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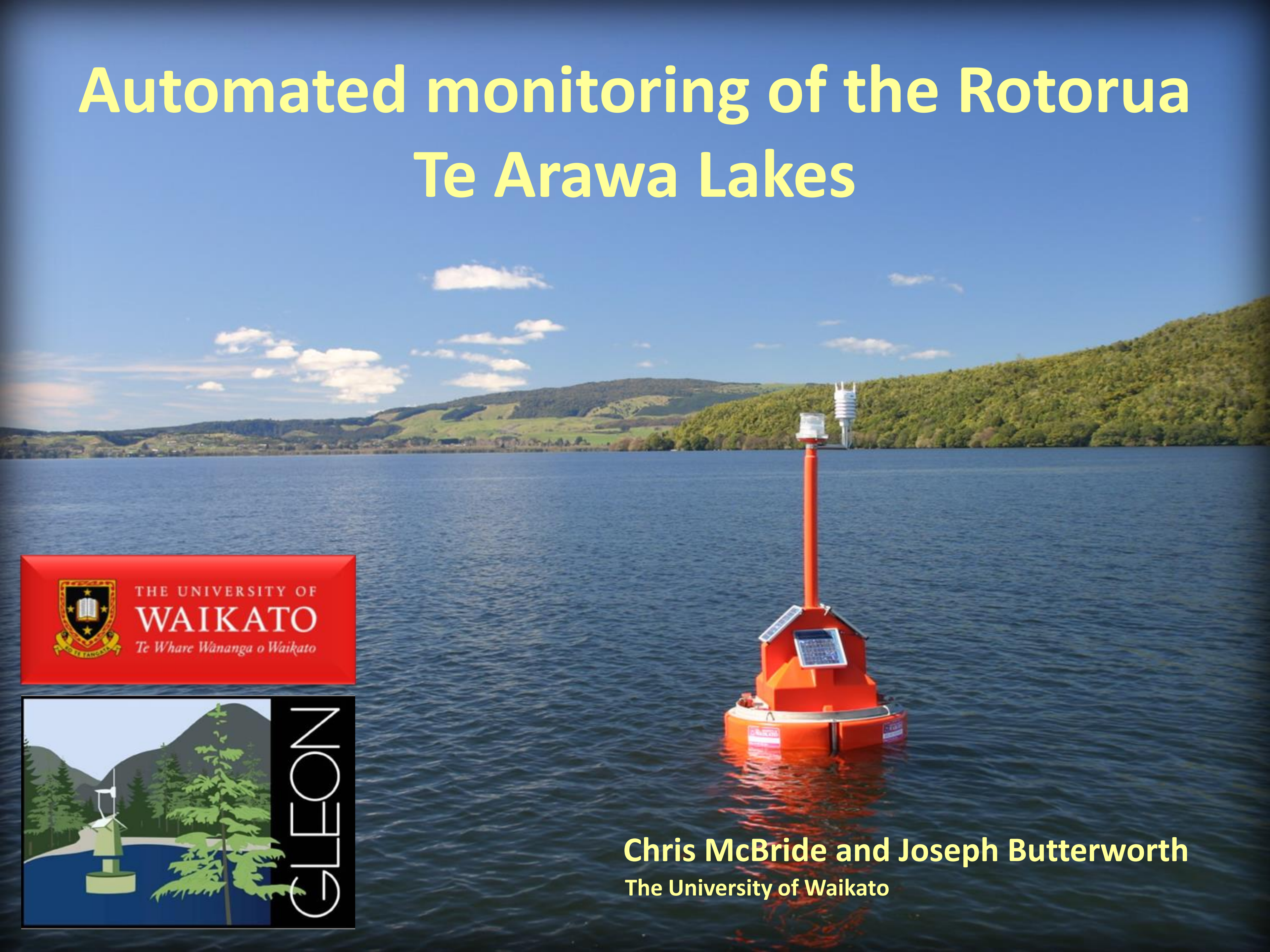
Bay of Plenty Regional Council Chair in Lake Restoration at the University of Waikato

David Hamilton (Lakes Chair), Chris McBride (Technical Officer), Joseph Butterworth (Technical Officer), Ian Kusabs (PhD student/consultant), Ari Santoso (PhD student), Theodore Kpodonu (PhD student), Ryan Mallett (MSc student), Wang Me (PhD student), Hannah Mueller (PhD student), Monica Peters (PhD student), Grant Tempero (Post-doc), Mat Allan (Post-doc)

Leverage
and synergistic activities

Automated monitoring of the Rotorua Te Arawa Lakes



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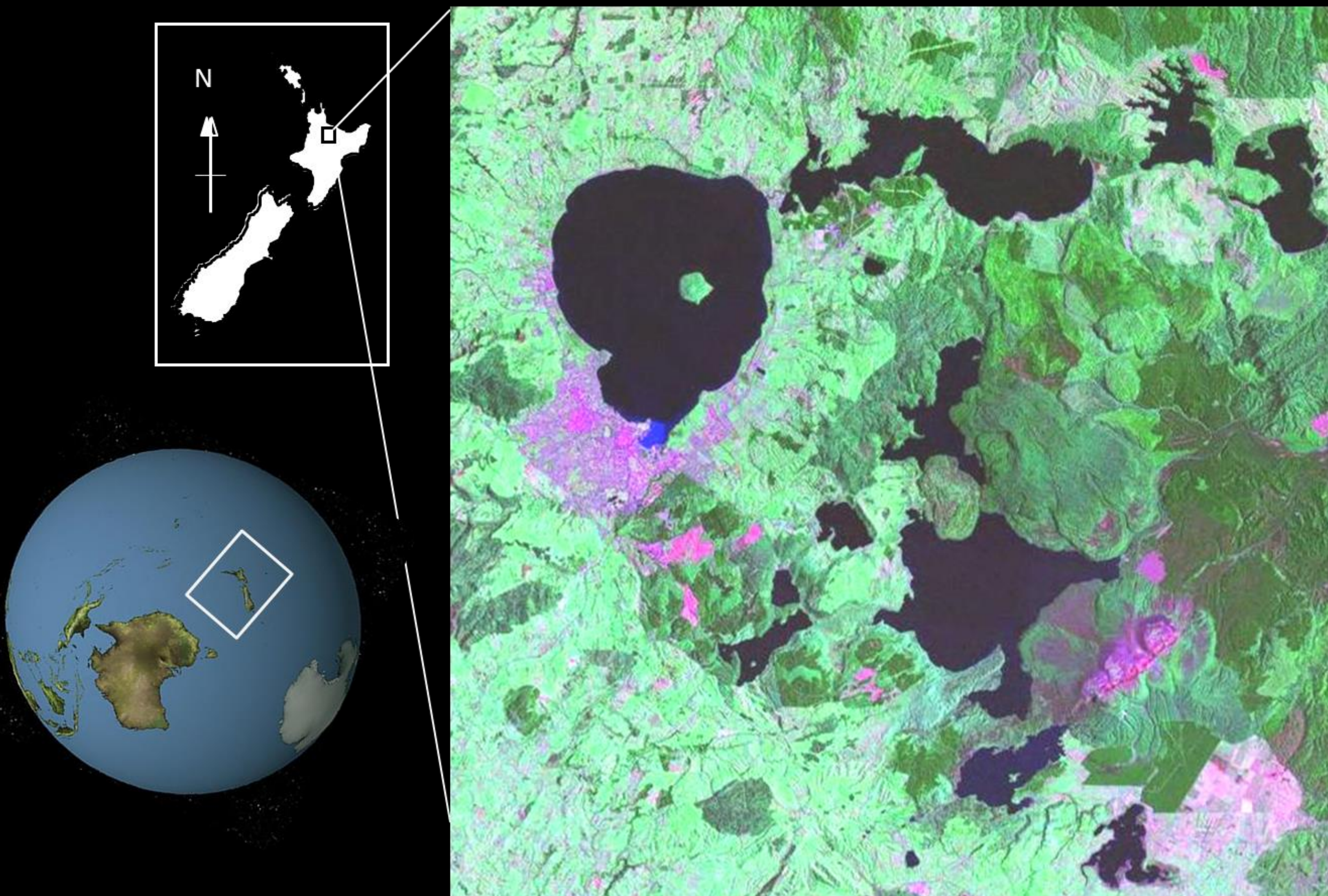
Te Whare Wānanga o Waikato

GLEON

Chris McBride and Joseph Butterworth
The University of Waikato

Rotorua Lakes District, Lake Rotoehu



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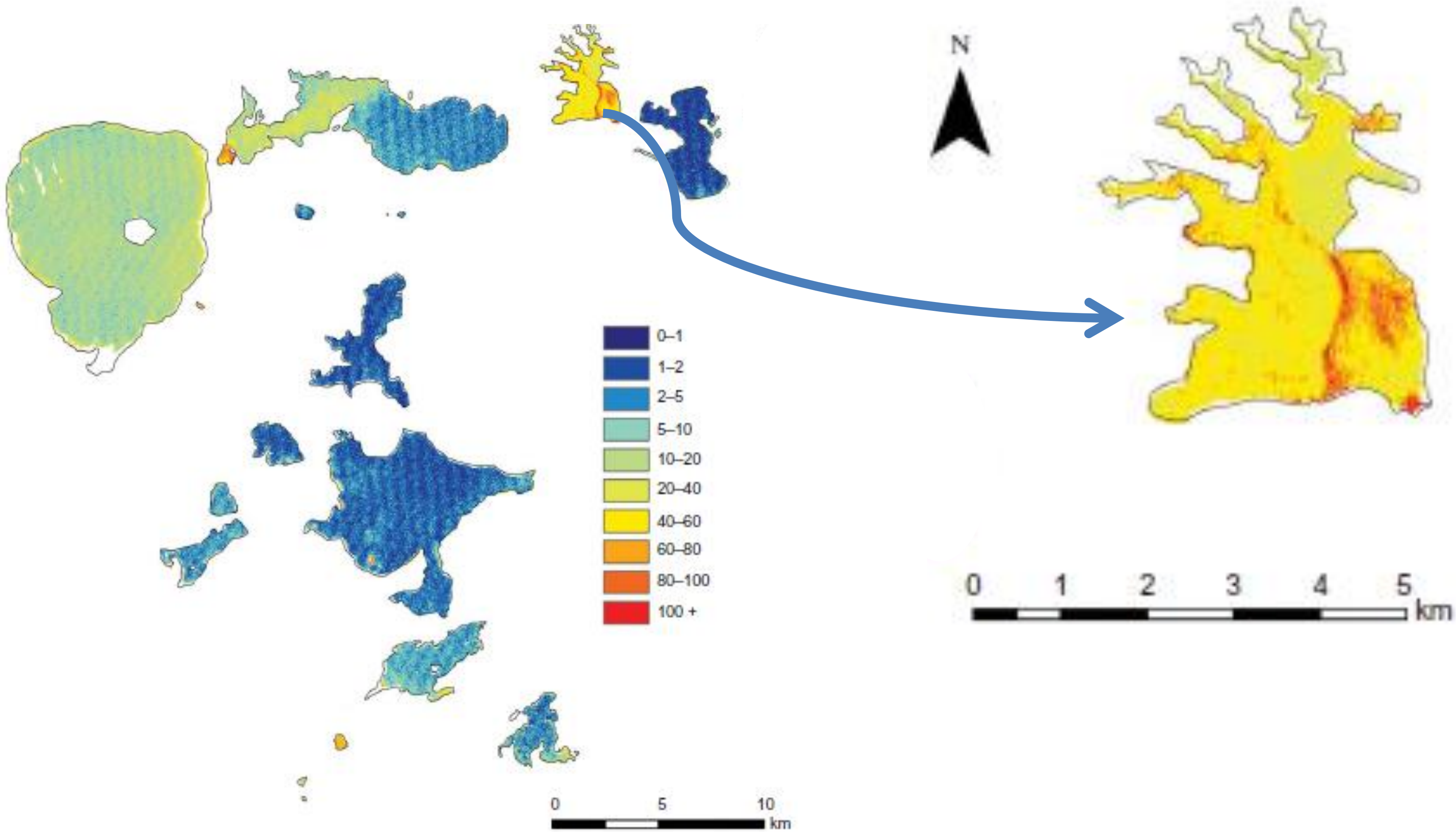
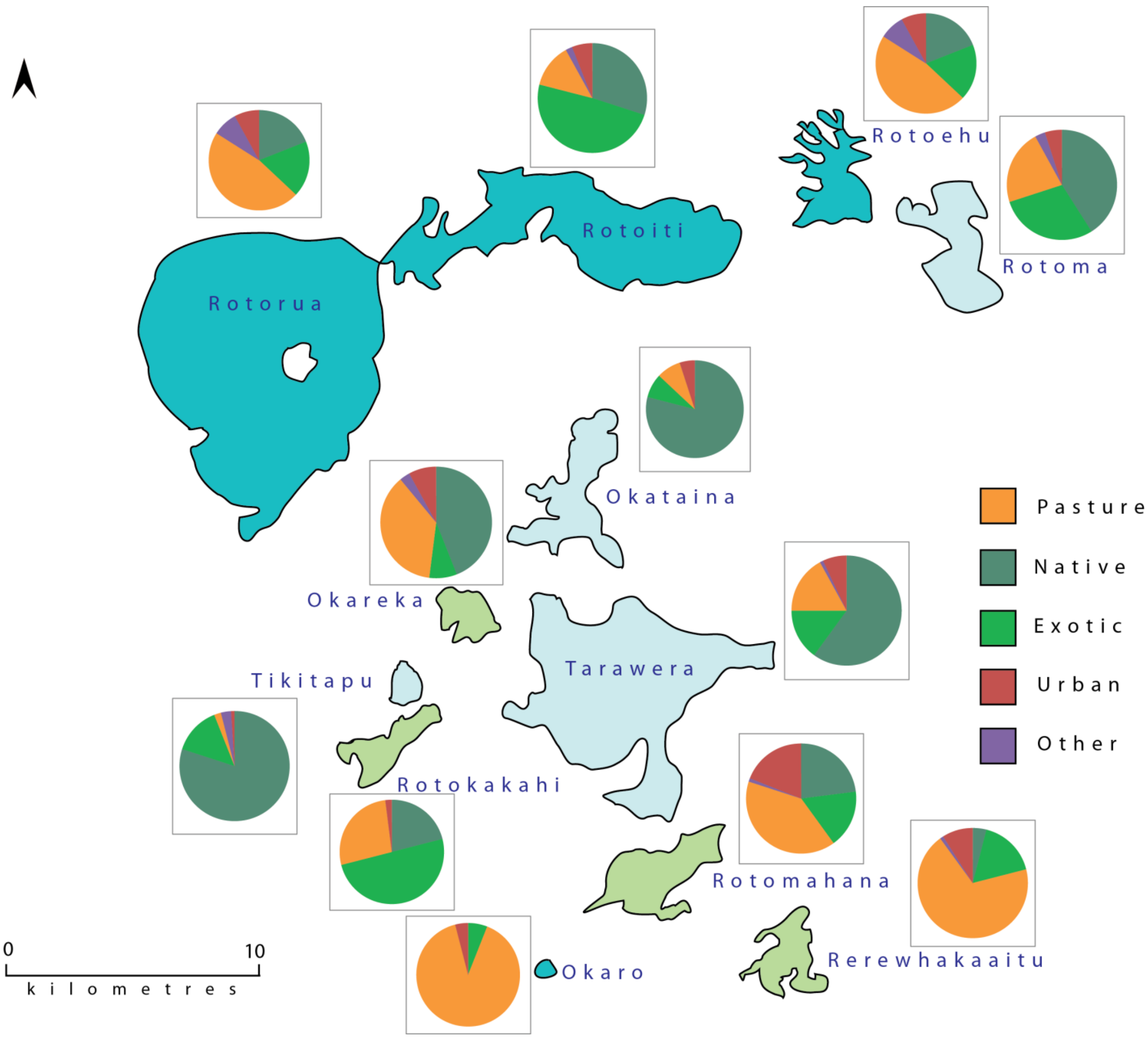
GLEON

Landsat-derived chlorophyll *a* in the Rotorua lakes

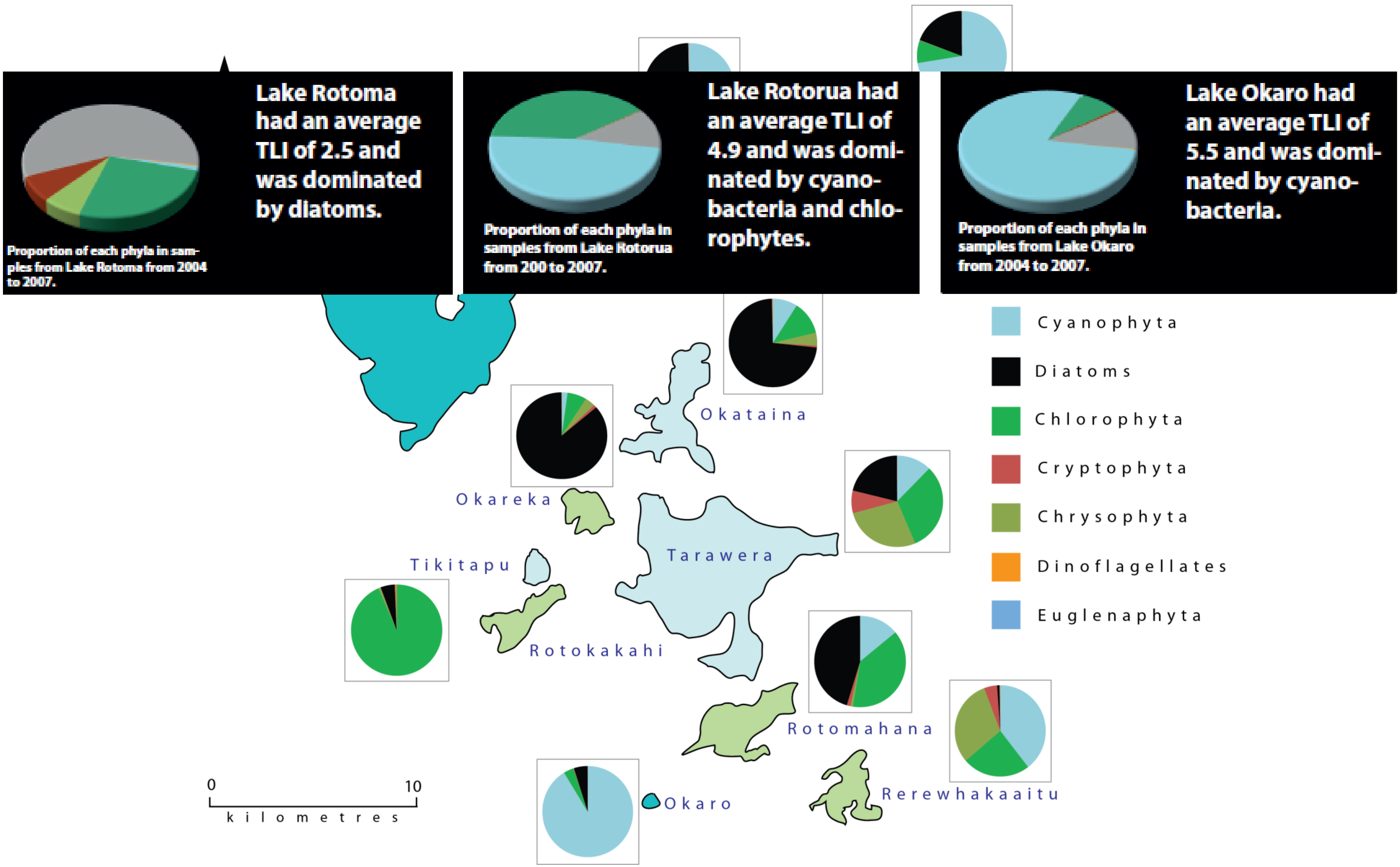


Allan et al. 2011: Landsat remote sensing of chlorophyll *a* concentrations in central North Island lakes of New Zealand. *International Journal of Remote Sensing* 32(7): 2037-2055

