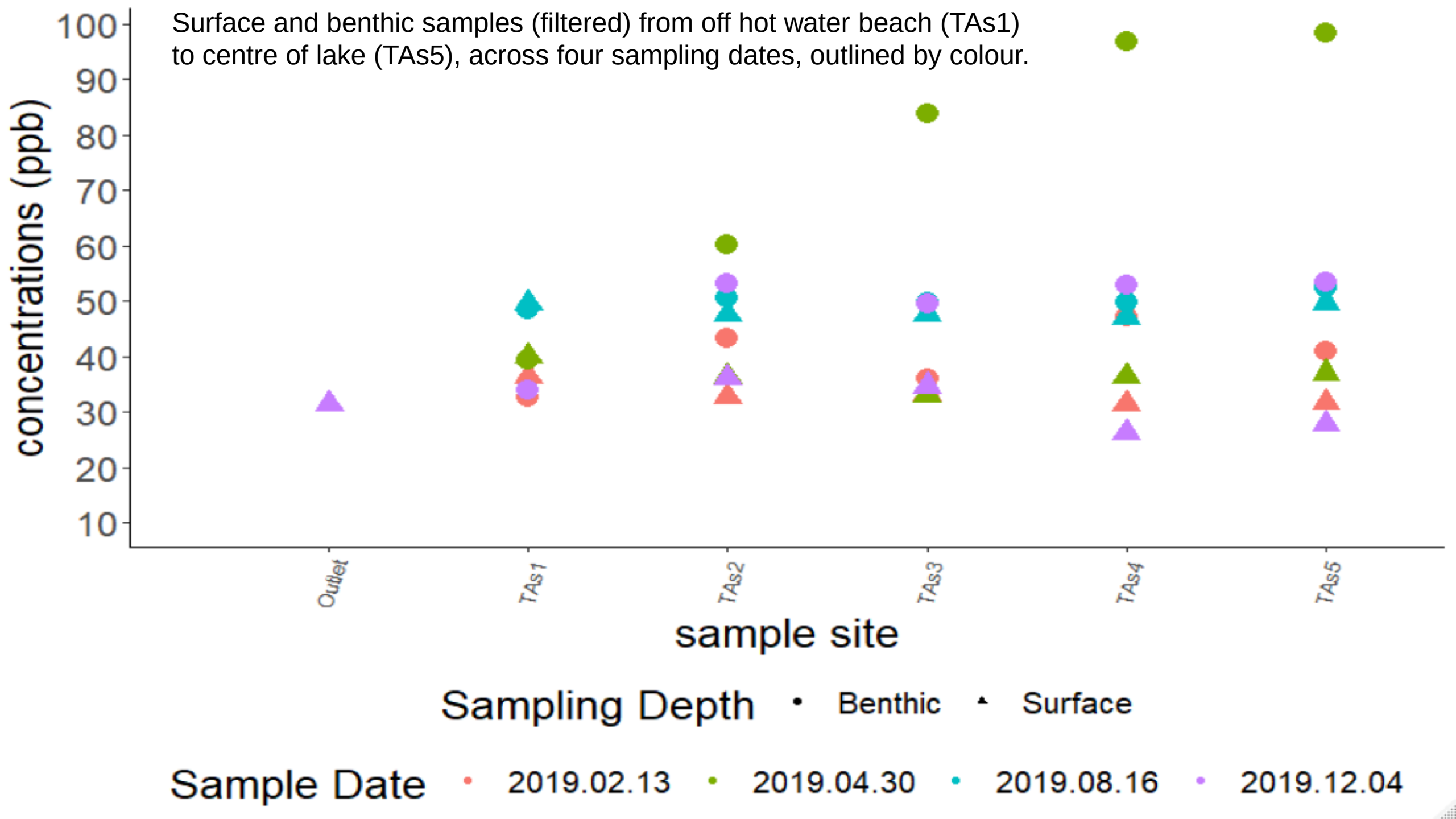
Term	Estimate	Std Error
Intercept	-0.0078	0.0013
DRP	0.980	0.070

RSquare	0.899
Root Mean Square Error	0.0027

Ok if we can spot the outliers?
Then subtract (1-4 ppb) for As.

So: how does well does this predict the NIWA NRWQN results at the outflow?

Surface and benthic samples (filtered) from off hot water beach (TAs1) to centre of lake (TAs5), across four sampling dates, outlined by colour.



