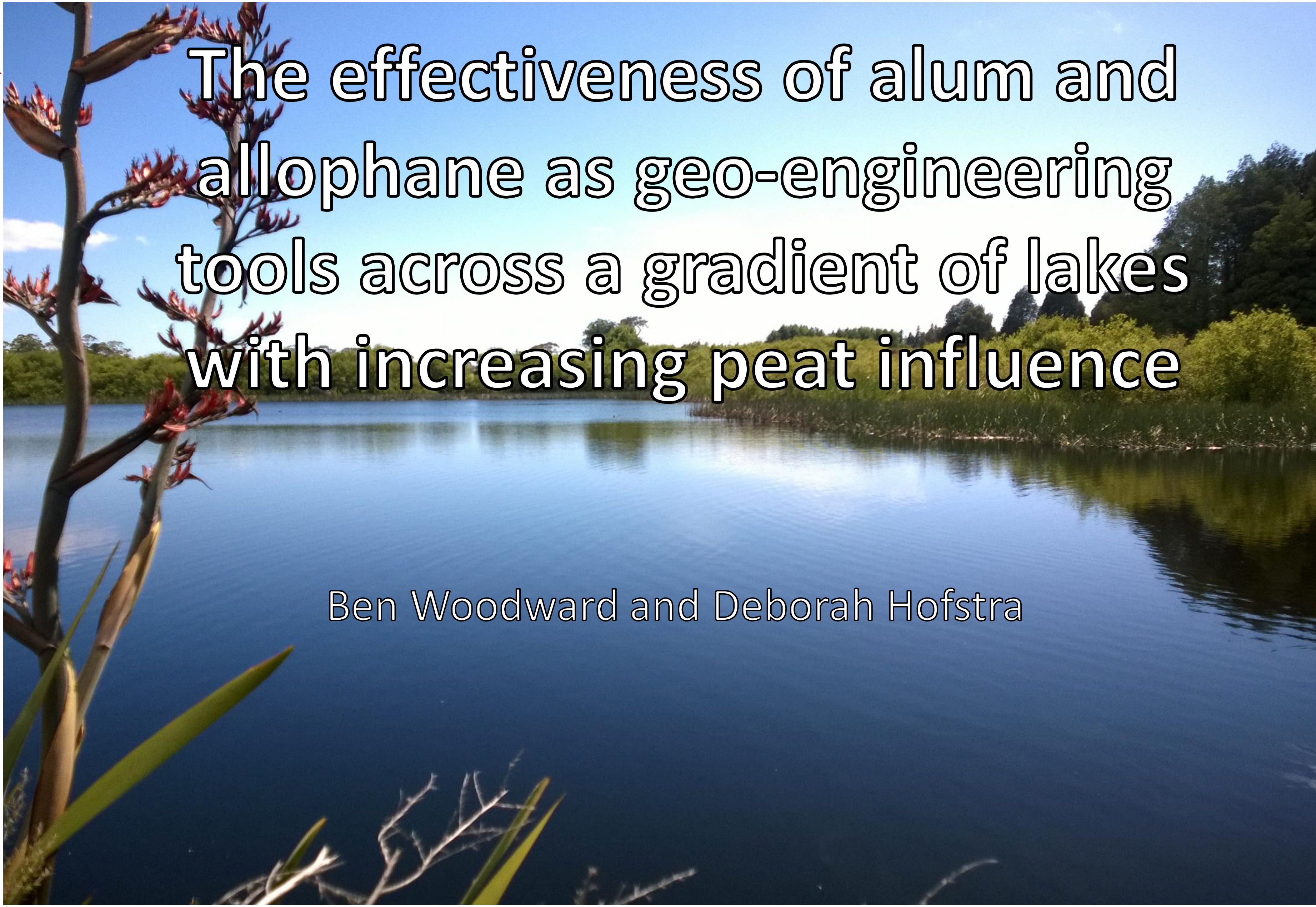
The effectiveness of alum and allophane as geo-engineering tools across a gradient of lakes with increasing peat influence

Ben Woodward and Deborah Hofstra



The state of lakes in New Zealand

- 36% of lakes rated poor or very poor,
- 28 % rated moderate,
- 36% rated good.

Source; Larned et al, 2015

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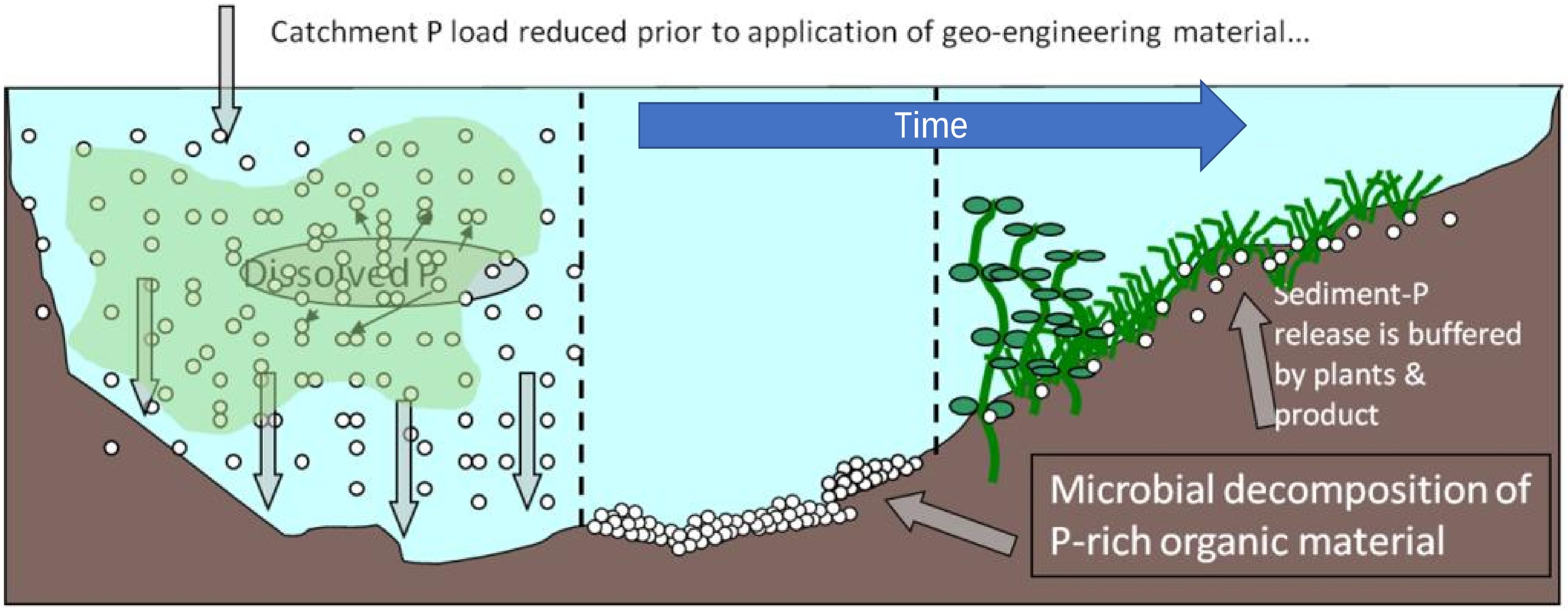
Degraded shallow lakes

