TROUBLE MAKERS

Catfish, Lakeweeds and Nutrients
- Complex Lake Systems Restoration

Lakes WATER QUALITY Society

Symposium Proceedings

Thursday 31st August and Friday 1st September, 2017
Millennium Hotel, Rotorua

Proceedings

ROTORUA LAKES SYMPOSIUM 2017

TROUBLE MAKERS

Catfish, Lakeweeds and Nutrients -

Complex Lake Systems Restoration

2 Day Symposium
Thursday 31 August and Friday 1 September 2017
Millennium Hotel, Rotorua

Hosted by

LakesWATER QUALITYSociety

EDITOR'S NOTE

I received material for the Symposium Proceedings as fully transcribed audio tapes and PowerPoint files. I then endeavoured to edit the spoken word to a written word format and included graphs and pictures from the PowerPoint slides, with discretion, in the body of each presentation. Where possible slides that contained only words were incorporated into the document text. Not all slides were included. The papers were sent to the original presenter to ensure they were satisfied with the transcription.

Panel discussions and the Mayoral Forum have also been included. These are a little more difficult to transcribe and there may be some errors or misinterpretations in the editing.

I would like to thank all the presenters who have kindly helped with editing. It is a mammoth and laborious task. In the interests of expediency and accuracy I very much appreciated their support. I would also like to thank Janine Gauldie who transcribes the tapes extremely well and quickly, John Gifford and Warren Webber, LWQS members, who kindly helped edit some of the papers, Liz Miller who sits all the way through the symposium and notes the names of questioners and something of their comments so that we have an accurate record, and my husband John who looks for spelling, grammar and senseless meaning and does not mind the hours I spend on the computer. There will be further mistakes but it is more important to produce this document as quickly as possible.

Ann Green

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The LWQS Symposium steering committee: Chair - Don Atkinson, Event Organiser – Warren Webber, Ian McLean, John Gifford, Stewart Edward

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KEY NOTE SPEAKERS

Lindsay Chadderton

Lindsay Chadderton is both a kiwi and the Aquatic Invasive Species Director for The Nature Conservancy's Great Lakes Project. He joined the Conservancy in 2007, where he was tasked with establishing the conservancy's aquatic invasive species program for the Great Lakes region.

Lindsay is part of the team that developed the environmental DNA surveillance method used to track the invasion of Asian carp in the Chicago Area Waterway System that artificially connects the Great Lakes to the Mississippi River basin. He is currently focused on developing new methods for controlling invasive species in the Great Lakes and improving surveillance and response capacity across the Great Lakes region.

Dave Hansford

Dave Hansford is an award-winning writer and photographer based in Nelson, specialising in science and environment issues. He spent 14 years as a press photographer before turning to freelance writing in 2002.

He has worked as a science reporter for National Geographic News and environment writer and columnist on The Listener, and in 2012, had a regular environment slot on TVNZ's Good Morning show. His writing and photography has also appeared in North and South, Good, NZ Business, BBC Wildlife, Australia Nature, Action Asia, Destinations, Wilderness, Forest & Bird and Seafood magazines, as well as newspapers around the world.

Prof. Brendan Hicks

Brendan Hicks is a Professor in freshwater ecology based at the University of Waikato in Hamilton.

Brendan's research is in freshwater fish ecology, quantification of fish abundance, and responses of native fish communities to invasive fish. Brendan uses stable isotopes to investigate aquatic food webs, and otolith microchemistry to examine fish life histories.

Prof. David Hamilton

David Hamilton is currently Deputy Director of the Australian Rivers Institute, Griffith University, Brisbane.

He served as the inaugural Bay of Plenty Regional Council Chair in Lake Restoration, University of Waikato, for 15 years (2002-2017) following 12 years at the Centre for Water Research, University of Western Australia. His Ph.D. research at the University of Otago initiated a career in which he has linked research in lake water quality modelling with practical solutions for lake restoration.

Rod Oram

Rod Oram has 40 years' experience as an international business journalist. He has worked for various publications in Europe and North America, including the Financial Times of London.

He contributes weekly to Nine to Noon on RNZ, Newsroom.co.nz and the Larry Williams programme on Newstalk ZB. Rod is also a frequent public speaker on business, economics, innovation, creativity and entrepreneurship, in both NZ and global contexts.

For more than a decade, Rod has been helping fast-growing New Zealand companies through his involvement with The ICEHOUSE, the entrepreneurship centre at the University of Auckland's Business School.

Sir Rob Fenwick

Sir Rob is a conservationist and businessman with a diverse background in resource recovery, biodiversity, heritage conservation, science and iwi governance. He co-founded Living Earth and led the passage of waste minimisation legislation in New Zealand. He established the NZ Antarctic Research Institute for climate change research and led the restoration of heritage buildings in Antarctica. He is a key figure in Predator Free NZ and the campaign to save the kiwi from extinction. For Ngati Whatua he helped establish the successful broadcasting venture Mai FM. He is a director of Ngati Whatua Orakiei, Te Papa, two national science challenges and chairs the panel reviewing the New Zealand fishery system.

Knighted for services to business and the environment, he is an inductee of the NZ Business Hall of Fame; the Sir Peter Blake Medallist 2015; has an honorary doctorate in Natural Resources from Lincoln University, and the Fenwick Ice Piemont in Antarctica is named for him.

Mace Ward

Mace Ward is General Manager Parks, Sports and Recreation, Auckland Council

The Parks Sport and Recreation department of Auckland Council is responsible for 4000 parks (45,000 hectares), 42 pools and leisure centres, sport and recreation management, and the administration of co-governed land, including the Tupuna Maunga.

The department seeks to the inspire Aucklanders to be more active, connect to nature, provide outstanding park destinations, conserve natural and cultural heritage and increase Auckland's Maori identity.

PROGRAMME

Catfish, Lakeweeds and Nutrients - Complex Lake Systems Restoration

Thursday 31st August, 2017

7.30 Registration

Session 1: Scene Setting
Chair: Don Atkinson, LWQS

8.30	Mihi Whakatau and Karakia *Dr Ken Kennedy*
8.40	Te Arawa - Kaitiaki of the Rotorua Te Arawa Lakes *Sir Toby Curtis, Chair, Te Arawa Lakes*
9.00	The State of the Rotorua Lakes in 2017 *Prof. David Hamilton, Australian Rivers Institute*
9.30	Lakes Water Quality, Lake Weed and Pest Animals *Hon. Nick Smith, Minister for the Environment*
10.00	Morning Break (30 mins)

Session 2: The Pest Fish Threat
Chair: Hon. Todd McLay, Minister of Trade

10.30	The Pest Fish threat and the Great Lakes Example *Lindsay Chadderton, The Nature Conservancy*
11.00	Pest Fish throughout New Zealand *Natasha Grainger, Dept. of Conservation*
11.20	Lake Rotoiti Catfish Incursion *Prof. Brendan Hicks, University of Waikato*
11.40	Catfish in Lake Taupo *Michel Dedual, Dept. of Conservation*
12.00	Potential Effects of Catfish on Koura in the Te Arawa Lakes *Ian Kusabs, Ian Kusabs & Assoc.*
12.20	Discussion (10 mins)
12.30	Luncheon Break (60 mins)

Session 3: The Lake Weed Menace
Chair: Mayor Steve Chadwick, Rotorua Lakes Council

1.30	Lake Weed Then and Now - The Rotorua Te Arawa Lakes *Tracey Burton, NIWA*
1.50	Lake Biosecurity – Local Actions and Results *Hamish Lass, BoP Regional Council*
2.10	Deoxygenation Impacts of Lake Weed *Max Gibbs, NIWA*
2.30	The Restoration of Native Aquatic Plants *Deborah Hofstra, NIWA*
2.50	Discussion (10 mins)
3.00	Afternoon Break (30 mins)

Session 4: Whole-of-Lake Weed Strategies
Chair: John Gifford, LWQS

3.30	Strategies to Manage Aquatic Plants - towards shared understanding *Mary de Winton, NIWA*
3.50	Best Practice Toolbox for Whole of Lake Weed Strategies *Paul Champion, NIWA*
4.10	Chemical Control of Lake Weeds *Rohan Wells, NIWA*
4.30	Discussion (20 mins)
4.50	Free Time (50 mins)

5.30	**Annual Mayoral Speaker Forum: Sustainability** Sir Howard Morrison Performing Arts Centre *Panel: Sir Rob Fenwick, Rod Oram, Eamon Walsh*
7.00	**Symposium Dinner & Entertainment** **Millennium Hotel**

Friday 1st September, 2017

7.30 Registration

Session 5: The Eight Lakes of Tarawera
Chair: Alan Skipwith, Te Pumautanga o Te Arawa

8.20	Mihi Whakatau and Karakia *Dr Ken Kennedy*
8.30	Predator free New Zealand by 2050 - Benefits for the Lakes *Martin Kessick, Deputy Director-General, Biodiversity, DOC*
8.50	Tarawera Lakes Restoration Plan: Overview *Chris Ingle, BoP Regional Council*
9.10	Groundwater Study - The Eight Lakes Catchment *Paul White, GNS Science*
9.30	Modelling The Eight Lakes of Tarawera *Chris McBride, University of Waikato*
10.00	Morning Break (30 mins)

Session 6: The Eight Lakes of Tarawera (continued)
Chair: Stewart Edward, LWQS

10.30	The Cultural Perspective: Lakeweed and Pest Animals *Nicki Douglas, Te Arawa Lakes Trust*
10.45	The Impact of 1080 on Aquatic Ecology *Alastair Suren, BoP Regional Council*
11.05	1080 and the Fight to Save New Zealand's Wildlife *Dave Hansford, Investigative Journalist*
11.25	Case Sudy - Hunua 1080 Project *Mace Ward, Auckland Council*
11.45	The Nutrient Impacts of Forestry *Peter Beets, Scion*
12.05	Farmer Perspective *Chris Sutton, Rerewhakaaitu*
12.20	Discussion (10 mins)
12.30	Luncheon Break (60 mins)

Session 7: Responsibilities, Value and Funding
Chair: Bill Cleghorn, BayTrust

1.30	Clean Lakes - What Value? What Cost? *Hannah Mueller, Kessels Ecology*
1.50	Lake Tarawera - the Costs of P mitigation and Pest Control *Greg Corbett and John Paterson, BoP Regional Council*
2.10	The Cost of Aquatic Weed Control in the Rotorua Te Arawa Lakes *Paul Champion and Rohan Wells, NIWA*
2.30	NEXT Foundation: Perspective on Funding *Jan Hania, NEXT Foundation Environmental Director*
2.50	Discussion (10 mins)
3.00	Closing Comments *Warwick Silvester / Kit Rutherford*
3.20	Closing Karakia *Dr Ken Kennedy*

Symposium Concludes

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WEB *www.lakeswaterquality.co.nz*

Register *https://symposium-mayoral-forum.lilregie.com/*

FOREWORD – ROTORUA LAKES SYMPOSIUM 2017

TROUBLE MAKERS

Catfish, Lakeweeds and Nutrients – Complex Lake Systems Restoration

Don Atkinson
Chair, LakesWater Quality Society Inc.

This was the Society's 10th Symposium and was held at the Millennium Hotel, Rotorua on the 31St August and 1st September. It built on our 2015 Lake Weed and Wallabies Symposium and themed around eradication of catfish, the spread and now dominance of lake weeds and the requirement to control browsing animal pests causing erosion.

The confirmation of the arrival of the bullhead catfish in Lake Rotoiti has rightfully been reviewed with trepidation. Lindsay Chadderton from the Nature Conservancy, Great Lakes Project gave us valuable insight into pest fish spread and their Mississippi/Great Lakes projects. This complemented our speakers on controls and eradication. The eradication of catfish, at this stage of the incursion, will be a first and its difficulty should not be underestimated.

NIWA lead the Lake Weed Menace and Strategies session. The confirmation that in most of our lakes invasive aquatic weeds now occupy approximately 90% of the flora is validation that without lake wide intervention we will lose our lakes to weeds. The speakers were able to outline control strategies on a lake wide basis, provide broad costings and give us hope that the lakes can be restored to pre-1960's native flora levels. The challenge is with us all.

The pre-dinner Mayoral Forum gave a wide-ranging discussion on sustainability.

The second day was based on the Eight Lakes of Tarawera, their current state, understanding of the ground water flows, present limitations to scientific knowledge and challenges in completing modelling of the complex. Focus was then shifted to control of pest animals, 1080 use and an insightful view of the public reaction by author Dave Hansford. Progress made and challenges remaining to the rural sector were discussed.
The final section laid out the opportunities and costs associated with restoration. The importance of the lakes and tourism to our district economy was presented by Hannah Mueller. Jan Hania from the NEXT Foundation outlined opportunities and challenges in funding.

Thanks go to the session chairs for the excellent conduct of the programme – Todd McClay, Minister of Trade: John Gifford, LWQS; Bill Cleghorn, Bay Trust and Warren Webber, LWQS.

I acknowledge and thank our sponsors for their continuing support of our symposia. Without that financial assistance we would be unable to bring together the contributors, our thanks go to Bay of Plenty Regional Council, Rotorua Lakes Council, Bay Trust and the Rotorua Energy Charitable Trust.

Finally, I would like to recognise the work and assistance from my committee and more particularly Warren Webber, Ian McLean, John Gifford, Stewart Edward and Libby Fletcher and Ann Green for her role as editor of these Proceedings.

We look forward to all readers having a fuller understanding of the challenges and solutions in our quest to restore our lakes. It takes a village to raise a child and a community to save a lake.

Don Atkinson
Chairman LWQS

Session 1 : SCENE SETTING

INTRODUCTION - Don Atkinson, Chair, LakesWater Quality Society

This symposium has three key themes starting with the bullhead catfish which our society wants to eradicate from the lakes. We recognise that is a huge task but one worth pursuing over the next few years.

The second theme is about invasive aquatic weeds, a subject of our last symposium but that was principally around Endothall and consents. Now we want a broader discussion because the lakes have been deprived of good care in the management of aquatic weeds. They have invaded our lakes with the first intrusion of lagrosiphon in the 1950's and now most of our lakes have up to 90% of their plant matter consisting of invasive weeds. We have only done window dressing by spaying around boat ramps, jetties and swimming beaches. That is like keeping the front paddock in good grass and the other thousand hectares, over the ridge and out of sight, left to revert to gorse. Aquatic plants, being mostly under water, are not widely seen but they are destructive to our native plants. Unfortunately, hornwort has taken hold over most of our lakes and it will get worse unless we are prepared to really face the problem.

The final day is focussed on the Tarawera complex of the eight lakes system. Six of these lakes are outside of Deed Funded lakes, this fund was allocated by Government, Regional and District Councils in 2006 to manage and restore Lakes Rotorua, Rotoiti, Okareka, Rotoehu and Okaro. We have had great success where money has been expended in the restoration of these lakes. But we must recognise that all lakes in the Tarawera complex are deteriorating and there is only one track laid out at the moment - continuing deterioration.

We have a good start with the Tarawera sewerage which was recently given seed funding from the Government Clean Water Fund. Congratulations to Libby Fletcher, Chair of the Tarawera Ratepayers Association, for the good work she has been doing. The farmers are also engaged but there is plenty more work needed.

We have talked a lot about the bushed areas of the catchment and the wallabies and other pests destroying the understory and enabling erosion, nothing has been done. I hope by the end of these two days we will have increased our understanding of the issues, know the science and have an idea of costs. We need the resolve, at both public and political levels, what resources need to be provided and then to commit to actions.

It takes a village to raise a child and it takes a community to restore a lake. We must attack these issues from every angle as a community and involve both regional and central government.

SESSION CHAIR – Hon Todd McClay, Member of Parliament, Rotorua

Todd is the Member of Parliament for Rotorua and also holds the portfolios of Minister of Trade, Minister for State Owned Enterprises and Associate Minister of Foreign Affairs.

Welcome to this year's LakesWater Quality Society Symposium. We will be talking about important issues, not only to Rotorua and its lakes, but to all of New Zealand. Pests as well as lake water quality are closely tied together. In 1961 some residents of Lake Rotoiti formed the Lakeweed Control Society to focus on lakeweed in their lake. In my experience as your local MP the residents of Lake Rotoiti often come together with great passion to talk about their lake and others. In the 1960s and 70s the group was chaired by Leonard Leary with a very effective committee, and then in 2000 it was transformed into the Lakes Water Quality Society chaired by Ian McLean to deal with the wider challenges of lake water quality. The first symposium was in 2001 on research needs of the Rotorua Lakes. In 2005 John Green as chair was part of a group that collectively went to government seeking funding support and raise the importance of lake water quality in the Rotorua Lakes. I congratulate LWQS for the commitment in reaching out to the community for respectful dialogue and greater understanding of water quality issues which has delivered results. Lake Rotoiti has had the greatest improvement in lake water quality of any lake in New Zealand and can be put down to the hard work of local people and the great amount of money Steve Chadwick delivered to Rotorua as Member of Parliament.

TE ARAWA – KAITIAKI OF THE ROTORUA TE ARAWA LAKES

Dr Sir Toby Curtis, PhD, KNZM, FCCEAM, EAAUT
Chair, Te Arawa Lakes Trust
toby@tearawa.iwi.nz

Sir Toby has been teacher, principal, lecturer, researcher, and a senior academic in tertiary education. Today, he is very much involved and committed to Iwi development and the advancement of the Maori economy. He has also chaired various Ministerial Committees that promoted health, broadcasting, education and social development.

He chaired the North Harbour Secondary Schools Union, and the National Maori Sports Association. He is currently Chair of Te Arawa Lakes Trust, Chair of Rotorua Te Arawa Lakes Strategy Group, a member of both the Iwi Leaders Forum and the Police Commissioner's Forum. He is recognised as a Fellow of the Commonwealth Council of Educational Administration and Management for his contribution to international education.

TRANSCRIPT

Tihei Mauri Ora
E noho ana au I tooku taumata o **Matawhaura**
Ka titiro whakararo ki te **Roto wai-iti i kite ai a Ihenga**
Tau ana te titiro ki te waimarino, ko **Korokitewao**
Ka huri te titiro ki **Takapuwhaea**, ki a te **Taakinga**
Ka rere te titiro ki te **Rotorua-nui-a-Kahumatamomoe**
Te moana I kautia ai a **Hinemoa**
Ka tungou au ki te **Motutapu a Tinirau**
Ko **Mokoia** teera e pukanakana mai ra
I totope te kawakawa ka whakavipo i te ia ki **Ohau**
Ka tukituki taku hoe ki nga toitoi toki onewa
Ka taka rawa ki te awa ki **Okere**
Te kainga I nohoia ai a **Ngati Hinerangi**
Ka huri taku titiro ki te **Kaituna**
Ki nga hukahuka wai o **Tapuika**
Ka tere taku tae atu ki te **Akeake**,
Te Kurae-o-te-ihu-a-Tamatekapua
Te uurunga o take waka o **Te Arawa**
Te Arawa waka mai **Maketu ki Tongariro**
Te Arawa tangata, **Nga Pumanawa e Waru** e tau nei…..
E he Te Arawa e!
E he Te Arawa e!
Ko te Whakaariiki, ko te Whakaariiki
Tukua mai ki a piiri,
Tukua mai ki a tata..
Kia eke mai ki runga
Te paepae poto o
Houmaitawhiti

I start this morning by reciting what we call a patere talking about Te Arawa's interest and relationship to the lakes and the water. Matawhaura is our mountain on Lake Rotoiti. When I went to school in Auckland we travelled on the New Zealand Road Service transport bus, returning for the holidays along the Mamaku ranges. Those that came from Lake Rotoiti always looked out to see the lake and the mountain Matawhaura. As soon as we saw it a little touch of emotion welled up in our hearts. Mataatua people living in Whakatane felt the same thing when they travelled back home, descending the Rotoma hill, they looked out for Putauaki (Mt Edgecumbe). It gave them the same feeling of emotion.

That is Matawhaura in the background. I grew up seeing it most mornings, even this morning on the way in. It does something to the mind and spirit growing up beside a lake; it becomes part of my identity and blood stream.

Waimarino Korokitewao is always calm even if the rest of the lake is rough. We called it the swimming pool. As children we would swim and dive where they had the skids. They transported the logs to Rotorua by barge where they were cut up for timber. In other words a place that has special meaning for us who lived by the lake and I always look to see if it is still calm.

This is another view of Matawhaura we see as we come down the Mamaku ranges.

Lake Rotorua or Rotorua-nui-a-Kahumatamomoe is one of our ancestors. Kahumatamomoe was the second son of Tama-te-kapua, the captain of our canoe. Most of Te Arawa are derived from Kahumatamomoe. Other people are descendants of Tuhoro-mata-kaka, the older brother, such as the Hauraki people who are having a lot of fun with different tribes at the moment and also Ngāti Whātua. We in the Te Arawa rohe all descend from Rotorua-nui-a-Kahumatamomoe. So when we mention his name when welcoming people we are saying that Kahumatamomoe as our ancestor is welcoming you in spirit as well.

Mokoia has its own story with Hongi Hika who was Ngapuhi. I remember a person from Ngapuhi came and recalled how Honi Kika belted the daylights out of Te Arawa. The man did not like the way he was being spoken to and said, 'You need to get your facts right.' The Ngapuhi guy said, 'Why?'

'You are talking about Ngāti Whakaue, not Te Arawa!'

Tutanekai lived on Mokoia, one night Hinemoa found her way over by swimming there. Shortly after they married. As a consequence of this union on that island most of us from Te Arawa are the descendants.

I wanted to show you what a special relationship we have with Rotorua and other places. Ngāti Hinerangi, Kaituna and Tapuika are all people of importance in Te Arawa, because when we mention them they also welcome you. This is also my way of expressing my appreciation to our Mayor and the Council for making Rotorua City the first bilingual city in the world.

I want to talk about a couple of other things. When I was young I did not realise that we were brought up in a poverty stricken home. We went down to the lake to wash our face and clean ourselves even in winter. But if it was too cold we boiled the water so we did not feel the cold. As children we drank the water from the lake, it was so clean. It is not quite the same now.

Around Rotorua there is a strong connection by the people to Hawaiki where we originated from in the central Pacific. Before we came to Aotearoa we were known as Ngāti Ohomairangi but when we arrived here it changed to Te Arawa. The change came about when the canoe reached Te Korokoro o Te Parata (The throat of Te Parata), a mid-ocean whirlpool and as it was going down Ngātoro-i-rangi was persuaded by his wife to say another prayer so that the canoe could rise and go into safer waters. He asked the gods to save them and said, 'Ngahue i te parata eke eke eke taku waka Te Arawa Te Arawa e'. The canoe rose out of the whirlpool safely. From then on we became Te Arawa.

However we do have Ngati Uenukukopako at Rotokawa making sure that Te Arawa does not forget its origins. Their marae is called Ohomairangi and our new polytechnic is called Toi Ohomai, the short version of Ohomairangi. Oho means ‘to awaken’ and mai means ‘all of us’, ‘to awaken the spirit to learn about the knowledge that is available’, whether it is celestial or terrestrial. So Ohomai is part of our lives and Toi is the part that belongs to Mataatua in case they come back to shoot us for not including them so we can all live in peace.

Before Ngāti Pikiao had complete reign over Lake Rotoiti in a sense it was owned by Tuhourangi. When Tuhourangi was an old man one of Pikiao's grandsons, Takinga (I mentioned in the song) went to him and said,

‘E koro kua tae ki te wa me hoki ra koe ki te waa kainga.’
‘Old man, I think it is time for you to go home where you belong.’

The old man listened to Takinga suggesting that he did not belong in Rotoiti, he belonged to Tarawera. Tuhourangi thought about it and realised that maybe he should because Takinga and his brothers had military platoons that could outwit and kill Tuhourangi's bands of warriors. So Tuhourangi went back to Tarawera and everything was left to Ngāti Pikiao. Ngāti Pikiao are very lucky because we now live in peace with Tuhourangi.

I want to move to matters of ownership. We have had some fun, Hon Mr McClay, with your government and previous governments. They do not want to talk about ownership of the water. I wonder why? People and governments have their reasons but I want to say this. The former Prime Minister told the world that no one owned the water but no Maori accepted that. If no one owns the water how can individuals sell the bloody stuff and make millions of dollars? Or is it in certain instances? We started guessing those people might be mates of the Prime Minister? We have all those kind of thoughts. Rotorua at some stage should make a stand on that. Are we going to tell the government that we should not sell our pristine water?

I attended a conference earlier in the year at Lincoln University and nearly every scientist intimated that it is just a matter of time until our lakes and rivers will be contaminated. Why are we selling good water when at some stage we may not have good water for ourselves? I hope Mayor Chadwick that Rotorua can make a stand on this matter because it affects us totally. People are bound by certain rules and regulations and perhaps it is time to visit those rules and regulations.

When we discussed this with Minister Adams, as Minister of the Environment at the time, we came to appreciate and respect her very much. At a meeting when we thought Government were on one side of the table and Iwi the other, I led our little group in to talk to them and exchange ideas. But on this occasion she wanted to talk with Local Government who were sitting on the opposite side. When we arrived we decided to sit at the end of the table so we could leave the battlefield to them and sit and watch.

Just as we sat down she said, ‘What are you guys doing there?’