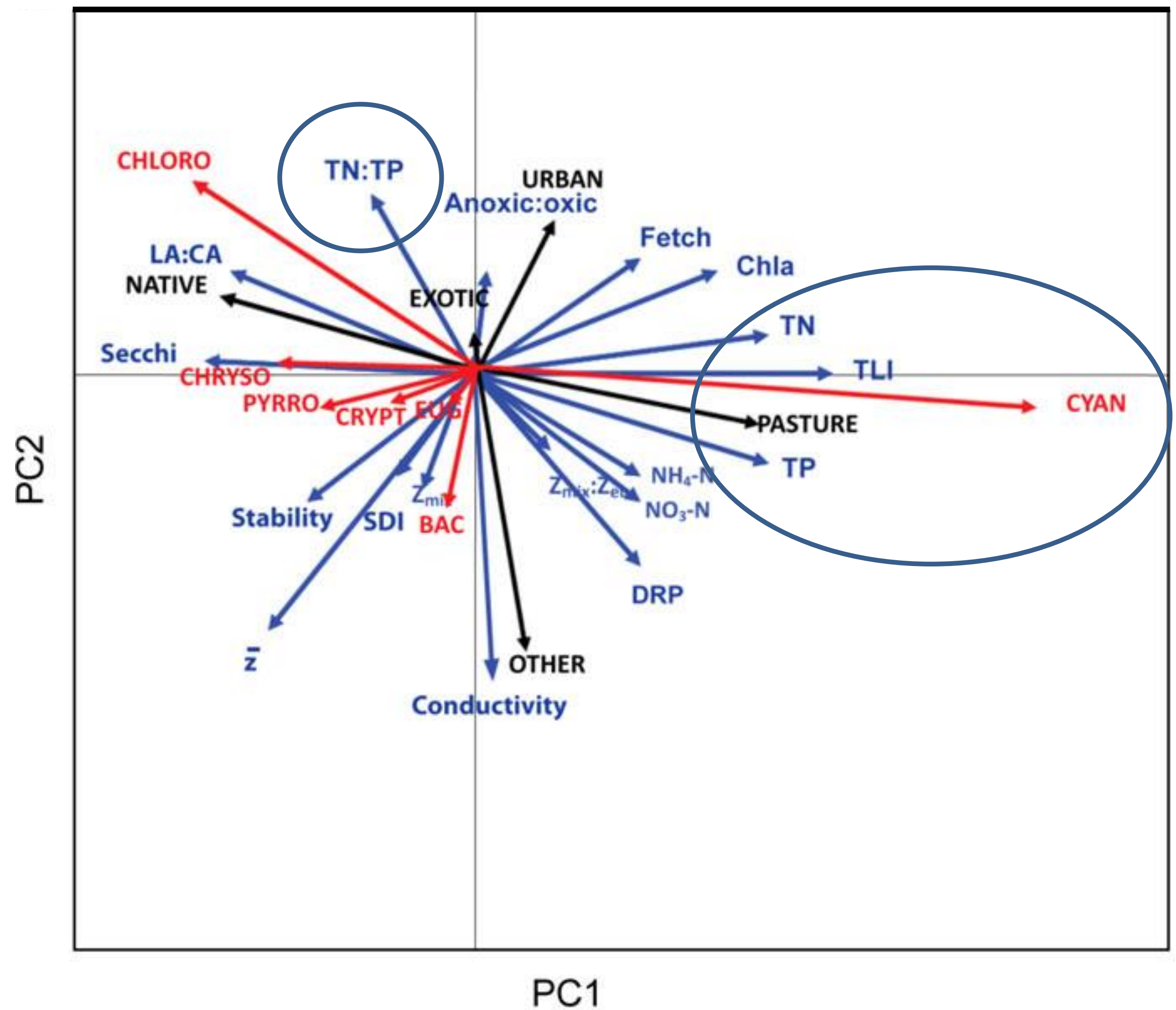
Land use around Rotorua lakes



Phytoplankton composition in lakes



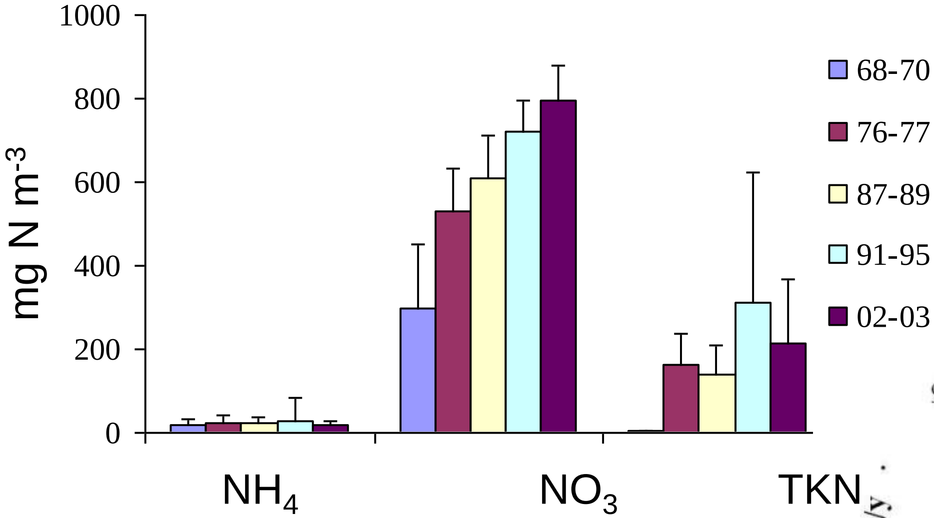
PCA analysis of influences on phytoplankton composition in Rotorua lakes



Paul, W. et al. (2012). Hydrobiologia

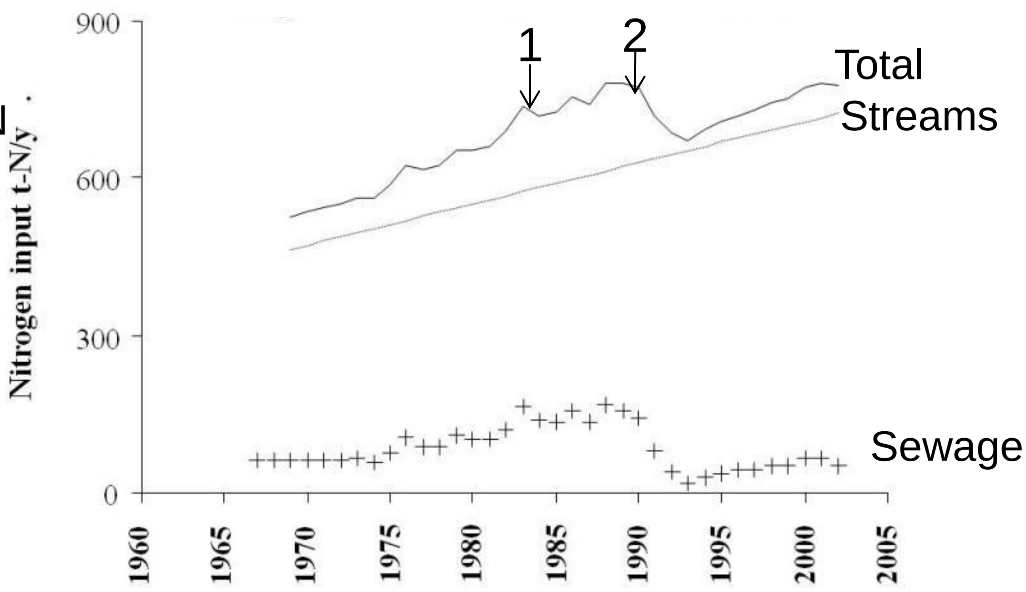
Removing wastewater inputs from the lake in 1991

Nitrogen concentrations, Ngongotaha



(1) Kaituna catchment control scheme

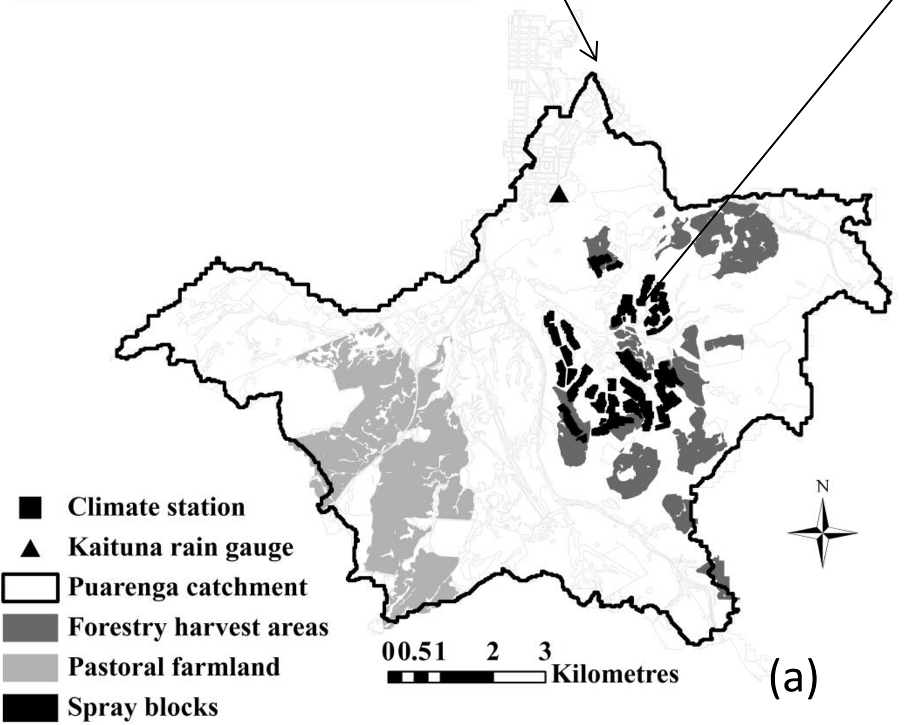
(2) Advanced WWTP land treatment

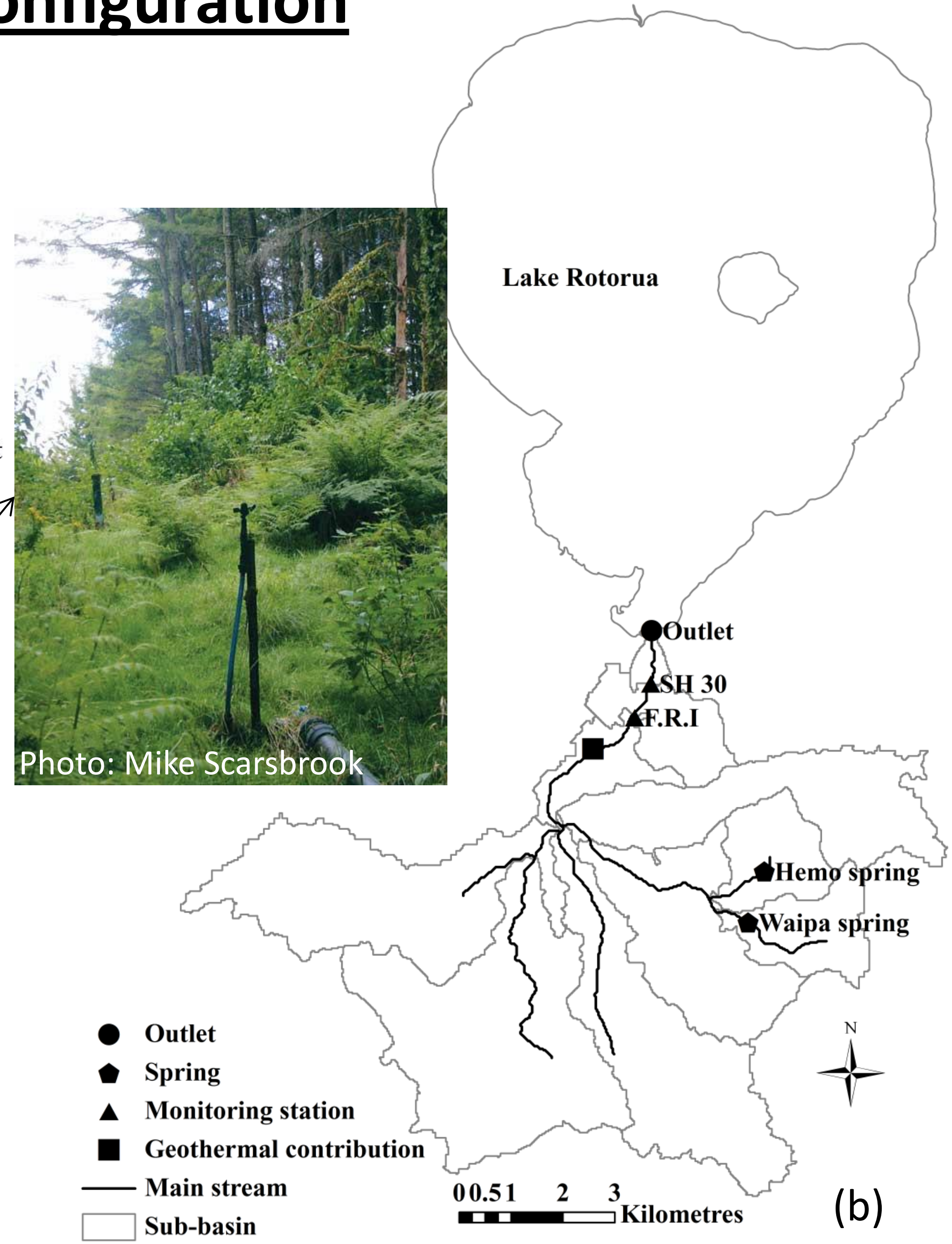


Rutherford et al. (2004)

➢Model configuration

Treated sewage effluent from Rotorua city was spray-irrigated into Whakarewarewa Forest.

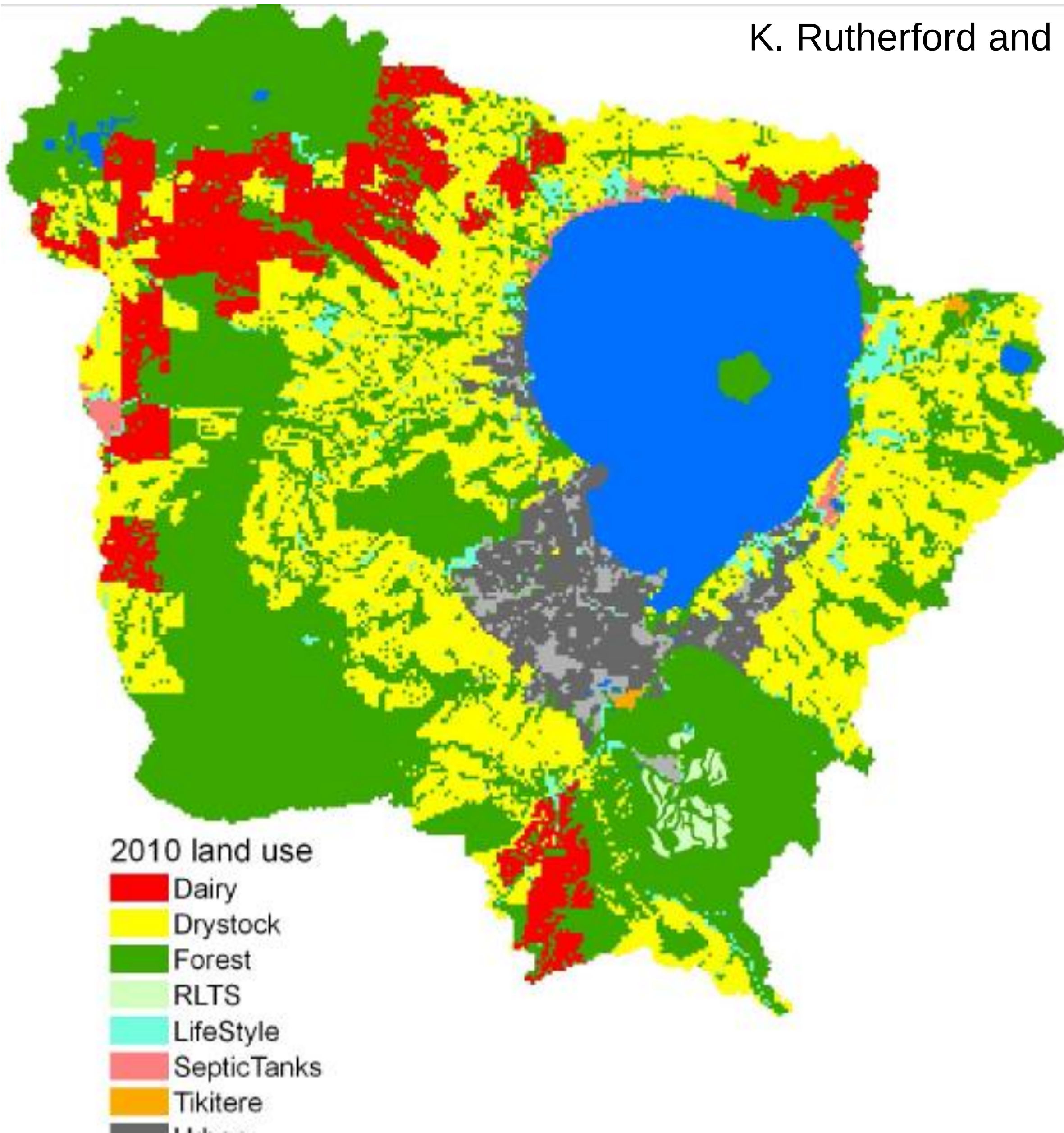




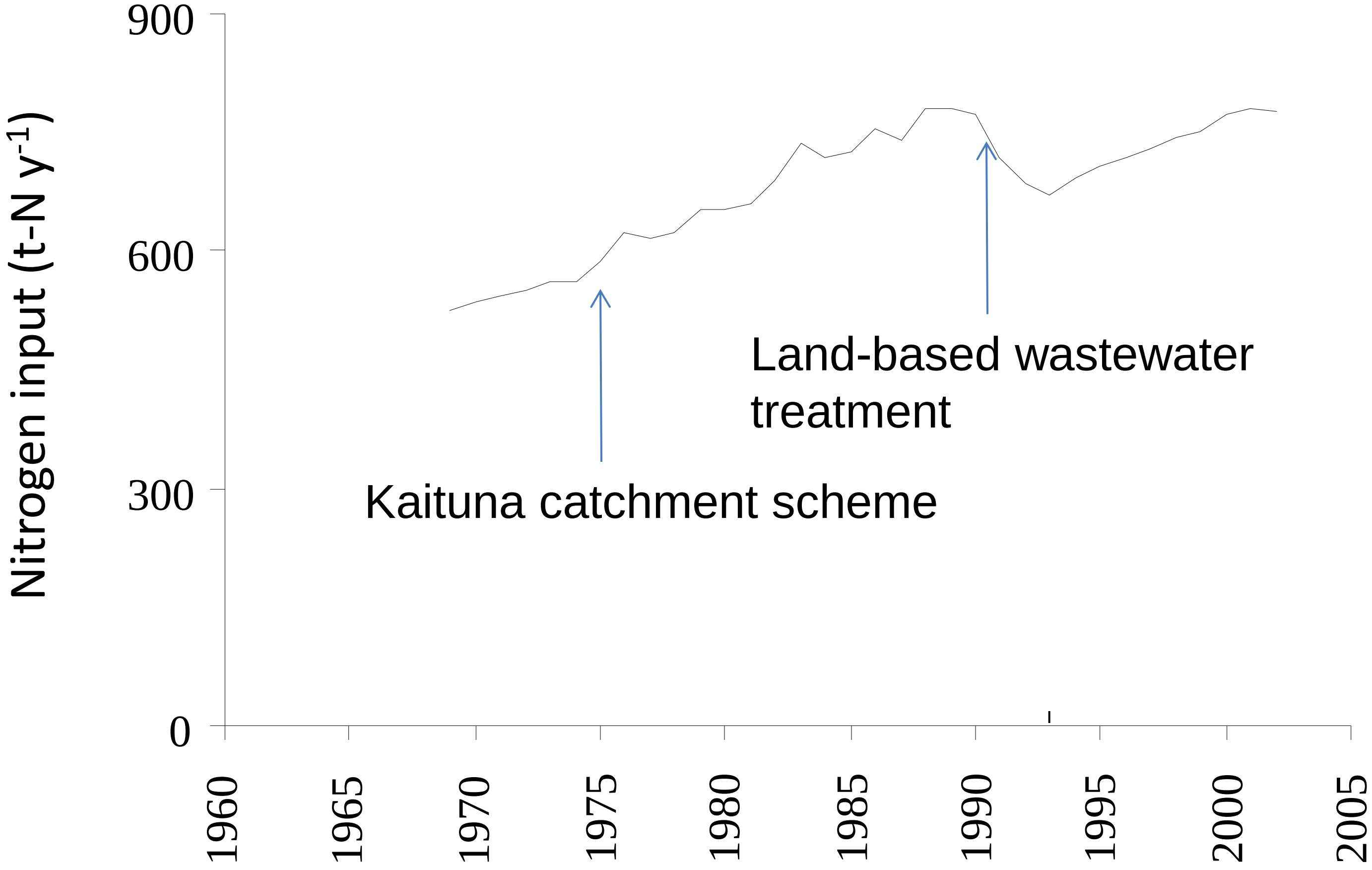
http://www.niwa.co.nz/publications/wa/vol16-no4-december-2008/natural-purification-of-groundwater