Rahuiroa

Favorite Waterbodies

Lake Tarawera
Updated 7/10/2019

Surface km²: 42
View Download Map

View waterbodies to add as favorite

Lake Tarawera

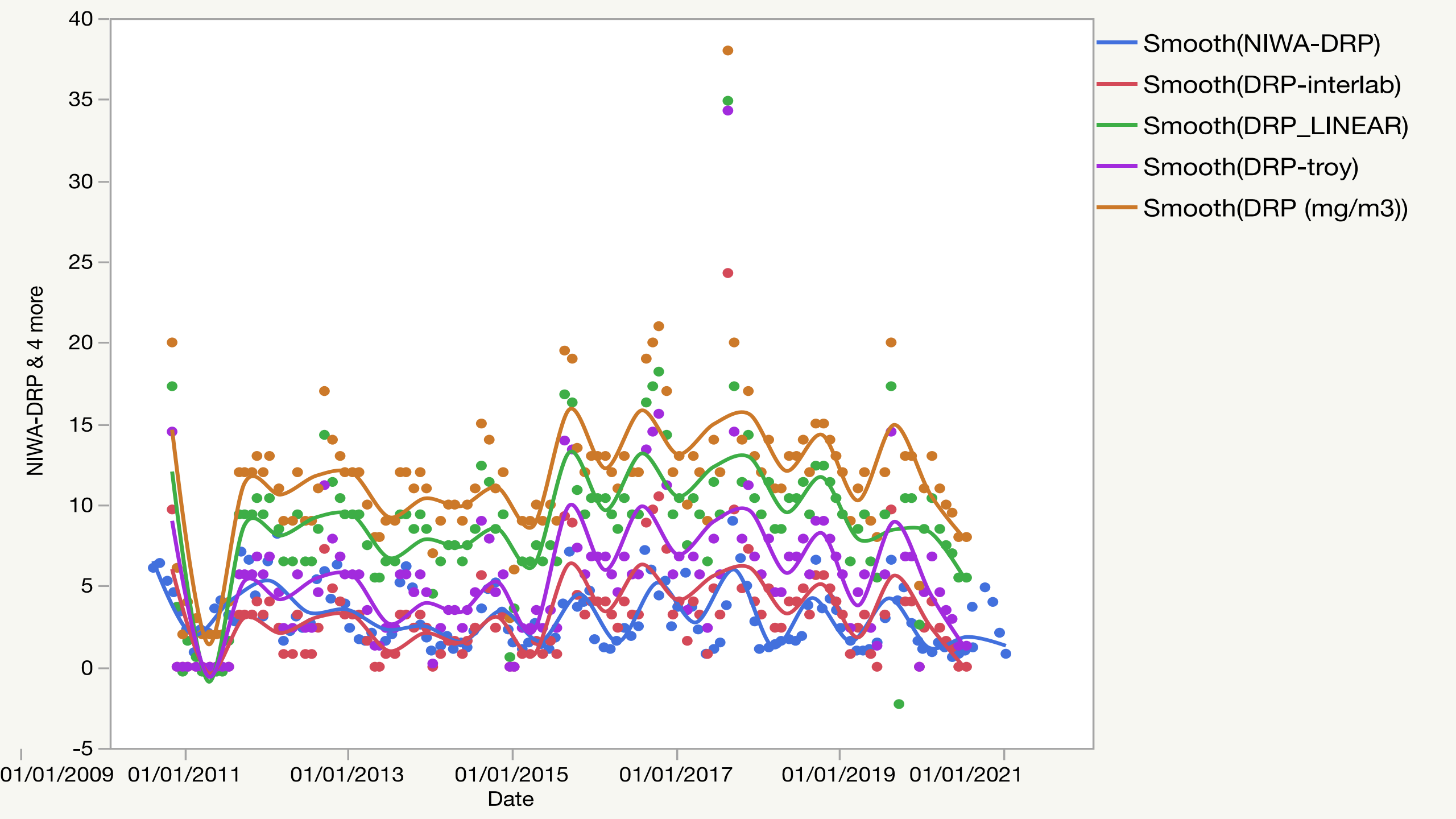
Lake Tarawera

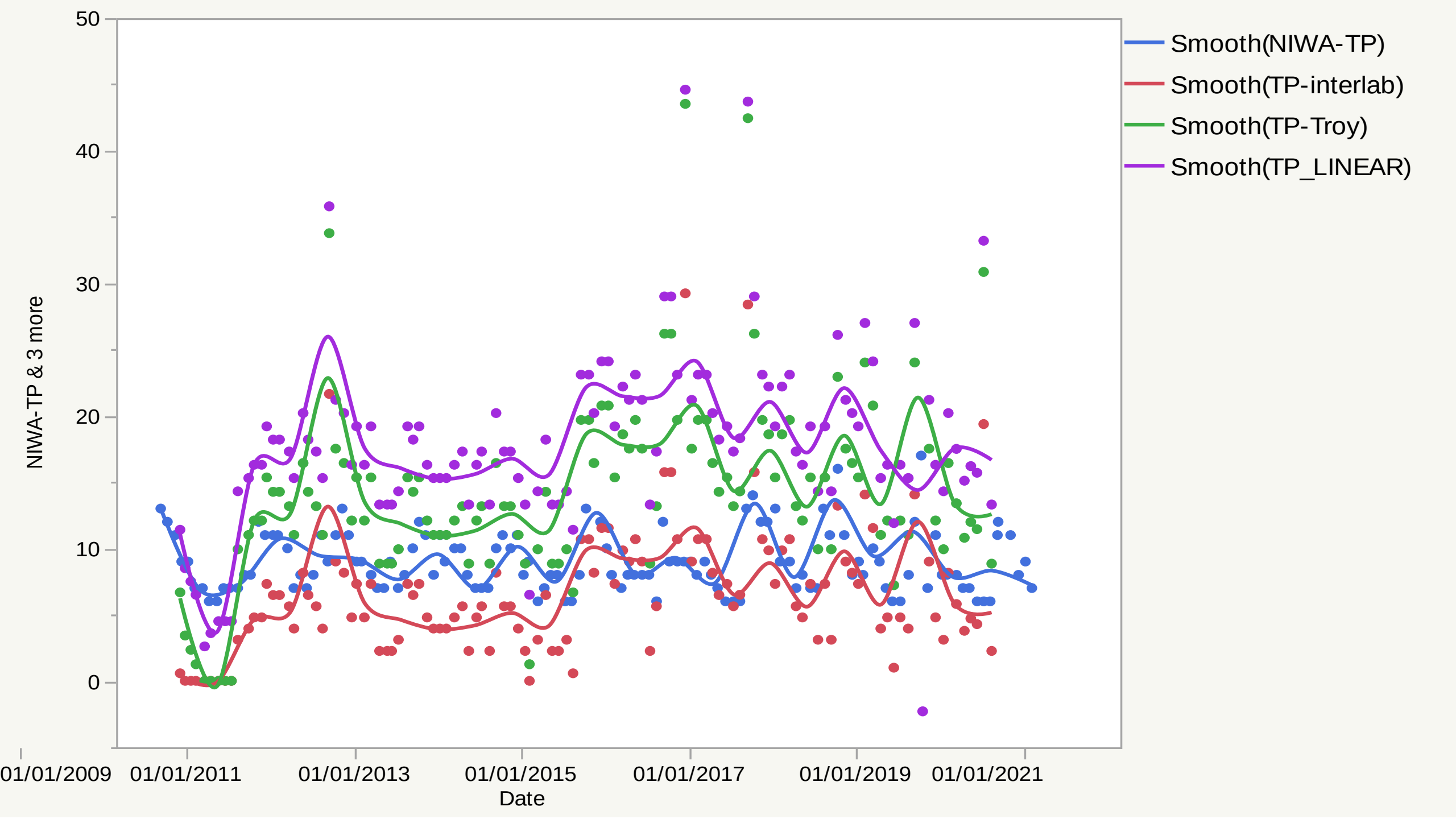
LAKE TARAWERA

Lake Tarawera S

Dr Amanda French

Kirstie Kay

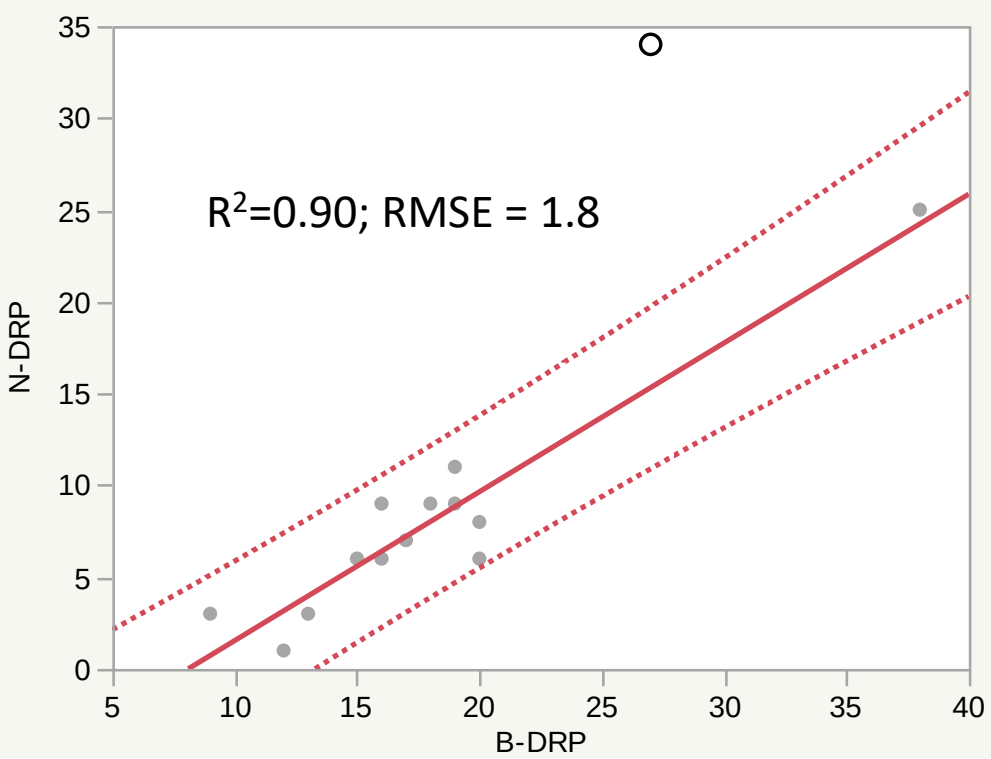

40
35
30
25
20
15
10
5
0
-5
NIWA-DRP & 4 more
01/01/2009
01/01/2011
01/01/2013
01/01/2015
01/01/2017
01/01/2019
01/01/2021
Date