FORCING A CHANGE OF STATE

Following successful reduction of catchment P inputs, internal loading feedback mechanism is disrupted using geo-engineering products providing an opportunity for aquatic macrophytes to re-establish lake bed sediments



Modified from MacKay et al. 2015

The treaty of Waitangi and co-governance

- A treaty between the British and the Māori chiefs
- It recognised Māori ownership of their lands and forests
- Māori have co-governance of natural resources in New Zealand

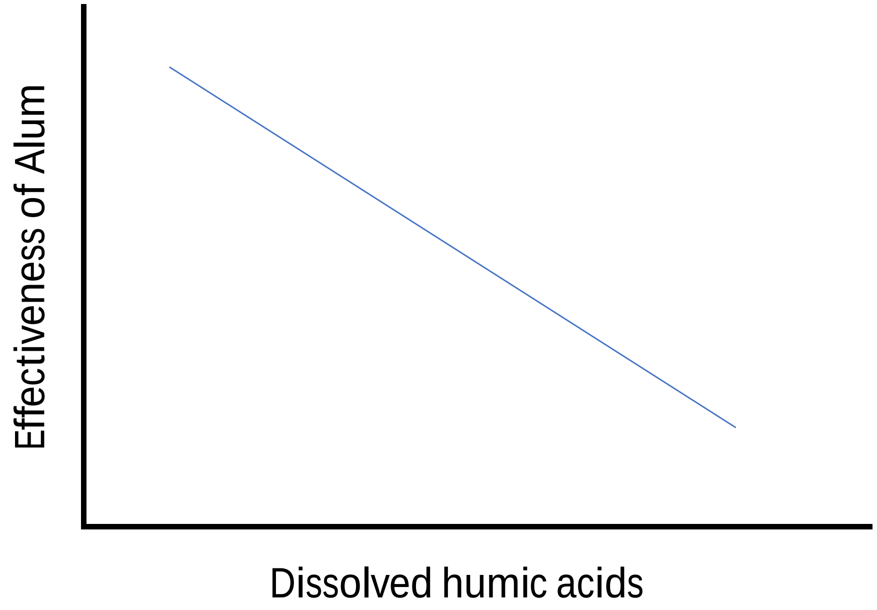
- In the context of lake management this means that local Māori groups (Iwi) need to approve of methods used to rehabilitate lakes.

- Iwi measure water body health in a holistic, value based method
- Generally, Iwi groups see adding “chemicals” to water bodies as being an unhealthy practice

Alum and Allophane

Alum

- Aluminium sulphate ($Al_2(SO_4)_3$) is a flocculent and a capping agent
- Probably, the most commonly used lake geo-engineering product around the world



Allophane

- Allophane is a naturally occurring clay mineral found in allophanic soils
- It has a high content of iron and aluminium giving it a high phosphorus binding capacity