We said, ‘We are sitting here so you can have a free flow of ideas with the Local Government representatives.’

She said, ‘Since when do you make the decision on where you sit?’

We said, ‘No one told us where to sit so we were just using our initiative, Minister.’

She said, ‘I want you to come and sit right here next to me.’

We looked around and I said, ‘Hang on, if we sit by you and our people found out, they would have strong words about why we joined the enemy because the Crown is seen as the enemy for doing what they did in the past.’

She said, ‘Mr Curtis and all the rest of you just keep your mouths closed and come and sit here.’

So we all sat there beside her and thought that was wonderful. To make sure that we are not attacked I keep telling the story in case somebody hears that we became turncoats!

To finish up, the Pakeha definition, as we see it, is that any commodity that you can sell for financial return, whatever that commodity or resource is, is saleable. Our definition is that if we have a commodity or Maori resource, our aim is not to turn it into a saleable commodity but to protect that commodity and pass it on so that future generations will enjoy it. However, despite that we still have not reached a stage where we can sit down and talk freely about it with Government.

When I was appointed Chair of Te Arawa Lakes Trust I thought it was a big job to do. How are Te Arawa going to clean up the lakes? But as time went on I noticed various Pakeha community groups out there, planting stuff, picking up rubbish, cleaning the place. I thought goodness they do far more than Te Arawa. I am not talking about the Council; it is groups like LWQS and others here. Many of us have come to the realisation that if you are born beside a contained mass of water you develop a relationship with it. In my view, you have as much ownership of Lake Rotorua and Lake Rotoiti and any other lake that Te Arawa has. I will finish on that note so that Te Arawa can have a crack at me later.

No reira tēnā koutou kia ora huihui mai atou.

Chair - Hon Todd McClay

Thank you for your dedication and kind words and thank you also for chucking that ownership issue off to the local council. Good luck with that one Steve!

I am very pleased to hear what you had to say. To imagine you as a young boy drinking from Lake Rotoiti is a wonderful sight. The work that so many people in this room have done, and others in our community, will mean that one day in the not too distant future, if we continue to be focussed, if we work hard, if we keep our eye on the prize, then another young man, one of your great grandchildren, again may sit there on the steps of that Marae and wander down to drink from our lake.

THE STATE OF THE ROTORUA LAKES IN 2017

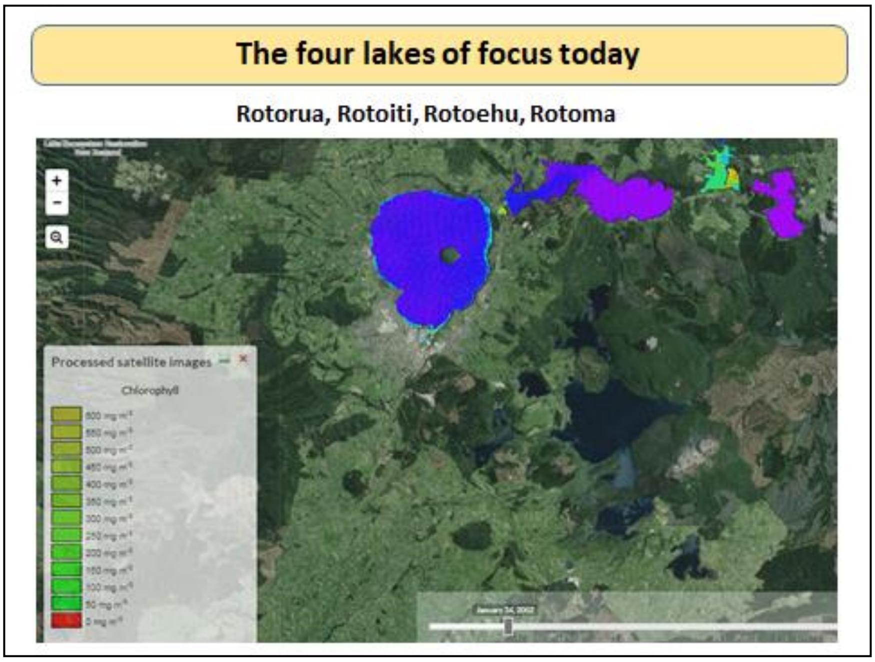
Professor David Hamilton
Australia Rivers Institute
david.p.hamilton@griffith.edu.au

David Hamilton is currently Deputy Director of the Australian Rivers Institute, Griffith University, Brisbane. He served as the inaugural Bay of Plenty Regional Council Chair in Lake Restoration, University of Waikato, for 15 years (2002-2017) following 12 years at the Centre for Water Research, University of Western Australia. His Ph.D. research at the University of Otago initiated a career in which he has linked research in lake water quality modelling with practical solutions for lake restoration.

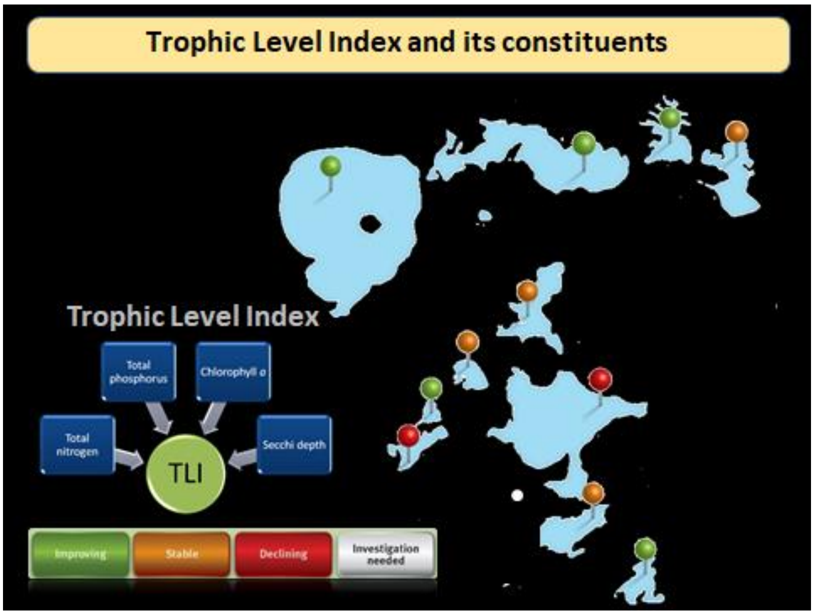
TRANSCRIPT

Tena koutou katoa

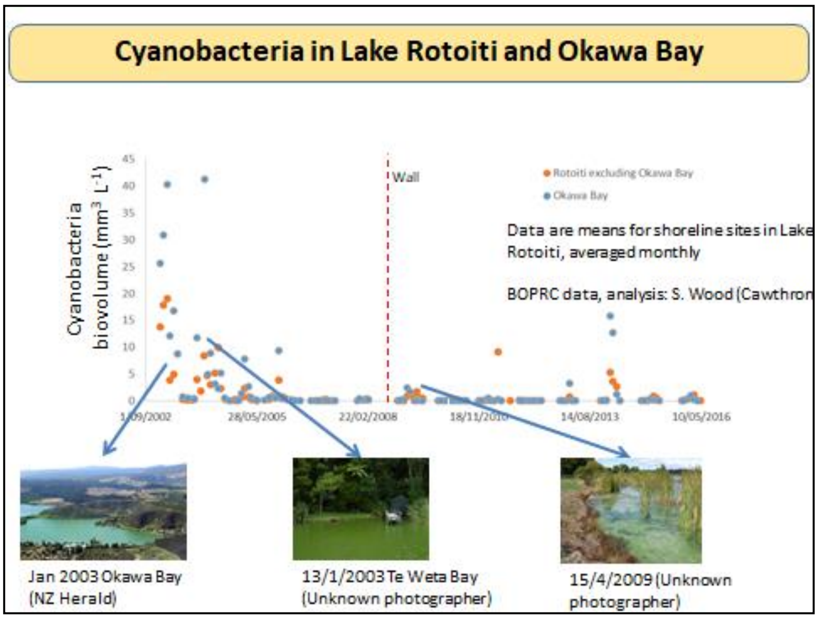
I have been asked to give an overview of the Rotorua Te Arawa Lakes and then focus on just four of the lakes. Chris McBride will pick up other lakes. I would like to acknowledge Warwick Silvester who set up the Lakes Chair, Simon Stuart who is working outside the rohe, on Lake Taupō, but has a great body of knowledge on the food chain in that lake, with potential applications to the Te Arawa lakes. Also to Kohji Muraoka who helped me over the last 24 hours, putting data together which enabled me to synthesise my thoughts on these lakes.



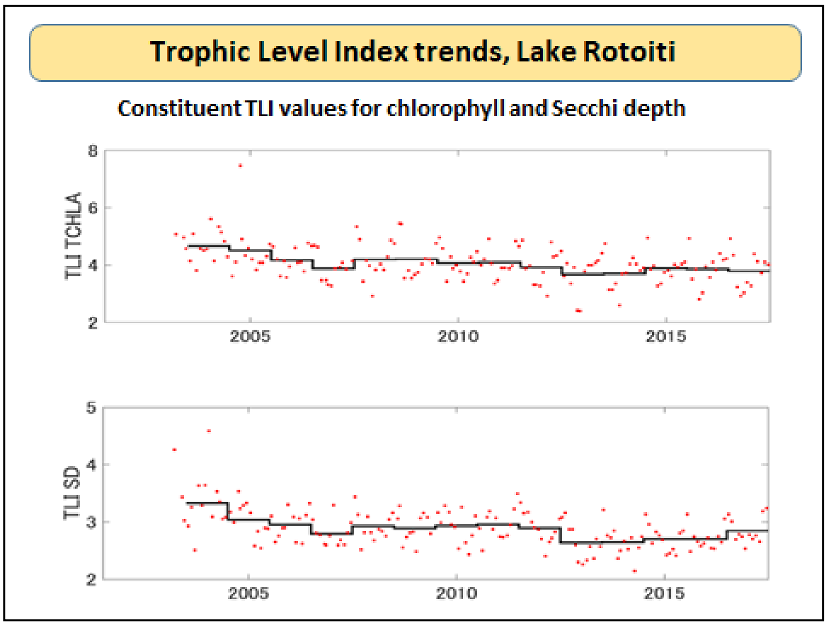
This slide shows the focus today, Rotorua, Rotoiti, Rotoehu and Rotoma, in a satellite image taken in 2002. It was opportune that I picked the image to show Rotoehu in bloom, given by the colour. The same red colour is also shown in Okawa Bay at that time.



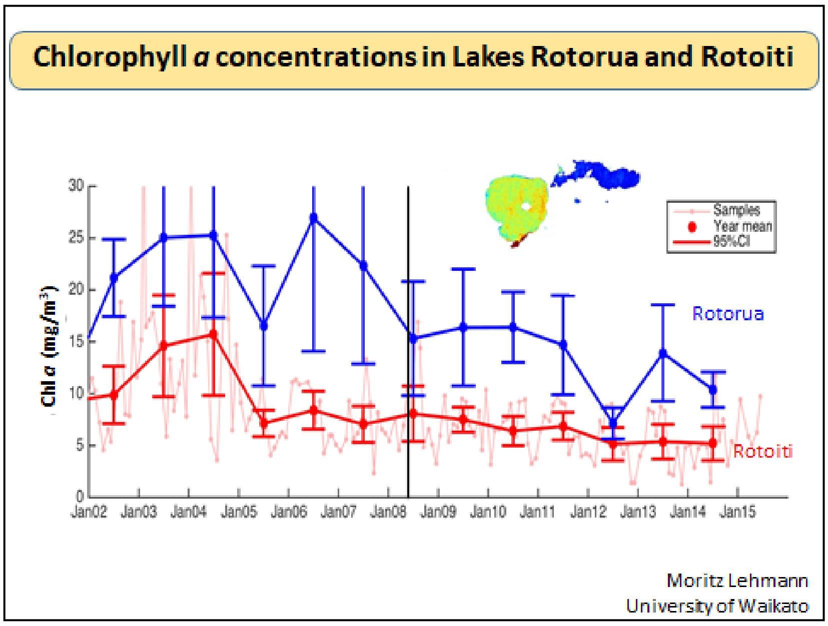
The Bay of Plenty Regional Council uses these lakes as an opportunity to measure the Trophic Level Index (TLI) which is an indicator embedded in their regional plan and policy. It is used to give an indication of whether the lakes are improving, stable or declining. This slide indicates that there is a variety of different trophic level states, and lakes may be improving or declining. It is one of our scientific challenges to put this information together.



This illustrates some of the things that happened that drove public expectations that it has to get better: in Okawa Bay, Te Weta Bay and near the diversion wall. High cyanobacteria concentrations mean the algae become visible and the public respond to this particular group of phytoplankton because they tend to float and get pushed into bays. Their proliferation is the most obvious manifestation of changes in water quality. During 2004/5 there was a period in Lake Rotoiti and Okawa Bay when things were quite nasty. Blooms have occurred occasionally since that time, for example, after the wall was put into Lake Rotoiti.

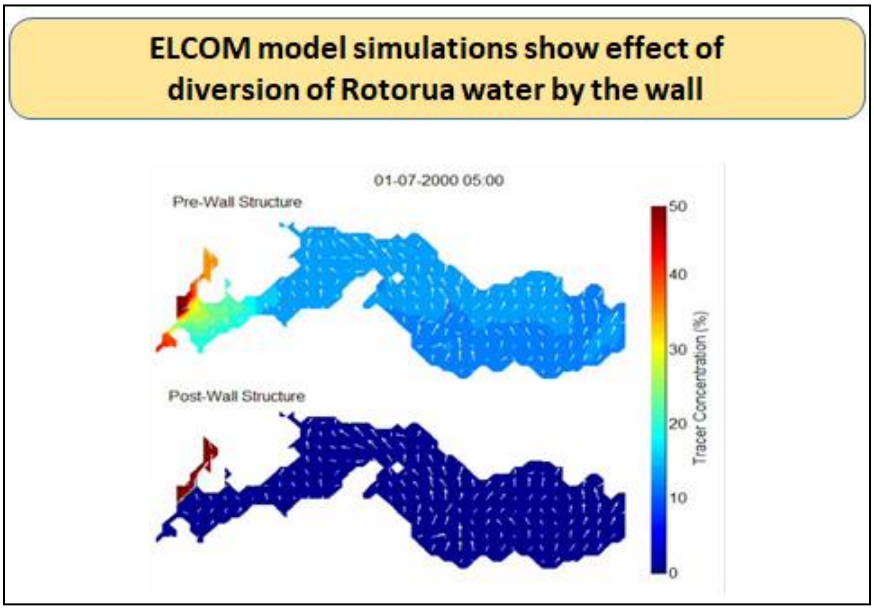


You can look at this in terms of four different constituents included within the Trophic Level Index Looking at these constituents individually, total nitrogen and total phosphorous tend to be drivers of water quality and chlorophyll *a* and Secchi depth give an indication of water clarity.

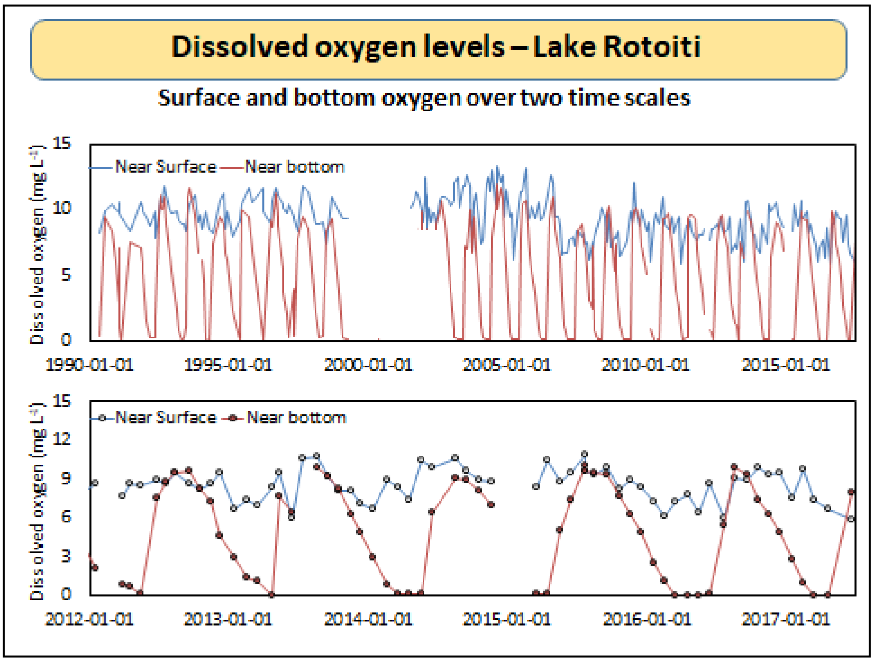


Here chlorophyll *a* has decreased progressively and clarity has improved. However, in more detail there are quite large changes that have occurred in the last decade. The black line represents the wall implementation. The period is from 2002 to 2016 and shows that Rotorua has a higher level of chlorophyll *a* than Rotoiti does. Many people attribute the wall to the improvement in water quality, and it has, but things had improved immediately before the wall implementation as well as since that time. There was a shift in Rotorua around 2006/2007. It is no coincidence that alum dosing started in 2006 and was reinforced with dosing another inflow in 2010. Rotorua has continued to improve.

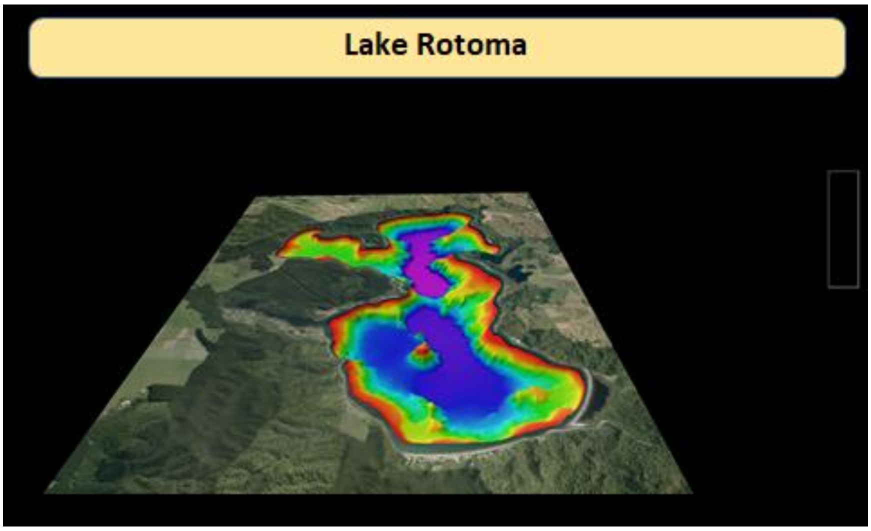
That is not the full story. The wall has cut off the connection between Rotorua and Rotoiti and that is very obvious from this photo. The models below show very little exchange now between those two lakes. The top one shows pre-wall with a tracer put through the Ohau Channel. That tracer is dispersed throughout the lake as opposed to the current situation where the tracer comes in through the Ohau Channel and is moved out to the Kaituna River.



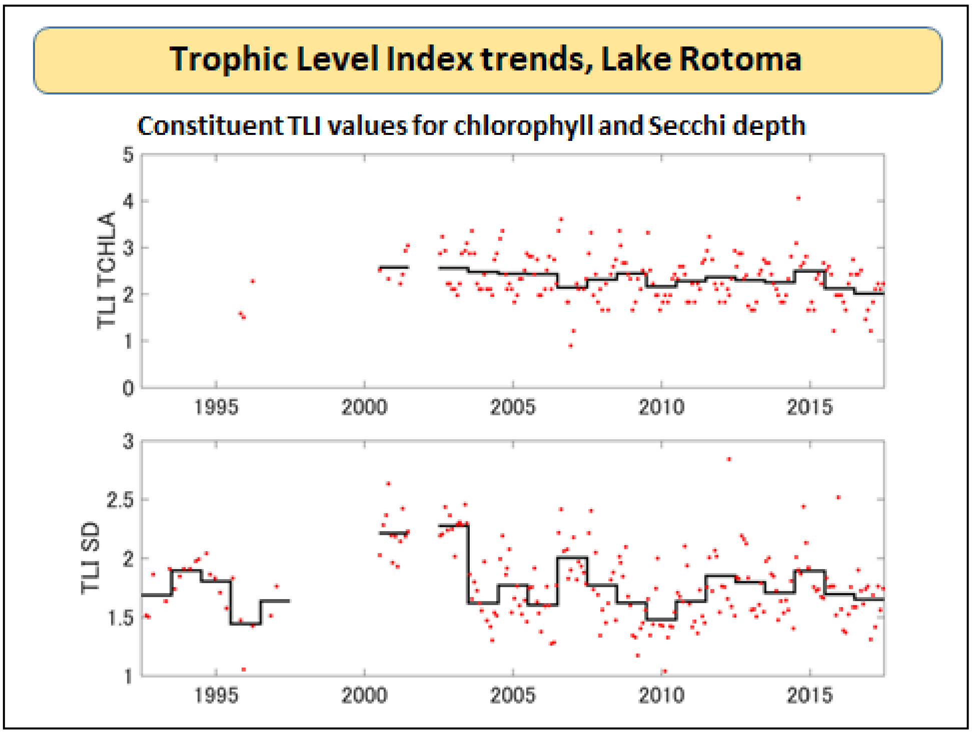
I get back on my old hobby horse here. The Trophic Level Index is a good indicator but, for me, ultimately the state of the lakes is given by the levels of dissolved oxygen. I want to again thank Kohji Muraoka for putting this slide together. The graph below shows near-surface and near-bottom concentrations in Lake Rotoiti, showing a very strong annual cycle. Oxygen goes up when the lake mixes with aeration from the water surface; a healthy case. For about 9 months of the year the lake does not mix and oxygen in the bottom waters declines at a rate that is dependent on quantities of algal production from the surface. What stimulates that algal production is nutrients. At times there is complete loss of oxygen in the bottom waters. In the last decade trophic state has improved considerably in Lake Rotorua. Overall, the best integrators of many the diverse processes operating in a lake are dissolved oxygen levels in bottom water.



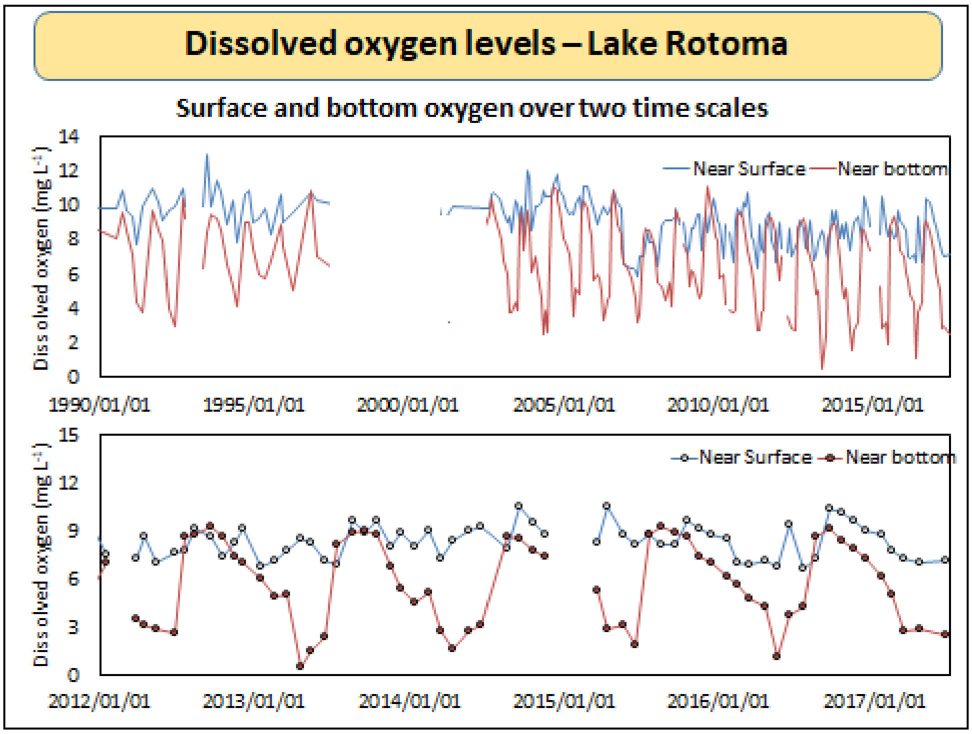
In the Rotorua Te Arawa Lakes sampled by Bay of Plenty Regional Council I regard Rotoma as being closest to the native condition. This is Rotoma looking to the north. The little island sometimes appears in the lake but not at the moment. The Trophic Level Index values show the trends, which are generally fairly positive. Levels are going down and therefore water quality may be improving. (Slide next page)



But I look to dissolved oxygen as the best indicator in those bottom waters. (Slide next page) Of particular significance is that none of the monitoring in the 1990s indicated there was a huge loss of dissolved oxygen. It is similar through to 2002 but looking more closely, the dissolved oxygen levels appear to have got lower. For example in 2013 there was a very low level of dissolved oxygen. What is going on? Well that is why we have scientists who are interested in probing this; I cannot offer you a definitive answer at this stage.