Smooth(NIWA-DRP)
Smooth(DRP-interlab)
Smooth(DRP_LINEAR)
Smooth(DRP-troy)
Smooth(DRP (mg/m3))


50
40
30
20
10
0
NIWA-TP & 3 more
01/01/2009
01/01/2011
01/01/2013
01/01/2015
01/01/2017
01/01/2019
01/01/2021
Date
Smooth(NIWA-TP)
Smooth(TP-interlab)
Smooth(TP-Troy)
Smooth(TP_LINEAR)

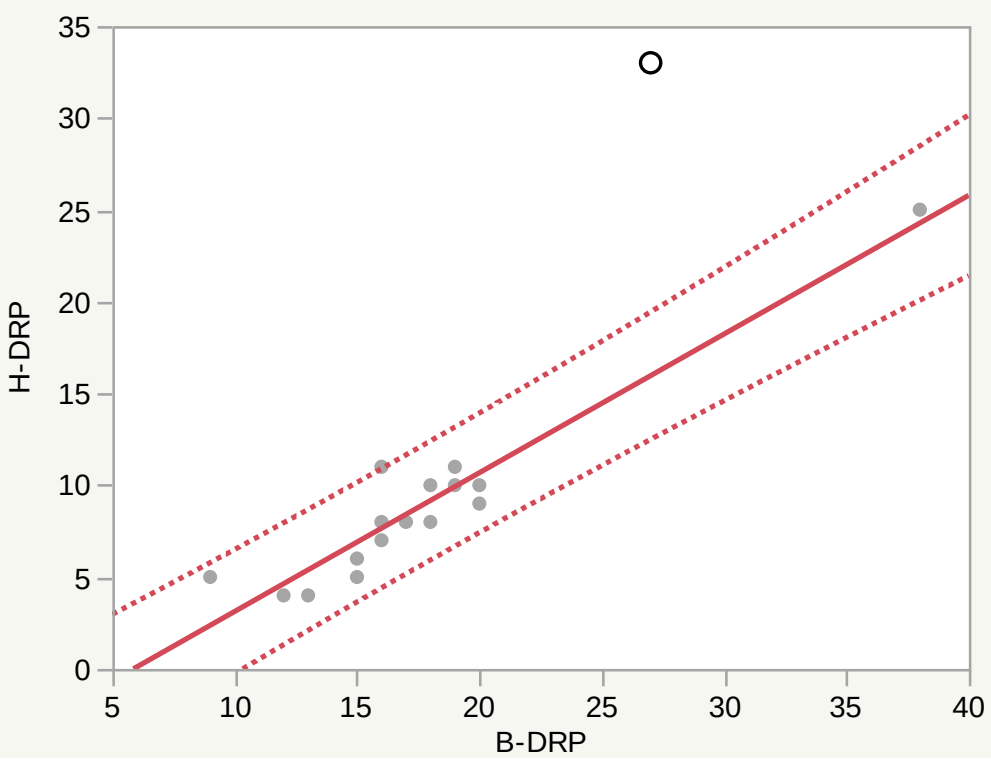
We appear to be lacking some knowledge of a combined effect?

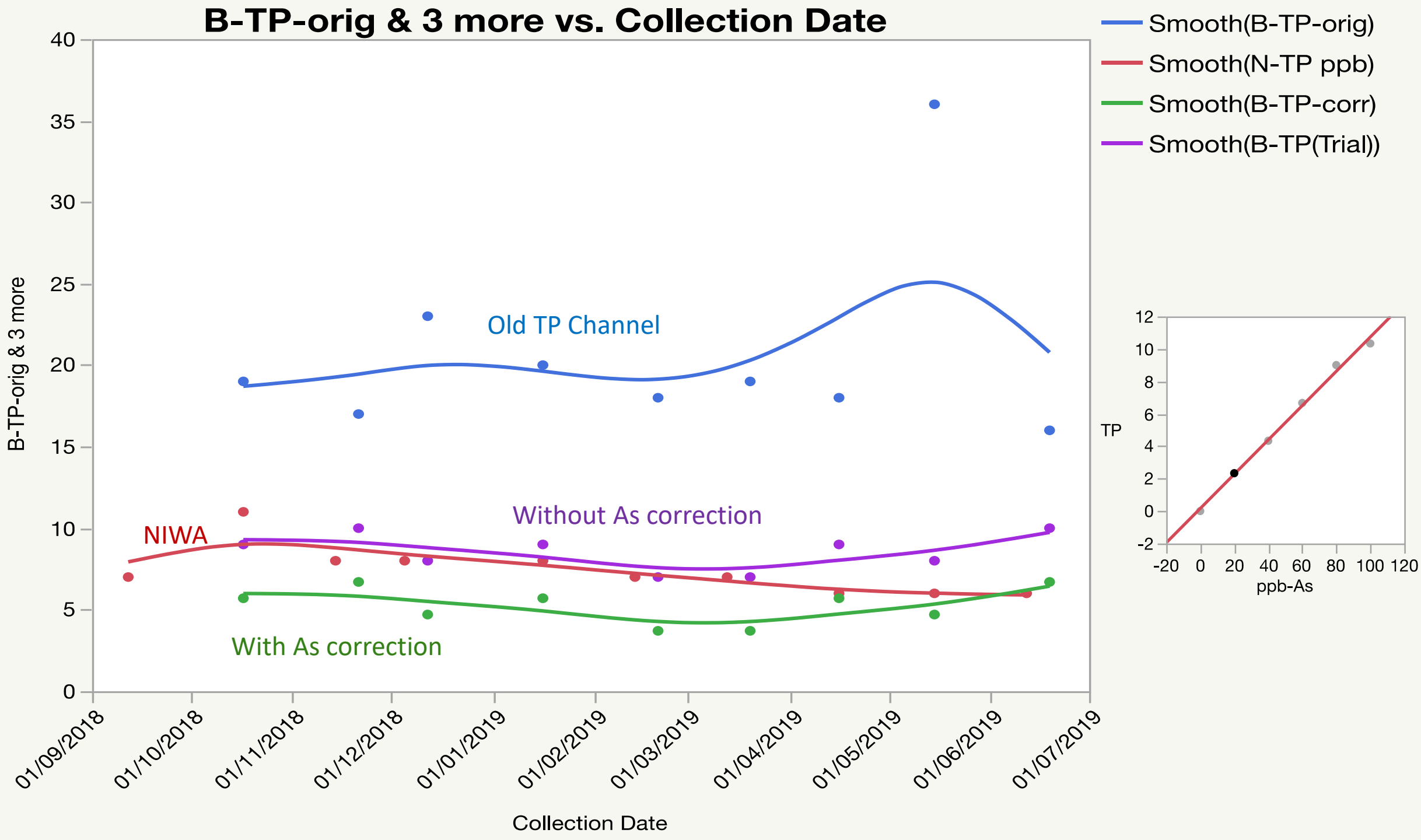
But at least… we had interlab comparisons (they agree within error).