Regional changes in land use: Lake Rotorua

K. Rutherford and C. Palliser (NIWA)

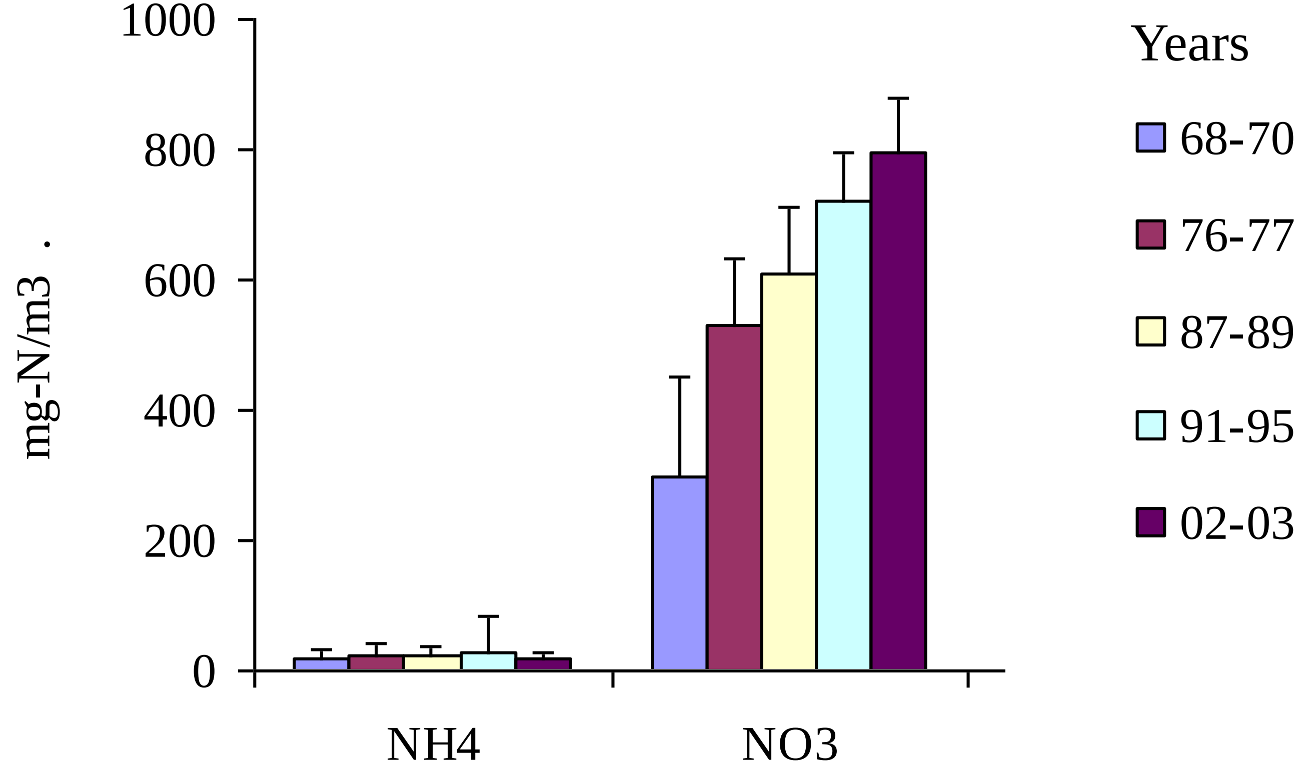


Total nitrogen loads to Lake Rotorua




Lake Rotorua, January 2007
Photo: Wendy Paul

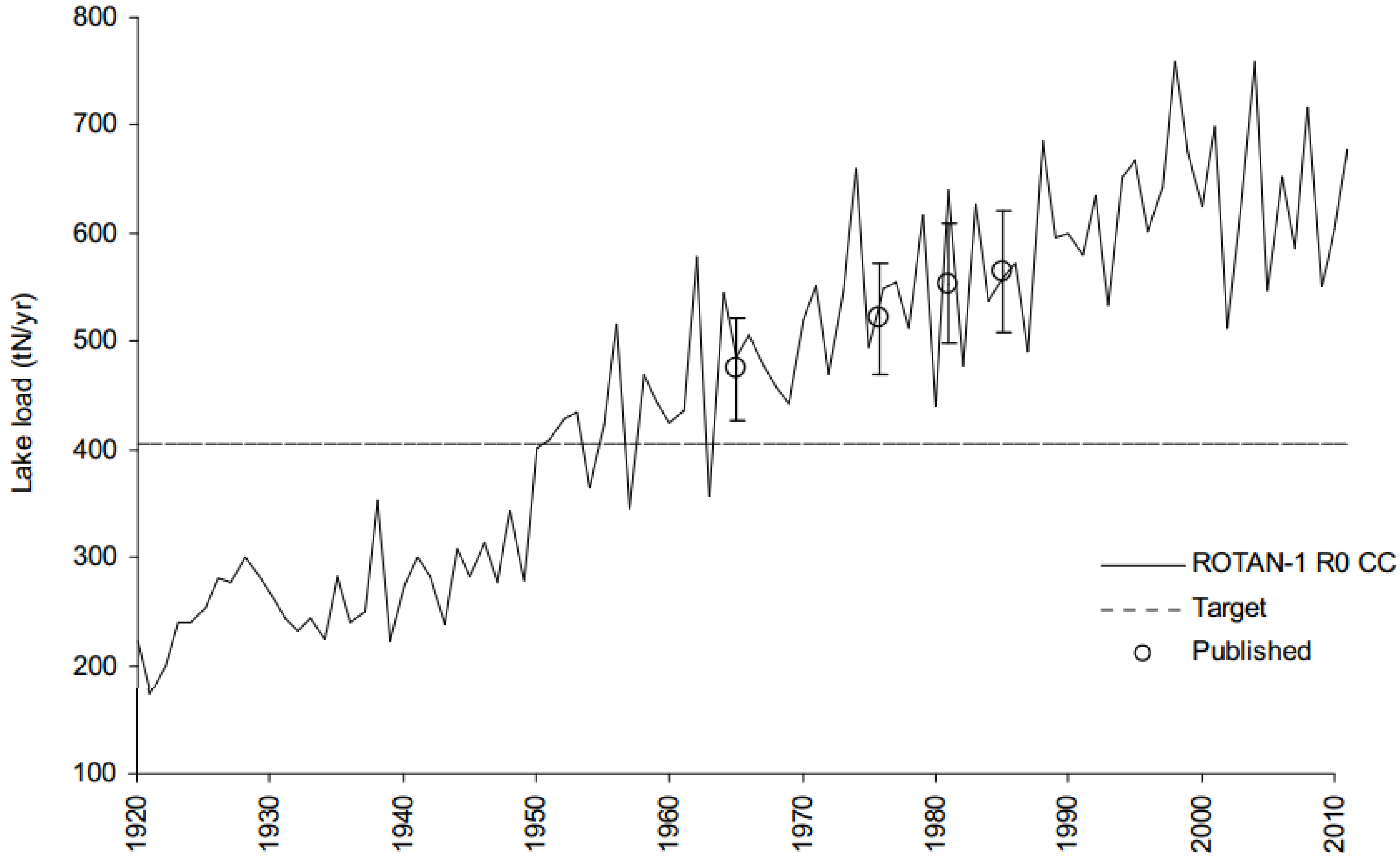
Example: nitrate in Ngongotaha Stream



NIWA
Taihoro Nukurangi

K. Rutherford

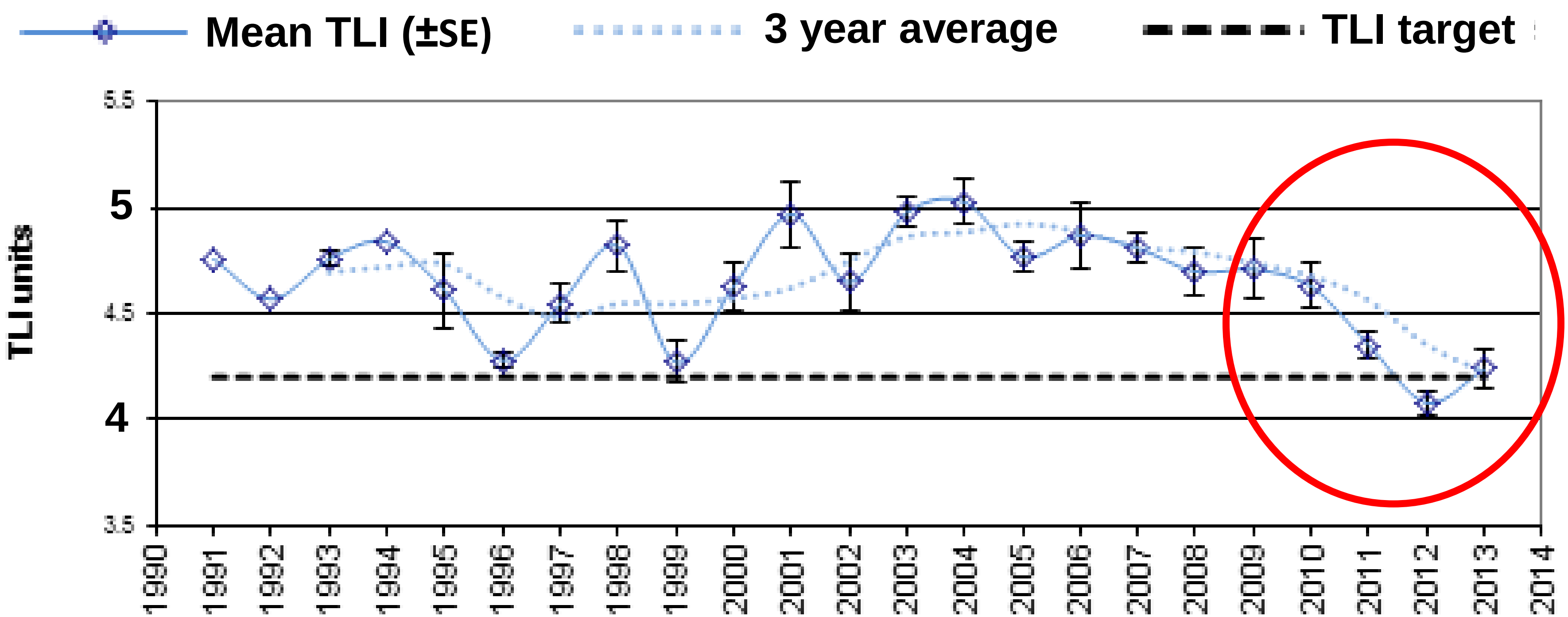
Nitrogen inputs to Lake Rotorua (ROTAN model)



NIWA Taihoro Nukurangi

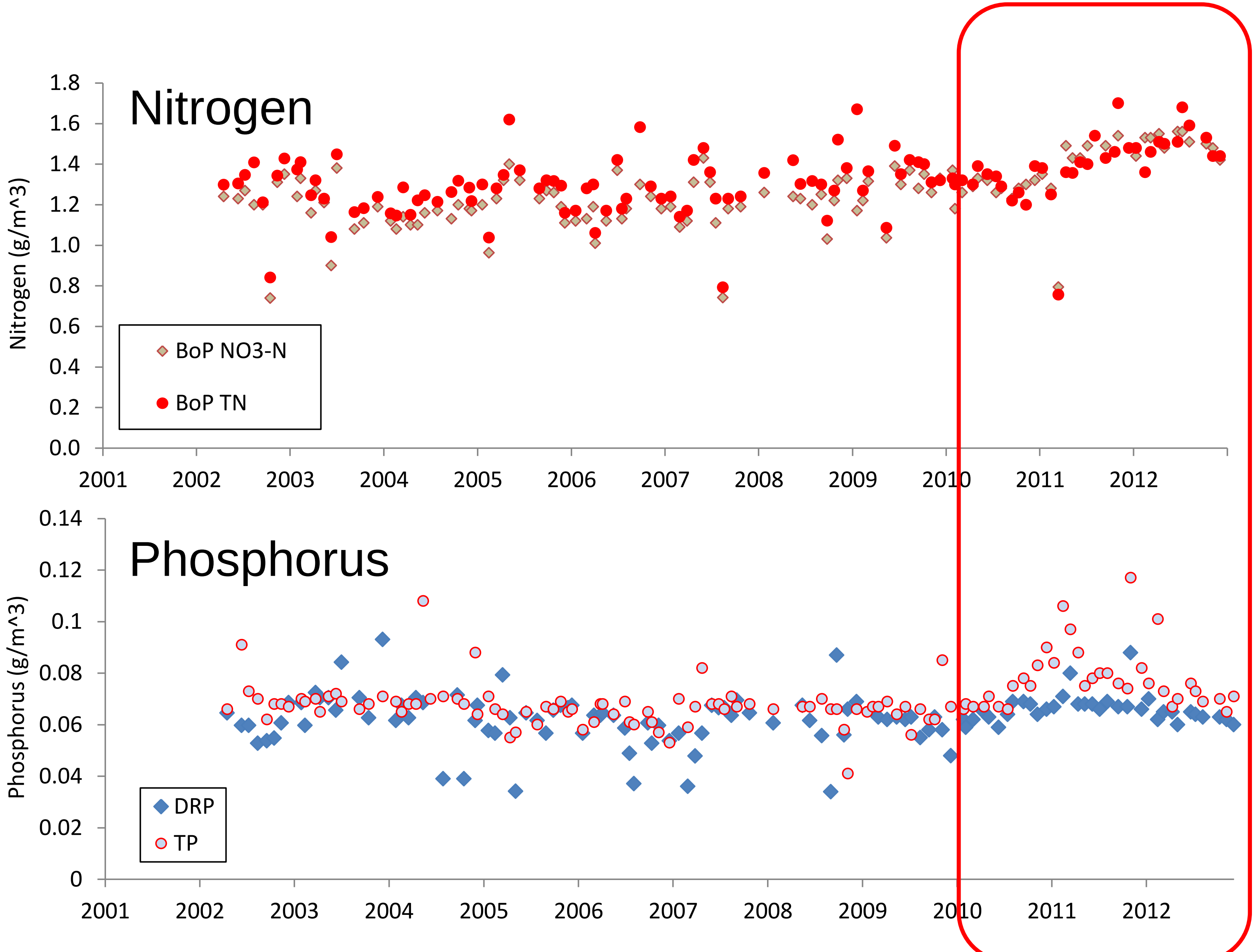
K. Rutherford & C. Palliser

Lake Rotorua TLI

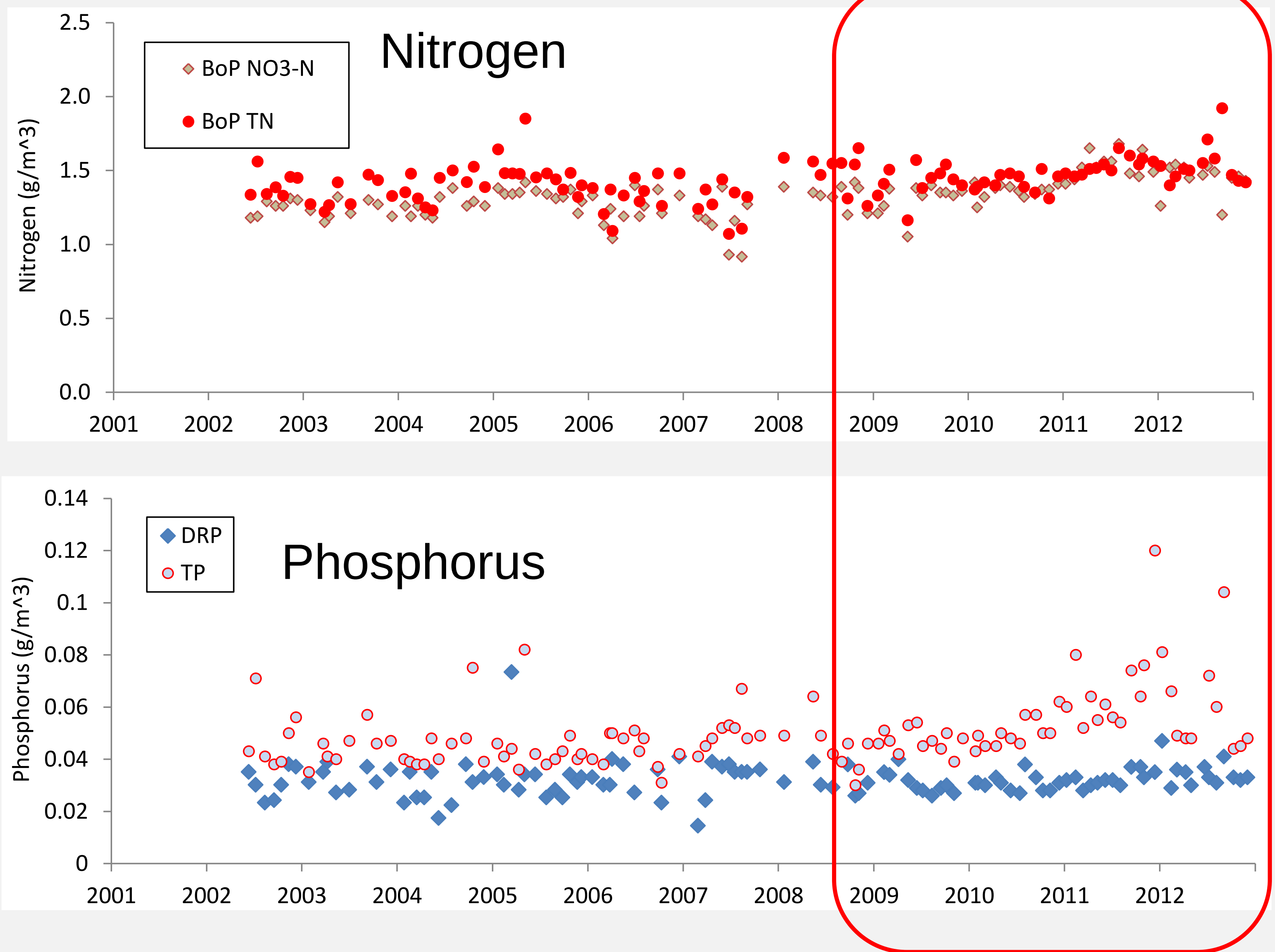


Source: BoPRC (Scholes 2013)