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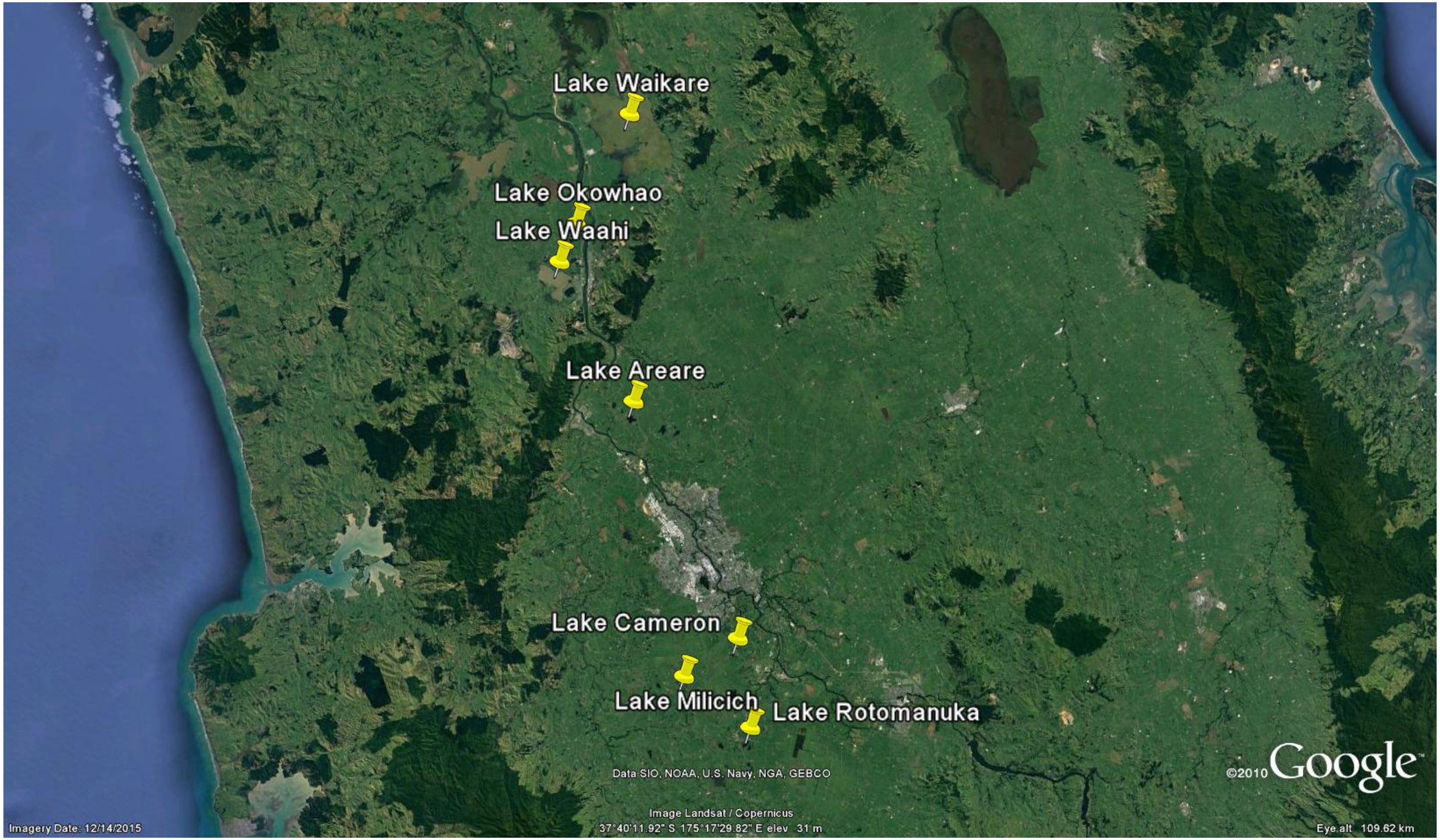
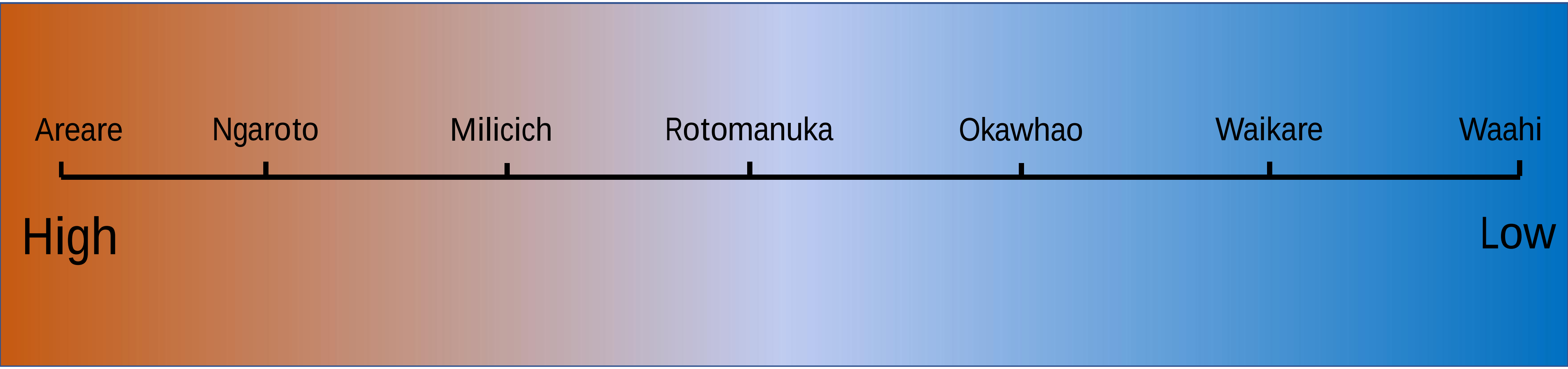


Lake Waikare
Lake Okowhao
Lake Waahi
Lake Areare
Lake Cameron
Lake Milicich
Lake Rotomanuka
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Imagery Date: 12/14/2015
37°40'11.92" S 175°17'29.82" E elev 31 m
©2010 Google
Eye alt 109.62 km

The lakes



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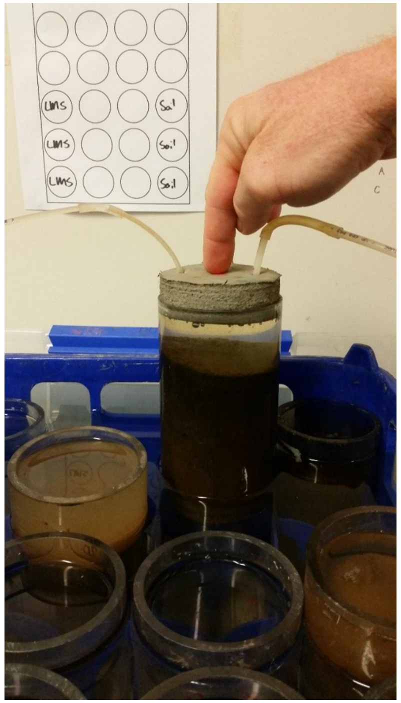
The experiment

Gibbs et al (2011)