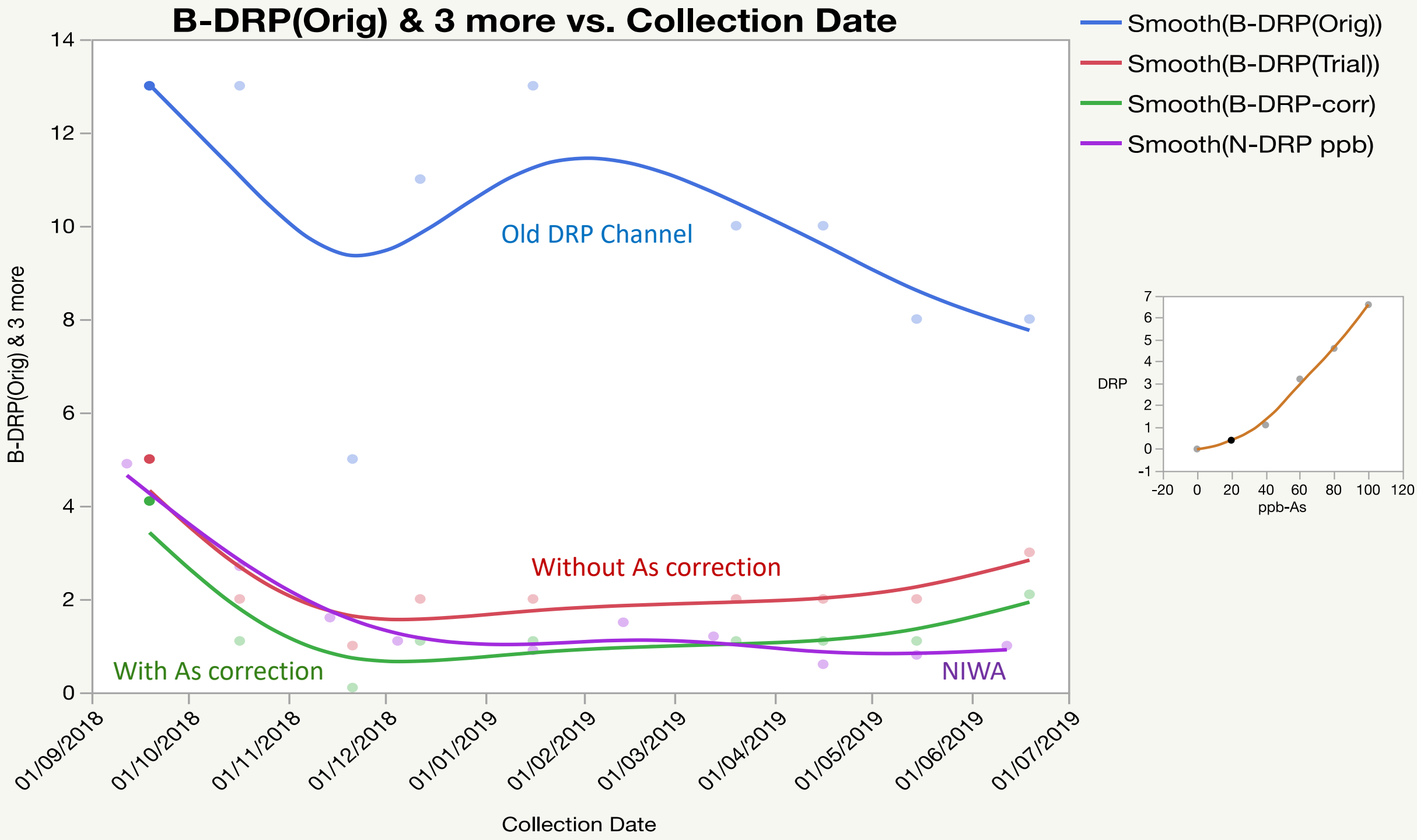
N-DRP = -6.57 + 0.81*B-DRP



H-DRP = -4.43 + 0.76*B-DRP

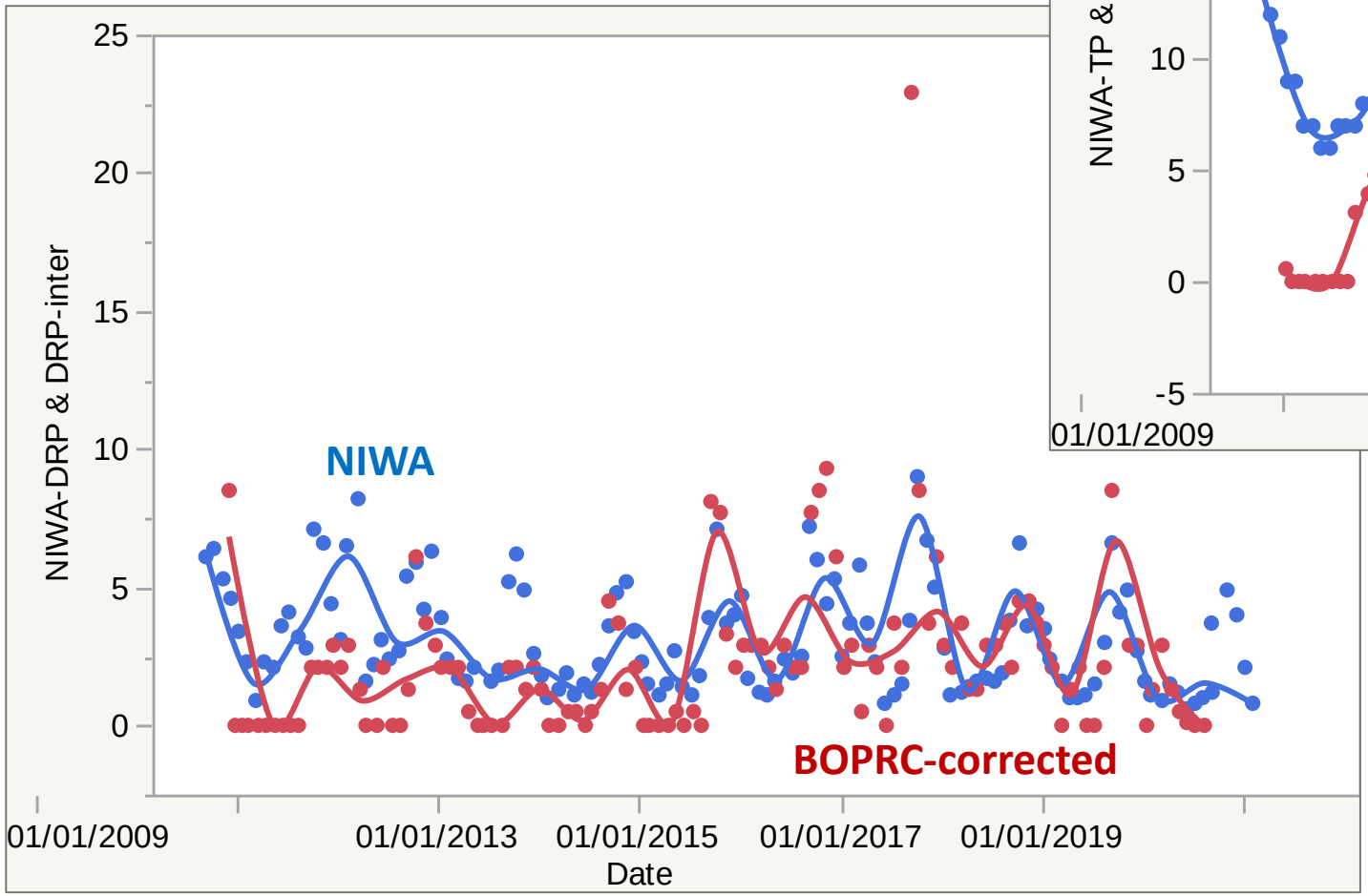


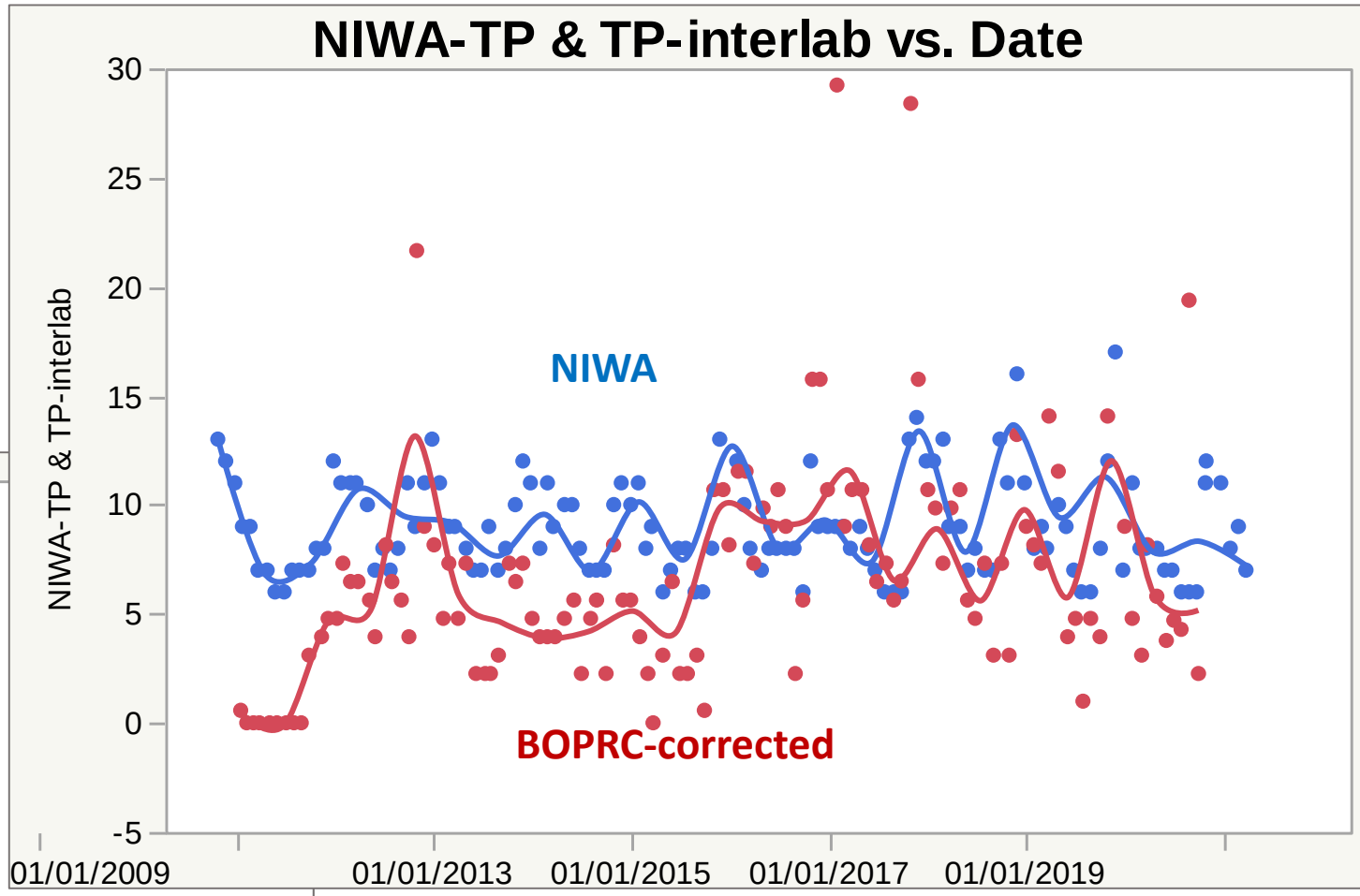

B-TP-orig & 3 more vs. Collection Date
Smooth(B-TP-orig)
Smooth(N-TP ppb)
Smooth(B-TP-corr)
Smooth(B-TP(Trial))
B-TP-orig & 3 more
Collection Date
Old TP Channel
NIWA
Without As correction
With As correction
TP
ppb-As


B-DRP(Orig) & 3 more vs. Collection Date
Smooth(B-DRP(Orig))
Smooth(B-DRP(Trial))
Smooth(B-DRP-corr)
Smooth(N-DRP ppb)
B-DRP(Orig) & 3 more
Collection Date
Old DRP Channel
Without As correction
With As correction
NIWA
DRP
ppb-As

Corrected records at outlet

DRP





Imperfect but extension to hypolimnion should be sufficient to support modelling, as long as sensitivity to data uncertainty is considered.