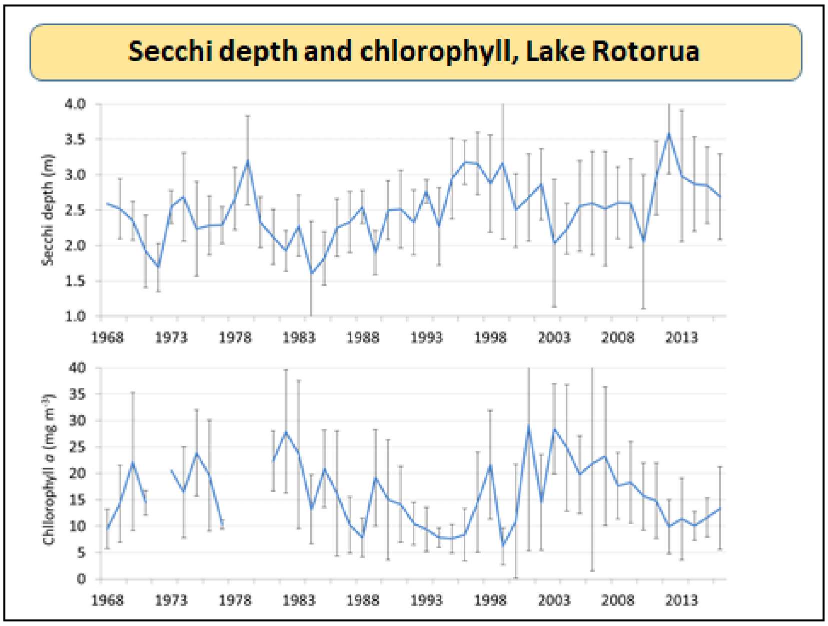
Trophic Level Index trends, Lake Rotoma
Constituent TLI values for chlorophyll and Secchi depth
TLI TCHLA
TLI SD
1995
2000
2005
2010
2015



Dissolved oxygen levels – Lake Rotoma
Surface and bottom oxygen over two time scales
Dissolved oxygen (mg L⁻¹)
Near Surface
Near bottom
1990/01/01
1995/01/01
2000/01/01
2005/01/01
2010/01/01
2015/01/01
2012/01/01
2013/01/01
2014/01/01
2015/01/01
2016/01/01
2017/01/01

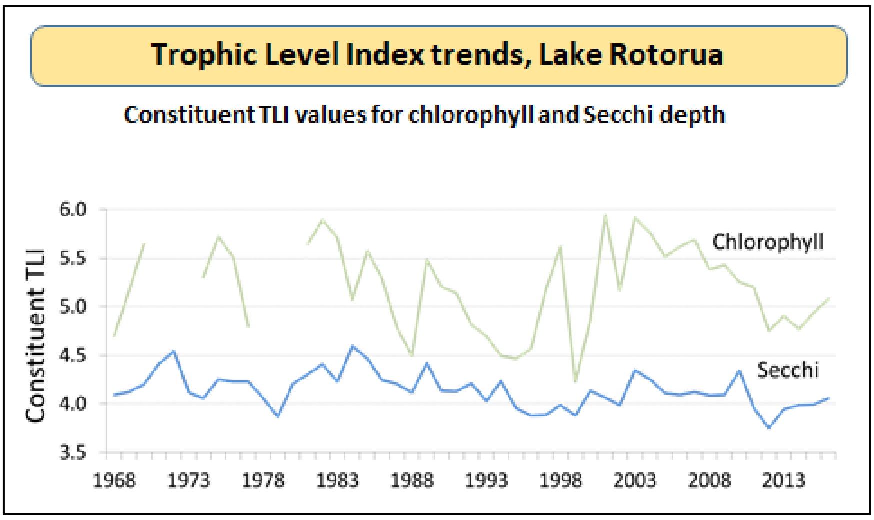
I want to acknowledge Kit Rutherford. Chris McBride has effectively become a curator of the Lake Rotorua data and been able to synthesise the historical work on this lake.

This slide shows the Secchi depth and chlorophyll *a* values as an indicator of the algal concentrations in Lake Rotorua. It is hard to say what is going on in this lake. However we can say that the 1990s was a period when chlorophyll *a* levels were quite low and visibility, i.e., Secchi depth values, were quite high. This high clarity brought a false level of comfort that the improvements in removing the Rotorua wastewater in 1991 had improved the lake.

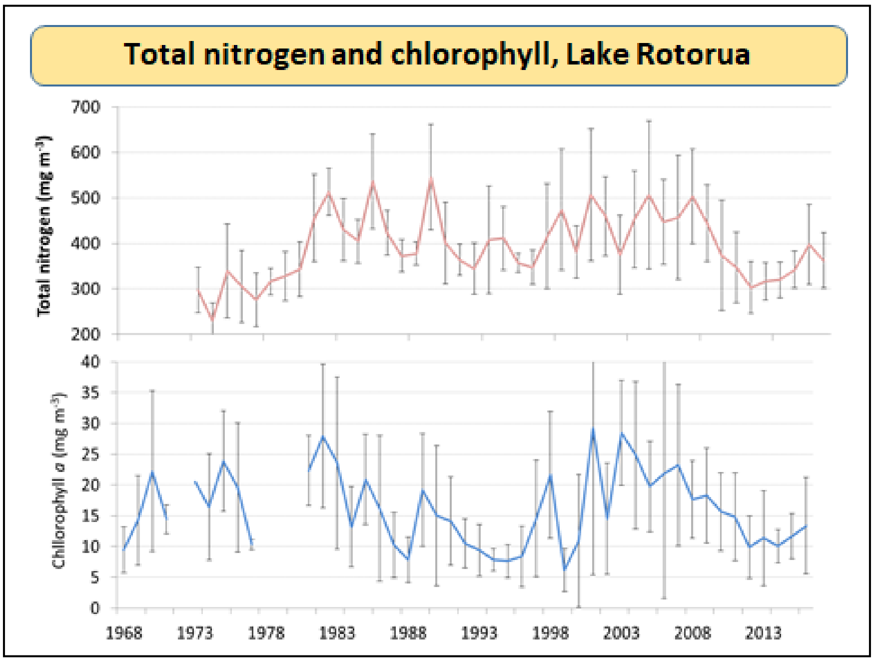


But by 2003/2004 things had got markedly worse. Chlorophyll *a* levels were way above what we had seen before and brought massive blooms. I show relationships between clarity and chlorophyll. They are not straightforward but generally the lower the clarity the higher the level of algal concentrations in the lake, but suspended sediment also contributes to loss of water clarity.

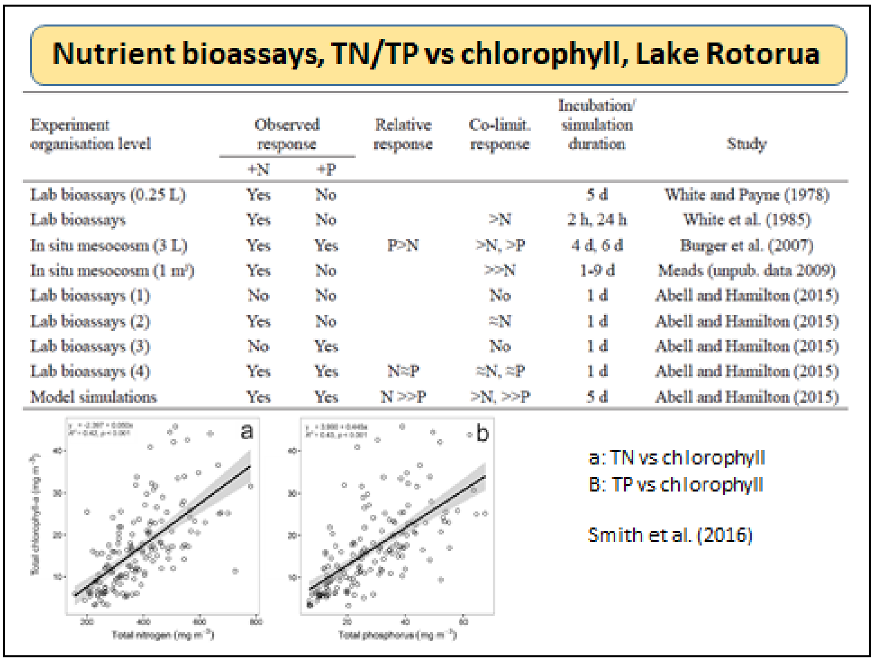
This slide shows a remarkable record of nearly 50 years of data from 1968 thanks to several people in the room who have assisted greatly with bringing it together. It shows chlorophyll *a* concentrations and Secchi depth values.



The slide below shows that total nitrogen has gone up and down over the years but it is no coincidence that it was down to relatively low levels around 2012-13, comparable to the 1960s/1970s, as a result of alum dosing. You can see in the mid-2000s very high concentrations of total nitrogen and correspondingly very high concentrations of chlorophyll *a*. I could show you a very similar plot for phosphorus through time as well.

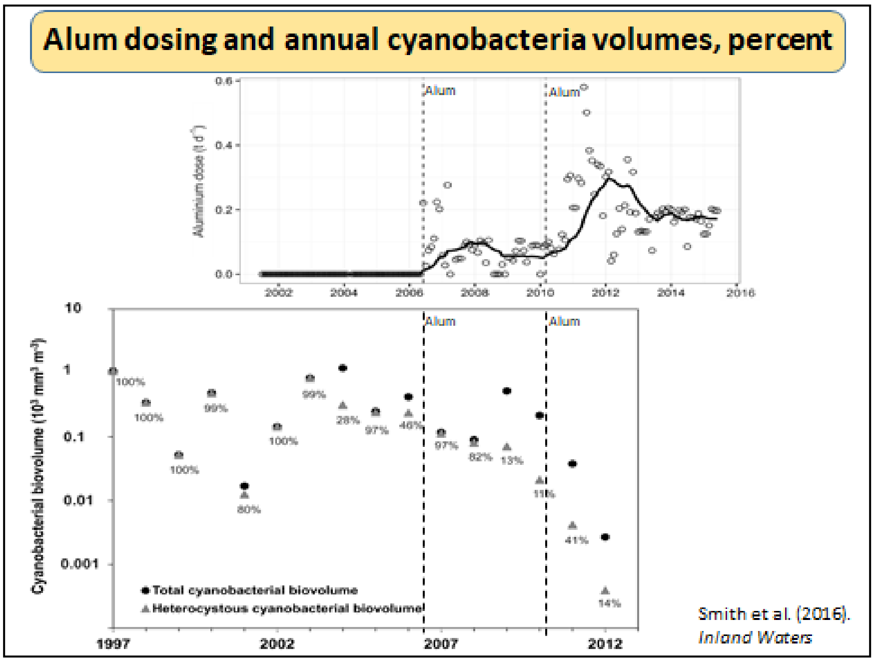


Just to re-emphasise that point about the importance of nitrogen and phosphorus, when you add these nutrients they stimulate algal growth. The slide on the next page is a paper synthesising all of the work that was done to add nutrients and see whether nitrogen or phosphorous stimulated algal growth in Lake Rotorua. I do not think you can separate these to nutrients – is it nitrogen and phosphorus? It is both. You might try to limit one nutrient, for example, but you immediately run into limitation by another. So both nitrogen and phosphorus are extremely important, and at certain times of the year, or at certain depths or locations, nitrogen might be limiting algal growth to a greater extent than phosphorus or vice versa.

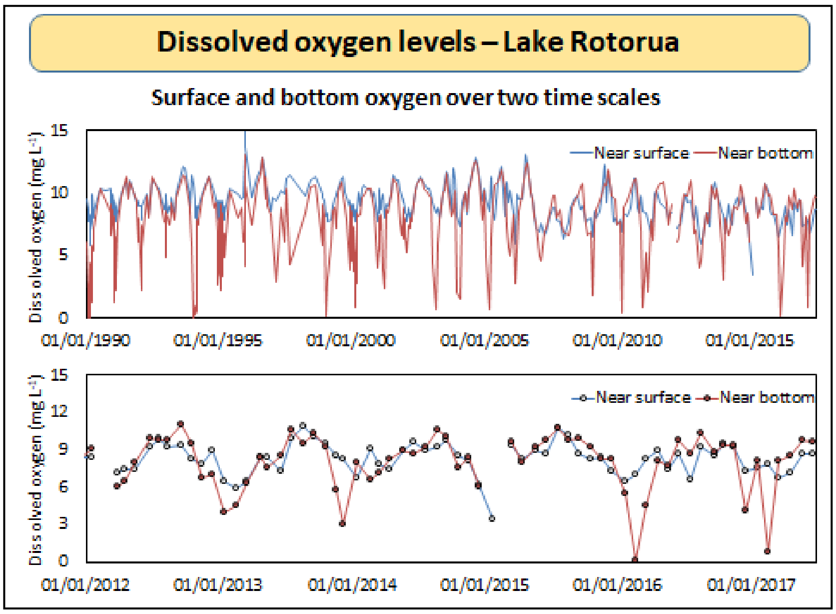


Experiment organisation level	Observed response +N	Observed response +P	Relative response	Co-limit. response	Incubation/ simulation duration	Study
Lab bioassays (0.25 L)	Yes	No			5 d	White and Payne (1978)
Lab bioassays	Yes	No		>N	2 h, 24 h	White et al. (1985)
In situ mesocosm (3 L)	Yes	Yes	P>N	>N, >P	4 d, 6 d	Burger et al. (2007)
In situ mesocosm (1 m³)	Yes	No		>>N	1-9 d	Meads (unpub. data 2009)
Lab bioassays (1)	No	No		No	1 d	Abell and Hamilton (2015)
Lab bioassays (2)	Yes	No		≈N	1 d	Abell and Hamilton (2015)
Lab bioassays (3)	No	Yes		No	1 d	Abell and Hamilton (2015)
Lab bioassays (4)	Yes	Yes	N≈P	≈N, ≈P	1 d	Abell and Hamilton (2015)
Model simulations	Yes	Yes	N >>P	>N, >>P	5 d	Abell and Hamilton (2015)

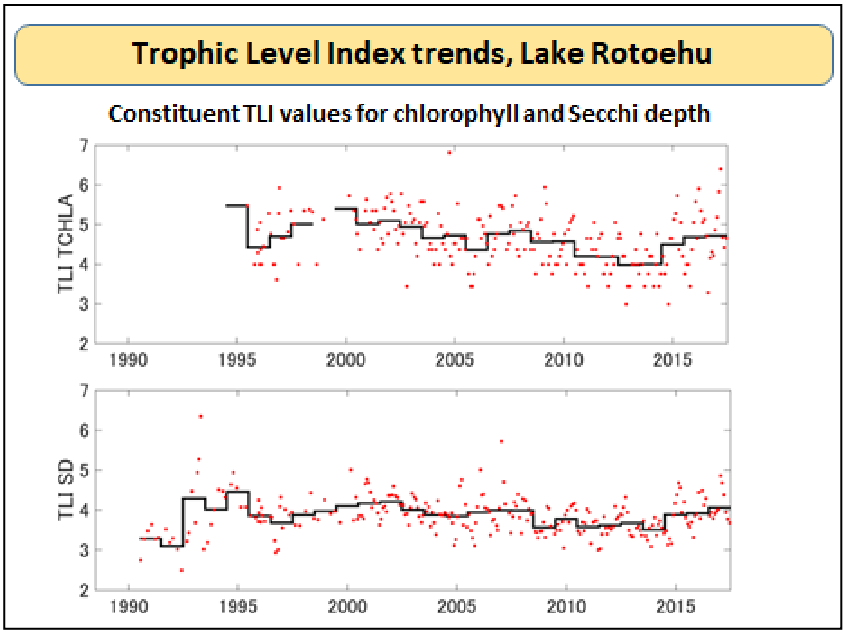
To re-emphasise the importance of alum, particularly in terms of water clarity in Lake Rotorua, dosing started in 2006 and ramped up in 2012. Below shows the percentage as well as the concentration of cyanobacteria. By 2012, at the maximum dose rate, we had reduced cyanobacteria to low concentrations. Unfortunately we do not have time to discuss the pros and cons of using alum.



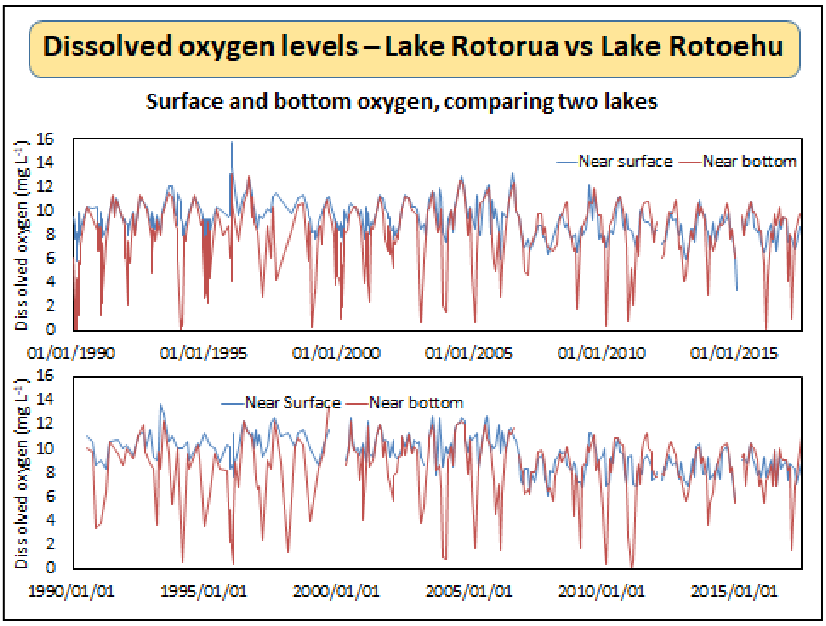
Again, I go back to dissolved oxygen in the next slide but we have to be very careful about using it as an indicator in Lake Rotorua because the lake has quite a different mixing regime from the deep lakes. The deeper lakes stay stratified for about nine months of the year. Rotorua mixes intermittently for most of winter and at times during summer. That mixing can be intermittent, interspersed with periods of calm when the lake stratifies.



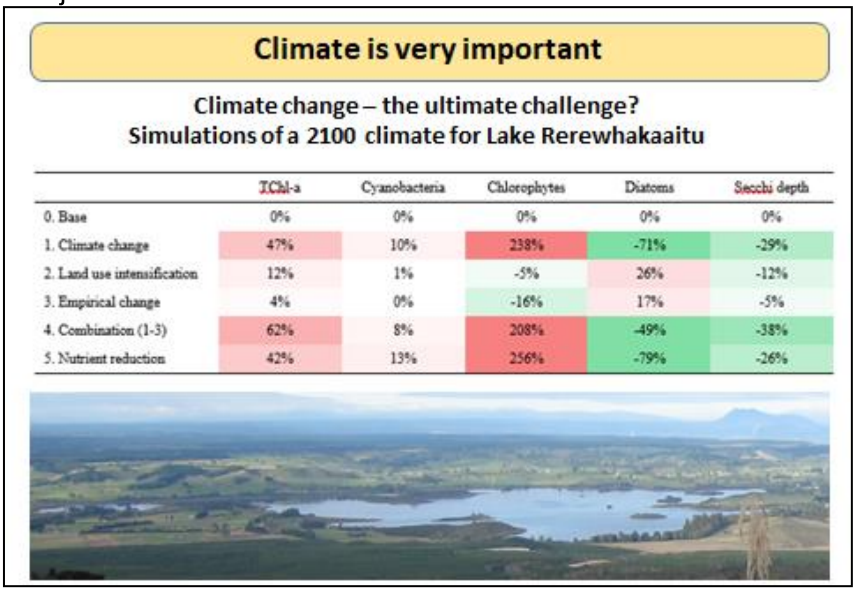
The consequence of the mixing regime is that dissolved oxygen decreases quite markedly and through the 1990s dissolved oxygen reached concentrations of zero. But these are monthly samples and it can be quite difficult to interpret them in a lake that mixes intermittently. What you can say is that the period through the 1990s, when the wastewater was first taken out, looked quite promising for water quality improvement, but overall there are periods of quite marked decline in dissolved oxygen. More recently, from 2012 to 2015, dissolved oxygen in the bottom waters did not decline much at all. As alum has been reduced it clearly shows that dissolved oxygen again goes back into decline – decreases. However it is not only the alum, it is also the climate.



Lake Rotoehu is the last of the four lakes I will talk about and is very similar to Lake Rotorua in that it is shallower and mixes intermittently, dispersed with periods of stratification. Looking at chlorophyll *a* levels we see that the TLI value has declined over time, which is very positive. The clarity has increased slightly. Turning to dissolved oxygen in the graph below and plotting Rotorua at the top and Rotoehu down the bottom of the graph it is clear that dissolved oxygen is almost a mirror image through time in the two lakes. If it is very hot during the summer these lakes stratify for longer and lose dissolved oxygen from the bottom waters.

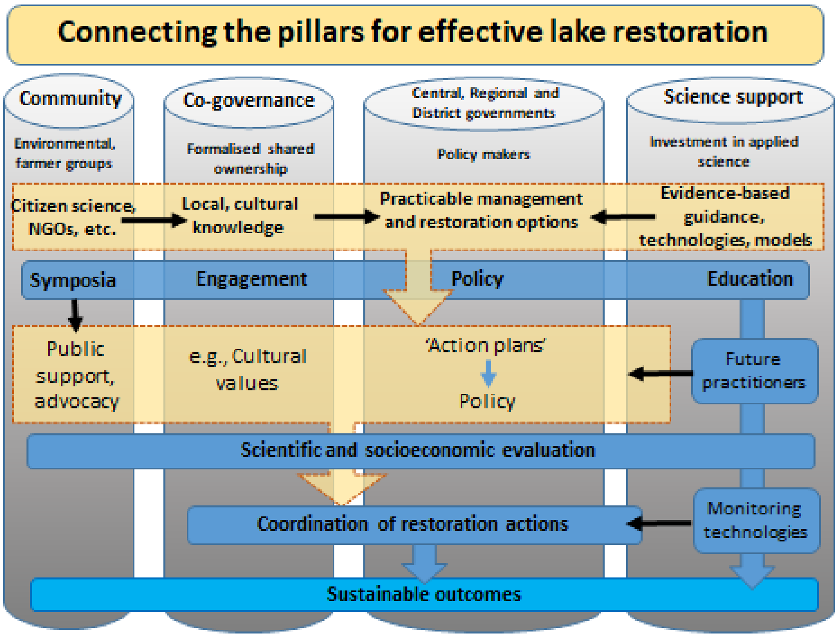


Basically you can pick out the hot years in these two lakes. Both of the lakes have had alum dosing which may have improved conditions. Last summer was very hot. The dissolved oxygen decline has a remarkable similarity in the two lakes, which suggests that climate is a major driver.



	TChl-a	Cyanobacteria	Chlorophytes	Diatoms	Secchi depth
0. Base	0%	0%	0%	0%	0%
1. Climate change	47%	10%	238%	-71%	-29%
2. Land use intensification	12%	1%	-5%	26%	-12%
3. Empirical change	4%	0%	-16%	17%	-5%
4. Combination (1-3)	62%	8%	208%	-49%	-38%
5. Nutrient reduction	42%	13%	256%	-79%	-26%

Last night I spoke at a farmers' meeting at Lake Rerewhakaaitu and suggested that climate change maybe the ultimate challenge. The slide above models chlorophyll *a* and cyanobacteria, as two indicators of water clarity. We looked at a 2100 climate comparing various scenarios using models, to see how much things would change. Overall, looking at chlorophyll *a*, we can see that with climate change alone we will be dealing with major changes, particularly with lakes that are shallower and mix intermittently such as Rerewhakaaitu, Rotoehu and Rotorua. We know we have major challenges ahead as the climate warms and can expect, based on the best knowledge that we have, that things are going to change quite substantially. Rerewhakaaitu, for example, will have a 50% increase in chlorophyll *a* and 30% decrease in water clarity.



This slide demonstrates what I call the pillars of lake restoration, which can be transferable all around the world. These concepts are a linear flow of community co-governance and the way in which governments are able to address lake restoration with science support. What makes the Rotorua Te Arawa Lakes programme particularly valuable is the way the pillars are interconnected. The LakesWater Quality Society and Te Arawa Iwi are key drivers.

Andy Bruere and the Bay of Plenty Regional Council have done a tremendous job too. Here in Rotorua the community has come together to achieve sustainable outcomes. That is pretty unique right around the world. The University of Waikato has a key role to play with the Chair in Lake Restoration, being able to connect with research globally and providing opportunities for future practitioners here. Dr Ian Kusabs' graduation is one of my proudest achievements. It is a privilege being able to watch over people passing through the education system and becoming practitioners working in their rohe. My colleague, Chris McBride is another example and is driving world leading technology development.

Please feel free to contact me. To finish I want to acknowledge people who have supported me, many of whom are in this audience and made this possible. Thank you.