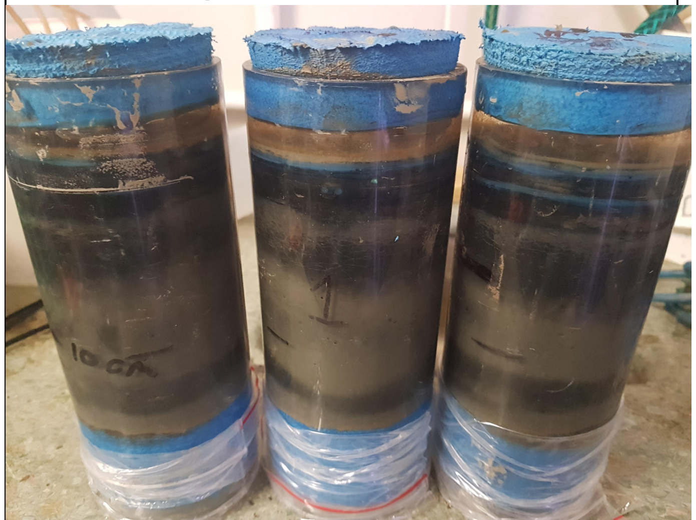
3 replicates of;
Control
Alum
Allophane

Dose rates based on TP in the top 4 cm of sediment

2 days anoxic
1 day rest
2 days oxic
1 day rest
2 days anoxic
1 day rest
2 day oxic

Lukkari et al (2007)

Phosphorus fractionation

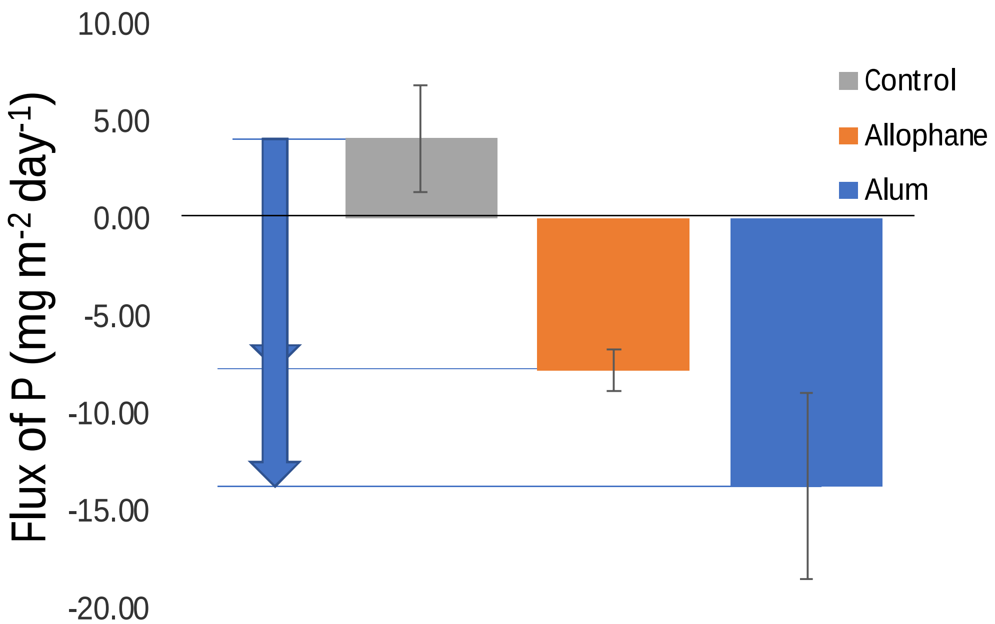


- Refractory organic P (furnacing and HCl)