Rotorua inflows: Awahou



Rotorua inflows: Waiteti



Storm flow pollution

•Most sediment and phosphorus is transported to freshwaters during short periods after heavy rain which are not well–monitored
•A study of two major stream inflows to Lake Rotorua found: 50% of P loading to the lake occurs c. 15% of time and 50% of sediment loading c. 1% of time[1]

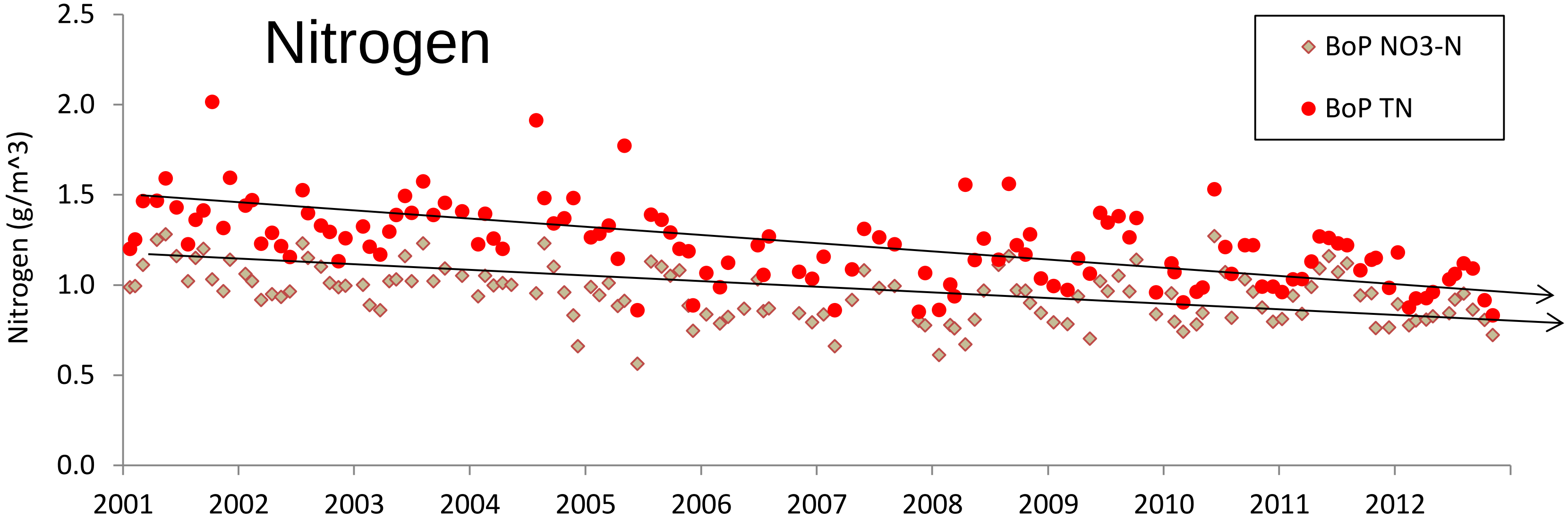
Detainment bunds[3]
•'Soft engineering' (as opposed to higher-cost constructed wetlands) designed to treat storm flow pollution from farmland with minimum detriment to productivity
•Pond storm water with controlled release to allow sediments to settle
•Co-benefits: flood risk management, soil conservation, increased economic sustainability
•Currently being trialled in the catchment of Lake Rotorua

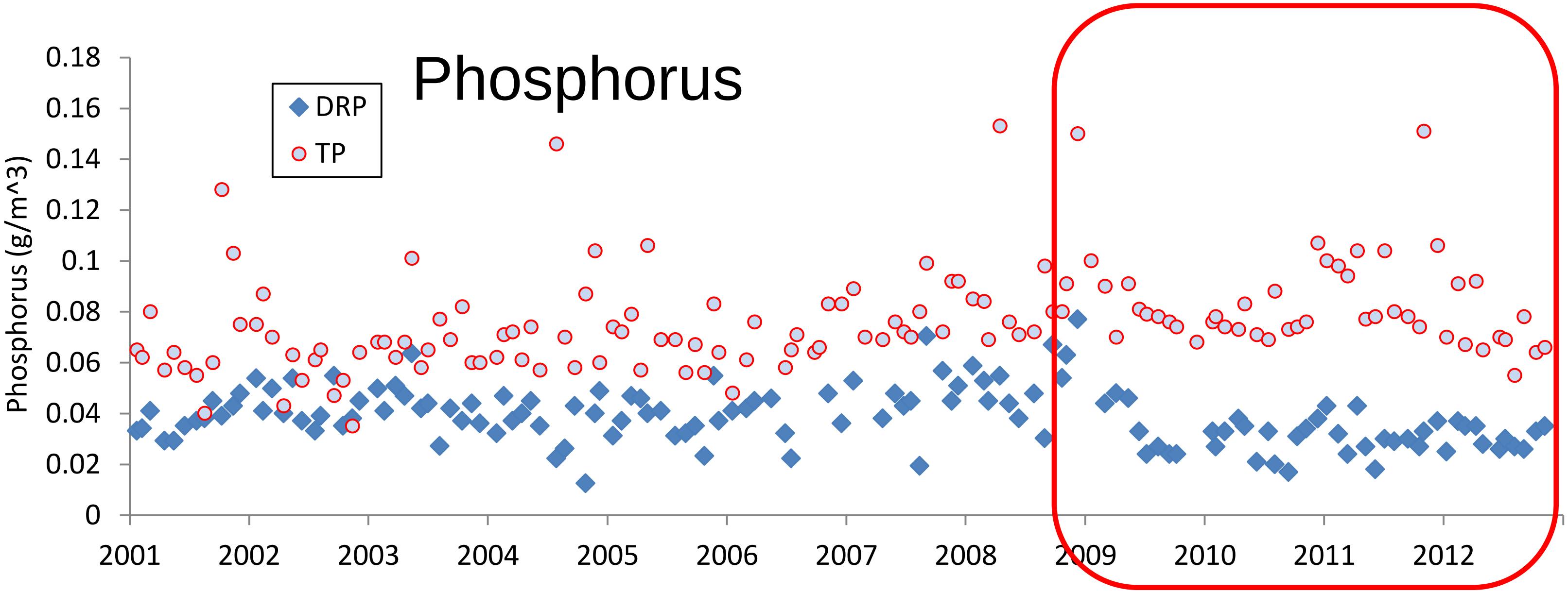
Pilot detainment bund, Rotorua

Ephemeral stream on farmland

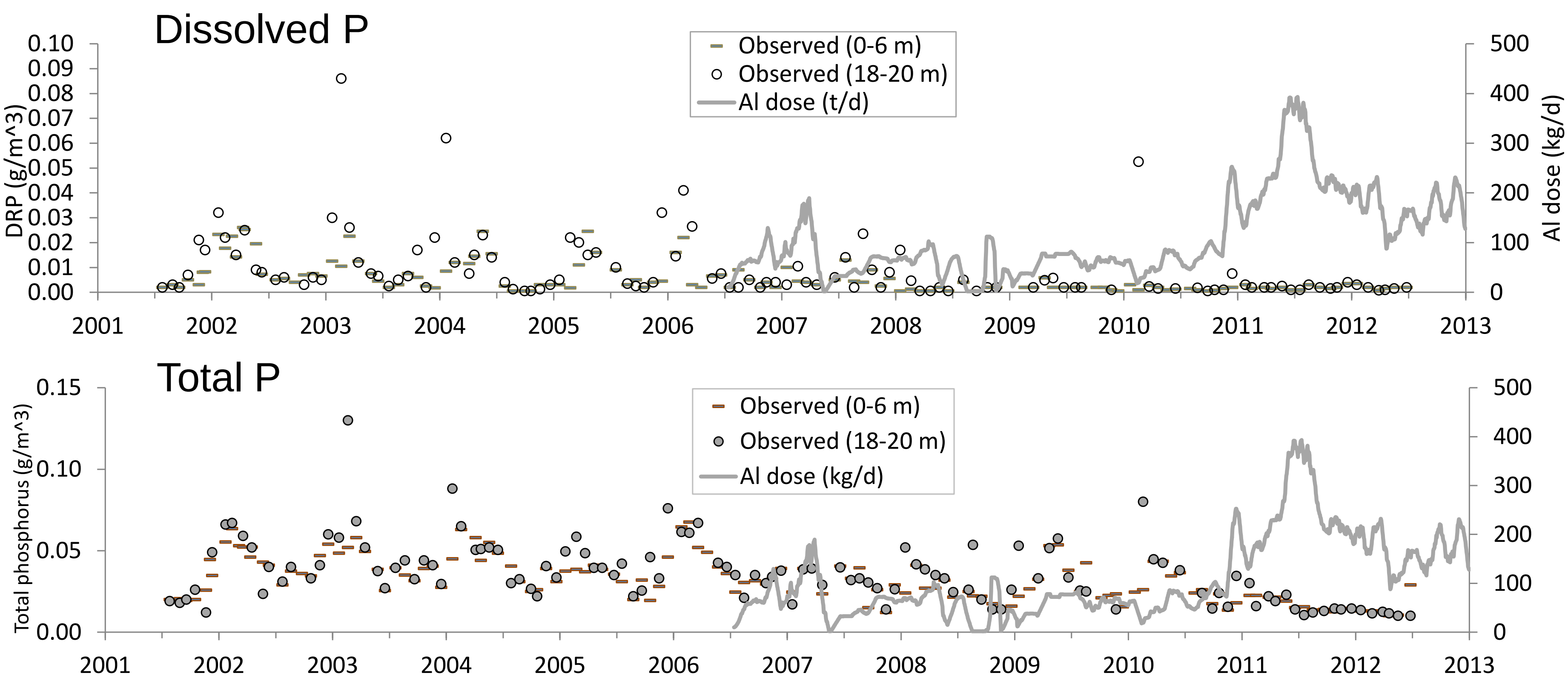
Deposited sediments

Rotorua inflows: Puarenga



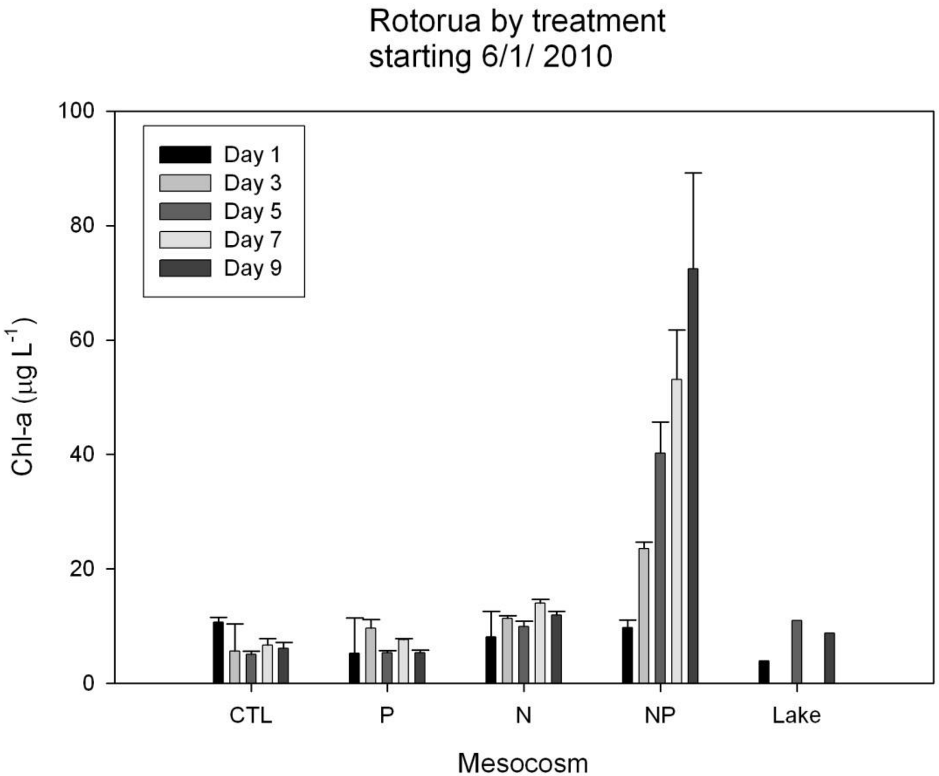


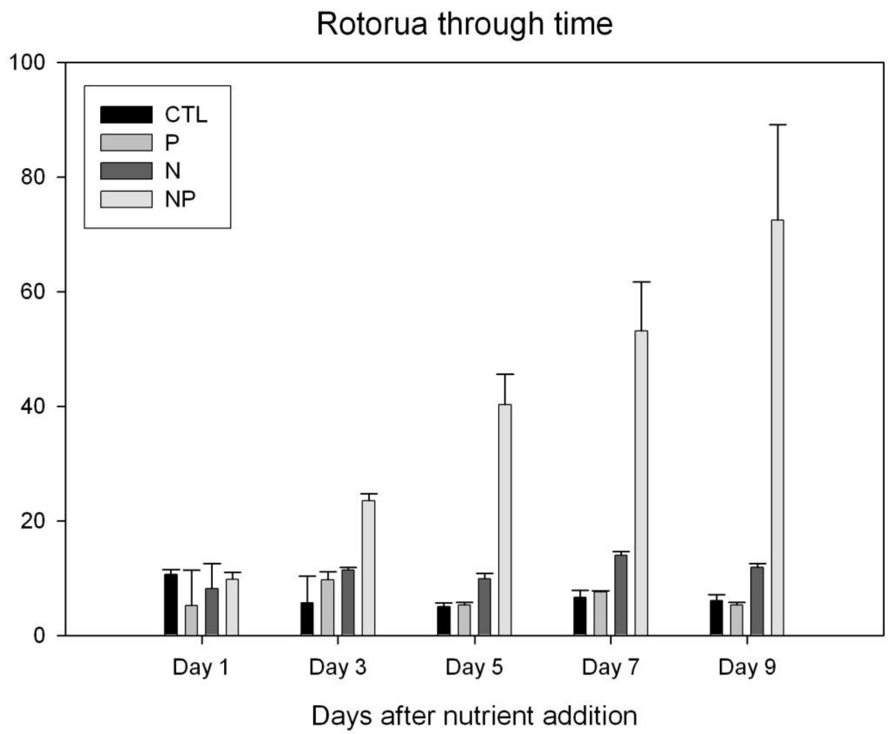
Alum and phosphorus in Lake Rotorua



Nutrient limitation in Lake Rotorua

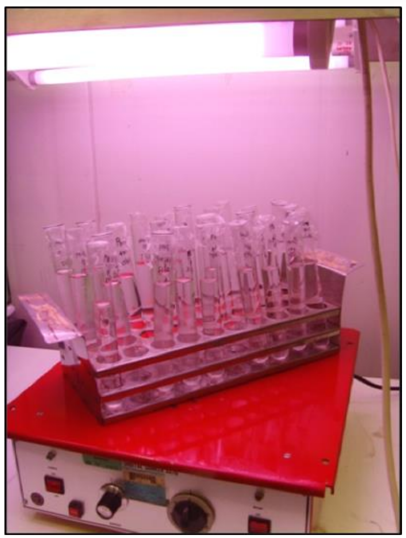
(In-lake mesocosm study of nutrient enrichment – H. Meads, unpubl.)