A great deal of progress, but danger of another year going by.
Recommendations:

1. Formalise these corrections as priority for BOPRC.
2. Advising and review required from UoW or statisticians to prevent further delays or errors.
3. Quickly review any additional explanations for trouble converting between old/new: Si, As data and proxies
   a) Use in Lake Tarawera model (as described in following slide)
   b) Use in TLI review (as described in following slide)
4. Continue work to understand improvements and historic issues (MSc thesis planned)
5. Review apparent ‘break’ in BOPRC records at ~2015

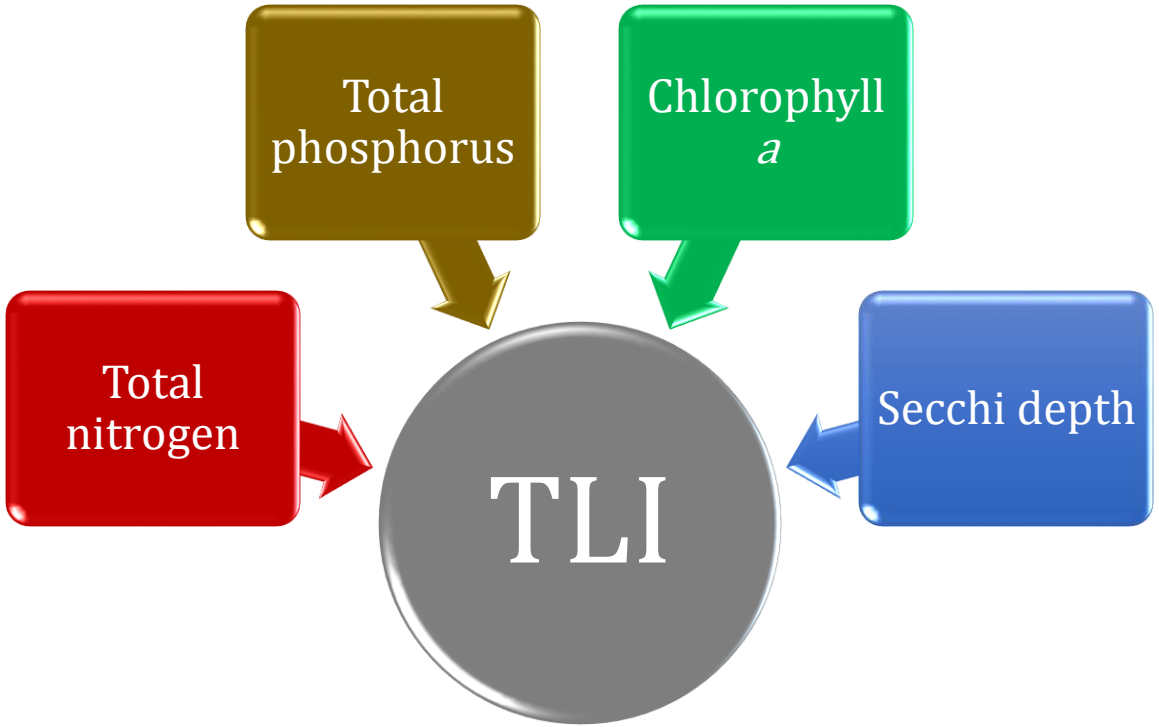
Tarawera Lake Model

- Use NIWA NRWQN data preferentially for epilimnion
- Use smoothed, corrected BOPRC post-2009 data to understand hypolimnion, and hypolimnion-epilimnion difference.
- Evaluate model sensitivity to uncertainty in corrected data
- Incorporate any further revisions or issues and document dataset for use in model.

TLI Review

- Take the opportunity to ensure a systematic approach to TLI that is similar across lakes.
- Correct for Si and As interferences in all cases, using direcet measurements where possible.
- Revisit baseline in Tarawera using NRWQN data (‘early 1990s’ but currently based on 1994 only). Similar review of other lakes.
- Improve methods intercomparison.
- For Lake Tarawera, one conundrum remains. N & P increased by ~1/3 but the outcome measures – Secchi & Chl-a – have not.

Trophic Level Index



'Trophic State'

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2 – 3	Good water quality (oligotrophic)
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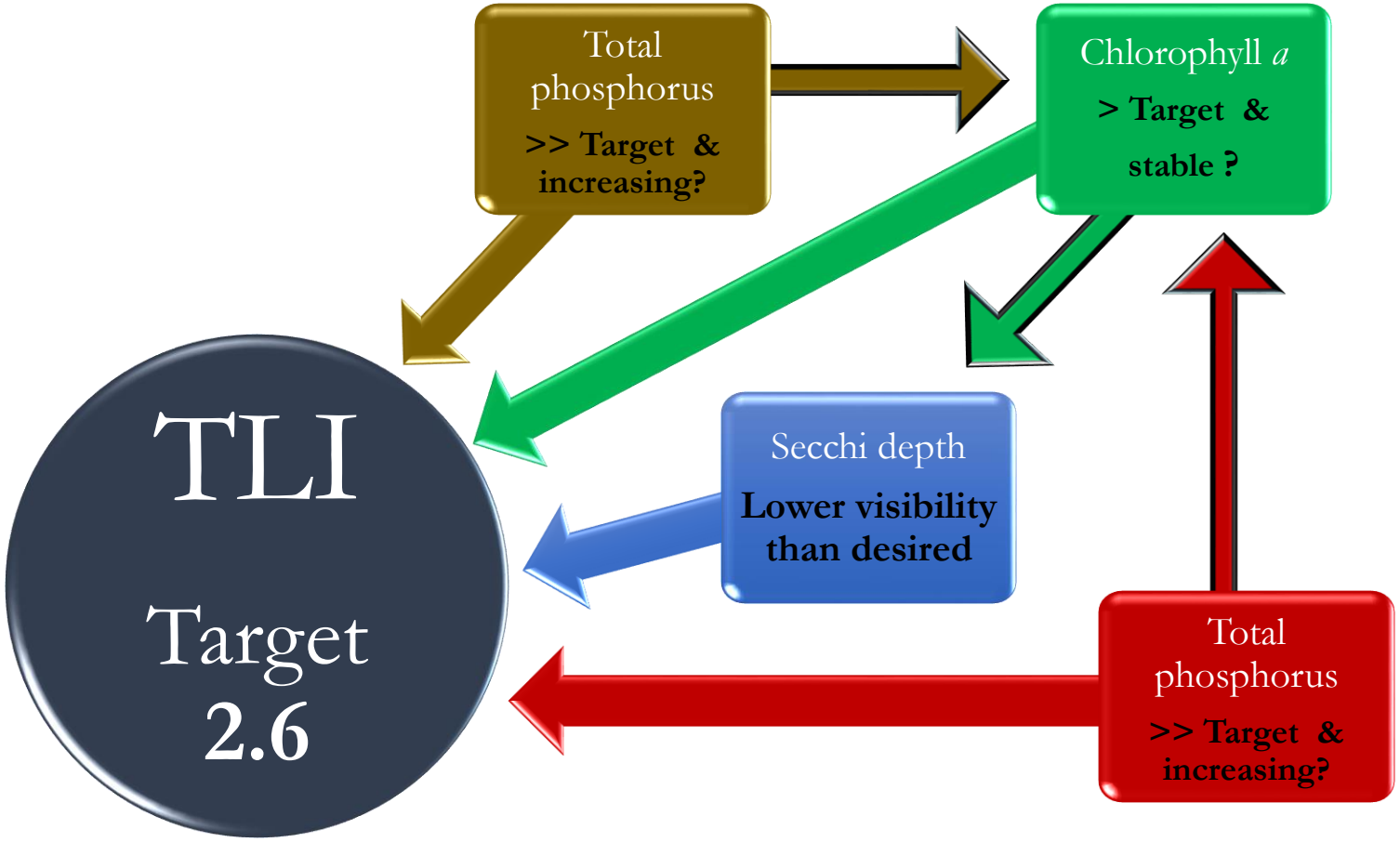
Greater than 5	Very poor water quality (supertrophic)