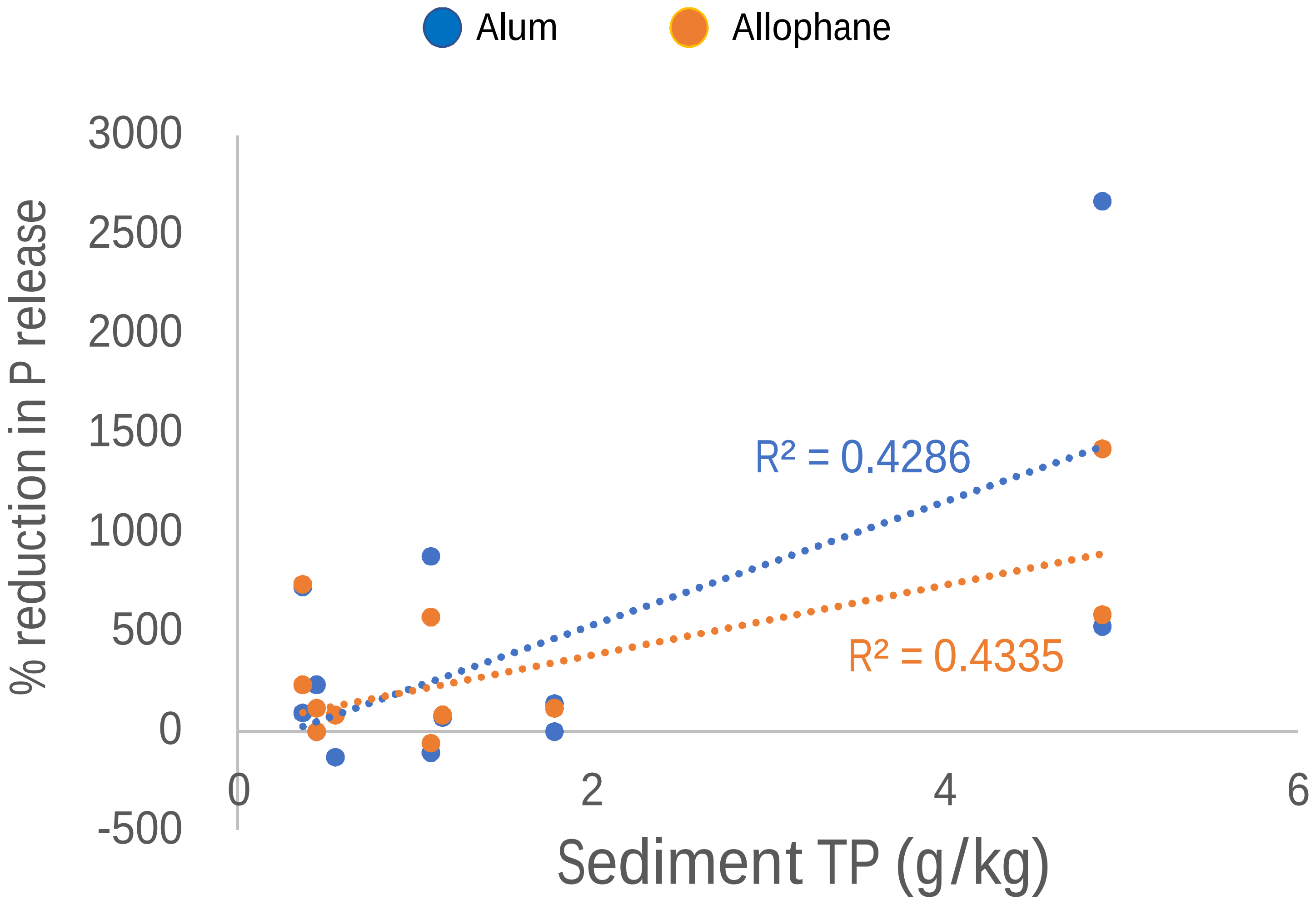
Using the top 2 cm of sediment

The format of the incubations results

The results of the incubations will be expressed as a % reduction of P flux from the control



Aerobic periods and sediment TP



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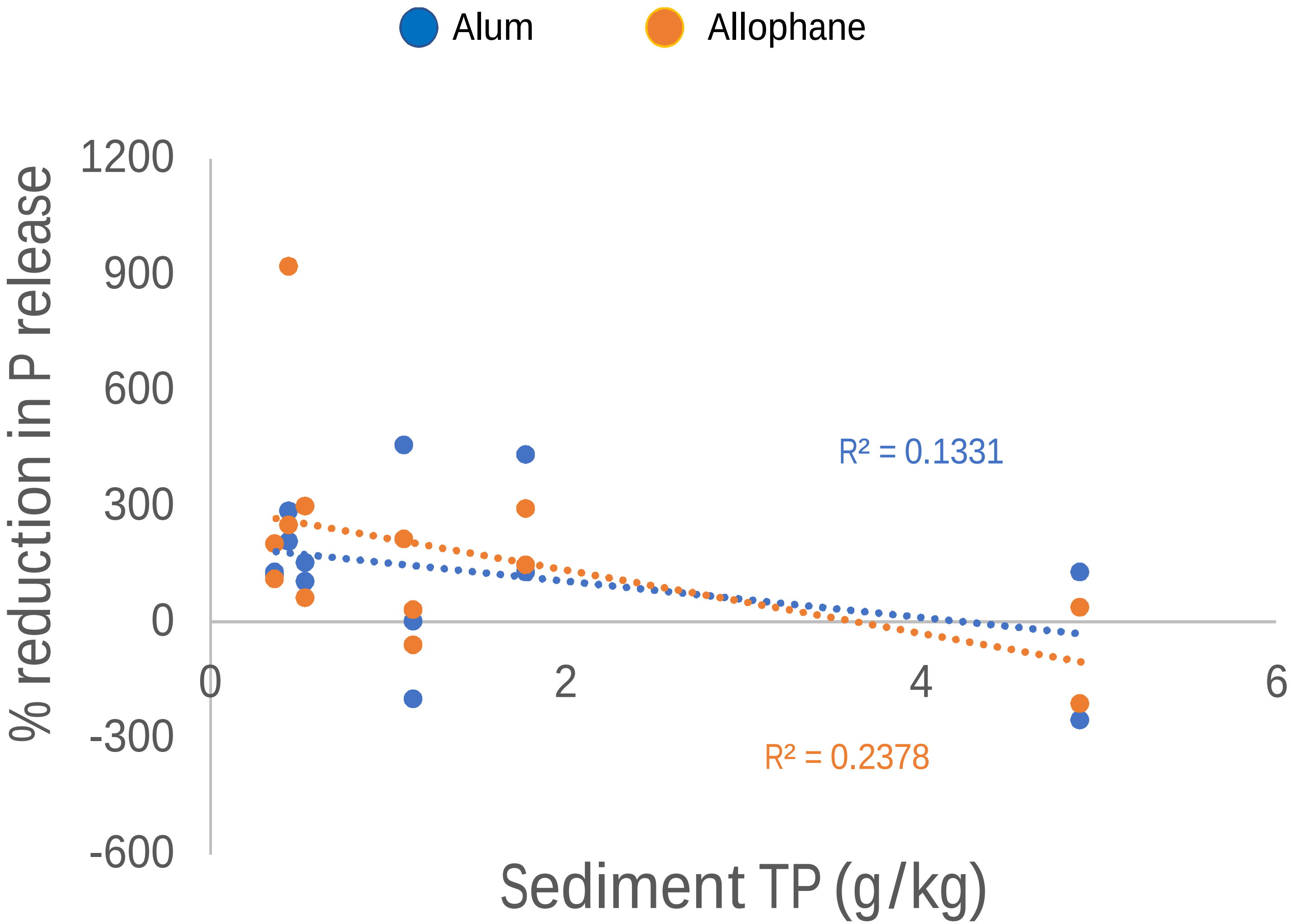
Anoxic periods and sediment TP