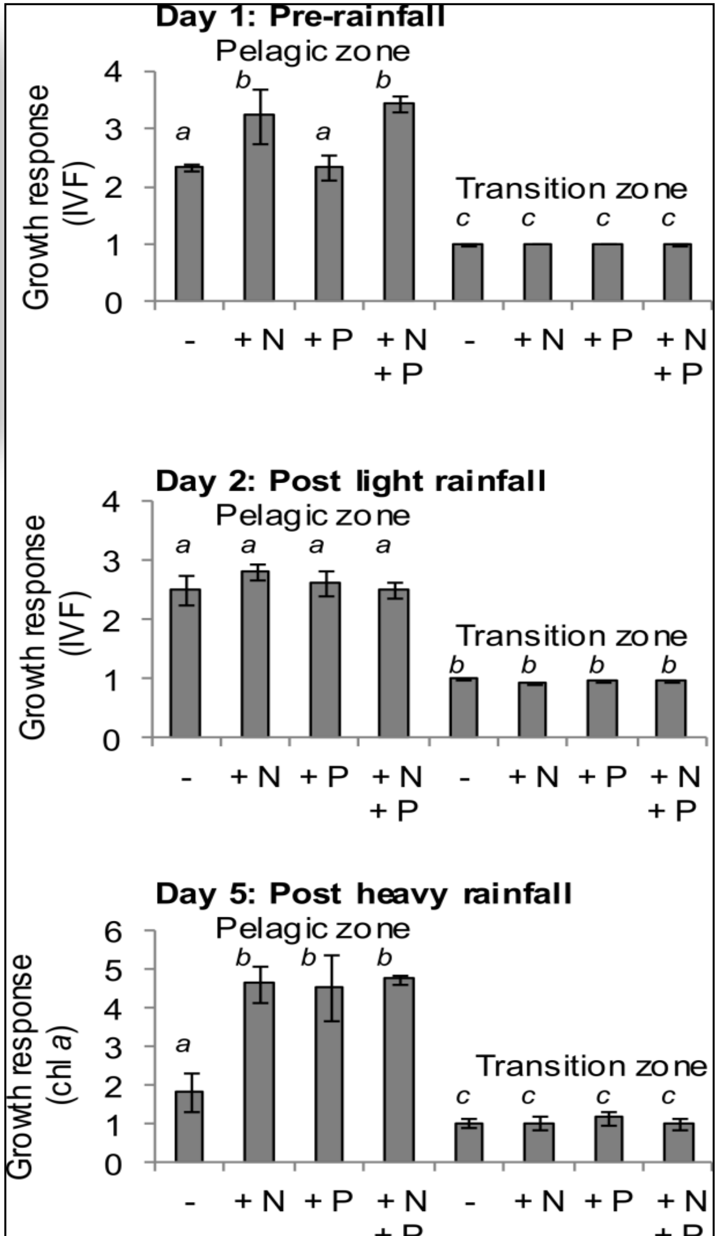




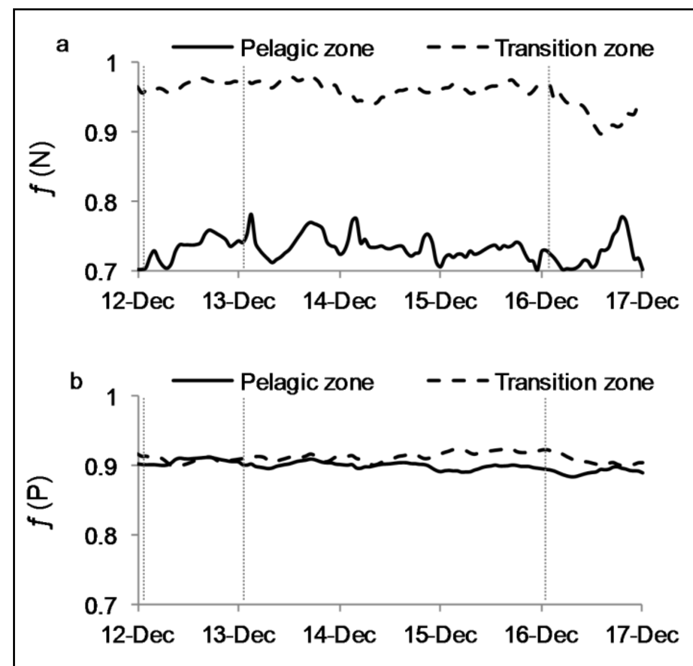
Addition of BOTH nitrogen and phosphorus stimulates far greater algal production than either nutrient alone

Phytoplankton nutrient limitation



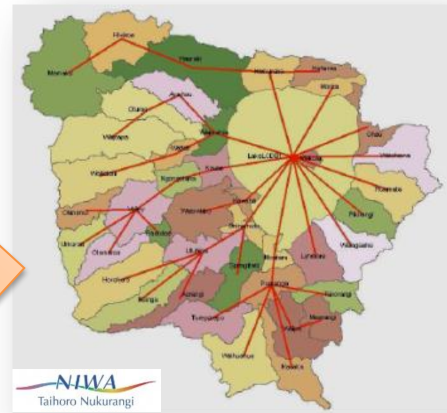


- •Phytoplankton community–level nutrient limitation status varied in time and space
- •ELCOM–CAEDYM broadly reproduced these observations

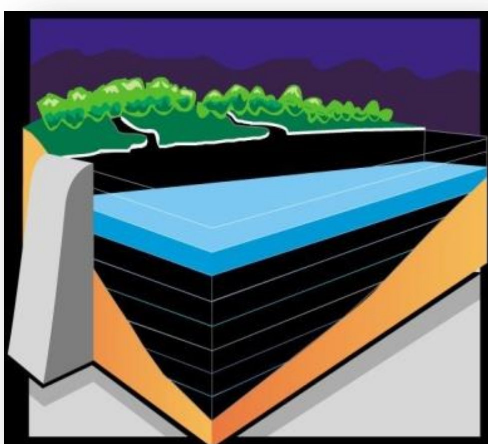


Coupled catchment-lake ecology models

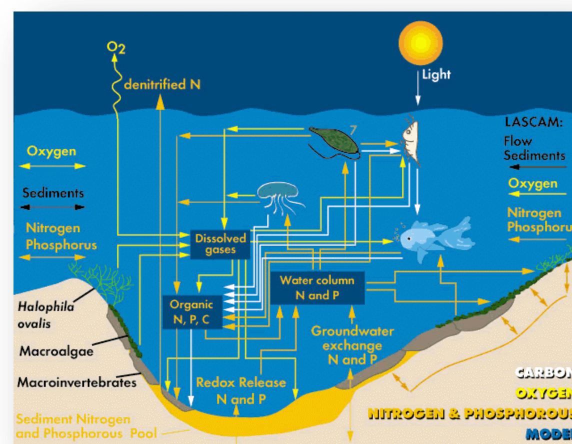
ROTAN – Rotorua Taupo Nitrogen model



DYRESM - Dynamic Reservoir Simulation Model

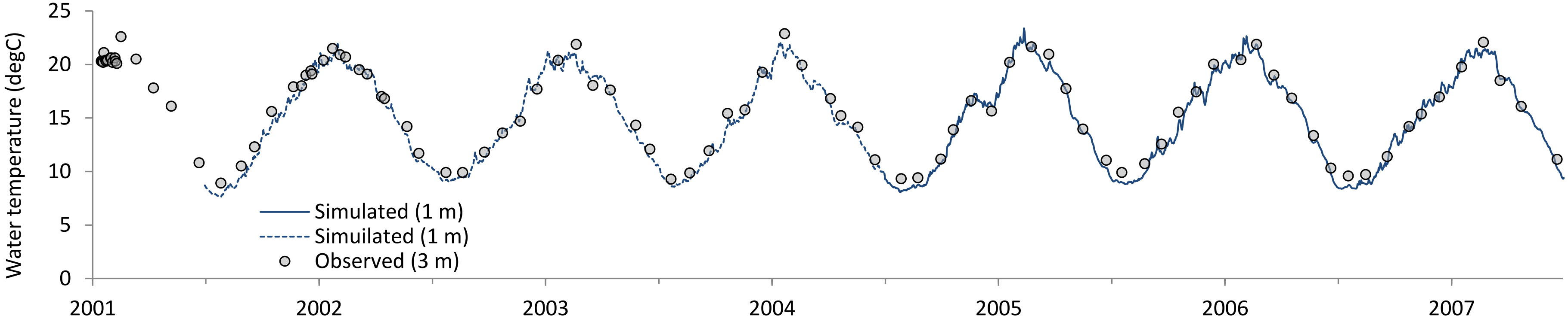


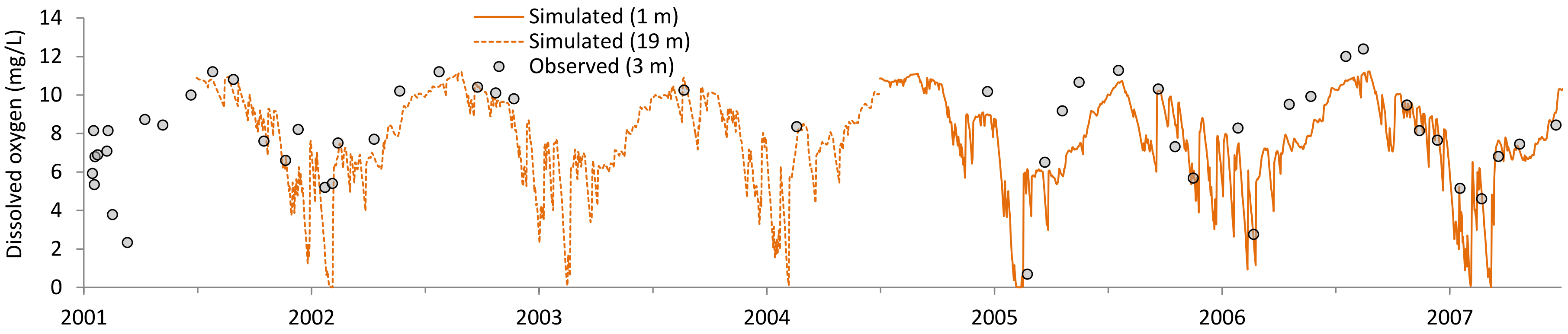
CAEDYM - Computational Aquatic Ecosystem Dynamics Model



Model calibration and validation

8 measured variables (3 different depths) were compared to the model output

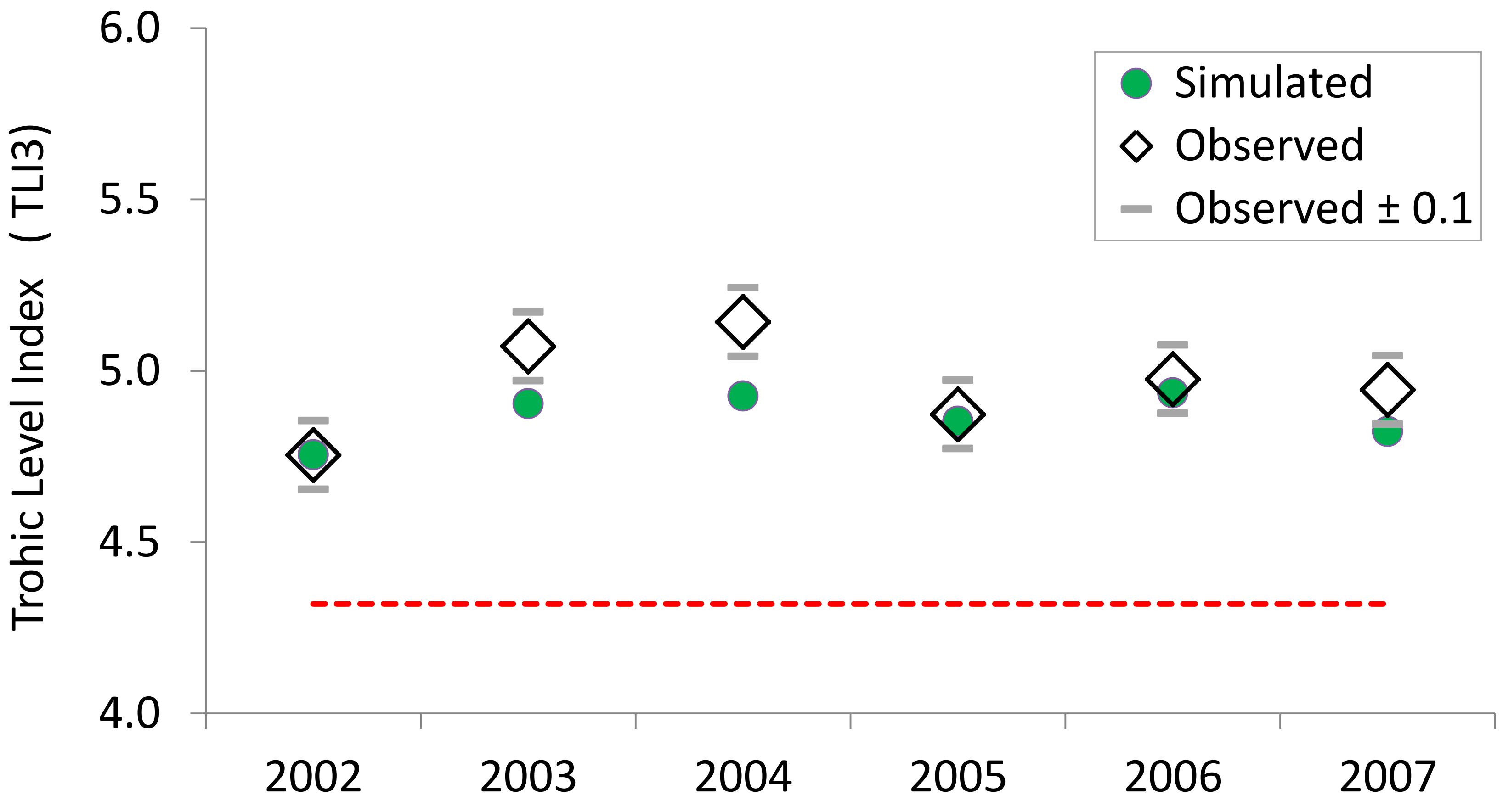




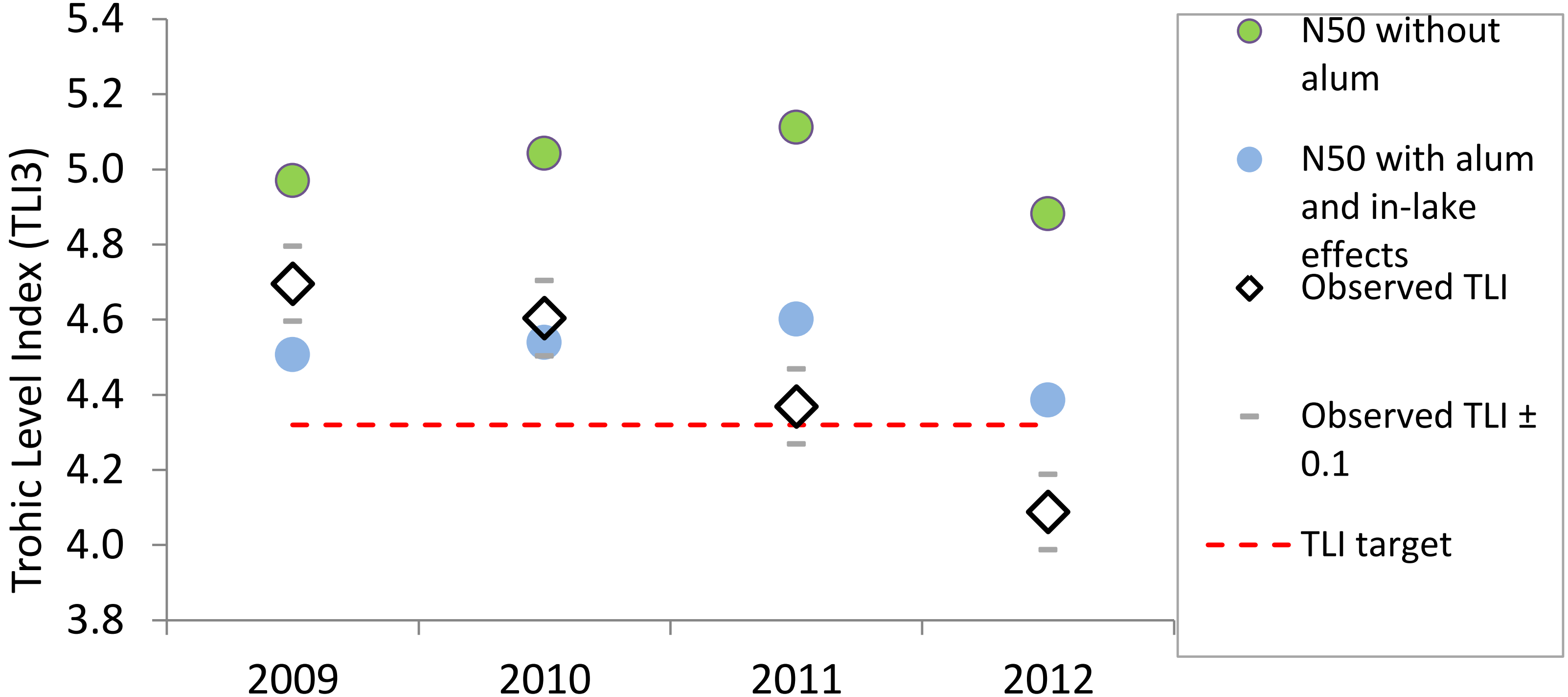
Examples: Surface water temperature and bottom dissolved oxygen concentration