Source: factsheet - rotorualakes.co.nz

Tarawera TLI target = 2.6 (~1994 levels)

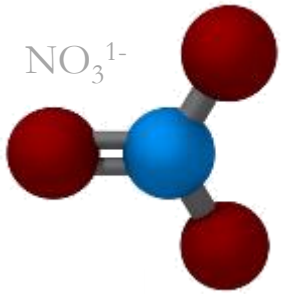
Water quality summary

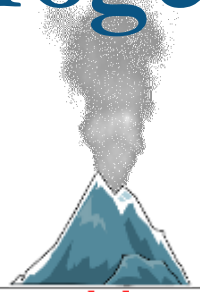
State of water quality in Lake Tarawera

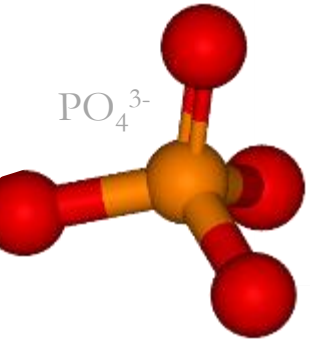


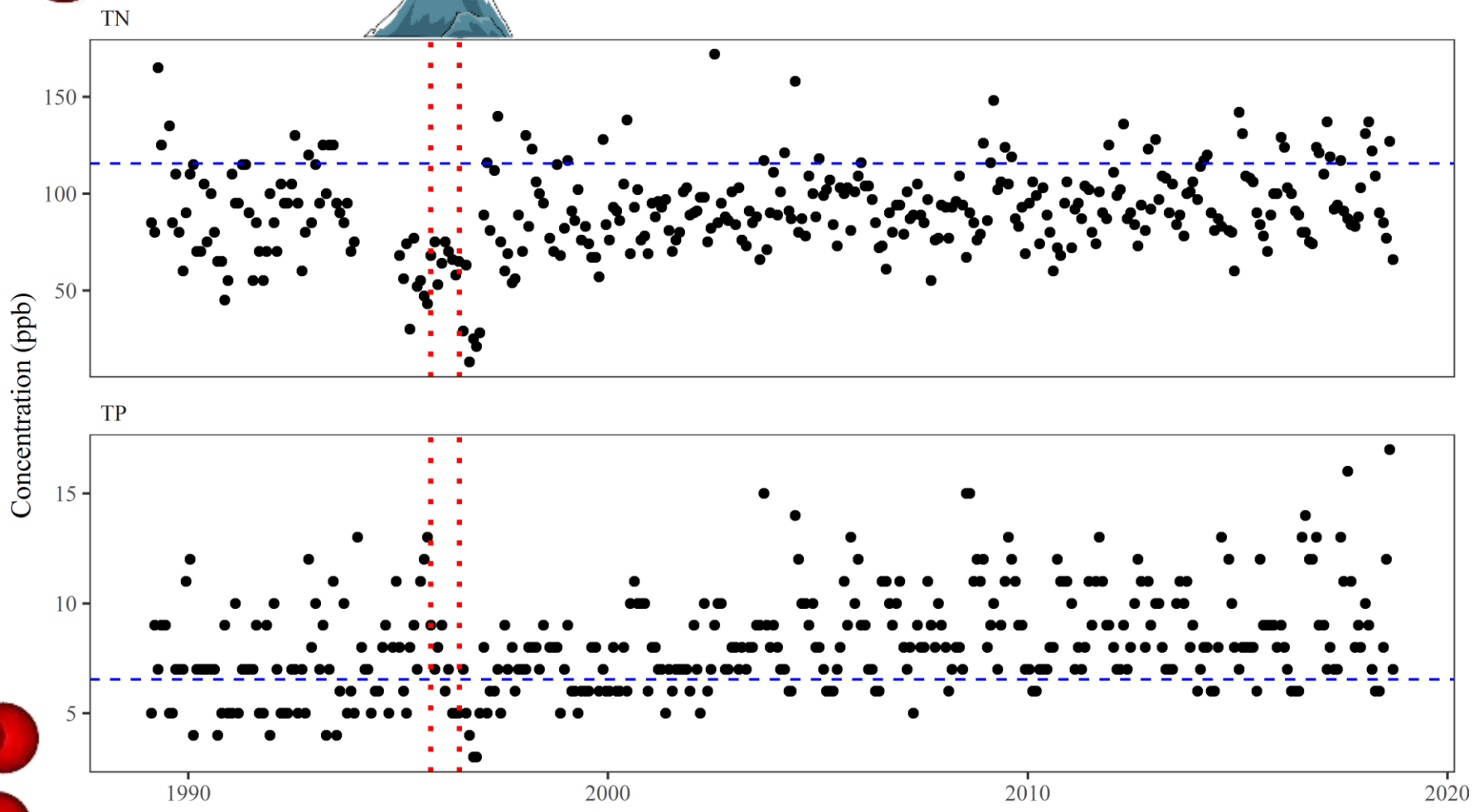
→ Also review basis for TLI target by reviewing early 1990s data