- Chris McBride, Kohji Muraoka
- New Zealand Ministry of Business, Innovation and Employment (UOWX1503). Enhancing the health and resilience of New Zealand lakes
- Bay of Plenty Regional Council – Lakes Chair
- NIWA: long-term data sets

LAKES WATER QUALITY
LAKE WEED AND PEST ANIMALS

Hon Dr Nick Smith
Minister for the Environment
n.smith@ministers.govt.nz

Nick has previously been the Minister of Conservation. During his time in these two portfolios he has been responsible for establishing two national parks and 17 marine areas. Nick played a very important role in the emissions trading scheme. He is the founder of the Blue Greens, which is a group in the National Party that recognises those who care very deeply about the environment. They meet annually around the country in a synopsis of summit like this. He has won the Nelson seat 10 successive elections in a row.

TRANSCRIPT

Chair - Hon Todd McClay

There are many people in this room who have worked hard behind the scenes, achieving things that seemed large or small at the time, but set us along the path for the Rotorua Lakes to make more progress more easily than any other region around waterways in the country.

In 2011 the Waiora Agreement was signed between the Lake Rotorua Primary Producers Collective, a group of dairy, dry stock farmers and landowners and the LakesWater Quality Society. They agreed to work together to achieve a clean and healthy Lake Rotorua through the reduction of nutrient emissions. For the first time targets were agreed to ensure a sustainable rural sector and a sustainable environment in the Lake Rotorua catchment. Environmentalists and farmers agreed to work together in a common cause. After a few meetings they realised that the environmentalists were business people and the business people understood that the farmers were environmentalists.

In 2013 this led on to the Oturoa Agreement between the Lake Rotorua Producers Collective with Federated Farmers, LakesWater Quality Society and the Bay of Plenty Regional Council. It was an agreement to resolve the appeal before the Environment Court over the Regional Policy Statement (RPS). They agreed to take a non-litigious approach to reach agreement around disputes and concerns in the future. They agreed to work to restore Lake Rotorua over a twenty year period and they agreed to a collaborative approach. They created the Stakeholder Advisory Group, (StAG) where all parties sat around the table, talked about the challenges and sought common understandings and solutions. It was a very important stepping stone towards the significant achievement we see now. There is still much work to do but we are much further along the pathway than any other part of New Zealand.

We had support from Government with Steve Chadwick as our local Member of Parliament at the time. They delivered $72.1M of Government funding for a total package of $144M, which included contributions from both the Regional and Local Councils, to focus on five Rotorua Lakes - Rotorua, Rotoiti, Rotoehu, Okareka and Okaro. LakesWater Quality Society and others were instrumental in going to Wellington to make the case and lobby for why our lakes were such a priority. But flexibility was needed to adapt the funding where necessary. In the case of Lake Rotorua, following those two agreements, it was decided that money would be better moved from in-lake solutions onto land. That was a very important development because it showed the rural community the importance of cleaning up the lakes and keeping sustainable agriculture and job creation in the local economy.

Only five lakes were part of that original plan. Additional funding helped other communities. Some years ago $4.5M was allocated to Lake Rotoma for a sewerage system and I am pleased that the final hurdle has been overcome to ensure that their water quality not only remains as it is today but also continues to improve. There has also been a recent announcement at Lake Tarawera of $6.5M contribution from Government to a reticulated sewerage system. It is a large contribution, one that recognises that this must be a partnership if Lake Tarawera is to remain a pristine lake.

Hon Dr Nick Smith

It is a pleasure to be invited to be part of this. The debate around fresh water in New Zealand has never been so strong and the delight in coming to Rotorua is that so many parts of New Zealand could learn from the experience here of pulling together a science-based collaborative approach for progress. Just listening to Professor David Hamilton's presentation, reinforcing how complex these fresh water issues are, signals the progress that has been achieved.

I would like to reinforce the Government's take on how we deal with fresh water challenges across our country. Firstly, we need to ensure that our decisions are based on good science. There is a real complexity of fresh water issues around New Zealand including pathogens like *E.coli*, nutrients like nitrogen and phosphorus, sediment and also invasive species. The idea that there is one simple fix-all approach is not sound and the way those different challenges interact together emphasises the importance of underpinning our approach with good science.

Secondly, if New Zealand is going to get on top of this problem we need to step away from the classic Kiwi approach to environmental issues of the good guys and the bad guys which is a very polarising argument. Instead it is about getting people, Iwi, councils, farmers and the broader community working together and involves a mutual respect. People have to get out of their comfort zone. We are all kiwis and aiming for the same thing.

The third part is to ensure that our responses are practical. I am in the middle of thorny detail around requirements on farmers to fence their stock out of streams. I am sorry; parts of New Zealand are tiger country. If we are to come up with a set of rules that improve fresh water quality we do need to recognise that not all farmland and water bodies are the same whether it be sheep, deer, beef or pigs. We need a nuanced approach in which farmers rise to the challenge, they also have to put their hands in their pockets, but we need to ensure that those rules are practical.

The last really tricky balance for us is to strike the level of national direction. How much do we prescribe from Parliament, how much do we do at regional level and how much do we do at community level? In my view, since the RMA came into effect in 1991, Central Government has been insufficient in providing leadership. That is true and why one of the key priorities for our Government has been putting in place the first National Policy

Statement on Freshwater Management. But we need to be careful not to excessively prescribe from the centre. It is about trying to get the right balance on what should be regulated nationally and what should be done locally.

The reality is if New Zealand is serious about improving its fresh water quality, it is going to cost, and that means a sharing of that burden. When we come to working out the costs of these mechanisms, if everybody is equally pissed off, we have probably got it right. If the taxpayer is feeling some pain, the team at council are feeling that the ratepayers are carrying as big a burden as they can and the farming and industry communities are feeling that as well, I am sorry, that is just the way it is. To make progress we all need to put our hands in our pockets.

Can I talk you through last month? Our Government made a batch of changes to the National Policy Statement. Why have we done it? What does it do? The first very clear message we got in 2009 was there were no national rules around fresh water quality. Through the collaborative process of the Land and Water Forum we came up with the first cut which was a substantive step forward. However in debating where the bottom line should be, a number of councils put the case that they had water bodies that would never practically get to a swimmable standard. So the standard was made that the absolute minimum bottom line legally would be a wadeable standard. In rough terms that is 1000 *E. coli* per 100 ml. The community said it was not very inspirational; we want better than wadeable.

Through the Land and Water Forum we decided to raise that standard. Kiwis want to be able to swim in their lakes and rivers and we subscribed to that. But if that is going to be robust and scientific, measurable and accountable we need to come up with a system for grading. So we did. The only other jurisdiction in the world that has done it is Europe. Ours is a bit tougher than the Europeans and all water bodies are graded from excellent to good, to fair, to intermittent and to poor. If we apply that standard over all our water bodies in New Zealand, 72% of them match up to those fair and better categories. The Government has said we want to get from 72% to 90% over the next twenty two years to 2040.

People still say that is not very challenging. Let me tell you how challenging it is, it means that we have to get 1,000 kms of waterways every year up a grade for the next 22 years at a cost of about $2 billion. But the real key is asking each of the regional councils to set targets for their areas, and it is no good having a target unless regularly reporting it.

Some people have said swimmability is just part of the picture, and they are absolutely right. An equally important issue, especially for Iwi, is the ecological health of our waterways. The changes we made last month require councils to measure the ecological health of the waterways, with a bottom line that can be achieved. We have directed regional councils what they must do if those ecological health parameters are not being met.

But the most difficult challenge around fresh water management in New Zealand is the issue of nutrients. Here in the Rotorua Lakes we are at the cutting edge. When I became Minister of the Environment I thought most problems confronted have been faced somewhere else in the world and we should learn from those. I chaired the OECD meeting of Environment Ministers in Paris last year and using my capacity as chair, I specifically asked for a section on nitrates and how they are managed across the world, with the idea of stealing some experiences. The most surprising part of that meeting of 36 different Environment Ministers was that when I suggested we had good research done at

Lake Taupo and the Rotorua Lakes, but were struggling, what were other countries doing? They replied that they were coming to New Zealand to learn from our experience. The view after that meeting was that research and actions in the Rotorua Lakes and Lake Taupo is world leading particularly in cap and trading nutrients. But it is a reminder of how challenging work around nitrates is.

The Government has set down an objective across New Zealand that councils need to limit nitrates. Some would say that all we need to do is cap the numbers of dairy cows but in the Government's view that is too simplistic. Science tells us that some soils in New Zealand have negligible nitrate leakage, despite intensive dairy farming. Soils do vary significantly. When we came to Government there was not a single area of New Zealand that had limits on nitrates. We now have 25% of catchments with limits in place. There are many difficult arguments in communities around New Zealand on how to put those nitrate limits in place. Where there are limits, it is even tougher for communities to know how to allocate those existing rights? That requires the Wisdom of Solomon.

The last change that we made to the national policy requirements for water is the inclusion of Te Mana o Te Wai[1] as a core legal principle that applies across all our waterways in New Zealand. I must credit the work of the Iwi Leaders Group and believe it is a substantive step forward.

Can I conclude by suggesting the next logical steps to improve fresh water if we were privileged to continue in Government after 23 September. The first one is developing good management practice for dairy, beef and cattle, deer and arable farmers, for land sub-dividers, for hydro and other water users, and that work has already begun. While we can have different regulatory rules we need to lift the practical management in all those areas and that would be a key priority for us.

The second is we need to finalise national rules on stock exclusion. At the moment two or three of 16 regional councils have tried it. We have some quite specific proposals and timetables through the Land and Water Forum. We now need to get right down to the nitty gritty and complete that work.

The third really tough issue is to set up a technical advisory group with Iwi leaders around the issue of allocation. Whenever there is a debate about allocation of freshwater most New Zealanders simplistically jump to the argument that this is about who takes the water, whether it be for irrigation, town supply or the teeny-weeny fraction used in bottling water. But that is not the tough part. New Zealand uses about 2% of its fresh water resource. The far tougher issue is the allocation of nutrient rights whether it be Rotorua, Southland, or my own community of Nelson. The current law for allocation is first in first served. There is a broad consensus that first in first served is not necessarily what is best for the community. The hard part to move forward is how might you do that and that is why we have that technical group.

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[1] [1] Described as "an overarching korowai for environmental management", this set of principles provides iwi and councils with increased visibility of the value and role of mātauranga in providing a more complete picture of the state of our takiwā and the adoption of the National Objectives Framework. Te Mana o te Wai speaks to the aspirations of many Kiwis who want clean, bountiful rivers and lakes for the generations to come. It recognises that the mauri, mana, and health of each body of water should be the primary consideration before looking at using it for other purposes. That means setting minimum limits that ensure that there is enough water in the river to sustain the ecosystems that rely on it, only then allowing water to be extracted to satisfy external requirements. This is something everybody in Aotearoa can identify with – it is not an exclusively Māori aspiration. Te Rūnanga o Ngāi Tahu, Te Karaka, 16.09.2016

The very last message is about a major piece of work on how we fund both the upgrade and future infrastructure for urban communities. In the debate raging at the moment around fresh water there is a view that this is about the farmers. The average *E.coli* level in urban waterways across New Zealand is 440 per 100ml. The average level in farming communities is 180. In our natural forests it is down at about 20. Urban New Zealanders have to do their share of the heavy lifting.

There is a huge challenge not just for your Council, who recently asked for Government support for Lake Tarawera's sewerage scheme with $6.5M, but for councils across New Zealand that require billions of dollars of investment for our wastewater and stormwater systems if urban New Zealanders are going to share in this challenge. As a country we have to do a much better job of managing our fresh water.

Can I conclude where I started? This community should be enormously proud of the constructive way in which it has engaged and made so much progress on this issue. I particularly want to pay tribute to the LakesWater Quality Society. It has been such a constructive player as this community has moved forward. May you maintain this resilience, this vision, this drive to improve water quality. You are inspiring other communities around New Zealand. In my other portfolio I have a meeting today with the local MP and Mayor around building issues. What is so challenging around an issue like water quality and environment is that a new building, or library or something, can be done in a couple of years. But water quality is a multi-generational issue and we need the strength of this society and its partners to see the distance and ensure that your children and grandchildren can look back on the vision and improvement that has occurred in the management and quality of these gorgeous lakes in the centre of our North Island.

Thank you for the invitation.

Hon Todd McClay

Nick, thank you very much for that and also for your commitment and help over many years to enhance the Rotorua Lakes restoration projects to move ahead. Nick has given a huge amount of support around the cabinet table to ensure that the funding that we have had has remained and been used well.

QUESTIONS

John Green, ex-Chair, LWQS: Thank you very much for coming. We have all been through the various stories you talk about. It is wonderful for Todd and Nick to stand up before us and summarise what has happened over the last 20 years and see that the politicians really understand the issues.

From my work as a finance director of many companies, I know that accounting standards can drive the behaviour of a company and can also drive very bad behaviour. But here in New Zealand we do not have accounting standards for environmental behaviour and to me that is something we need to invest in. The Accounting Society is not sure how to measure these standards nor who is accountable and who has to report. You previously stated at one of our symposia that you would like to see accounting standards and I know how difficult it would be to get them going but I would be interested in your comments.

Hon Dr Nick Smith: I am very proud that two years ago we passed through Parliament the Environment Reporting Act. It requires the Department of Statistics and Ministry for the Environment to produce once every five years a full state of the environment report, every six months a report on the state of our fresh water, our marine environment, our air, our climate and our land reports. In my view they are an important step to better accountability because you manage what you measure. But are we able to say we are getting better or not? The honest answer is that our database and reporting systems are all over the place.

For example, in the debate about what proportion of New Zealand waterways are swimmable or not, the problem is that every regional council measures it differently. Some only measure water quality for swimmability in places where it is trouble. Surprise, surprise if you only monitor in places where it is in difficulty your figures are pretty ugly. Others are quite cunning and only measure where it is pristine and their numbers look very good. Others do it randomly. How do you make some comparison? The new National Policy Statement introduced last month sets the standard on testing. In future I can have some rivalry with Steve Chadwick and Todd McClay, looking at my honest measure of water quality and say my fresh water is cleaner than yours, tidy your act up, or vice versa. But it can only be done if we have standards.

I am cautious of Treasury who tried to put a monetary value on our conservation and environmental assets. Like you all here I am very passionate about our Abel Tasman National Park down in my part of the world. Treasury spent $800,000 on all these accountants and treasury types to work out the value of the Abel Tasman to put on the Crown books. In my view it was a bit academic and stupid. There are some things that we cannot put a dollar value on and certainly I do not believe it can be the Abel Tasman. The Government has no intention of selling it.

However there is some really smart stuff. In Nelson the biggest industry is fishing. When I started as a politician the fisherman said their most important asset was their fishing boat and they did not like to be stopped from catching fish. When we moved to the quota management system suddenly the fisherman owns a $300,000 fishing boat but has $2M of quota. It was extraordinary for me as a Member of Parliament to receive a delegation of fishermen who said the stupid people in the Ministry for Primary Industries had set the quota too high and the banks have written a report which said if they carried on fishing like this that $2M of quota would soon only be worth $1.5M. I needed to sort them out. They need to conserve it better.

In other words you can use smart financial instruments to change behaviours. The whole notion of capping nitrogen and trading is part of that story but it is complicated, detailed and needs to be done very carefully. So yes there are opportunities and the Environment Reporting Act is a big step. It is in the detail where we need to be very careful because we are passionate about the environment but we also need to be practical.

Kevin Winters, BOP Regional Councillor: I wanted to tell you that it is a good news story here in the Bay of Plenty. We have redone all our fresh water streams through your swimmability targets and as of this week we are 93% compliant, which is the highest in the North Island. We are the best in the North Island.

Hon Dr Nick Smith: We look forward to check those numbers and make sure it all stacks up and will be delighted to know it is true.

Kevin Winters, BOP Regional Councillor: I have checked them too. We have two problems in the Bay of Plenty. The ones that pull us down are Lake Rotoehu and Lake

Okaro. They are our infants that we still have not got a handle on, for the rest, the progress has been fabulous. Remember, 93%, you heard it here first.

I also want to put a question to David Hamilton. Was I hearing you correctly in your alum dosing? We know it locks up P but did you say today that it is also affects nitrogen in the lakes. There was a downward trend and you said it was nitrogen.

Nick Smith: I saw the same graph and was equally interested.

Prof David Hamilton, Australian Rivers Institute: It is scientific detail but when alum binds with phosphorus it does not just bind with phosphorus, it binds with a lot of other particles as well. Some of those particles can also contain nitrogen. The nitrogen then washes out. But essentially alum's primary objective is phosphorus, and secondarily nitrogen.

Kevin Winters: That is really interesting to hear. I am on the Bay of Plenty Regional Council and the Lake Rotorua Incentive Committee which is buying nitrogen out of the catchment and it is really good news that alum binds nitrogen as well. Thank you for that.

Geoff Rice, LWQS: Kia ora koutou. David, I want to touch on the fact that Te Maru o Kaituna is an entity now and at the bottom half of this catchment which I consider to be a single body of water. There are lessons down there to be learnt from what has happened up here. What affect is the implementation of the diversion wall having on the Kaituna from Okere down to Maketu?

Prof David Hamilton: Originally when we did the projections we thought it would be neutral or possibly even negative on the Kaituna but we did not anticipate the huge improvements in water quality of Rotorua and Rotoiti. The blend of water was formerly 50/50 or even weighted more towards Rotoiti water but now it is 75% to almost all Rotorua water. So the improvement in Rotorua has underpinned the changes that have occurred in the Kaituna particularly if you think back to 2005 when it was not good.

Mayor Steve Chadwick, Rotorua: Welcome Minister, I hope you see the enthusiasm in the room for how we work together. We are looking at innovation, trying to move away from the only tools we know in the toolbox of rules and regulations. What is your view on natural capital? We would love to work on a catchment wide approach with the regional council and Iwi to find the best way to use our land within our catchment?

Hon Dr Nick Smith: Firstly, Steve, I want to reinforce the constructiveness of the LakesWater Quality Society. I have been to these symposia a number of times and what is most unique is that so many people are passionate about the lake and engaged with the science. I have difficult fresh water meetings all over the country, but what is so fantastic here is you being present and people being able to engage in the scientific detail.

On natural capital and new tools, I think the tools need to be at a regional level partly because the specific issues are quite unique. Looking at the lakes down in Wanaka, their particular issue is with lake snow which has a quite different set of parameters to the challenges here. With the rivers in my own area, it is *E.coli* which we really need to give a nudge. In other river systems the key issue is nutrients. So if we are going to develop new sophisticated tools it needs to be at the regional level. The Lake Taupo cap and trades scheme is right up there in innovation and financial incentives for change. If councils like Rotorua have ideas for new policy tools for natural capital, but do not have the legislative tools from Parliament to give them a go, they need to engage with Parliament about how it can be done. I believe that going forward Parliament will give a smorgasbord of tools to councils who must then find the ones appropriate to their challenges and apply them in their communities.

Hon Todd McClay

Ladies and Gentlemen it has been a privilege to chair the first session this morning. I would like to recognise those here who are from the rural sector. Over the last 4 or 5 years the way that all groups and communities have come together constructively to find a way forward is not only encouraging, it deserves recognition. I very strongly believe that the overwhelming feeling among the Rotorua catchment and more widely is that the rural community are part of the solution to a clean and healthy lake and having sustainable agriculture.

I commend everybody in the room for the work that they do and we must keep that in our foresight because the economy of Rotorua is doing extremely well. It is very carefully balanced but we need jobs and investment, we need the drive that comes from the rural community that props up so many businesses, not just out on the land but in our cities and towns.

Session Two : THE PEST FISH THREAT

SESSION CHAIR : Don Atkinson, Chair LakesWater Quality Society

THE PEST FISH THREAT AND THE GREAT LAKES EXAMPLE

Lindsay Chadderton
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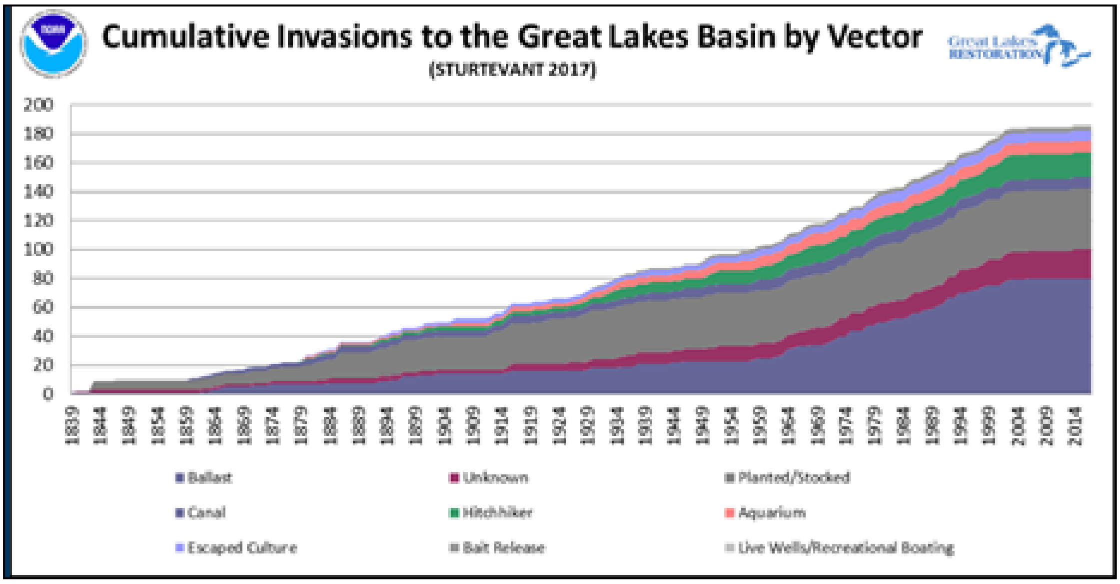
lchadderton@TNC.ORG

Lindsay is the Aquatic Invasive Species Director for The Nature Conservancy's Great Lakes Project. He joined the Conservancy in 2007 where he was tasked with establishing the Conservancy's aquatic invasive species programme for the Great Lakes region. He is part of the team that developed the environmental DNA surveillance method used to track the invasion of Asian carp in the Chicago Area Waterway System that artificially connects the Great Lakes to the Mississippi River basin. He worked for the Department of Conservation in New Zealand for 17 years, managing projects in marine, freshwater and terrestrial ecosystems.

TRANSCRIPT

Today I will talk about some of the innovations and lessons from the Great Lakes with regard to managing pest fish. I will start by putting the region into context from a New Zealand perspective and then I will focus on some surveillance tools, surveillance planning and control methods being developed in the region. I believe that many of the problems you face are the same as those in North America. However, there is significant investment occurring in the U.S. to manage a variety of species and overlap in issues may provide opportunities for collaboration. David Hamilton talked about linking this region to the world for water quality and monitoring and I believe the same applies to pest fish management. Certainly, the Great Lakes region has already gained from ongoing aquatic plant management collaborations with Paul Champion (e.g. Gantz et al 2015).

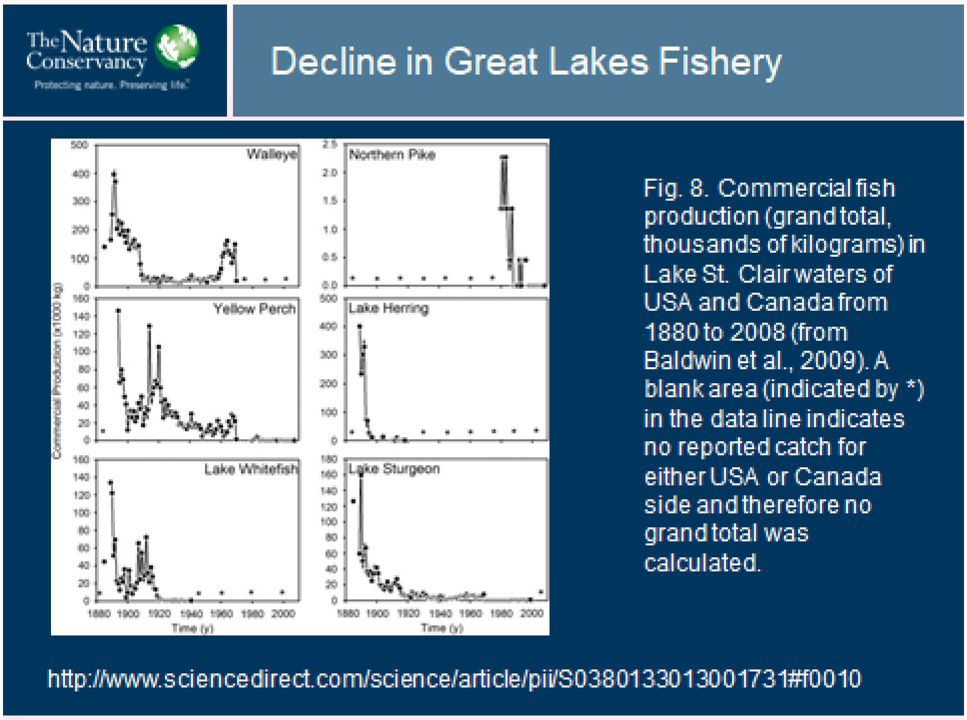
The North American Great Lakes, are five lakes, the largest, coldest and deepest of which is Lake Superior in the north. Lake Michigan and Lake Huron flow into Lake Erie, the smallest and warmest of the lakes, the latter flowing into Lake Ontario and then down the St Lawrence River and into the Gulf of St Lawrence and Atlantic Ocean. The region is bounded by two countries, eight states, two Canadian provinces, 54 million people and $4.5 trillion economy, and about 20% of the earths freshwater. These are large water bodies but in many ways the issues that they face are similar to those faced by the Rotorua Lakes District.