Model calibration and validation: TLI3

Modelled TLI usually within 0.1 units of measured TLI

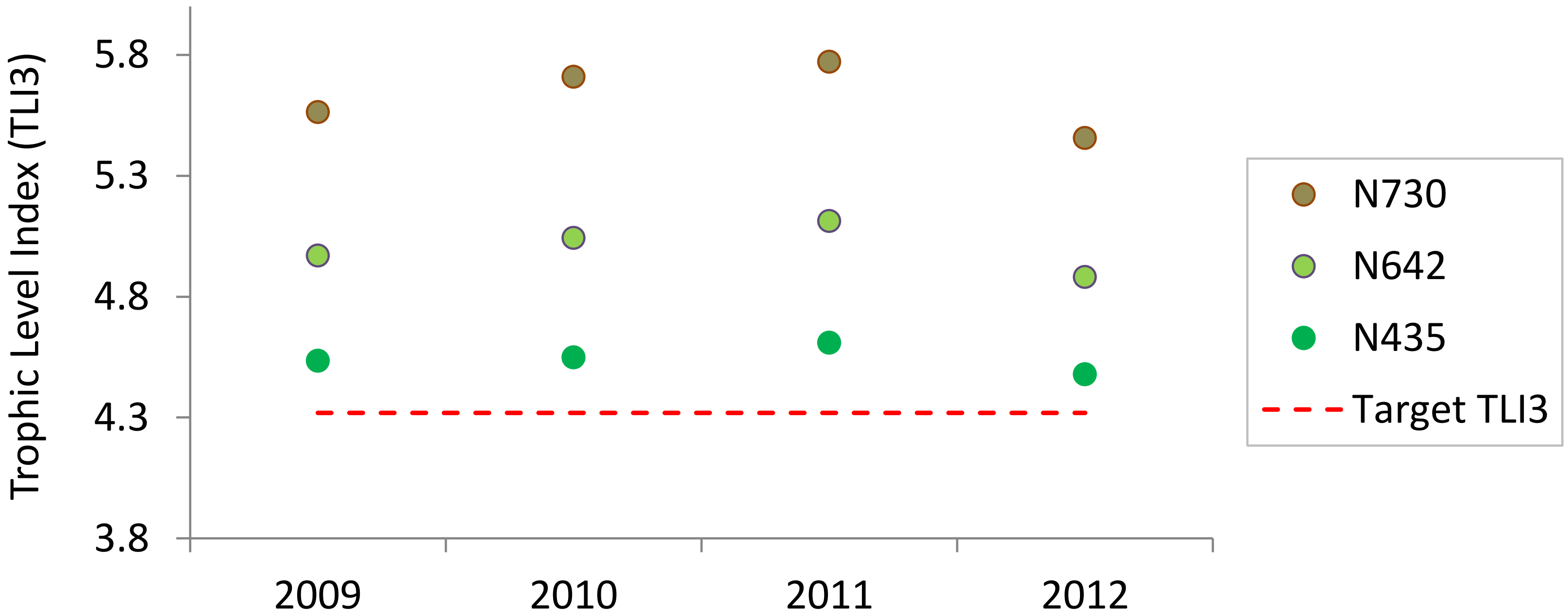


Model scenarios



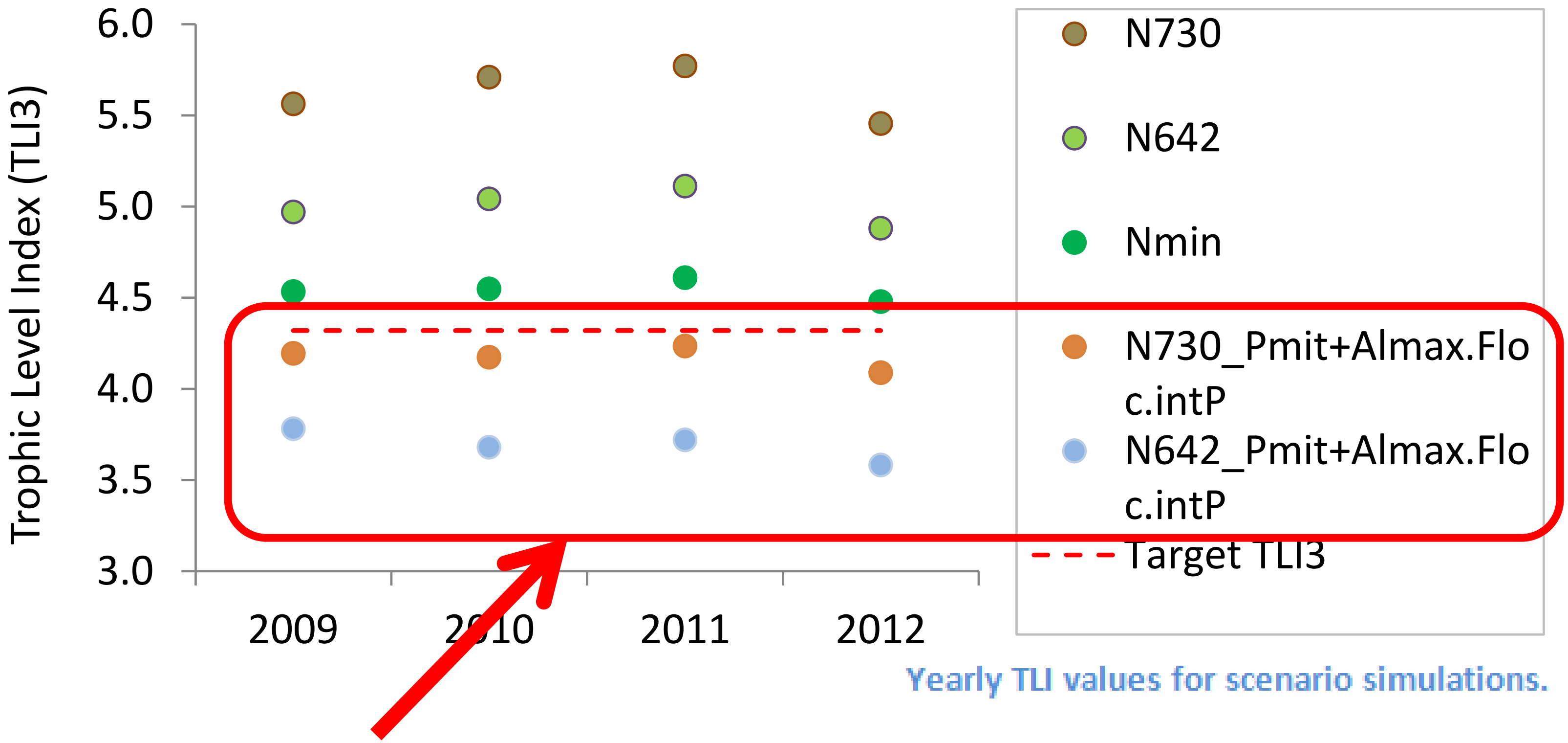
Comparison of observed Lake Rotorua Trophic Level Index (TLI) with simulated TLI for a scenario without any inflow alum dosing (green dots), and of alum dosing with in-lake effects (blue dots) including increased sedimentation of organic particulate matter (flocculation) and suppression of internal DRP release (50% reduction). The dashed red line is the TLI3-adjusted for Lake Rotorua (4.32).

Model scenarios: nutrient loads, no alum



Yearly TLI values for scenario simulations.

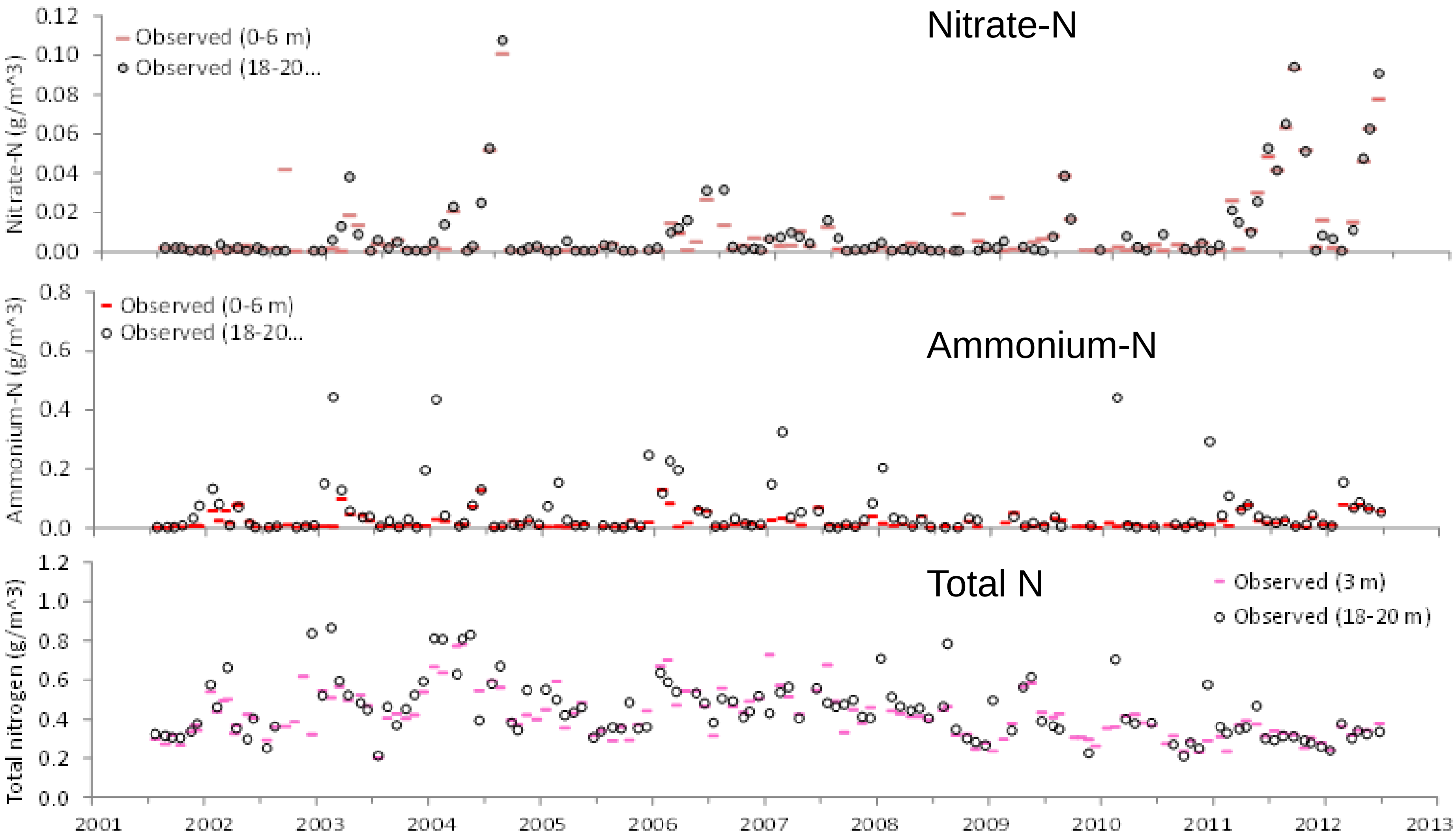
Model scenarios: all load scenarios including those with alum



Yearly TLI values for scenario simulations.

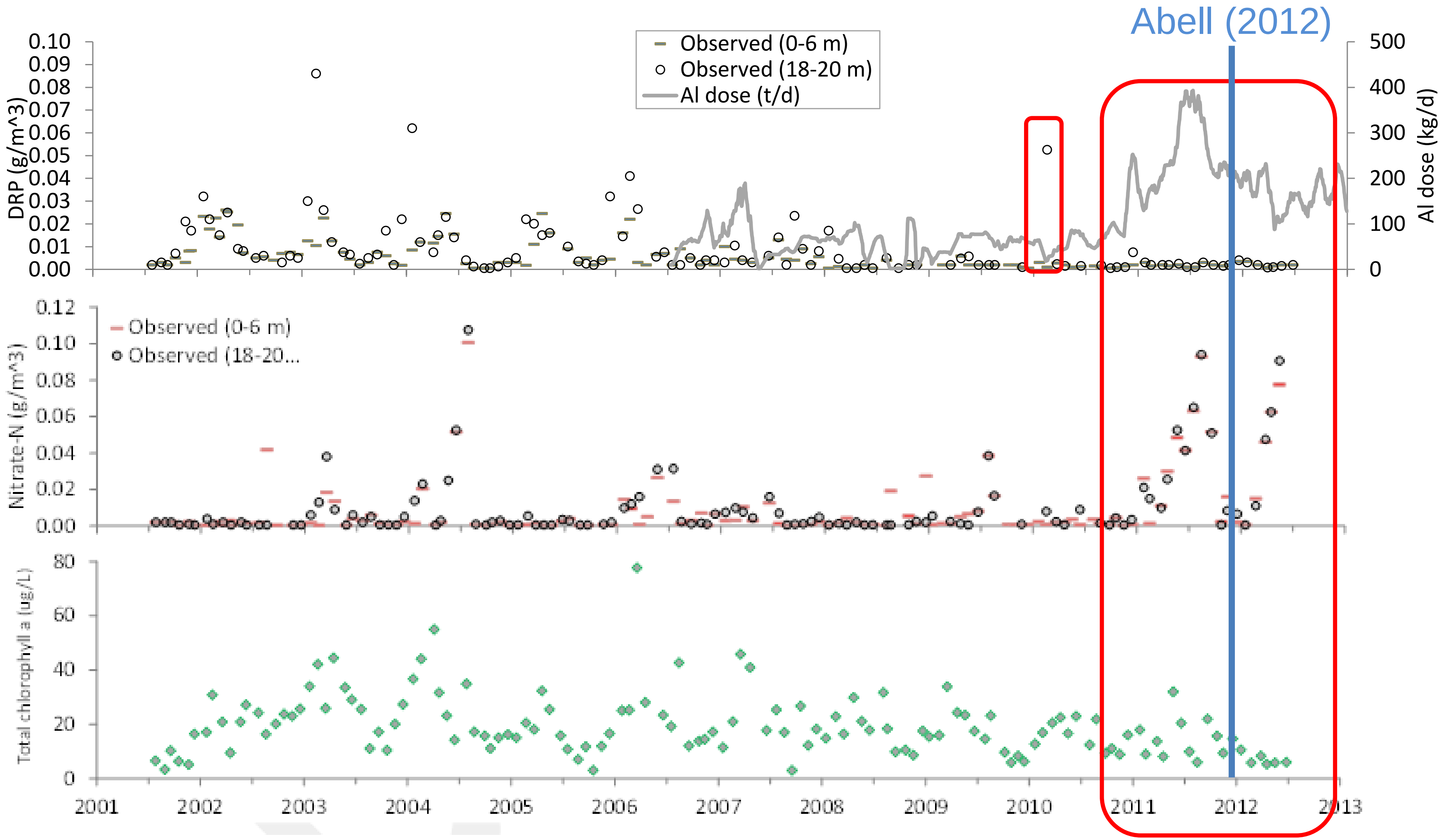
These scenarios include high alum dose rates to ALL inflows, and full in-lake effects including flocculation, internal load suppression and reduced bottom-water dissolved oxygen consumption!

In lake monitoring data

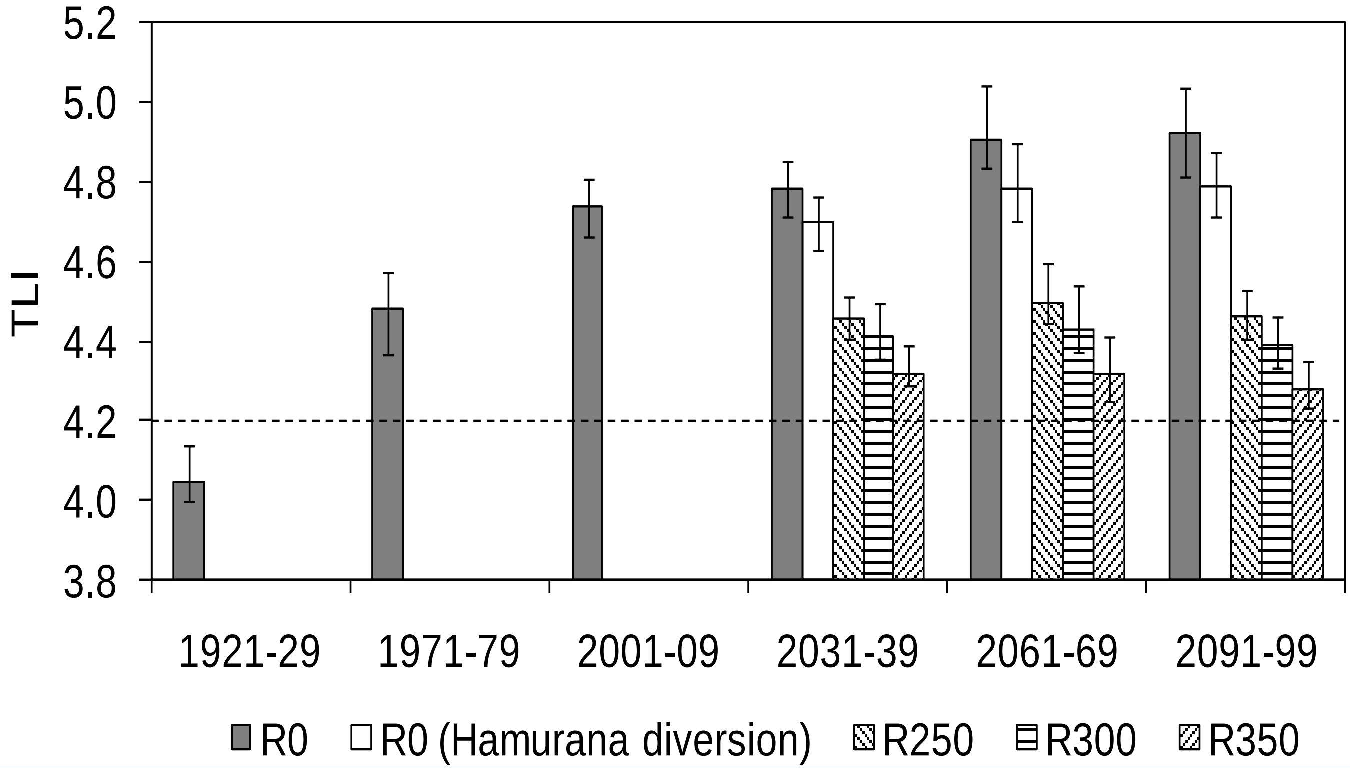


In-lake measurements for nitrate, ammonium, total nitrogen, dissolved reactive phosphorus (DRP), and total phosphorus at the surface (0 - 6m) and bottom (18 – 20m), and total chlorophyll a at the surface (0-6 m) from 2001 to 2013.

Potential for P-limitation (2011 – present), co-incident with increased alum dosing of inflows

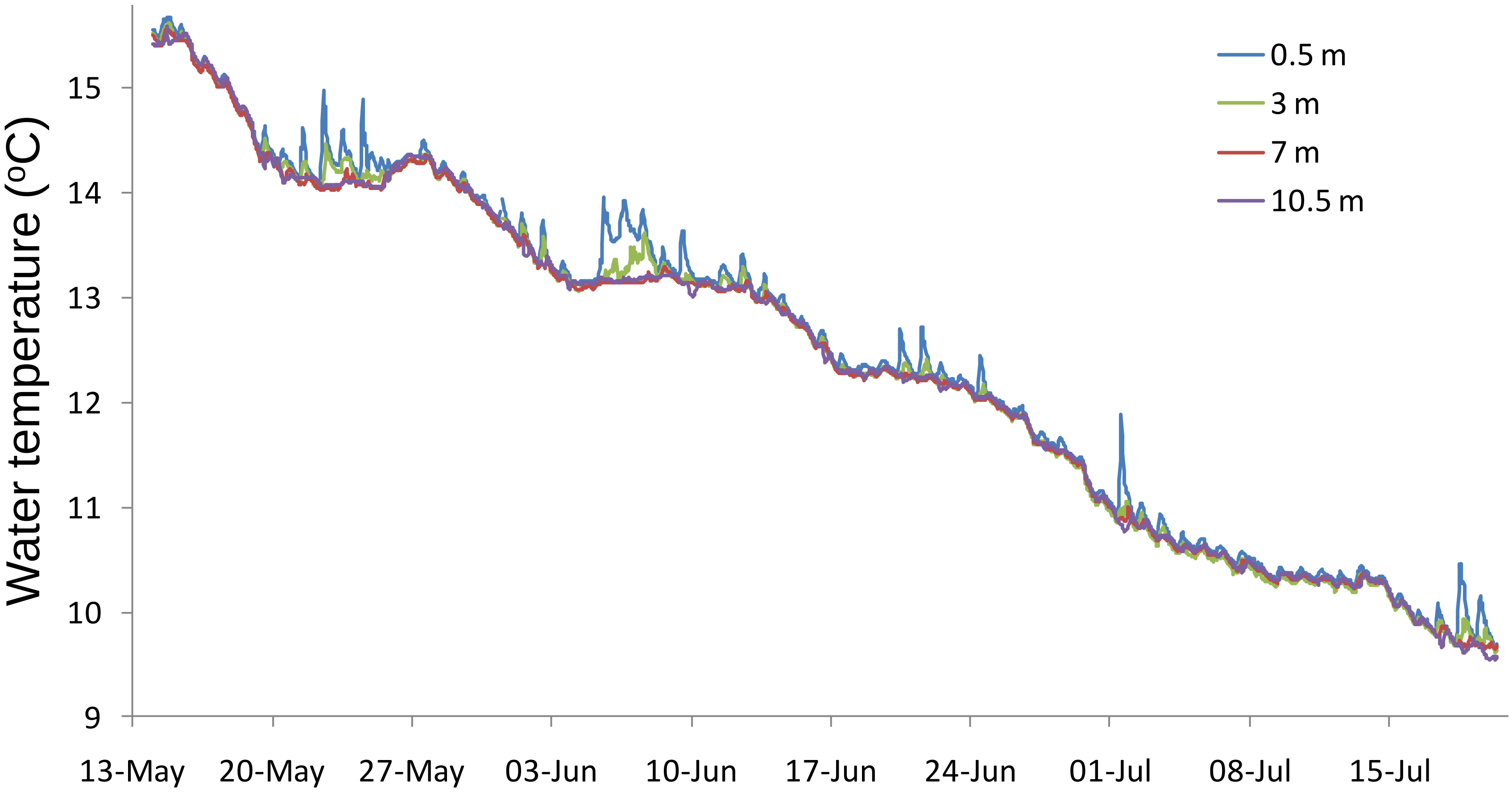


Effects of land use change and inflow diversion on Trophic Level Index (Target TLI = 4.2)



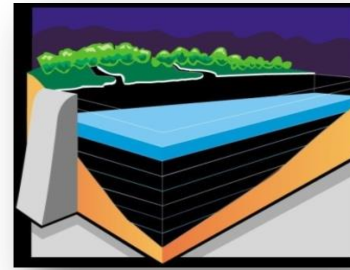
Lake Rotoehu

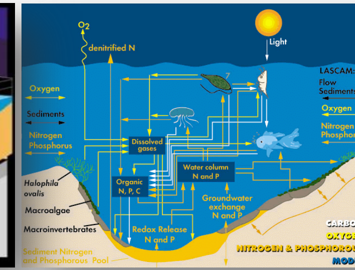
Lake Rotoehu: hourly-average water temperature