Nitrogen and phosphorus (total)







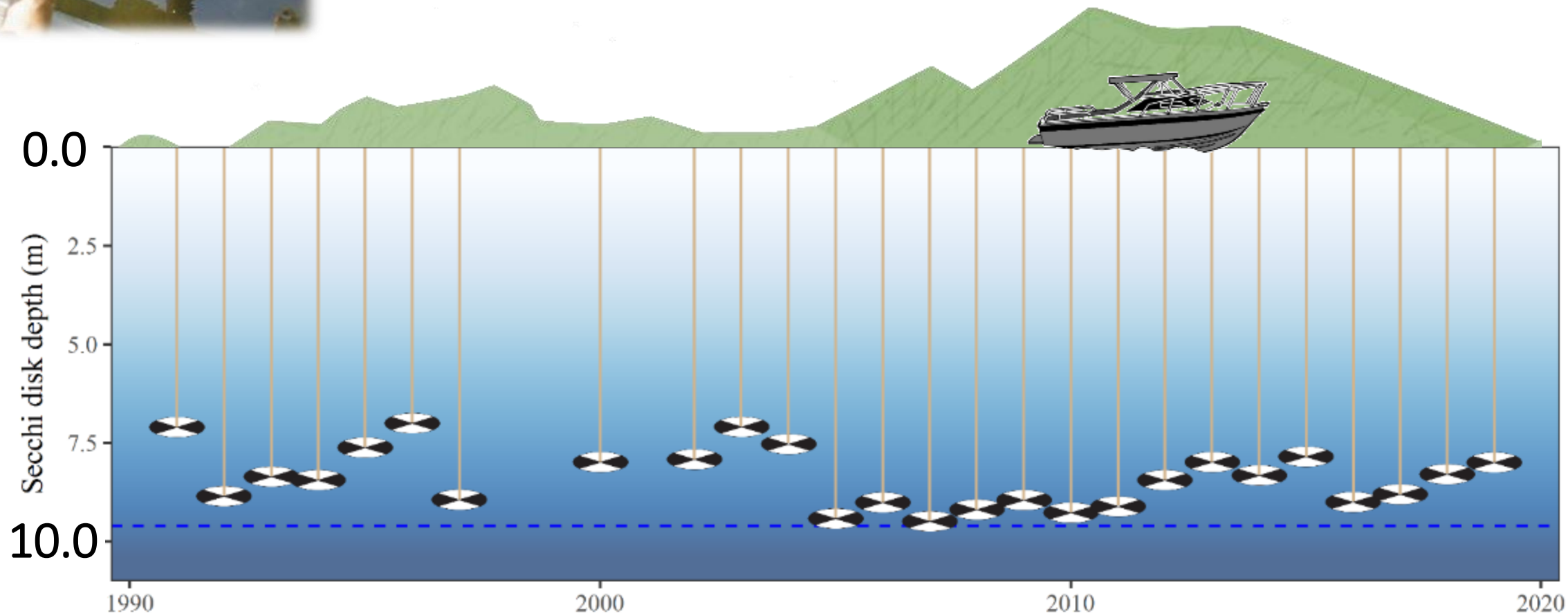


TLI (TN) = 2.6

TLI (TP) = 2.6

Data: NIWA NRWQN at Lake Tarawera outlet

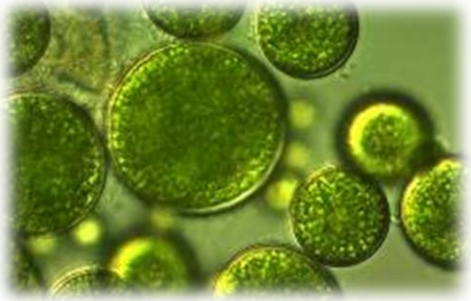
Water clarity over time



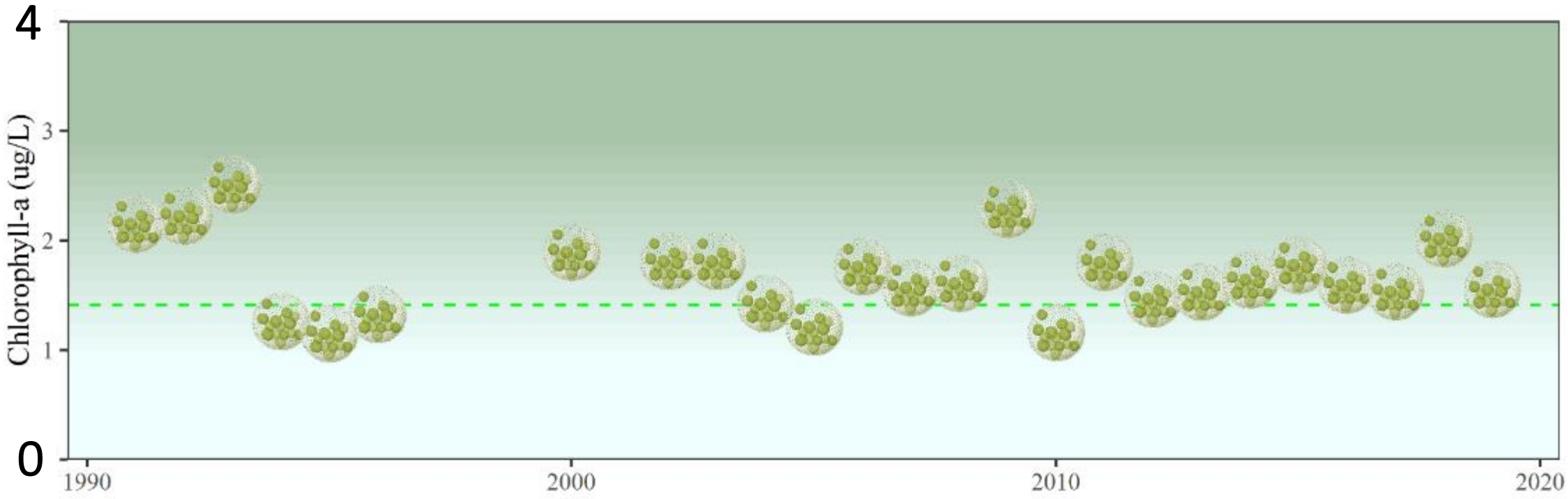
– – – – – Trophic level Secchi = 2.6

1970s: Secchi of 7 – 9.5 m

Data: BoPRC EDS at Tarawera mid-lake (Site 5)



Algal biomass over time



– – – – – Trophic level chlorophyll = 2.6

Data: BoPRC EDS at Tarawera mid-lake (Site 5)

Dr Amanda French

Kirstie Kay

Dr. Rachel Murray

Chris Eager (until Nov 2019)

Claire Eyberg

Meti Yulanti

Chris McBride

Dr Mat Allan (thru Feb 2020)