The Great Lakes has the distinction of being one of the most heavily invaded fresh water systems in the world. There are over 180 non-native species in the system of which about 30 are what we would call invasive. That means they cause net harm to the environment, economy or human health and cost the region hundreds of millions of dollars a year.

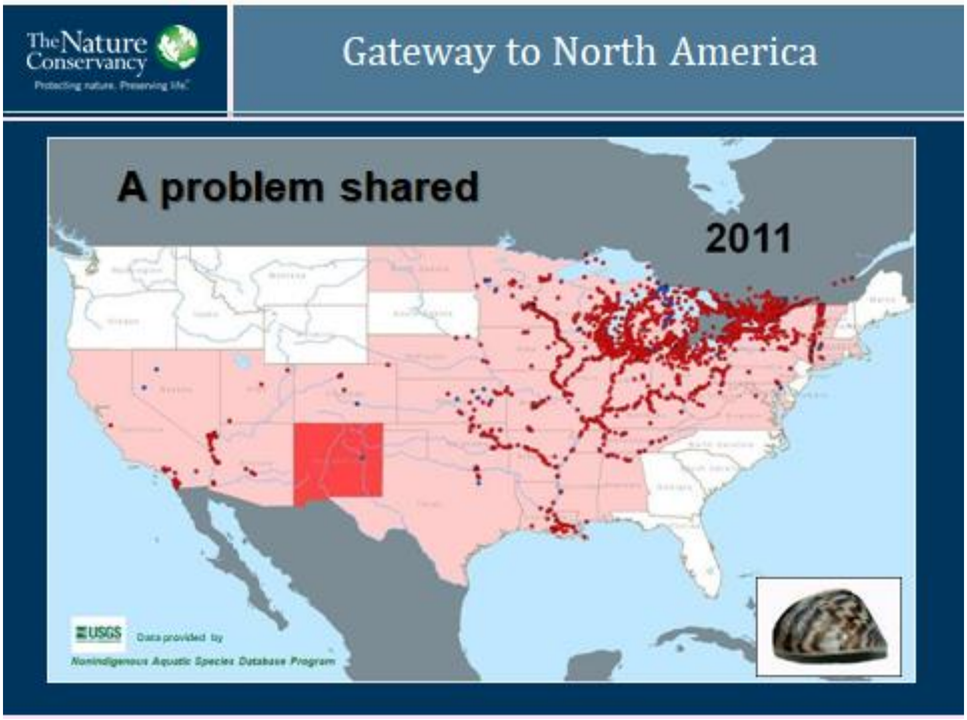
How do they get here? There are a number of pathways of introduction. The lakes are linked to the sea by the St Lawrence Seaway, maritime shipping and the discharge of ballast water has been an important pathway for introduction to the basin. In addition, stocking and the other live trades (e.g. water garden aquarium, bait, live food), canals and recreational boating have also been important.

The impacts on the lakes' systems has been dramatic resulting in wholesale changes to communities and food webs. These are now primarily based on invasive species. These graphs show historic fisheries data - the black areas represent native fisheries; Lake herring, chubs, lake whitefish, lake trout and yellow perch. (The scale is in millions of pounds). There were major fresh water fisheries within the Great Lakes but these have largely disappeared.



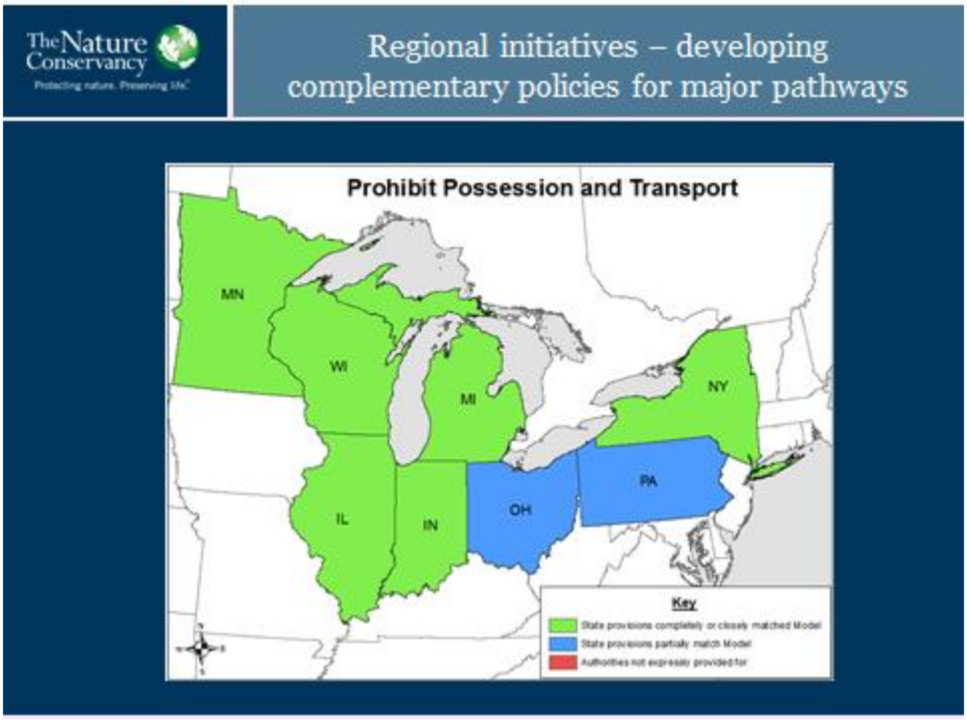
The Lake Trout fishery had largely declined by the 1950s a combination of over fishing, pollution and impacts from sea lamprey. The invasion of sea lamprey into the upper Great Lakes through the Erie and Welland Canals contributed to the decline. The other key species that has impeded lake trout recovery has been alewife, another introduction that entered the upper Great Lakes through the canal system. Alewife is an important prey species but the dependency on Alewife can cause a vitamin B deficiency that leads to aquatic plant management early mortality syndrome. Lake trout that feed heavily upon alewife produce eggs and larvae that die soon after hatching. So the fishery is now largely dependent on stocking.

The Great Lakes are also a gateway to North America. The next slide shows the history of spread for zebra and quagga mussels. These two species of mussel were introduced into the Great Lakes via maritime shipping. They spread rapidly throughout the great lakes and then into the Mississippi River Basin via the Chicago Area Waterway System, and then on trailer boats they have crossed the divide first introduced into Lake Mead and the Colorado river and they are now rapidly spreading through western states. These species



impact any major water user and also change the way nutrients move through lakes systems, having a devastating effect on the Great Lakes and elsewhere.

Over the last ten years management in the Great Lakes has primarily been focused on policies and getting the states and provinces to work together with a complimentary set of regulations to shut down these key pathways of invasion.



However, over the last 3 or 4 years there has been a growing emphasis on developing a region wide surveillance plan. The Bi-national Great Lakes Water Quality Agreement, a federal agreement between the Canadian and United States Government, was re-signed in 2012. It was a commitment to work on aquatic invasive species including the establishment of a regional wide surveillance plan.

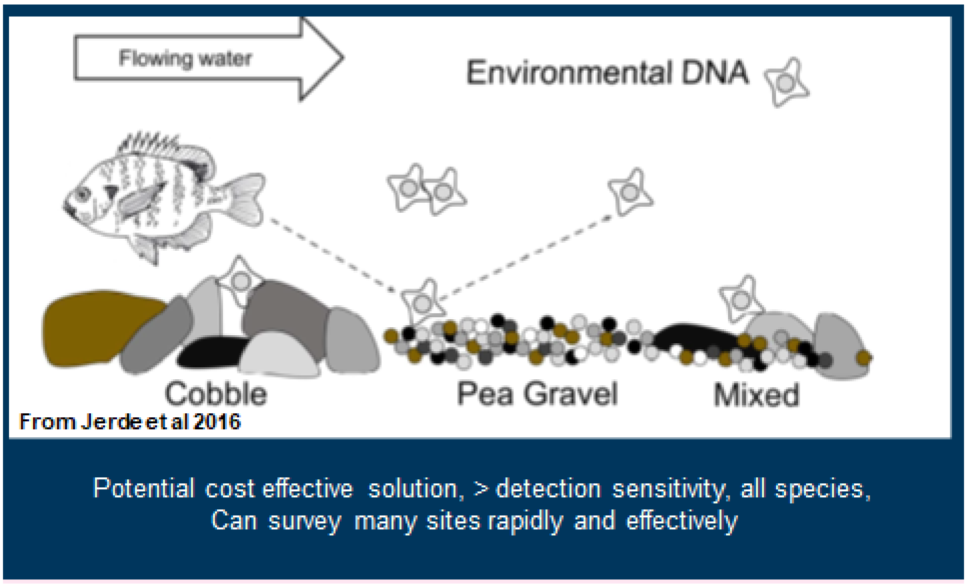
The plan considers the major pathways of invasion to identify key introduction hotspots. We combine data on surrogates for each of the major pathways of invasion. Slide 10 indicates the predicted problem areas – with the highest probability of new introductions. The red areas are the nexus of high population densities, major ports, canals, large marinas and recreational boating areas and large catchments with stocked ponds.

It is no coincidence that we see Chicago, which also has a link to the Mississippi River, Toledo, another key port in the basin that is associated with both Detroit and Toledo City, as regional surveillance priorities. These tools allow us to identity locations to work in and the information can be used to quantify how much effort might be required to monitor all high risks sites. Data important when making the case for federal investment in surveillance across the basin.

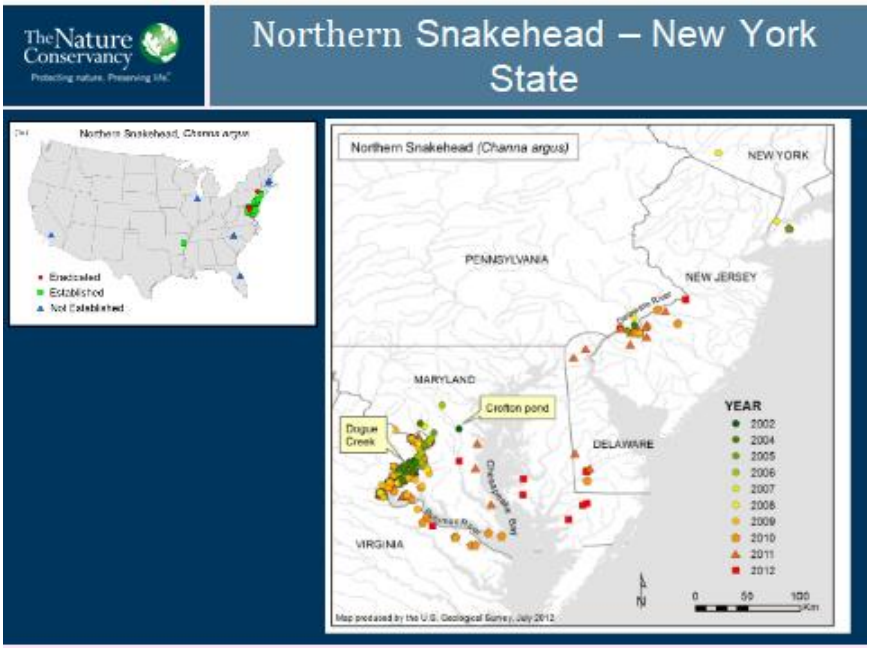
We know from work that USEPA and USFWS have undertaken that any site takes about a week to sample with traditional methods to provide an acceptable level of detection sensitivity (Hoffman et al 2011). Duluth Harbour is in the very western end of Lake Superior, about 10 to 12 kilometres long and the same inland. The Environmental Protection Agency monitor this area and estimate they need about 75 - 150 samples per year for a high enough detection sensitivity that there is a strong probability that an incipient species will be detected (Hoffman et al 2016). The problem with traditional sampling is it is incredibly resource intensive and costly.

How do we make surveillance more efficient and cost effective? To improve the probability of detection there are two choices. Either increase the effort or come up with smarter more efficient way to sample.

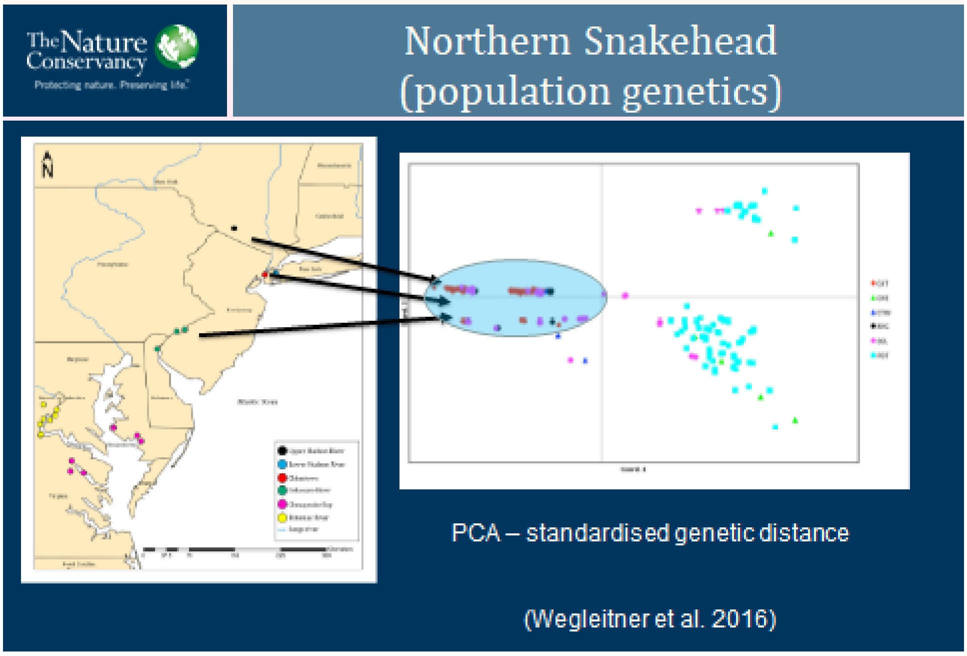
We all shed DNA. The same applies in the aquatic environment. Fish shed cells in their urine, in faeces, as water flows across their gills and as they lose scales. Some of that DNA is retained in flowing water. The heavier particles may settle out and the cellular material with more lipids may float and settle on the surface. In a new incursion traditional sampling methods aim to detect the small numbers of adults and/or juvenile fish in an incipient population. Whereas sampling can focus on more abundant early life stages or like larvae, or in this instance sampling could focus on a plume of DNA produced by the target organism. eDNA has the potential to be more cost effective, increasing detection sensitivity for all species and enable agency to survey sites more rapidly and more effectively.



This slide shows the eDNA method, starting with the collection of water samples that are then either centrifuged or filtered. It is the filtrate, the material left on the filter that is of interests. The DNA is extracted from the filtrate, amplified and then screened for the presence of the target species (see Jerde et al 2011).



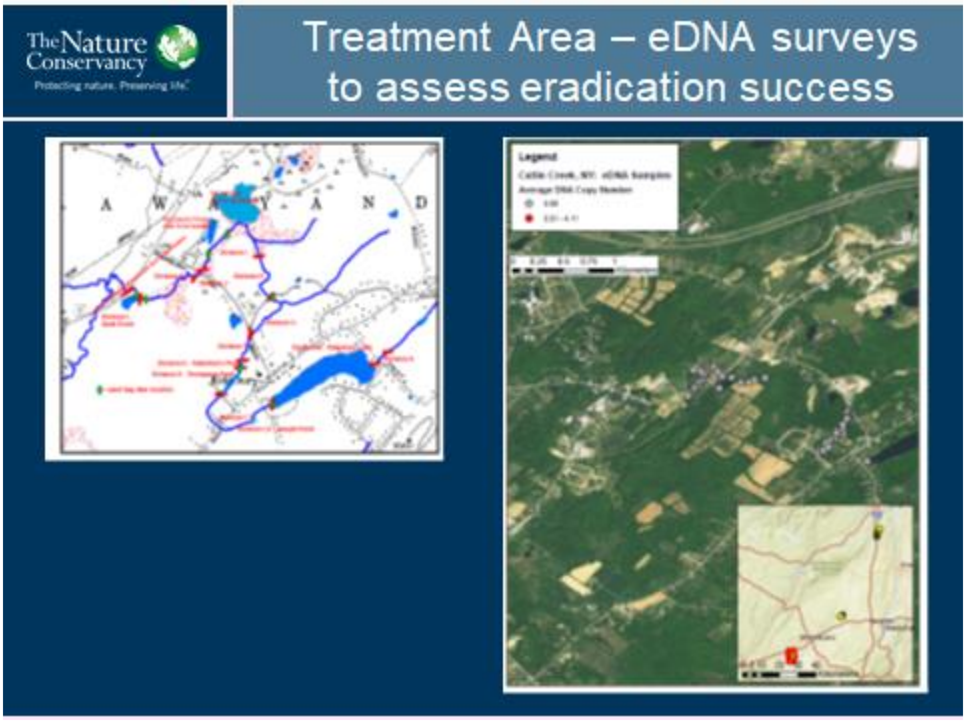
The Northern Snakehead is an example of a fish that is predicted to be an imminent invader for the Great Lakes. It is native to South East Asia, a large predatory fish and well established in Washington DC, Maryland area – first introduced in the Potomac. It has spread throughout the Chesapeake and then appeared in the Delaware system and up into New York City. We know from genetic analyses (Wegleitner et al. 2016) that we are dealing with at least two introductions into the United States. It is believed that they were illegally introduced primarily for food as it is a delicacy within some cultures. The trouble is this really large predatory fish has potential to do a lot of damage and be very invasive.



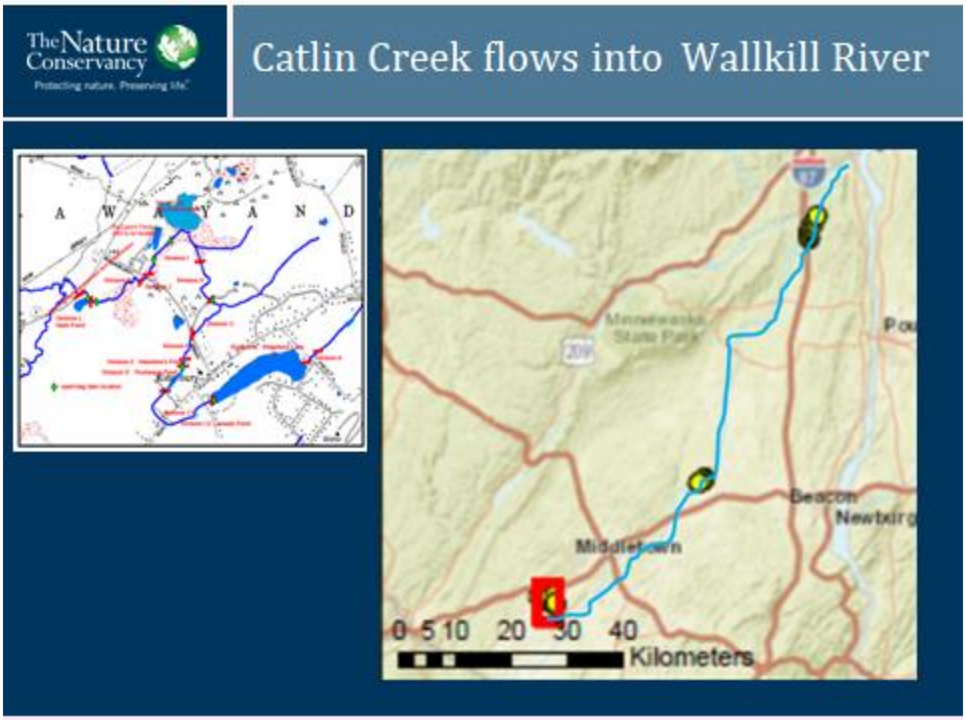
We were interested in the new introduction into Catlin Creek and Mid State New York. We know from genetic analyses that the fish in Down State New York and up in New York City originate from Delaware (Wegleitner et al 2016). What is not clear is where the introduction pathway is. We do know that in 2008 a new population of northern snakehead turned up in Catlin Creek in the Central Hudson Valley system. The fish were abundant in Ridgebury Lake and down through that river system.

The New York State Department Environmental Conservation put in a barrier and in 2008 they twice treated the system with Rotenone and they appear to have successfully eradicated all the fish in the treatment area. NYSDEC asked our team to survey the system using environmental DNA to confirm whether their eradication programme was successful. For 3 years we repeatedly sampled the system. The grey dots are samples we took about 4-5 months ago. Over the time we failed to detect the presence of fish so we are pretty confident that within this system the eradication programme was successful.

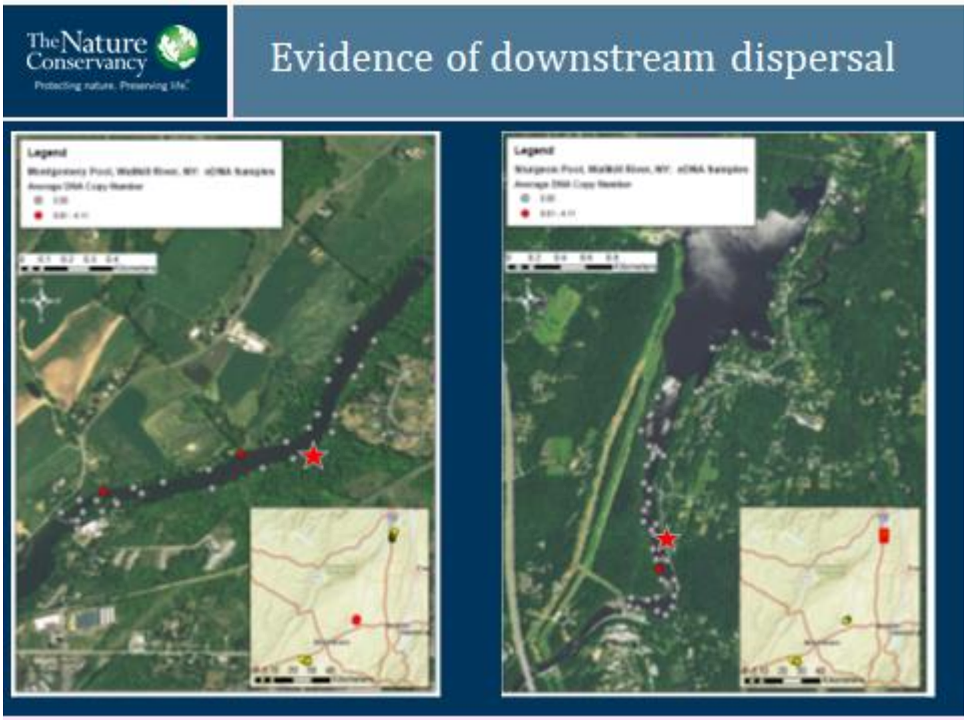
The next slide shows that this river system connects to the Wallkill River and flows down to the Hudson River and on to New York. We repeatedly sampled the Wallkill because we were concerned that by that time the barrier around the fish had been in the system for 2 to 3 years. We know from tag work done in the Potomac River that 30% of the snakehead population is prone to long migrations so there was a strong possibility that some fish may have leaked out of the system and moved downstream. While there may have been successful eradication of the core population there could well be individuals elsewhere in the system capable of creating a new population.



Unfortunately we found two reaches in Montgomery Pool and Sturgeon Pool where we detect snakehead DNA. In 2014 we had one detection in each pool and repeated sampling in 2017 showed repeat detections in both Pools. The fact that we have been able to detect the DNA of snakehead repeatedly provided fairly strong evidence that at least a small number of fish are probably present. The number of detections within that pool had not really changed over the 2 year period suggesting that hopefully we are dealing with a population that is not increasing – hopefully individual fish.

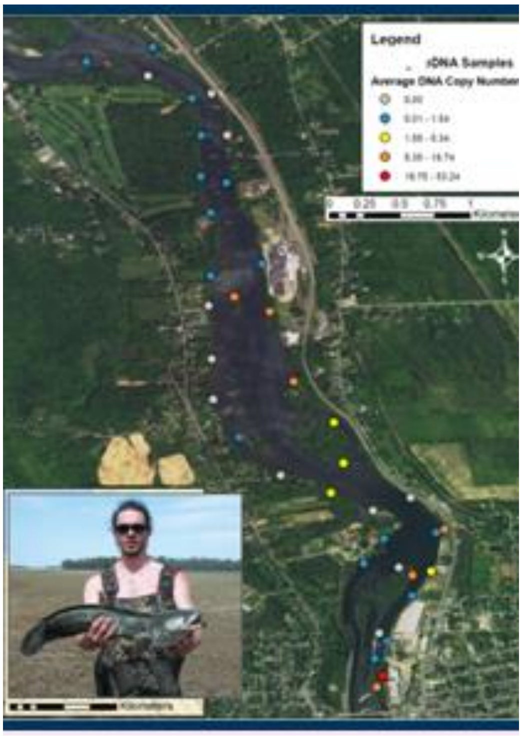


All this work has used a species specific primer to screen the sample for a single species. We are now moving to high throughput sequencing or next-gen sequencing methods (Olds et al 2016). The method enables the sample to be screened for the DNA of all the fish species in the sample (i.e. the whole community). An example of recent research is the study of Olds et al 2016. University of Notre Dame where researchers monitored Juday Creek through their campus for 17 years and 18 species have been detected using electric fishing nets. In a single eDNA survey they picked up 16 species and the two missed were single individuals collected once in 1 year over that 17 year period. It is highly probable that those species are not even present in the system at the moment.