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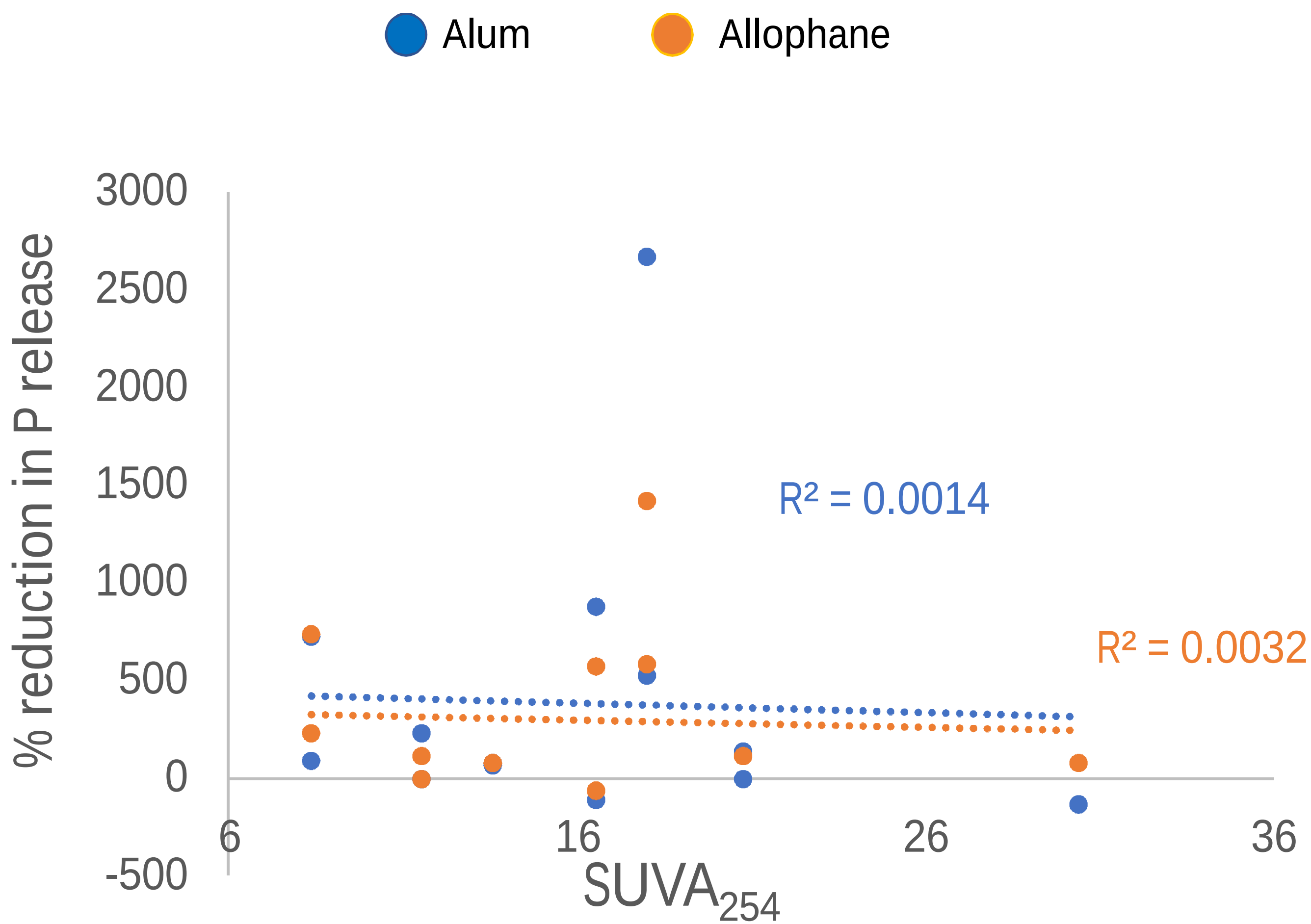
Aerobic periods and $SUVA_{254}$



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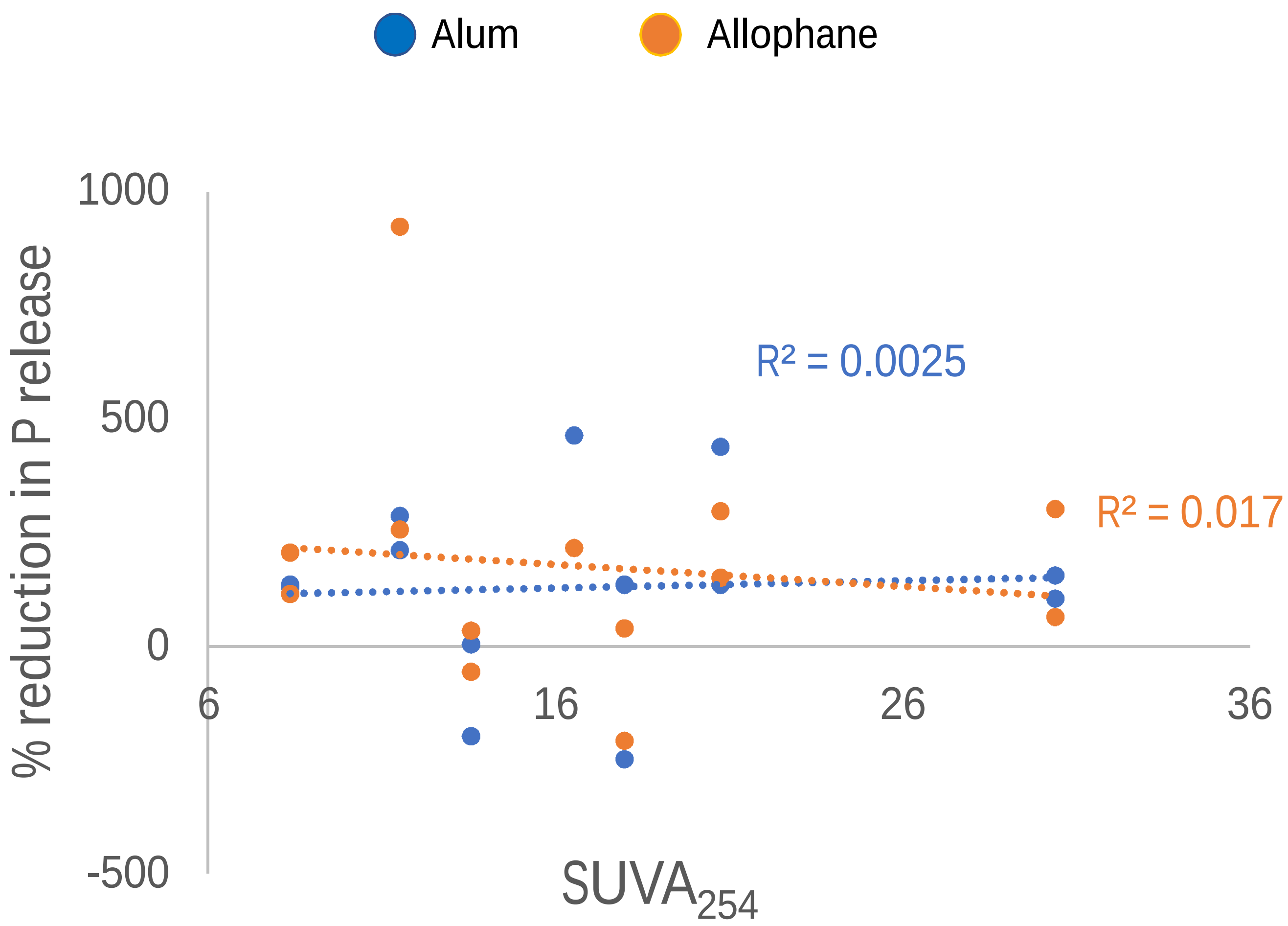
Anoxic periods and $SUVA_{254}$