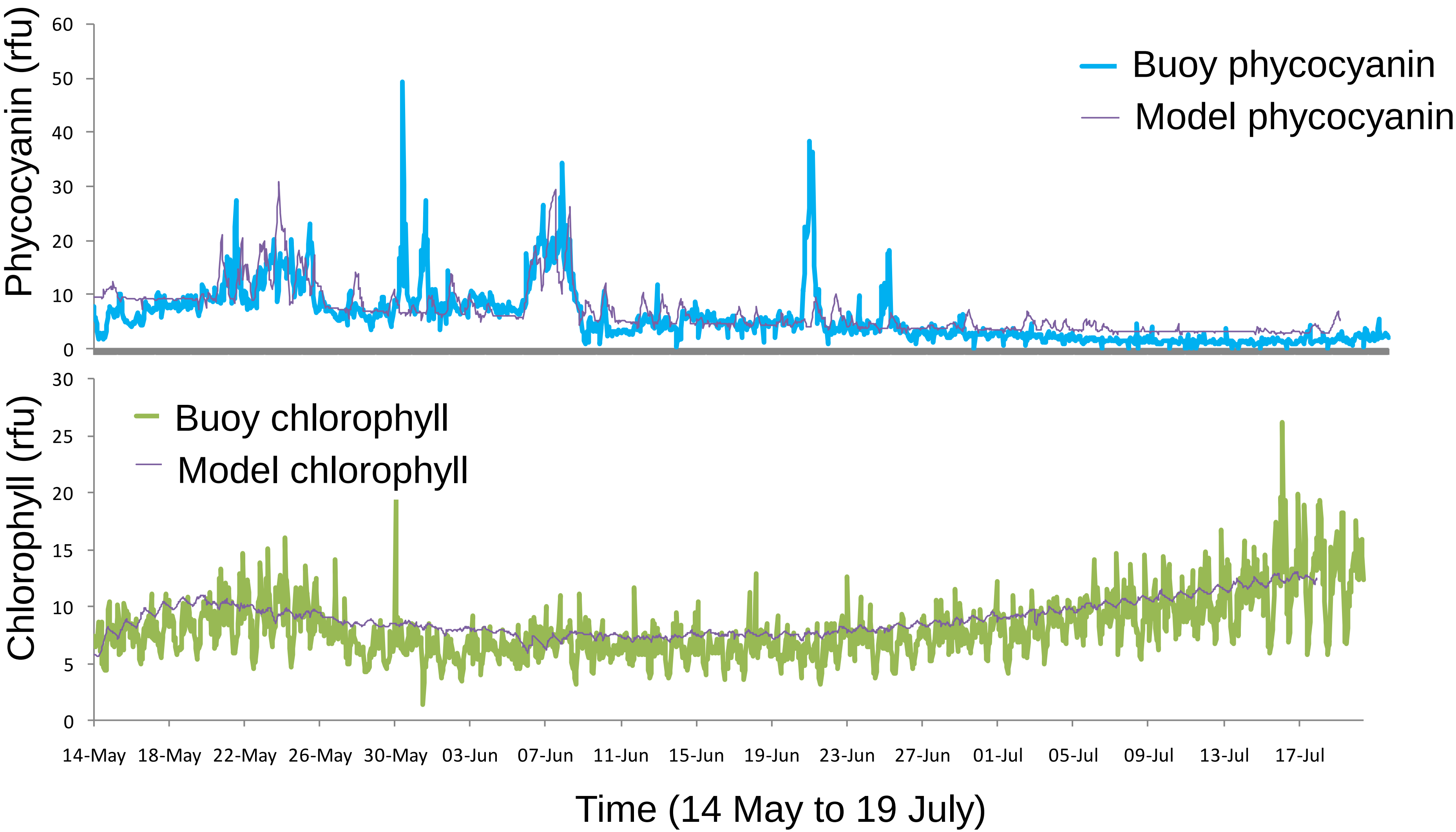
- Temperature cooling rapidly with onset of winter.
- Still get brief periods of stratification

High-frequency modelling: phycocyanin, chlorophyll

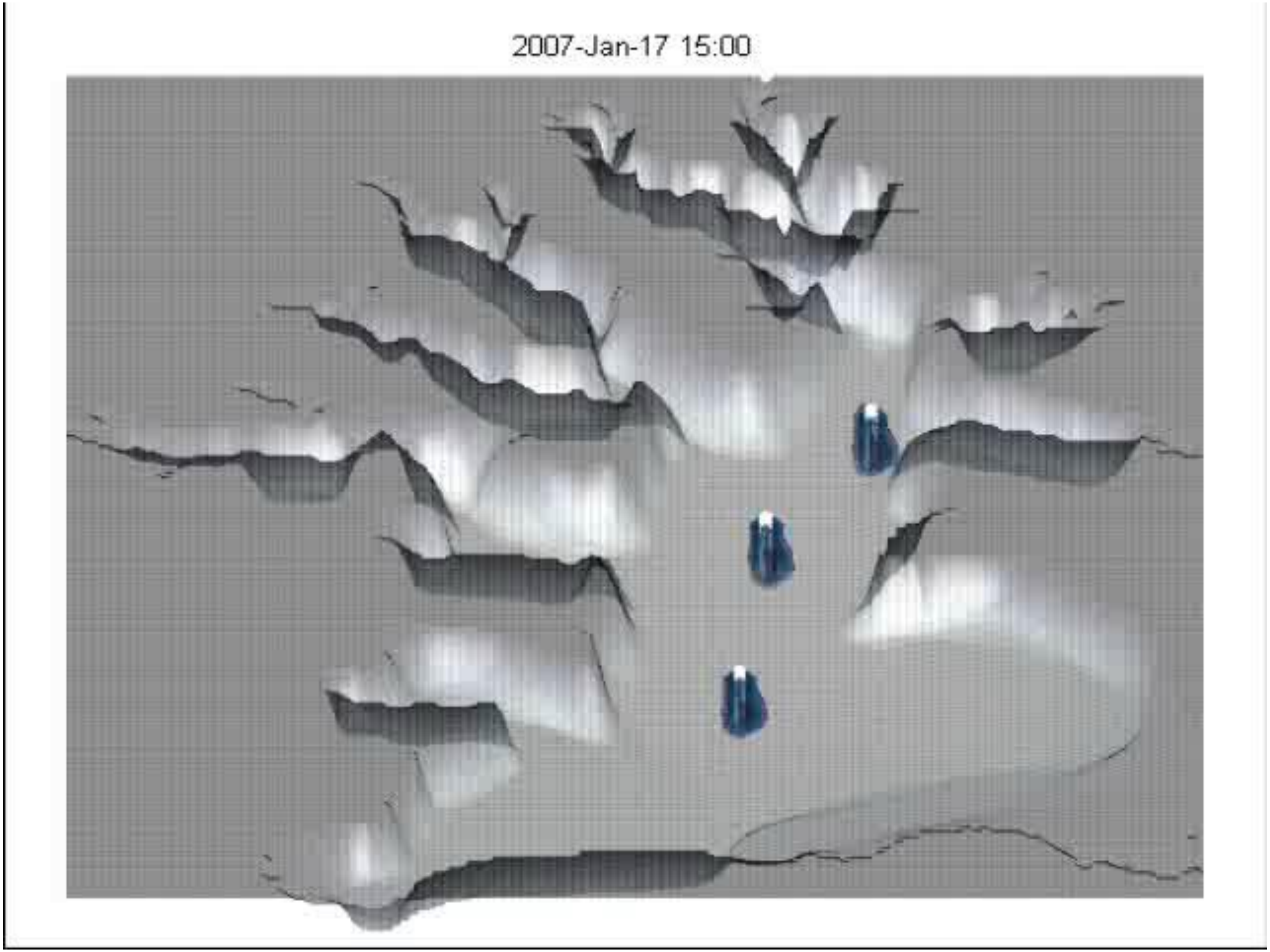




DYRESM-**CAEDYM**

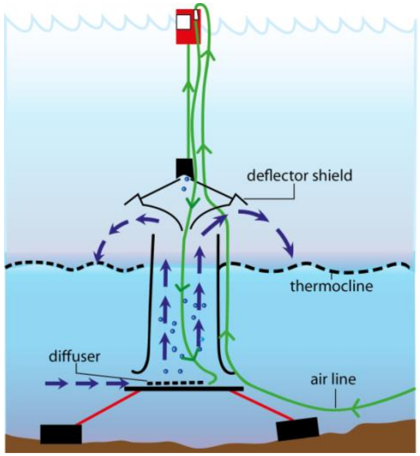


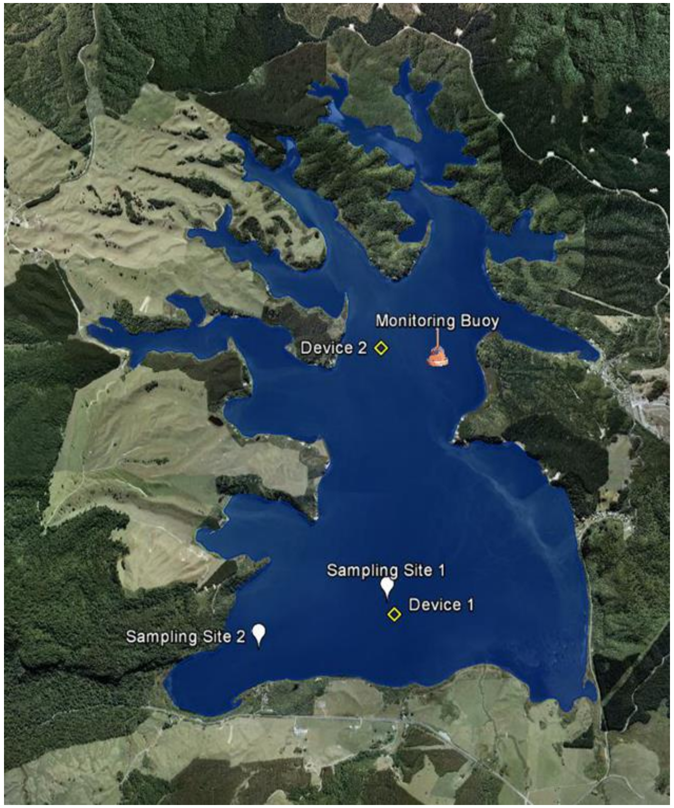
Lake Rotoehu destratification

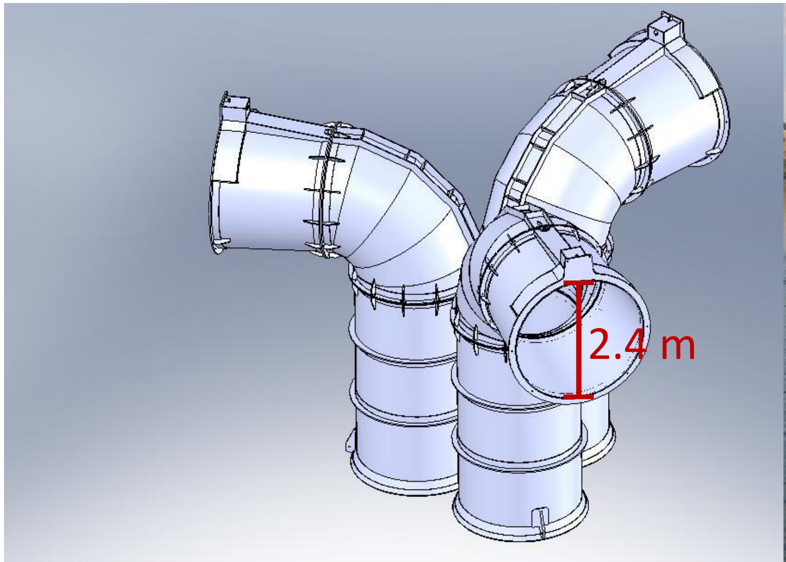


Lake Rotoehu: Artificial Destratification

- Air bubbles entrain cold bottom water.
- Colder water lifted above thermocline.
- Mixes and sinks causing breakdown of thermocline.
- Prevents anoxic release of nutrients







Lake Rotoehu destratification

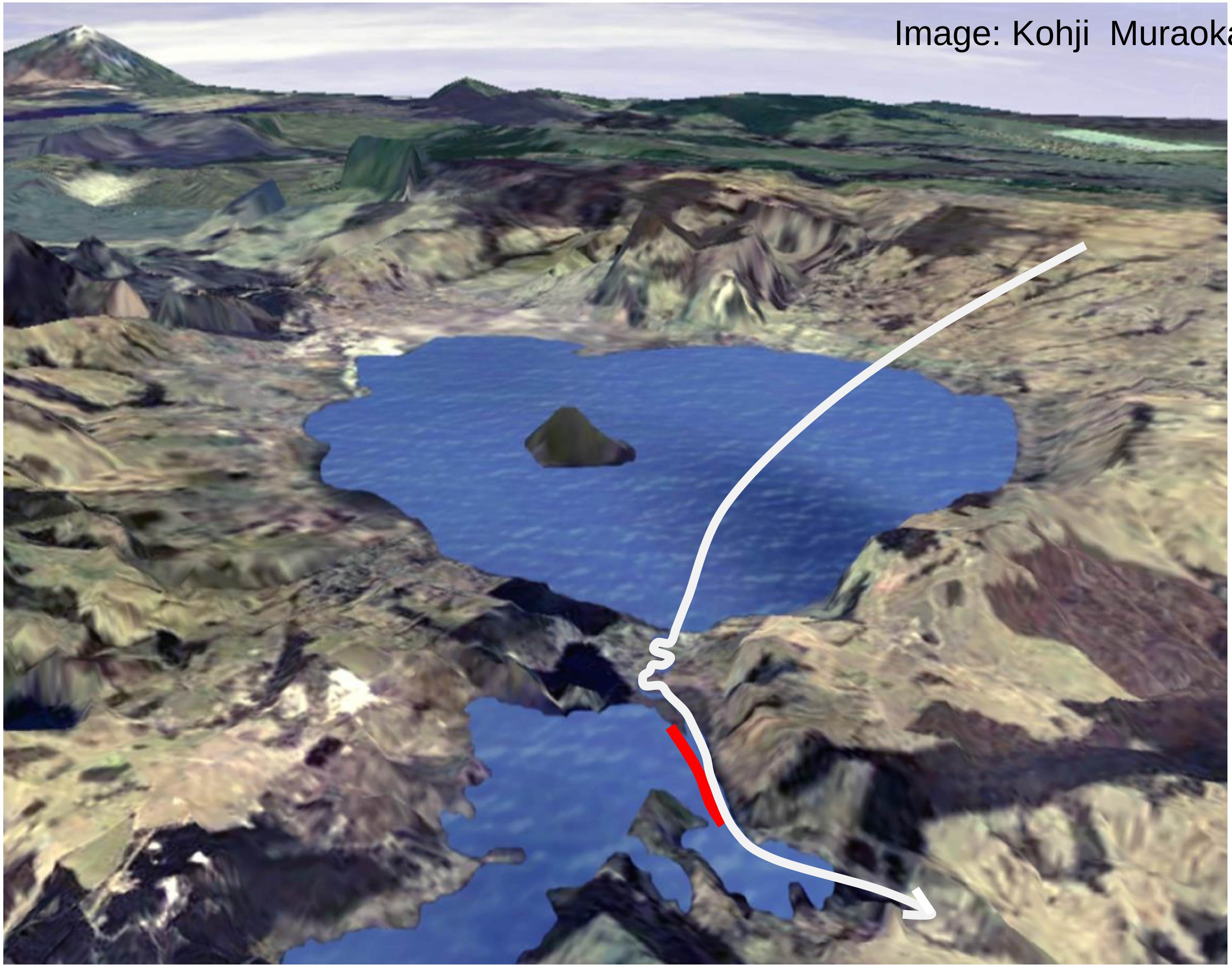
Weed harvesting, Lake Rotoehu

Lake Rotoiti

Inflows and outflows for Lake Rotoiti: Historical case

Photo: Environment BOP

Implications beyond Lake Rotorua: Ohau Channel diversion wall



Percentage of current Ohau Channel inflow versus cyanobacteria (as µg chl a L^{-1}) in Lake Rotoiti