Next-gen sequencing has a lot of potential to cost effectively enable whole communities to be surveyed, not just for invasive or pest fish, but also for other rare and threatened species of interested.

The last slide is another side in the system high risk site/system we investigated. There had been some general surveillance of that system using high throughput sequencing. We screened that and were not expecting to pick up DNA but we did from Northern snakehead. When we re-screened those samples with the marker we failed to detect the DNA and were confused. We then re-surveyed this reach. Two independent labs, two different trips, two new species specific markers and we detected the presence of snakehead DNA in both trips. Taken together those three independent detections suggest that snakehead are present and now the challenge is to confirm that. There are Fish and Wildlife Service Teams out there looking at this reach to confirm the presence of this fish. Hopefully it means we have detected this population early enough to do something about it.



Another advantage of using quantitative PCR, a method that allows you to quantify the amount of DNA in the sample, is where there are multiple detections, you can plot the copy numbers spatially. The red and orange indicate high copy numbers of DNA. The grey indicates no DNA was detected. This data suggests a plume of DNA in the system with fish perhaps concentrated in the upper reaches of the system. This sort of data can be used to focus survey effort – help identify where sampling should occur to maximise probability of capturing a live fish. i.e. where the highest probability of detecting fish is within the system?

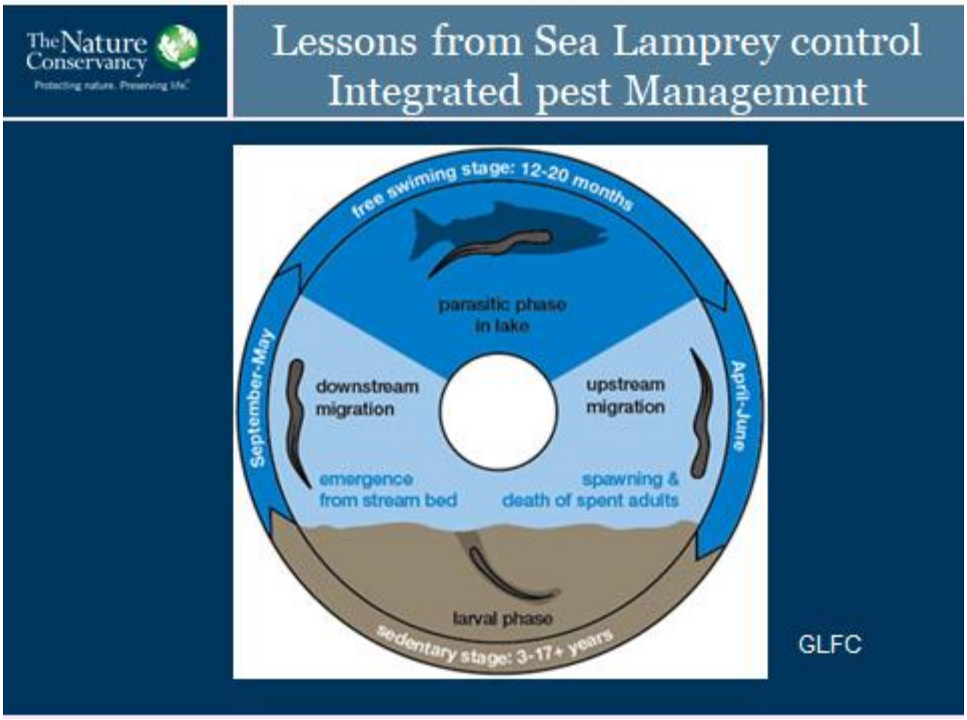
There are lots of unresolved issues with the management use of eDNA. This site and results are an example of some of the issues around management acceptance of this new tool. At this site we originally detected snakehead DNA during part of a general surveillance program – the samples were screened using High Throughput Sequencing and northern snakehead were detected.

- False positives – Because our initial detections effectively was a single positives - we could not completely rule out that this was a result of contamination.

- False negatives – i.e. failure to detect when the DNA is present. When the samples were resampled using a species specific marker we did. The marker that was used only worked with very high densities DNA so it failed to detect the presence of the fish.

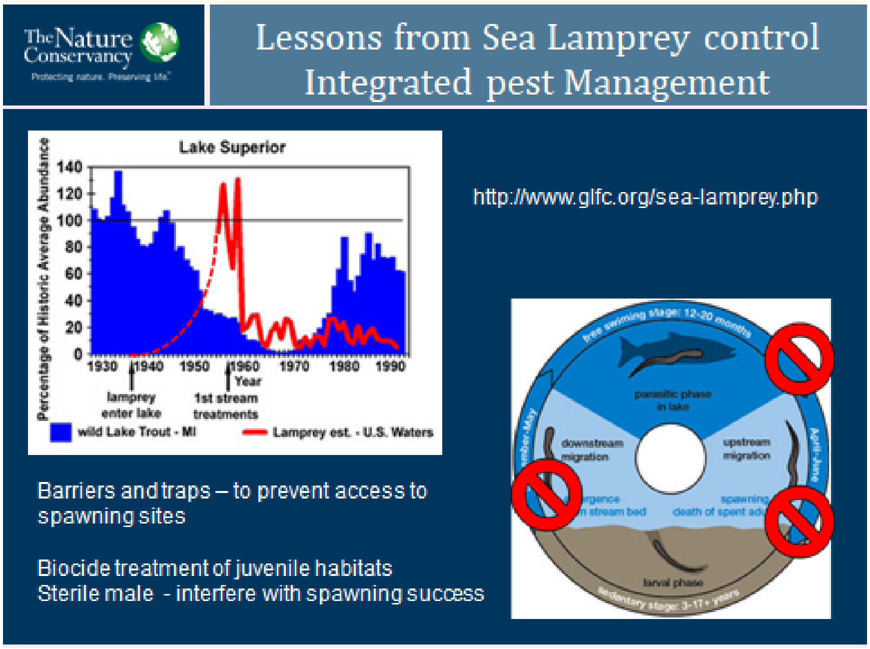
- eDNA capacity. The original samples were collected in 2014 – but results were not analysed and reported until 2016. Much of this work is being done through universities and there is no capacity to turn these samples around rapidly which affects the ability to operationalise the tool – provide results in a management timely manner.

Unfortunately too often we have found that when we detect the DNA of a problem species there has been minimal response efforts – in part because of mistrust of the method (i.e. need to see a fish before the results are believed). But there is also fatalism – owing to the fact that the response tools available are centuries old techniques like netting, fishing and the general fish toxin rotenone. They are pretty blunt tools that may not always be acceptable to the broader community.



However, there are lessons we can learn from the North American situation. A good example of an integrated pest management programme of an introduced fish is the Sea Lamprey control programme in the Great Lakes. This fish colonised the upper Great Lakes through the opening of the Welland and Erie Canals. It is in a parasitic phase when out in the lake, it moves upstream, spawns and the adults die. The larvae spend 3-17 years growing within the stream and then head back out to the Great Lakes. They have huge potential impacts upon the fishery. The Sea Lamprey Control Programme uses a combination of dams, barriers and traps to prevent adults lamprey moving upstream and accessing spawning habitat. Lampricide treatments are used to take out the larval phase before they recruit into the fishery. Sterile males have been used to interfere with spawning success. This programme has been incredibly successful and successfully supressed sea lamprey for the last 50+ years.

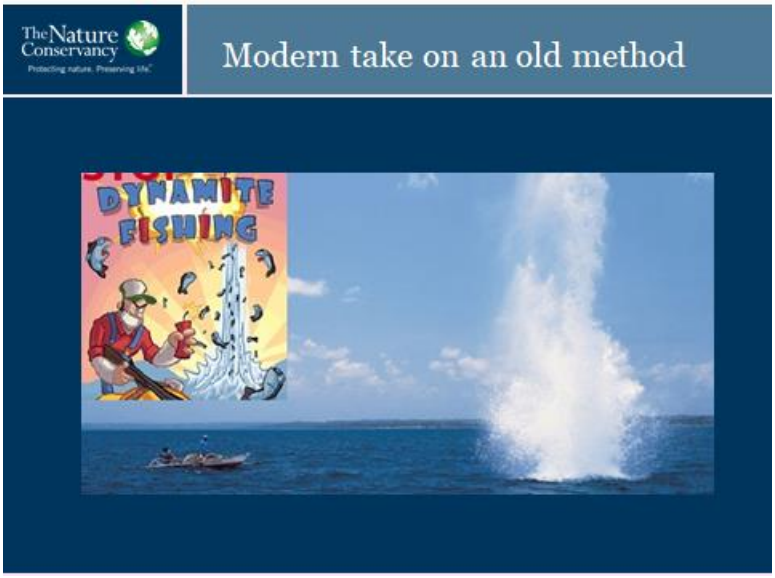
The slide below shows decline in the lake trout population. The introduction of sea lamprey coincided with the massive decline of that fishery but in the late 1950s the instigation of the Sea Lamprey Control Programme saw that population crash and it has been successfully sustained to about 10% to 20% of its original biomass. That programme continues to evolve with research into pheromone attractant and repellents that can be used to improve the success of the traps. Also there are efforts to refine the barriers to allow the native fish through but prevent sea lamprey passage.



The seemingly imminent invasion of the Great Lakes of Bighead and Silver Carp has seen a significant investment from the Federal Government in new response tools over the last six years. Researchers at United States Geological Survey (USGS) are working on novel toxin delivery systems, a micro matrix based on approaches used by the pharmaceutical industry. The approach aims to deliver particles scaled to the preferred food size for Asian carp. USGS are developing a particle with the toxin encapsulated to release into the water body. They have also looked at the feeding time and stomach enzyme activity of these fish and initial research suggests bighead and silver carp are active earlier than the native filter feeders. The results suggest it may be possible to treat selectively and take out bighead and silver carp with minimal impact upon the native community.

This is another tool we and others have been exploring - seismic technology.

It was originally developed by geologists and used by the oil industry to search for offshore oil reserves. The seismic guns put a pulse of sound into the water column. It was found that this could be associated with fish kills. USGS have tested this tool as both a control method and as a way to drive fish into nets.

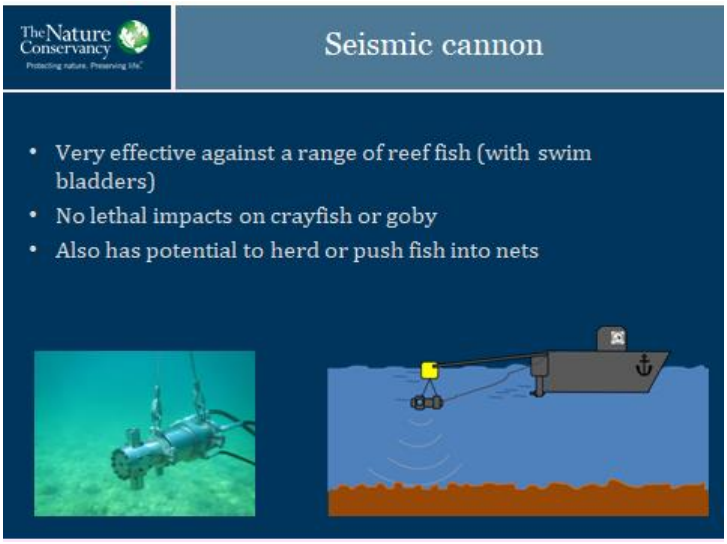


It is a modern take on an old fishing approach but it is nowhere near as exciting.

We have found it very effective against a broad range of fish as long as they have a swim bladder. But we were not able to detect any lethal effects on crayfish and goby, which was what we were trying to control.

It might have potential to selectively remove pest fish in the Rotorua Lakes without impacting koura and bullies.

Perhaps this technology has potential to target brown bullhead with few negative impacts on native species. It also has the potential to herd or drive fish using sound. It may be possible to drive fish into nets.



One of our target pest fish is round goby, a Ponto Caspian species. Within the Great Lakes system there are native fish spawning reef where lake trout, whitefish and herring lay their eggs. This species introduced through the ballast water pathway is now the dominant species on these reefs and makes up about 99.9% of the biomass. When we do underwater video counts on the reef this is all we see. We are lucky if we any other species. It is a key native fish egg predator and competitor feeding on a broad range of invertebrate prey.

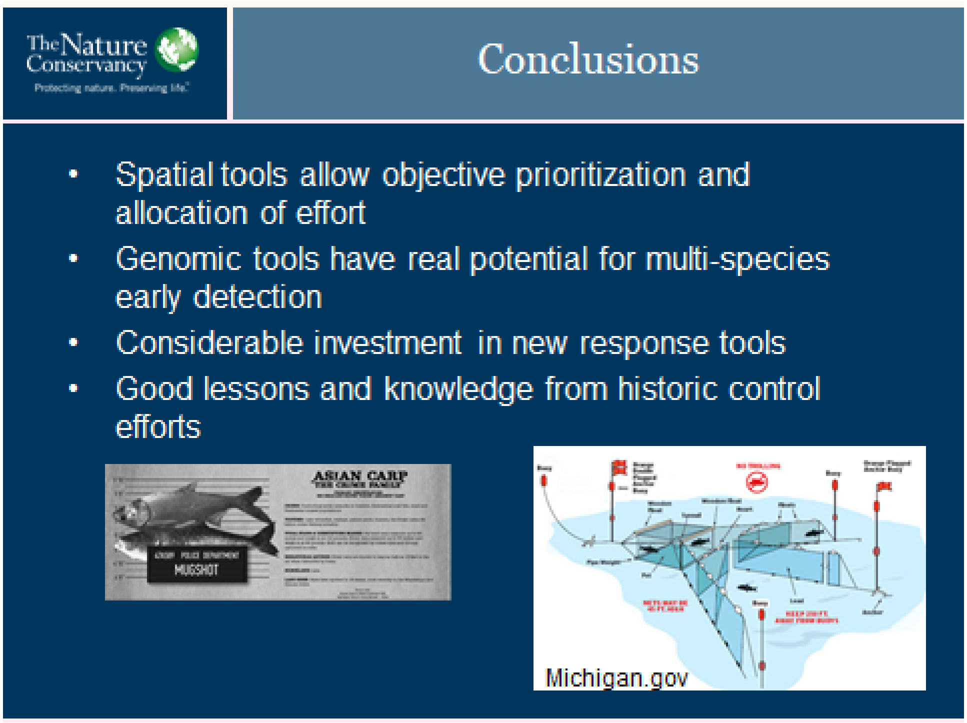
We tried seismic technology which did not work. And now we are testing electricity as a way of control. This shows a Benthic electrical ray used to suppress goby which is a grid laid on the bottom. We electrify it to hold the fish in the field for a time resulting in mortality. If we hold the fish in the field for 3-4 minutes we get 100% mortality. Those little white things are dead goby. But the killing field is small, only 10-15 centimetres above and around the array – we see 100% survival of fish 0.5m from the array. If we bait the array, (on the right) and leave it for 10 minutes we attract large numbers of goby rapidly into the field. So rather than relying on a set of passive tools and the natural movement of the species we can attract goby into this killing field, hold them there, and remove significant numbers quickly. This method may also have potential here particularly given the benthic behaviour of catfish.

In conclusion, in the Great Lakes there is an increasing emphasis in developing spatial tools to allow surveillance efforts to be prioritised.

Genomic tools continue to be refined for surveillance and appear to have great potential for a multi species early detection. Enabling quick coverage of large areas, cost effectively and probably a higher detection sensitivity than many of the traditional tools.

There is ongoing investment in new response and control tools and I think likely plenty of interest in interacting with New Zealand – given overlap in issues. That is something that my colleagues and I can help facilitate.

There are lots of good lessons we can learn from historic management efforts in the Great Lakes. Slide 34 shows a pound net set in the Great Lakes for lake trout. These are massive, structures set for extended periods - continuously fishing over multiple days. This may have potential for controlling brown bullhead within Lake Rotoiti if designed to allow escapement of non-targeted species.



Finally I want to acknowledge the LakesWater Quality Society. It is a pleasure to be here and I also want to note that The Nature is establishing a programme in New Zealand with links to its North American programmes. There may be opportunity for the Rotorua region to engage with my US counterparts and collectively share solutions and knowledge. Lastly I want to acknowledge that most of the work today is from multiple partnerships with my work colleagues and many agencies within the States. Thanks very much.


The Nature Conservancy
Protecting nature. Preserving life.
Partners and Collaborators
Great Lakes Restoration
U.S. Fish & Wildlife Service
United States Environmental Protection Agency
USGS
science for a changing world
DNR
Indiana Department of Natural Resources
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DNR
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pennsylvania
Department of Conservation and Natural Resources
Wisconsin
Department of Natural Resources
Minnesota
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Environmental Change Initiative
University of Notre Dame
CMU
Central Michigan University
Illinois
Department of Natural Resources
UT
The University of Toledo
Ontario
Ministry of Natural Resources

PEST FISH THROUGHOUT NEW ZEALAND

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Natasha has worked on aquatic biosecurity issues for the last 16 years. She has been involved in all aspects of aquatic biosecurity management - legal, policy, operational, technical and research. She co-edited the New Zealand Invasive Fish Management Handbook published in 2015 and has a good grasp of pest fish issues in New Zealand.

TRANSCRIPT

Kia ora koutou. I have been asked to give a general overview of pest fish in New Zealand. Introduced fish are highly adaptable, frequently invasive and often cause problems. They are difficult to detect and notoriously hard to eradicate. For that reason it is no surprise that a group of goldfish is known as troubling. But it is not all doom and gloom. I will talk about what species are pests, who has a role in managing them, what problems they cause, what has been done about them and what we still need to work on.

Fish introductions to NZ

Year	Sanctioned	Illegal
1861-1880	brown trout, perch, tench, goldfish, brook char, catfish	
1881-1900	rainbow trout	
1901-1920	salmon (3 spp.), mackinaw,	guppy
1921-1940	gambusia	
1961-1980	(grass carp, silver carp)	rudd
1981-2000		koi carp, golden orfe, caudo, swordtail
2001-2005		[gudgeon] [marron]

I will start with fish introductions to New Zealand. We have 19 species of naturalised fish and two species - grass and silver carp, not thought to be able to breed here. Most introductions were planned to establish fisheries with the exception of catfish. Nobody really knows why catfish were introduced to New Zealand and it is possible that the wrong species of catfish was introduced. Gambusia were introduced as a mosquito controller and a forage food for valued species like trout. All the introductions after the 1960s have been done illegally or accidentally with the exception of grass and silver carp.

Legal status of introduced freshwater fish

Freshwater Fisheries Regulations 1983		Biosecurity Act 1993	Conservation Act 1987	HSNO 1997	No Legal Status
Sports Fish	*Noxious Fish*	*Unwanted organisms*	*Restricted Fish*	*Prohibited Organisms*	
Trout (2spp)	Koi carp	Koi carp	Grass carp˚	Stickleback	Brown bullhead catfish+
Salmon (3spp)	Rudd (except A/W)	Gambusia	Silver carp˚	Pike family	Golden orfe
Brook char	Piranha	[Gudgeon]		Any venomous fish	Naturalised - aquarium fish*
Mackinaw	Pike	[Marron]			Aquarium fish in captivity
Tench	Walking catfish	Channel catfish			
Perch	Tilapia spp.		Green - naturalised	Grey – only in captivity	Blue – not in NZ at all
Rudd (A/W Fish & Game Region only)			Pink – possibly eradicated from NZ	Orange – can only breed in captivity	

+ Must kill on capture (Fisheries Regs)
*goldfish, guppy, swordtail, sailfin molly, caudo
˚ Animal Welfare Act 'pest'

Not all introduced fish are considered pests. There are various different legal designations for introduced freshwater species - sports fish and noxious fish fall under the Freshwater Fisheries Regulations. Unwanted organisms are designated under the Biosecurity Act and restricted fish fall under the Conservation Act. Prohibited organisms come under the Hazardous Substances and New Organisms Act. Then we have a bunch of fish that have no legal status at all.

Take away sports fish that are highly valued, and fish not thought to be present in New Zealand, and fish only in captivity, and fish we think we have eradicated and cannot breed here, the species left are considered pests in New Zealand.

There are also a number of other classifications done through regional pest management plans which are made under the Biosecurity Act and administered by regional councils. These vary between species and regions throughout New Zealand.

- Exclusion
- Eradication
- Containment
- Suppression
- Restricted
- Progressive control
- Total control
- Surveillance
- Site led

So what! Isn't it good that we have lots of fish species in New Zealand? The trouble is pest species cause problems on multiple levels. They adversely affect our native species, our freshwater ecosystems, whether it be re-suspension of sediments, excretion of nutrients, browsing or uprooting of macrophytes, causing changes to food webs and leading to algal domination of lakes.

Dictionary Definition of

Pest fish vs invasive fish

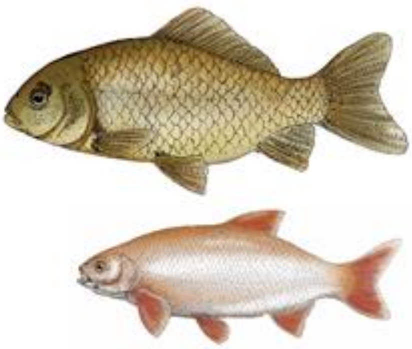
Pest species

- *Destructive animal that attacks crops, food, livestock, etc.*

Invasive species

- *Tending to spread very quickly and undesirably or harmful*

Many of our introduced fish species like trout are highly valued despite the impacts they have had on native species or the damage they have done to freshwater ecosystems. The terms pest fish and invasive fish are often used interchangeably in New Zealand and the dictionary definitions are not that different with the invasive definition probably highlighting the movement more than pest. In New Zealand the term pest fish is used to describe those species that have some classification in the legislation, and invasive is a more general term. So in my mind all our pest species are invasive but not all our invasive species are classified as pest fish.

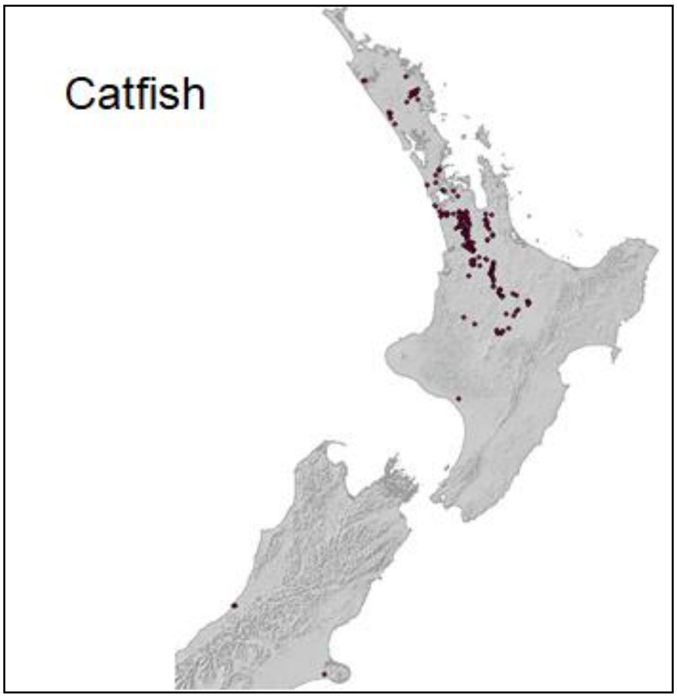


Feral goldfish and orfe

In the Waikato region rudd are classified as sports fish but are a noxious species in the rest of the country. Feral goldfish are well spread throughout the North Island and there is a debate about the effect that they have in some places and quite benign in others. They probably cause damage similar to what Koi carp do but in some places they are highly valued. Orfe or golden orfe were introduced into ponds in private property around Auckland. They have not been seen by a fisheries ecologist or scientist for about 20 years so we do not know if they are still present in New Zealand. The aquarium species that are found naturalised in some geothermal streams around the Central North Island are mainly aquarium escapees or releases. But I am not going to talk about these fish.

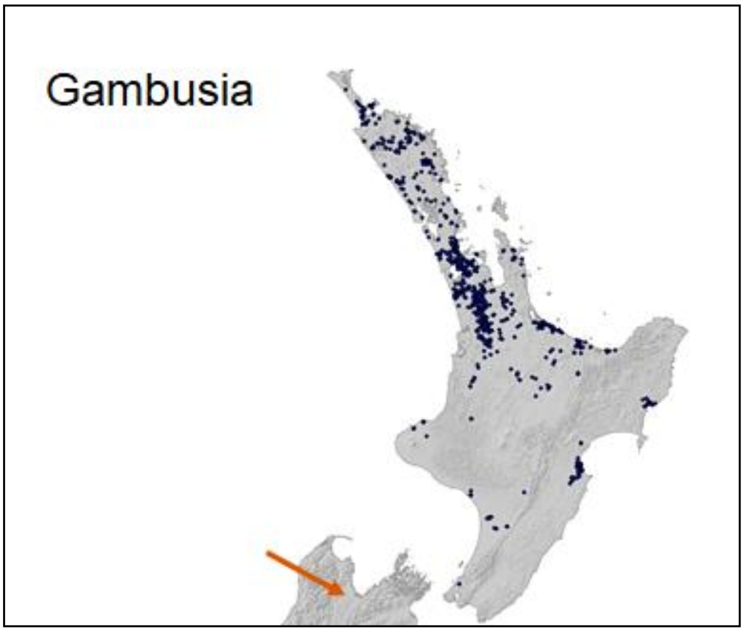
This morning I will focus on four fish all classified under the legislation.