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Overall percentage reduction across all Lakes

	Aerobic period reduction compared to controls (% ± SD)	Anoxic period reduction compared to controls (% ± SD)
Alum	381 ± 750	130 ± 204
Allophane	296 ± 417	175 ± 265

The format of the P fraction results

Phosphorus fractionation extractions

- Pore water and loosely bound P (NaCL)
- Redox sensitive P (NaBD)
- Al oxide and non-reducible Fe (NaOH)
- Apatite and other inorganic P (HCl)
- Refractory organic P (furnacing and HCl)

Mobile Phosphorus expressed as % change from control

Non-mobile Phosphorus expressed as a % change from the control

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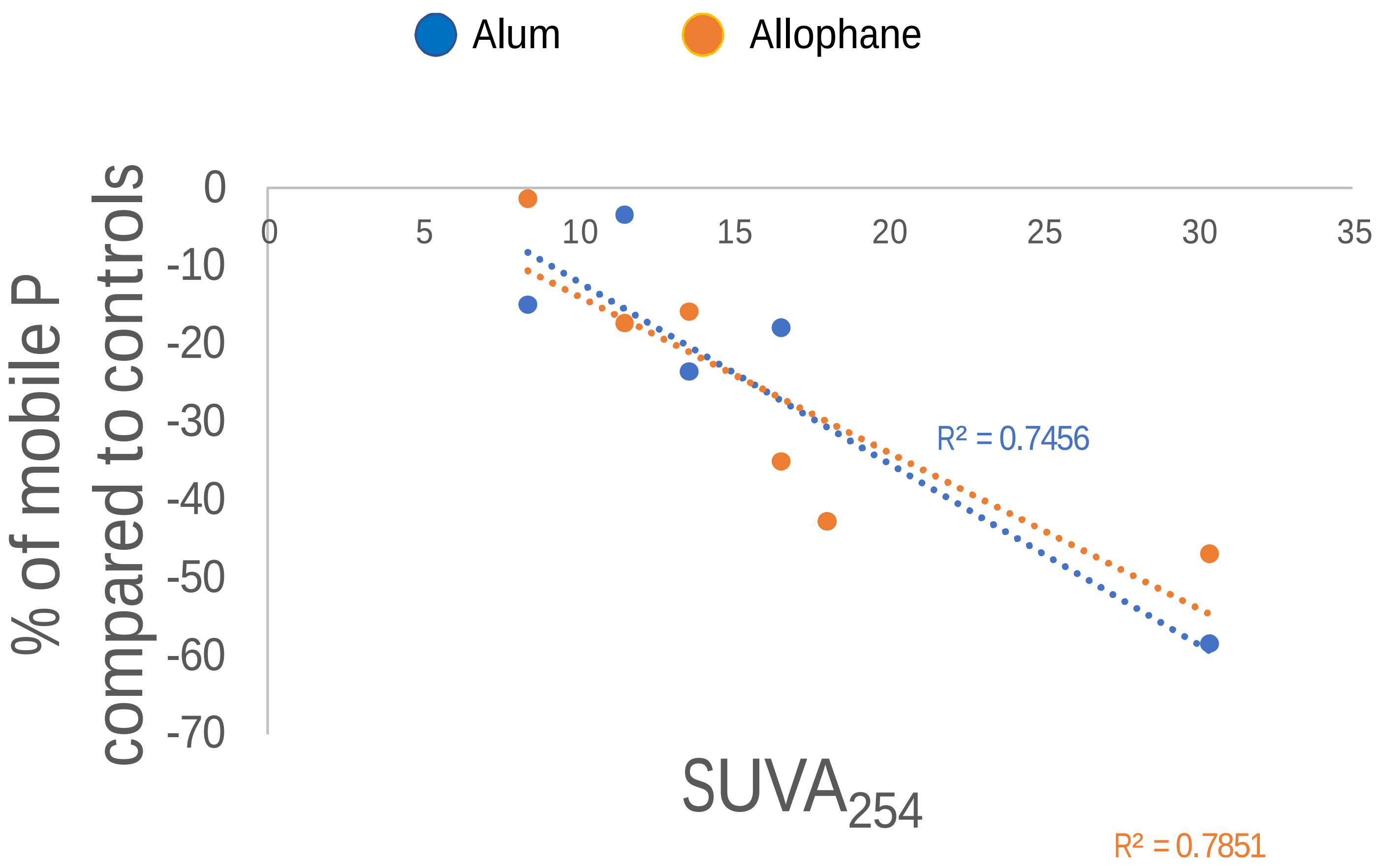
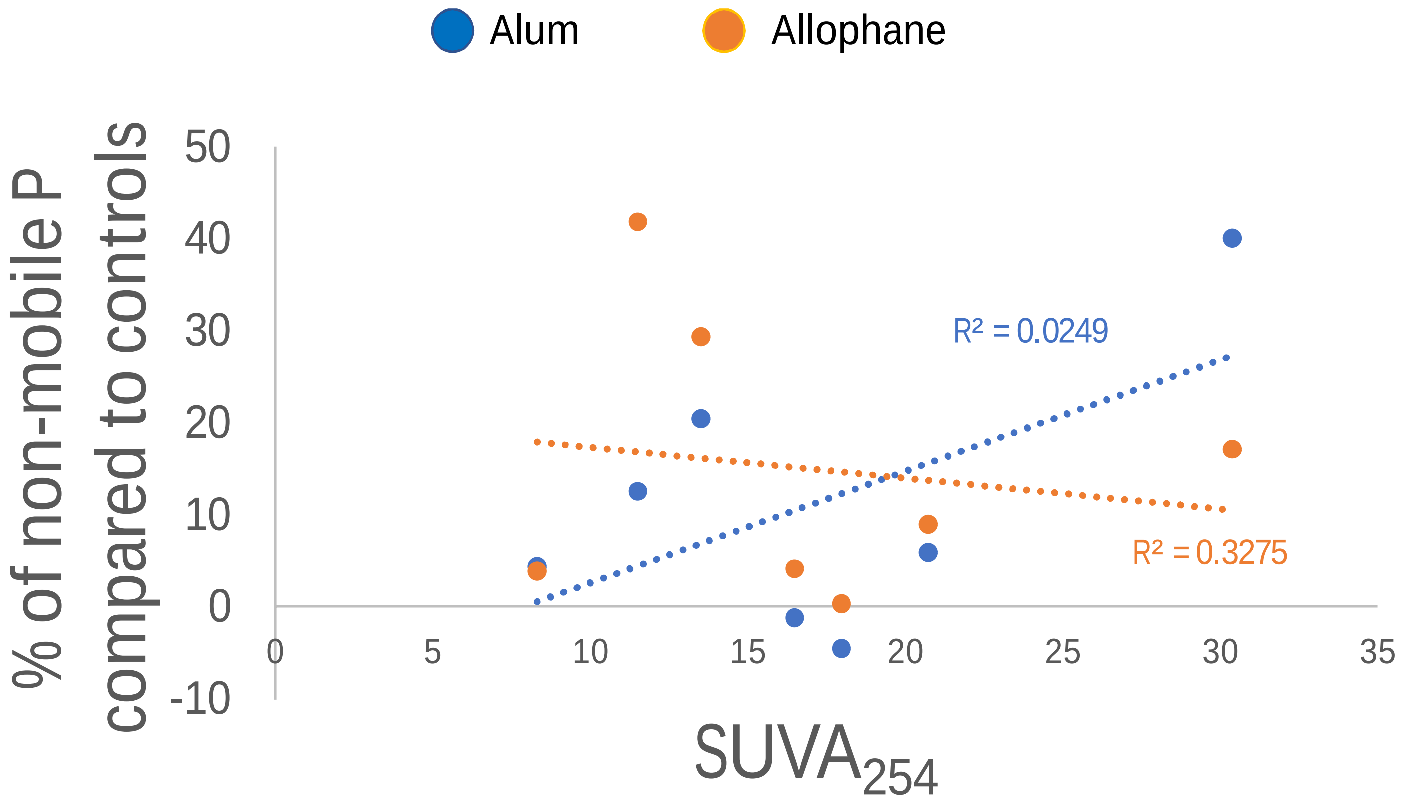
SUVA$_{254}$ and mobile P fractionations



$SUVA_{254}$ and non-mobile P fractionations



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Conclusions and further analysis

- Allophane seems to be a viable natural alternative to alum
- High total phosphorus in the sediment reduces the effectiveness of both alum and allophane under anoxic conditions
- The $SUVA_{254}$ did not affect P fluxes during the incubations - which was unexpected
- Increasing $SUVA_{254}$ decreased mobile P when alum and allophane were applied - which is the opposite of what was expected

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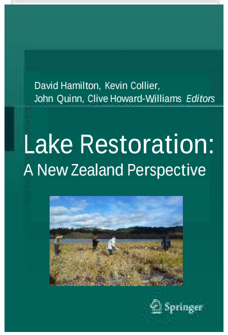

Lake Restoration Handbook

A New Zealand Perspective

Editors: **Hamilton**, D., **Collier**, K., **Quinn**, J., **Howard-Williams**, C. (Eds.)

Integrates leading technologies, models, indigenous knowledge, and citizen science on lake restoration

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Lakes across the globe require help. *The Lake Restoration Handbook: A New Zealand Perspective* addresses this need through a series of chapters that draw on recent advances in modelling and monitoring tools, citizen science and First Peoples' roles, catchment and lake-focused restoration techniques, and policy implementation. New Zealand lakes, like lakes across the globe, are subject to multiple pressures that have increased in severity and scale as land use has intensified, invasive species have spread and global climate change becomes manifest. This books builds on the popular *Lake Managers Handbook* (1987), which provided guidance on undertaking investigations into, and understanding lake ecosystems in New Zealand. *The Lake Restoration Handbook: A New Zealand Perspective* synthesises contemporary issues related to lake restoration and rehabilitation, integrated with social science and cultural viewpoints, and complemented by authoritative topic-area summaries by renowned scientists and practitioners from across the globe. The book examines the progress of lake restoration and the new and emerging tools available to managers for predicting and effecting change. The book will be a valuable resource for natural and social scientists, policy writers, lake managers, and anyone interested in the health of lake ecosystems.