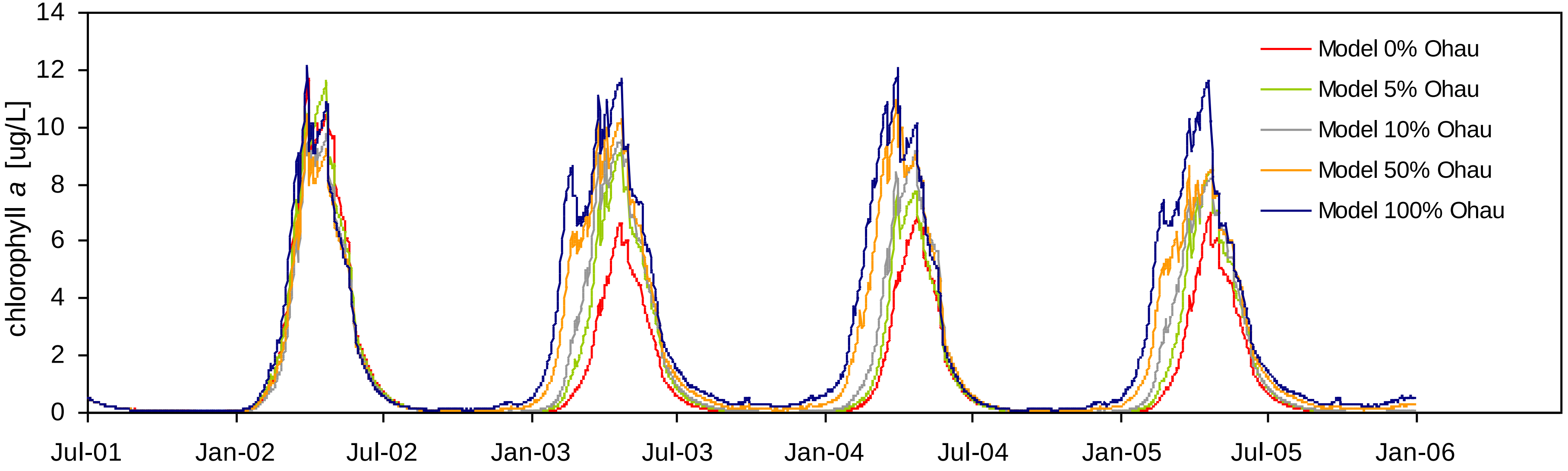
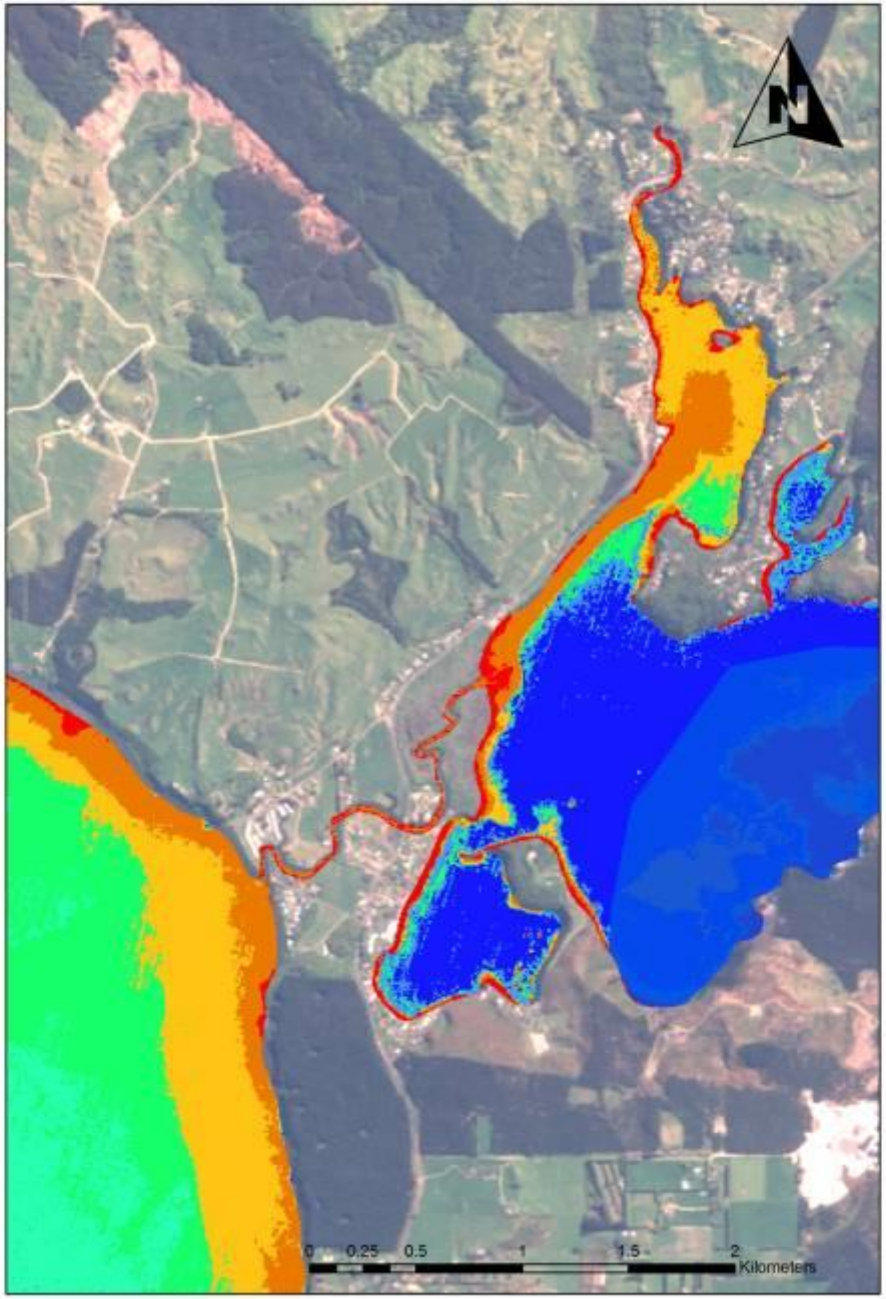
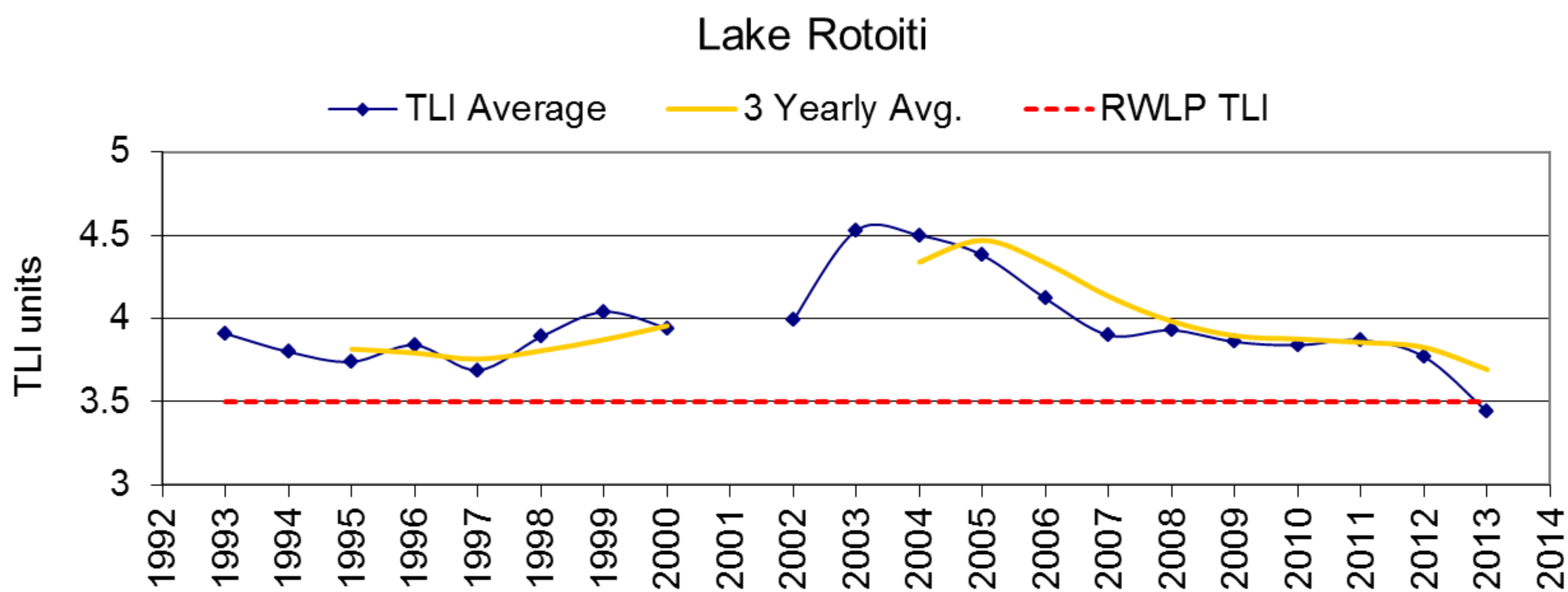


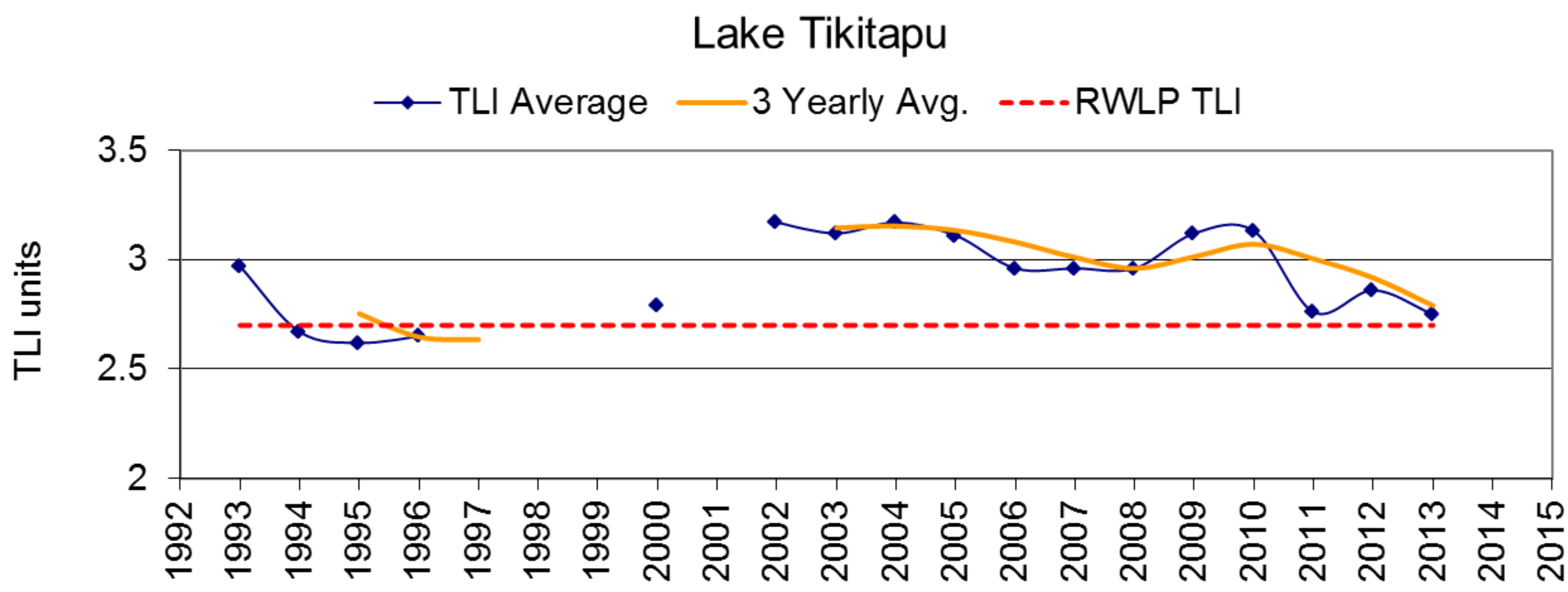

Photo: Andy Bruere, BOPRC

Satellite/aerial views of diversion wall, Lake Rotoiti





Lake Rotoiti
TLI Average
3 Yearly Avg.
RWLP TLI
TLI units
5
4.5
4
3.5
3
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014


Lake Tikitapu
TLI Average
3 Yearly Avg.
RWLP TLI
TLI units
3.5
3
2.5
2
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
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2004
2005
2006
2007
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2011
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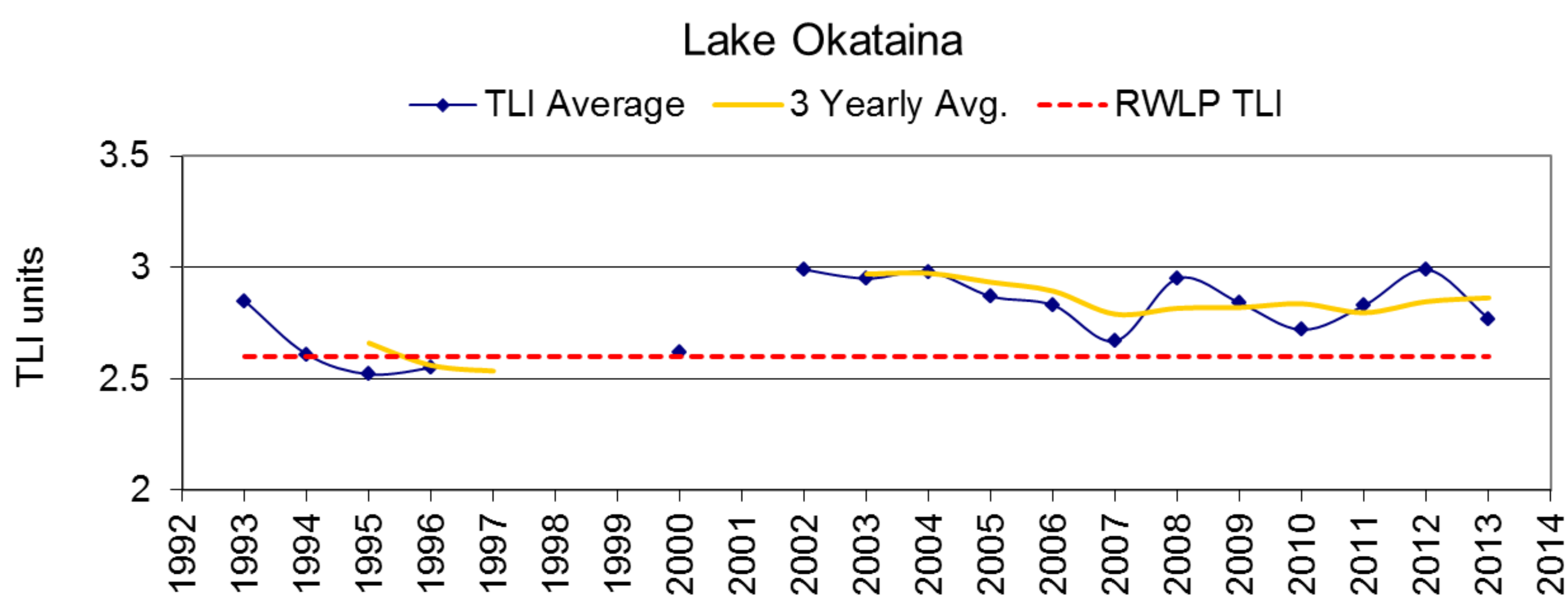
2014
2015


Lake Okataina
TLI Average
3 Yearly Avg.
RWLP TLI
TLI units
3.5
3
2.5
2
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

Vegetation disturbance and water quality of Lake Okataina

1314AD and 1886AD

1920's

1905

Reached here 1979

Changes in water quality

Post Tarawera

- Organic Carbon (+2%)
- Total pigments (No change)
- Phosphorus (+5%)
- Sedimentation (+2%)

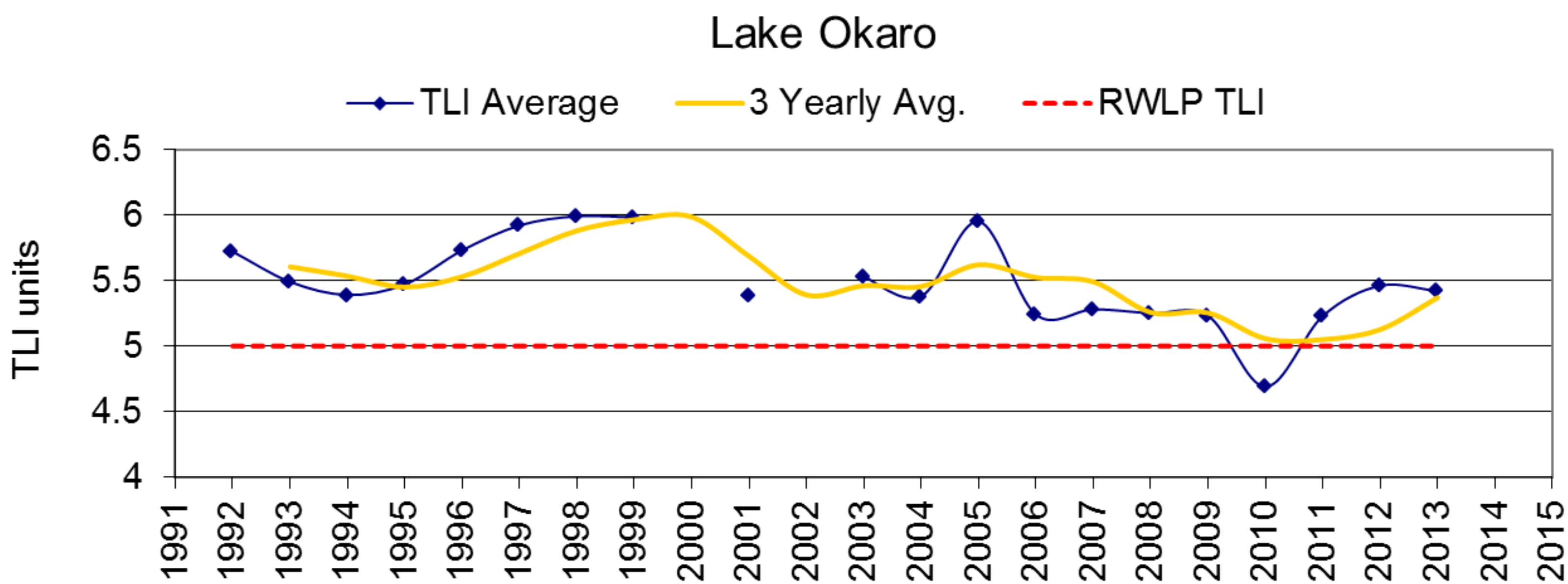
Post invasive wildlife introduction

- Organic Carbon (+19%)
- Total pigments (20%)
- Phosphorus (+21%)
- Sedimentation (+30%)

Lake Tikitapu, 2004

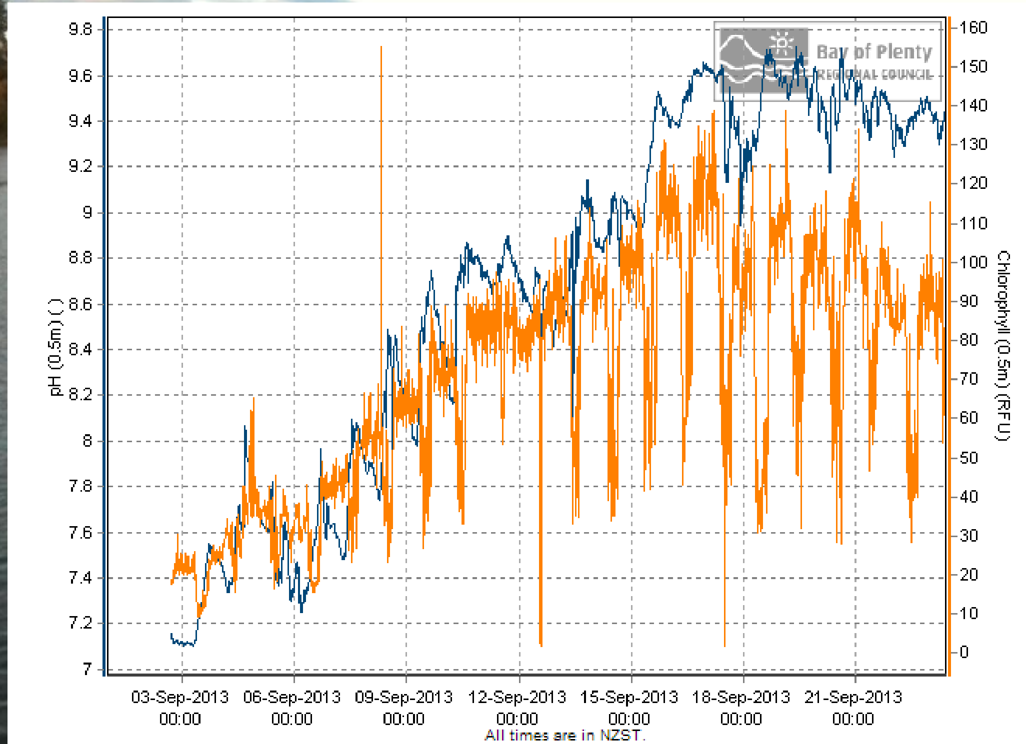
Potential to apply models to major lake ecosystem perturbations: Modified zeolite application to Lake Okaro


Lake Okaro constructed wetland
Photo A. Bruere, EBoP



Lake Okaro
TLI Average
3 Yearly Avg.
RWLP TLI
TLI units
6.5
6
5.5
5
4.5
4
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015

pH monitoring buoy for Lake Okaro



Colour	Samples	Point	Units	Format	Aggregate
		Lake Okaro Buoy : pH (0.5m)		Default	Plot Period
		Lake Okaro Buoy : Chlorophyll (0.5m)	RFU	Default	Plot Period

Point 1. Ecological processes in lakes will generally not follow linear trajectories expected from linear changes in external forcings (e.g. catchment nutrient loads)

Point 2. Reductions in external loading are fundamental to effective control of eutrophication. Diffuse sources now represent the greatest challenge to external nutrient reductions

Point 3. Despite many years of theoretical, empirical and modelling studies, we have often failed to adequately capture and quantify nutrient loads, particularly stormloads

Point 4. Opportunities exist to virtually revolutionise temporal and spatial coverage of lake ecosystems but require lake ecologists to adopt increasingly flexible, interdisciplinary communication linkages that may not necessarily initially be fully productive.