Catfish – 300 mm, prefer a wide range of habitats and slow flowing waters where they can use their chemosensory organs to hunt prey. They are very resilient and can survive long periods out of the water if their skin is kept moist. They can handle heavy metals and poor water quality. They are very opportunistic feeders and have a taste for our macro invertebrates, particularly kōura. They are known to modify invertebrate communities, ecosystem processes and nutrient statuses. They probably also compete with our native tuna or native eels. Their distribution is known to be from the Central North Island, the Waikato catchment and also spread up into Northland. We have two populations in the South Island which have been there since the 1800s, Lake Mahinapua on the West Coast and Lake Ellesmere on the east. We do not know why they have not spread and there are very low densities. It took us many, many years to find catfish in Mahinapua in our surveys.

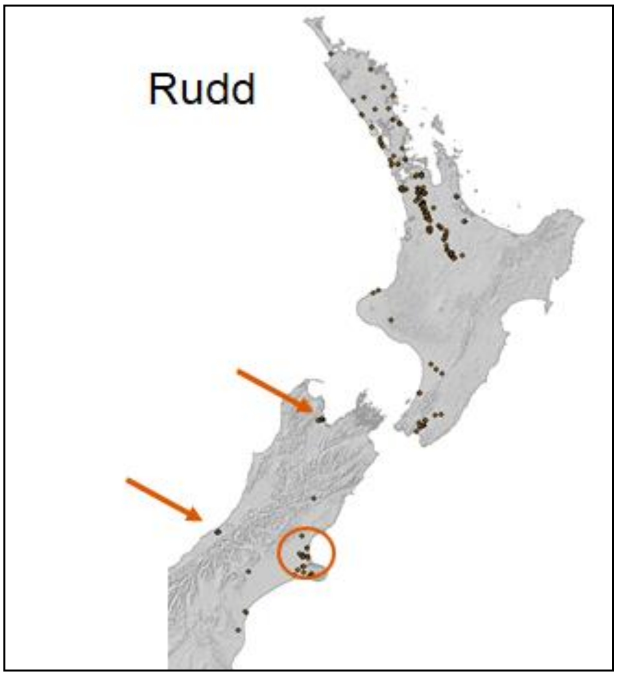


Gambusia – 30-60 mm, small fish, live bearers. The female is the larger animal. They have a very wide environmental tolerance managing to cope from ice cover through to water temperatures of 40 degrees. They handle oxygen depletion and very high salinities. They are known for their ability to gang up and nibble on native fish, eat their eggs, nibble their fins, eat their eyes. Their magnitude of problems is highly variable but probably their ecosystem effects have been underreported and through their selective removal of invertebrate grazers they can alter food webs. They are in the top half of the North Island

and in the last 20 years have spread east and south in the North Island and in 2000/2001 there was an incursion of gambusia into the South Island that has been subject to an eradication programme. We eradicated them from 68 sites and have 11 to go. We hope that eradication is still possible but they have been found in more natural systems in the Nelson region which makes getting rid of them a little harder.



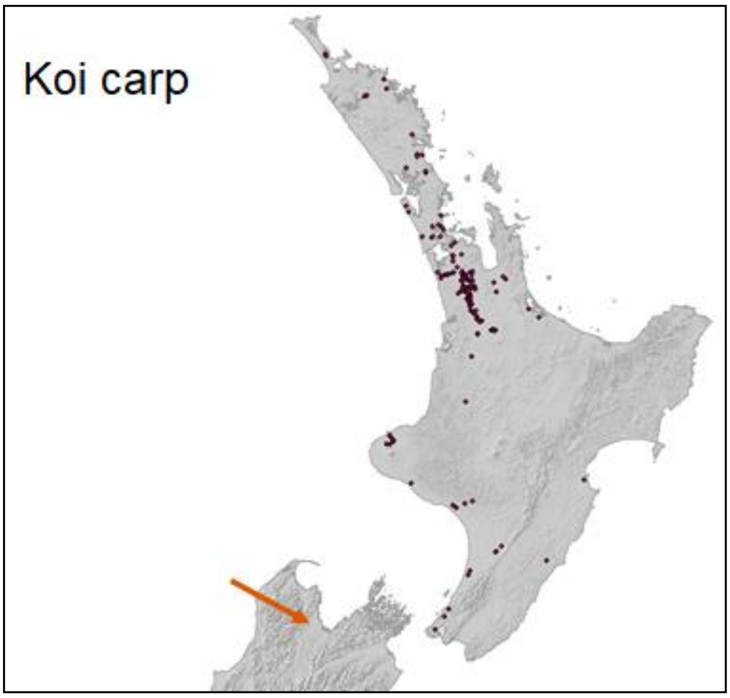
Rudd – 250-300 mm, unfortunately prefer lakes, ponds, wetlands and margins of rivers and streams. They prefer native macrophytes and have been implicated in their collapse and reduction of water quality and excrete phosphorus. They do not digest all their plant material so it is returned to the water column contributing to algal domination. Their diet overlaps with our native species of kōaro and dwarf īnanga and there is probably direct competition. They are found in the Waikato catchment and the lower North Island.



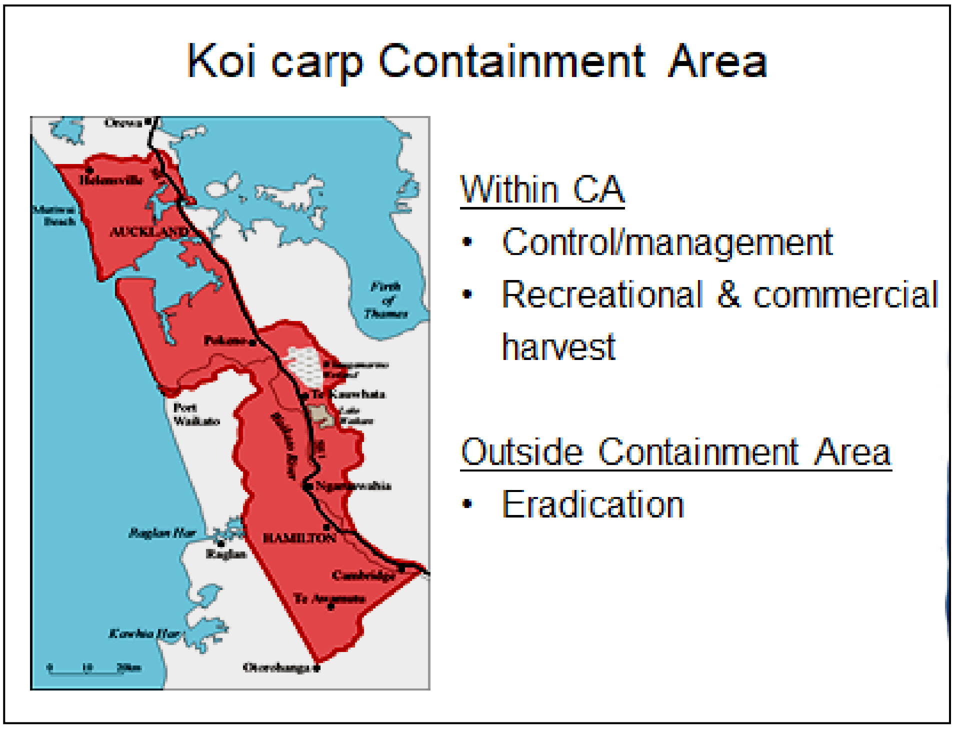
The distribution maps have been taken out of the New Zealand Freshwater Fish database and do not show the sites in the lower North Island that have been eradicated as have the sites in the South Island that are not within that orange circle. The rudd fishery around Canterbury is highly managed between the course fishers and the Department of Conservation and they are restricted mostly to ponds and sites outside of eradication programmes.

Associated with that gambusia incursion I spoke about, rudd were also detected and we still have a handful of sites in Nelson to be eradicated. Unfortunately we had a recent invasion in Lake Ianthe; obviously a long way from other known populations so human induced spread.

Koi carp – 600 mm, our most common pest fish species built up to large numbers and highly visible. They suck up sediments and sift out organic material leaving distinctive pock marks. They then re-suspend the benthic sediments and nutrients leading to increase in turbidity. They also dislodge macrophytes and destabilise the banks. They are also in the Waikato catchment and spreading into Northland and the lower North Island. Some of those sites have been eradicated. Unfortunately, koi carp were picked up in that incursion in Nelson in the early 2000s but we think we have now eradicated koi carp from the South Island, probably about 5 sites.



Koi carp are a little different in that they have a containment area. (Slide next page) Within the containment area is a control/management approach to their numbers where a recreation and commercial harvest is allowed. The commercial harvest is a restricted fishery that is controlled and outside the containment area our preference is still for eradication. This is slightly at odds with its unwanted organism designation.



Who is responsible for pest fish?

Before things get to the border the Environmental Protection Agency are responsible through the Hazardous Substances and New Organisms Act. At the border, and with a pre-border role as well, we have the Ministry for Primary Industries. Once into New Zealand, if there is a new incursion of pest fish the Ministry for Primary Industries is the lead agency. They would lead the response if we had an incursion of pike or largemouth bass.

For established pest fish species in New Zealand the Department of Conservation has a leading role under the Freshwater Fisheries Regulations and the Conservation Act but there are a lot of other players including regional councils, Fish & Game, Iwi. The legislation is driven within New Zealand by the Biosecurity Act and the Freshwater Fisheries Regulations under the Conservation Act.

Pest fish management principles –

- Prevent establishment into New Zealand. Once here prevent them getting into new places
- Once they are here, contain them where they are
- Eradicating priority pest populations
- Manage pest fish at high priority sites

This shows the distinction between a pest focus, which is targeting the organism or managing high value sites. It is an important thing when planning the management response.

A good pest fish programme

- Such a programme needs to be underpinned by public awareness and advocacy. Rivers and lakes can be like island catchments but if people are moving these fish around we will not get anywhere.
- It needs an inventory and surveillance programme, a detection programme that is manageable. Fish are notoriously hard to detect at low numbers and often by the time we detect them they are well established.
- It is important to have good local relationships and partnerships and ensure the programme meets all needs.
- Having a plan means knowing how to respond.
- It is vital to be backed up by compliance and law enforcement.

Success Stories

It is not all doom and gloom. The response to the South Island incursion of koi carp and gambusia went well because of the collaborations between agencies and stakeholders. One tool in our toolbox is the piscicide rotenone approved for use in New Zealand and we have done some eradications. As well as Nelson, in South and North Canterbury and the Lower North Island we have some control programmes. In Lake Rotopiko (Serpentine) Lake in the Waikato we actively control rudd and have managed to keep a native macrophyte community intact over the last 16 years.

There is a greater awareness of pest fish issues in New Zealand, some research and good surveys and awareness campaigns all supported by local initiatives. The Aquarium

Species Import Health Standard has been tightened up. When I first started working in this field there were thousands of fish that could be introduced into New Zealand. Whole genera were introduced but that list has been tightened up to include individual species, a much smaller list.

A whole lot of resources have been developed from survey guidelines determining eradication criteria, diving bird protocols to prevent by catch, cleaning your gear to prevent inadvertent spread of other pests.

Issues, Gaps and Challenges

There are no clear procedures or funding for response to important incursions and we lack some tools and the expertise and ability to respond as well. Management is fragmented with this overlapping jurisdiction and roles between agencies. Fish continue to spread but often at a regional level. If we act quickly then eradication is still feasible.

What do we need to focus on?

Pest fish work is hard. It is easy to ignore what happens under the water and hard to detect until they have established. To counteract that we need clear national direction that compels action. I am hopeful that the Freshwater Biosecurity Partnership will give leadership around the country. This group has grown out of the long-term Didymo response group, which has now widened to a Freshwater Biosecurity Partnership including people from industry, Iwi groups, regional councils and central government and Fish & Game.

We need clear funding priorities to make the case for increased investment or management. This work is often an easy area to cut funding from.

We need clarity on how to prioritise site or species incursions over other priority biodiversity work.

Collaboration is key, we need to work together to achieve pest fish control or eradication. We just need to get on and do it.

Thank you.

LAKE ROTOITI CATFISH INCURSION: SOMETHING NEW OR THE EMERGENCE OF AN OLD PROBLEM?

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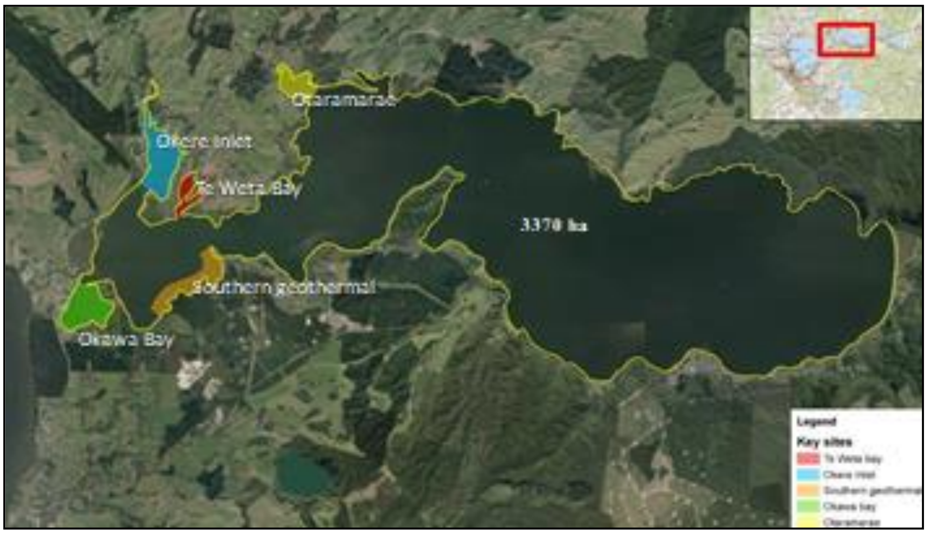
Brendan is a Professor in freshwater ecology based at the University of Waikato in Hamilton. His research is in freshwater fish ecology, quantification of fish abundance, and responses of native fish communities to invasive fish. Brendan uses stable isotopes to investigate aquatic food webs, and otolith microchemistry to examine fish life histories.

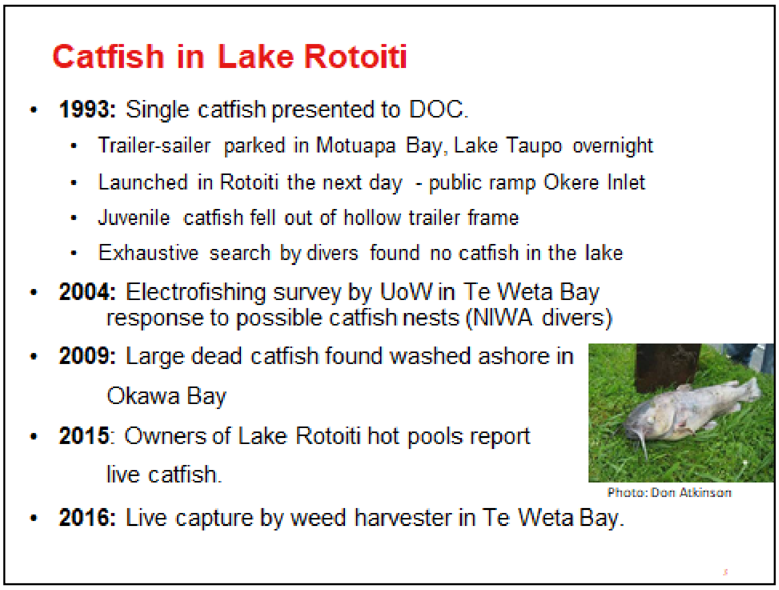
TRANSCRIPT

Kia ora everybody. I have been involved in pest fish research, control and generally understanding their life history and what we might do about them. For a number of years I have been called in by Bay of Plenty Regional Council to help with the catfish problem and I ask, 'Is this something new or the emergence of an old problem?' I suggest that maybe we have been waiting for this in Rotoiti but hoping that it would not happen.

Slide 2 shows Rotoiti and Otaramarae, Okere Inlet, Te Weta Bay, Southern Geothermal and Okawa Bay which are slightly isolated for a very particular reason.



One of my subthemes is a compelling story involving novel fishing methods. In 1993 a single catfish was presented to the Department of Conservation. Its origin was a trailer sailer parked in Motuoapa Bay in Taupo overnight, driven to Rotoiti, launched the next day on the public boat ramp at the Okere Inlet and a juvenile catfish fell out of the hollow trailer



frame. It was very much alive and kept in a tank for six months or so. An exhaustive search by divers, days after that boat was launched, failed to find any sign of catfish so everyone mopped their brow and figured that was the end of the story.

In 2004 NIWA divers found some depressions in the bed of Lake Rotoiti and we were called in to look for catfish with the electrofishing boat that we operate at University of Waikato. We did a general survey where we could fish; much of it is too deep for the boat. We focussed on Te Weta Bay as an obvious place but found no catfish. Just lots of bullies, smelt, goldfish and a few trout.

In 2009 a large catfish was found dead and washed ashore at Okawa Bay. (Above slide) The spade gives an idea of size, about 450mm. But was it really from the lake or did someone pull our leg? Jennifer Blair did some otolith microchemistry analysis on that very smelly fish exhumed after being buried for a week or three and in the end it could not be exclusively establish where it came from, but it did not look like from Taupo or the Waikato. It was reflective of Rotoiti water but we could not conclusively say with one fish.

In 2015 the owners of Lake Rotoiti Hot Pools reported a live catfish and in 2016 a novel fish collection device, a weed harvester in Te Weta Bay hauled ashore a catfish. That initial discovery caught two catfish within 30 minutes.

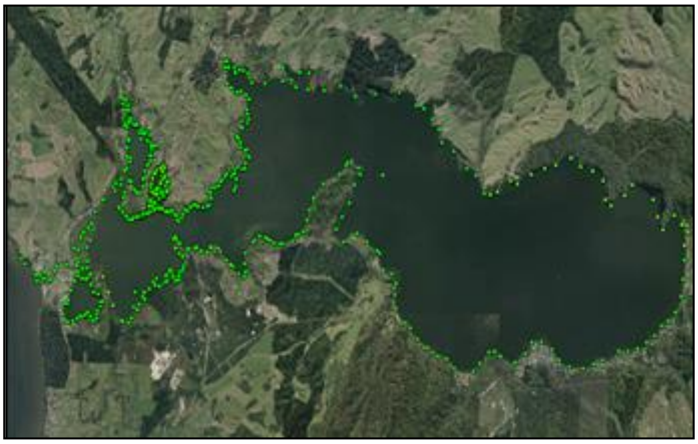
The incursion response began immediately. They set 21 20mm mesh fyke nets in Te Weta Bay baited with cheese and sardines. The next slide indicates green triangles, nets that caught catfish, the red triangles show nets that were set but did not catch catfish and they caught 52. The bad news was that catfish were there, and the majority of the catch were juveniles less than 100mm. The incursion response was activated which meant that further fishing and netting was focussed at the western end of the lake.

So Houston we have a problem.

The Bay of Plenty Regional Council Biosecurity staff and communications informed all key stakeholders and there was unanimous support for action. They wanted to know how they could support or be involved and what the Council was going to do. They made it clear they expected success.

But they had some questions –

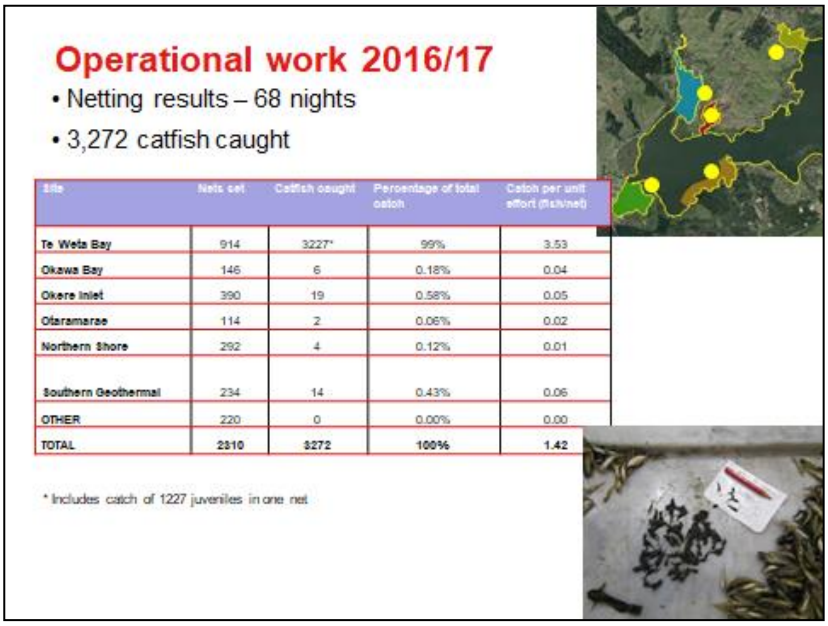
- How come the catfish were not discovered earlier?
- What are the impacts of catfish on koura, trout and water quality in the lakes of the region?
- Are there impacts of any eradication or surveillance work on other species?
- Are they in other lakes?
- What is the likelihood of eradication?



All great questions with no clear answers at this point. This incursion response was epic in scale and nets were set widely around Rotoiti. We used the electrofishing boat in Rotorua along the shoreline, through the Ohau Channel and then extensively in Rotoiti. We fished 29 kilometres. We caught one catfish in Te Weta Bay, which was no surprise.

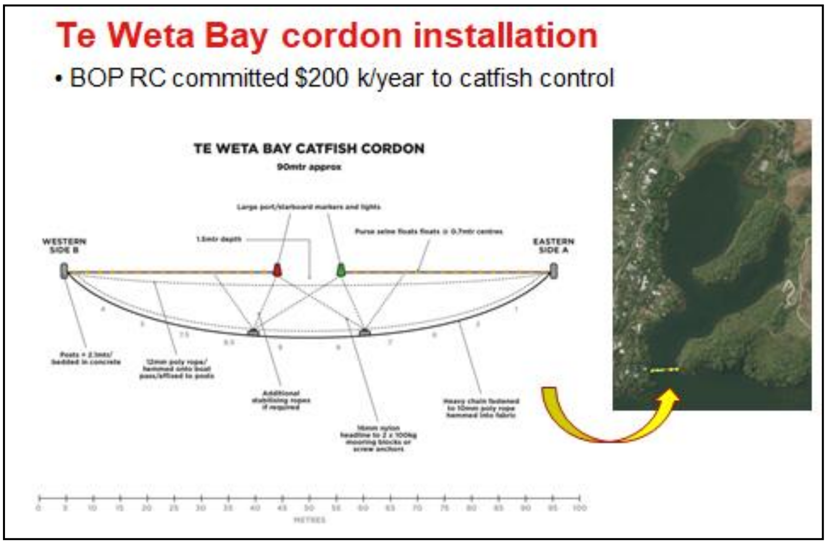
The boat is not the ideal tool for catfish. It is not great for a species on the lake bottom. Between April and July 2016 there were 34 net nights, 770 nets set and the entire lake surveyed. A total of 390 catfish were caught, 381 from Te Weta Bay, showing that was the focus of the problem. (Slide 9) This operational work continued through into 2017 and the large yellow dots show where catfish were found, mostly in Te Weta Bay. So 3,227 catfish were hauled out of Te Weta Bay, 99% of the total, 1,227 catfish out of one net which were

14mm tadpole-like babies. This was disturbing but there were low catches outside of Te Weta Bay including Okawa Bay and Okere Inlet.



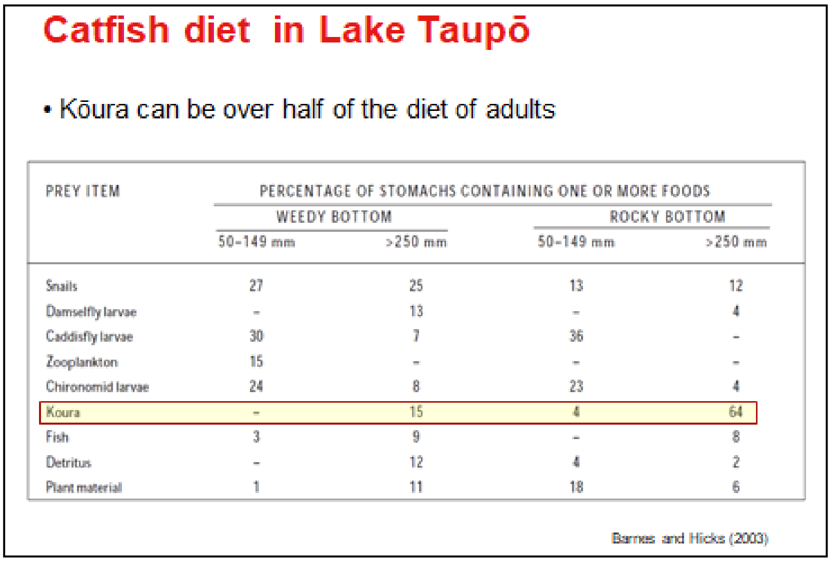
Site	Nets set	Catfish caught	Percentage of total catch	Catch per unit effort (fish/net)
Te Weta Bay	914	3227*	99%	3.53
Okawa Bay	146	6	0.18%	0.04
Okere Inlet	390	19	0.58%	0.05
Otaramarae	114	2	0.06%	0.02
Northern Shore	292	4	0.12%	0.01
Southern Geothermal	234	14	0.43%	0.06
OTHER	220	0	0.00%	0.00
TOTAL	2310	3272	100%	1.42

One major plus of the eradication programme was its being well-funded. Bay of Plenty Regional Council committed $200,000 a year for catfish control and the catfish incursion response team deployed a 90m cordon across the mouth of Te Weta Bay. Although catfish had been seen outside, it seemed sensible to contain them within Te Weta Bay. The V in the middle of the cordon is for boats to come in and out. It was installed in April 2017 and seen as a first step to contain the problem.



These pictures (next page) show that it is easy for boats to navigate through. The cordon goes right down to the bed and after a little bit of retrofitting is working beautifully and staying in place.

Catfish were introduced in 1877 to the Auckland region. They are nocturnal bottom feeders and eat a diverse range of food and prefer a shallow, weedy habitat in lakes and rivers, tolerant of high and low temperatures and low dissolved oxygen. They are a significant threat to koura and are throughout the Waikato River system including Lake Taupo. We have done some previous work there and understand some of their life history. They are tolerant of pollution and are sexually mature at 2 years of age and about 220mm long. Their peak gonad development is in September.



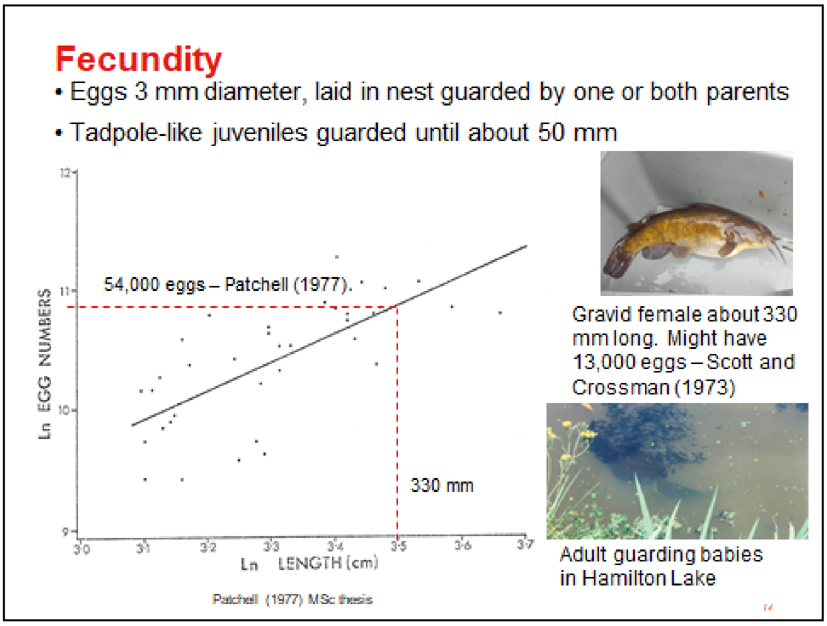
PREY ITEM	PERCENTAGE OF STOMACHS CONTAINING ONE OR MORE FOODS			
	WEEDY BOTTOM		ROCKY BOTTOM	
	50-149 mm	>250 mm	50-149 mm	>250 mm
Snails	27	25	13	12
Damselfly larvae	-	13	-	4
Caddisfly larvae	30	7	36	-
Zooplankton	15	-	-	-
Chironomid larvae	24	8	23	4
Koura	-	15	4	64
Fish	3	9	-	8
Detritus	-	12	4	2
Plant material	1	11	18	6

In Taupo, Grant Barnes did some work for his Masters looking at guts from hundreds of fish, which is a challenge to any student. He found that koura on rocky bottoms were larger but smaller on weedy bottoms. Catfish up to 150mm had a low consumption of koura but once they get large, about 250mm or so, about 60% of their diet can be koura. This could be because the koura like those rocky habitats too so the catfish and koura have more interaction in those particular places. Koura consumption was less of a problem on weedy bottom, probably because there are fewer koura.

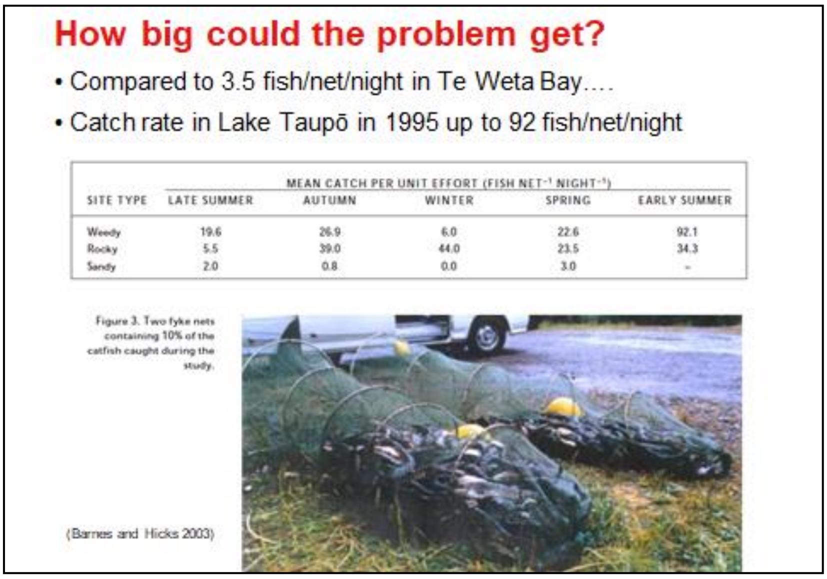
The next slide shows a picture of a gravid female from Rotoiti, about 330 mm long. They have a lot of eggs. I struggled to get the exact fecundity but it might be quite variable in the species, so it may be worth looking at in the Rotoiti population. A Canadian source suggests that a fish that size might have 13,000 eggs. Graham Patchell, for his Masters at the University of Waikato, related egg numbers to size and suggested if extrapolated it might be more like 54,000 eggs. That is a big difference, we do not really know but it is a lot of eggs either way. It is too many eggs to release into the waterways.

They are very good parents, which is unusual among fish, as most turn around and eat their young. Catfish will do that but mostly they guard the nest. In the photo below there is a parent guarding its school of young, keeping away predators and herding them nearby.

When the young are 50mm or so they disperse and take up life on their own without the parents to help.

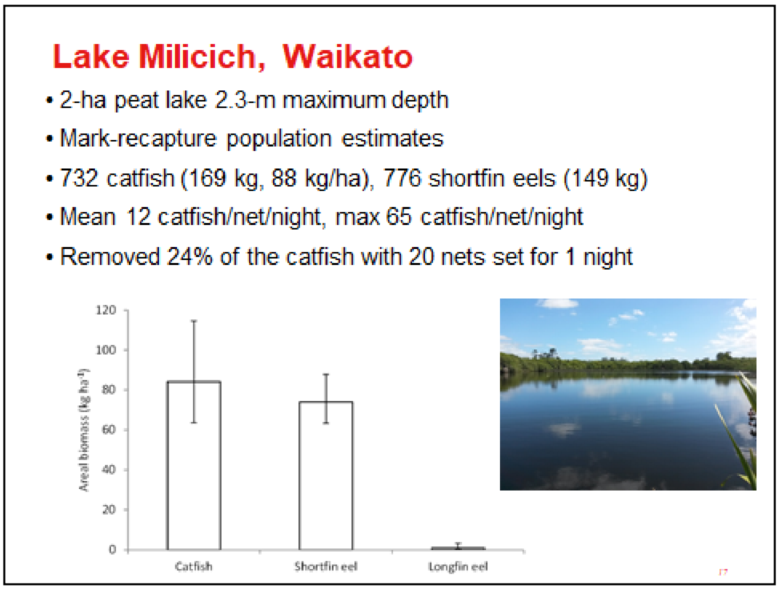


The graph above shows length on the X axis and frequency of Lake Rotoiti catfish. Juveniles are the most numerous class and through January, February, March, April and June grow very rapidly compared to any other catfish, growing about half a millimetre a day at least through the summer/early autumn period. It shows they have a good food supply, which is not surprising given that there are not many in the system yet.



SITE TYPE	MEAN CATCH PER UNIT EFFORT (FISH NET^{-1} NIGHT^{-1}) LATE SUMMER	AUTUMN	WINTER	SPRING	EARLY SUMMER
Weedy	19.6	26.9	6.0	22.6	92.1
Rocky	5.5	39.0	44.0	23.5	34.3
Sandy	2.0	0.8	0.0	3.0	-

How big could the problem be? The average catch in Te Weta Bay was 3.5 fish per net per night. In 1995 in Lake Taupo, where fish had been for at least 15 years, Grant Barnes caught up to 92 fish per net per night. Numbers of fish per net per night vary seasonally, highest in early summer in weedy habitats. We have got a handle on it, Rotoiti's catfish population is much lower and we would like to keep it that way.

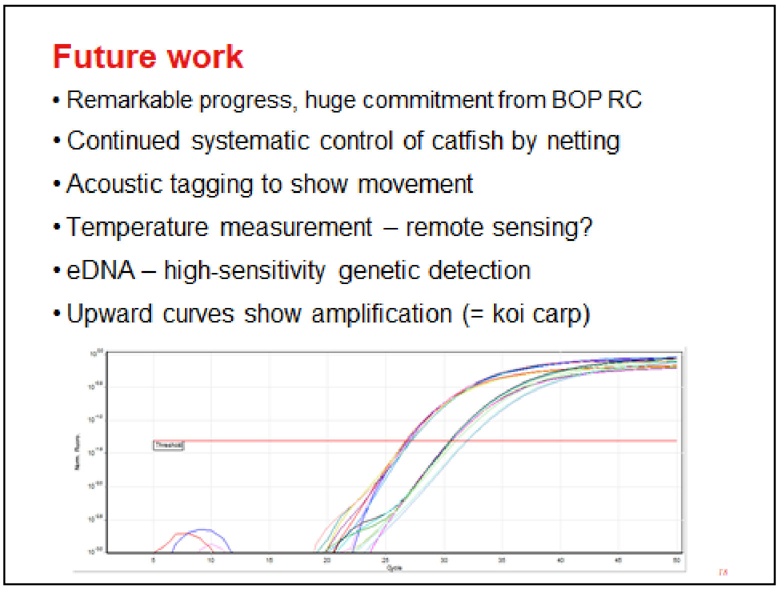


We did one of the first mark-recapture studies on catfish in New Zealand in Lake Milicich, Waikato, a 2ha peat lake, 2.3m deep. Fyke netting is really effective for catching catfish and eels. The mark-recapture population estimates were about 732 catfish and 776 short fin eels, roughly equal, but catfish weighed more because they are larger. Eels are long and skinny. That is about 88 kilos per hectare in a small lake, a very high density. However, the mean catch rate was 12 catfish per net per night, maximum 65. It all shows what happens when catfish are allowed to dwell in one place for a length of time. Although they are abundant in Rotoiti the catch rate is still considerably less. The good news for Lake Milicich is that we removed 24% of those catfish with 20 nets fishing in one night. It also showed that the biomass of the catfish at 88 kg/hectare compared to the shortfin eels at about 70 kg/ha.

We have made remarkable progress because of the huge commitment from Bay of Plenty Regional Council. Continued systematic control of catfish by netting is seen as extremely important. We are about to launch an acoustic tagging study using a tag that releases a small electronic sound picked up by a series of receivers under water. That will show if the catfish are moving out of Te Weta Bay despite the cordon. We will see if we can pick up catfish anywhere else.

Temperature measurement could also be useful. I think catfish like Te Weta Bay because it is warmer than the rest of the lake, but we have no evidence because we have not measured the temperature. Every time they set nets now they measure temperature then we can tell if there is any relationship between catches and temperature. We can also do this by remote sensing measuring the water temperature from satellite images, something we are looking into.

eDNA is a high sensitivity detection method. We have a project and funding for a proposal to begin an eDNA development protocol for catfish. The upward curve in the next slide shows amplification of koi carp, each line shows a water sample that we have taken out the DNA and the curves show that the DNA is amplified. The sooner they come up the more DNA and there is a quantitative element to it. It is a real problem. Catfish are wide spread and are not going away unless we take them out. They have the ability to spread further so it is very important work.



I would like to acknowledge that it is a huge effort and we have only just begun. Shane Grayling has done a lot of work as the leader of the Biosecurity Team and his contractor, Geoff Hewitt, built and installed the cordon and we could not have done it without him. I take my hat off to him and to Bay of Plenty Regional Council, thank you for your funding commitment and for releasing Shane to do his MSC.

Thank you.

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CATFISH IN LAKE TAUPO

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Michel works for the Department of Conservation and has been the science advisor in the management of Lake Taupo since 1992. Since the mid 1990's trout anglers have been raising their concerns about the potential impacts of catfish in Lake Taupo that lead the monitoring and research of catfish that will be presented today.

TRANSCRIPT

Good morning tena koutou katoa

I am here to explain how we have been dealing with catfish in Lake Taupo and also the research that we have done.

Worldwide there are about 3,000 species of catfish representing approximately one quarter of all fish species living in freshwater. In New Zealand there is only one species of catfish: the brown bullhead (*Ameiurus nebulosus*). These fish were officially introduced into New Zealand (Auckland region) early in the twentieth century and the first report of their presence in Taupo was made in 1985. This suggests that brown bullhead were probably introduced a few years earlier but it is still unknown how and especially why they were released in the first place. However we all agree that this was not a great idea and Iwi and anglers were very concerned. It is also worth noting that while many species of catfish are highly valued and economically important, the brown bullhead do not enjoy the same reputation. Furthermore, the knowledge of the ecology and behaviour of brown bullhead is very fragmentary.

What are the known impacts of catfish:

- Catfish damage other species by predating on and competing for food of small native fish species, and freshwater crayfish
- They stir up the bottom which reduces water quality for other animals and plants.

As manager of the largest trout fisheries in the country we obviously were very concerned and in 1995 we commissioned Grant Barnes, a Masters student from Waikato University, to look at the first thing that worried us - do catfish eat juvenile trout?

We also wanted to know their diet and their abundance, if we were dealing with a population getting bigger or if it had reached a maximum, and have they spread throughout the entire lake? Grant Barnes found that the catfish were abundant in the shallow weedy and rocky habitat especially in the southern part of the lake and that they did not prey on juvenile trout, so for us that was a relief.

However, his master thesis was based on a single year of observations. We decided to keep the programme going and since 1996 we have been monitoring the abundance of brown bullhead on a monthly basis in three sites using fyke nets. Two of these sites were where they were most numerous and another where we should not see any catfish according to our knowledge of their biology.

We first scuba dived in the lake to see what this species looked like. Originally brown bullhead lived in very murky waters in America but in Lake Taupo the water is so clear that for the first time it was possible to observe catfish in action. Slide 1 shows catfish schooling in mid-water above the sandy bottom. In these situations they are really curious and easy to approach and observe.

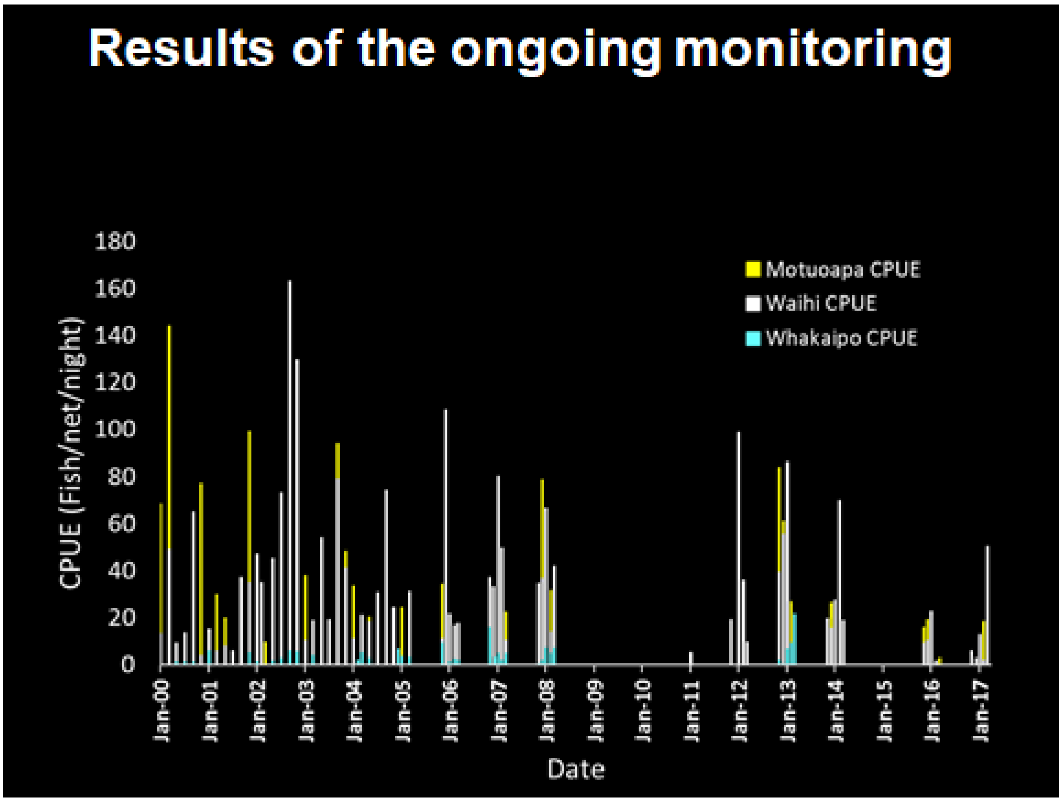
In Slide 2 we can see another type of behaviour where bullheads are alone tacked on the bottom and really shy disappearing very quickly when approached.

We do not know the reasons for these two types of behaviour and I do not know if it is the same in Lake Rotoiti, but this gives us a first clue: If you want to catch bullhead you need to target them both close to the bottom and in mid- water.

Slide 3 is another shot of those fish from underneath, not desirable but beautiful. In this situation we could virtually catch them with a hand net as they did not try to escape capture. That gives us another clue: they can be very vulnerable in some situations.

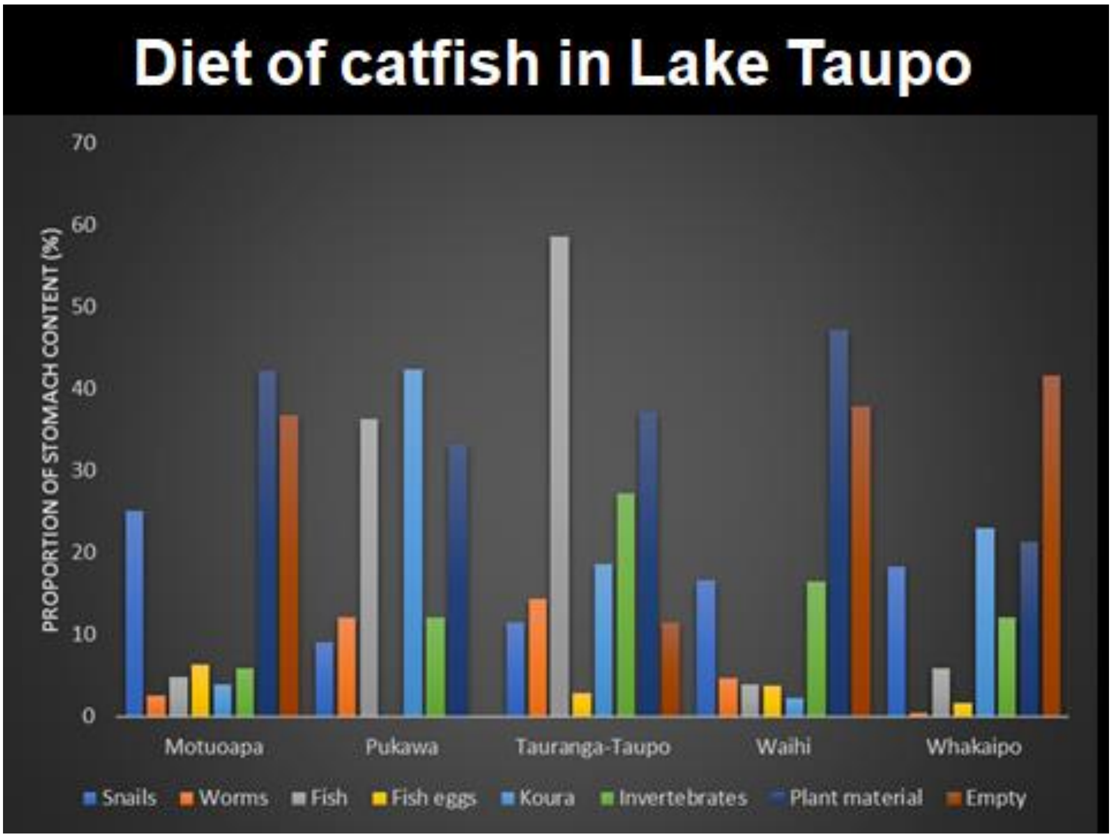
However, there were still some unknowns from Grant Barnes study that was carried out mainly in habitat with no trout. We wanted to know if catfish can share the same habitat as trout and if they did could they predate them?

Slide 4 is the result of the monthly monitoring that we did from 2000 until 2017. The results show that the catch rate (the number of fish caught per night in each net) is extremely variable and that there is no clear long term trend. The lack of trend suggests that the population has reached a plateau and it is not exploding. That is good news.



The other thing to point out is the catch rate at Whakaipo which is in the northern end of Lake Taupo. The Whakaipo Bay has very clean water with a barren sandy bottom similar to the majority of Lake Taupo. We used that site as a control because if catfish can survive in that habitat we would have a major problem. It would mean that they are likely to invade virtually the entire lake. However, the results indicate that the population of bullhead in Whakaipo is extremely low with no increasing tendency suggesting again that bullhead are not likely to invade the entire lake.

It was also important to look at diet and in Slide 5 you can see the distribution of prey found in more than a thousand catfish. Every month we analysed the stomach content of catfish of different size classes. We found that in certain areas and at certain times there was a large proportion of fish in their diet, such as in Tauranga-Taupo, but overall snails, invertebrates and plant material were by far the most important prey in the diet of catfish in Taupo.



There were also a lot of empty stomachs which may sound very strange but in fact it is easy to understand. The fish got caught in the net soon after it started eating and its stomach remained empty simply because it did not have time to eat.

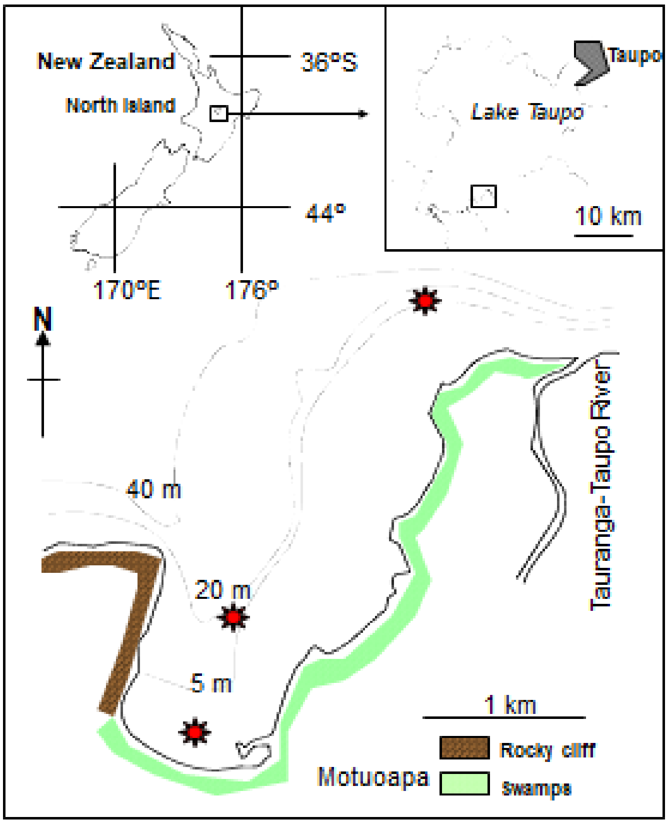
However, we were still not 100% satisfied that catfish are not a problem in Taupo so we did an acoustic tracking experiment using transmitters equipped with a pressure sensor allowing us to define at what depth tagged fish are swimming. In other words we observe if the fish stay in shallow water or go in deep water. We also had several listening locations allowing us to determine if there is any horizontal movement and how much the catfish are roaming in Lake Taupo.

The transmitters were about the size of a finger made by a Canadian company –

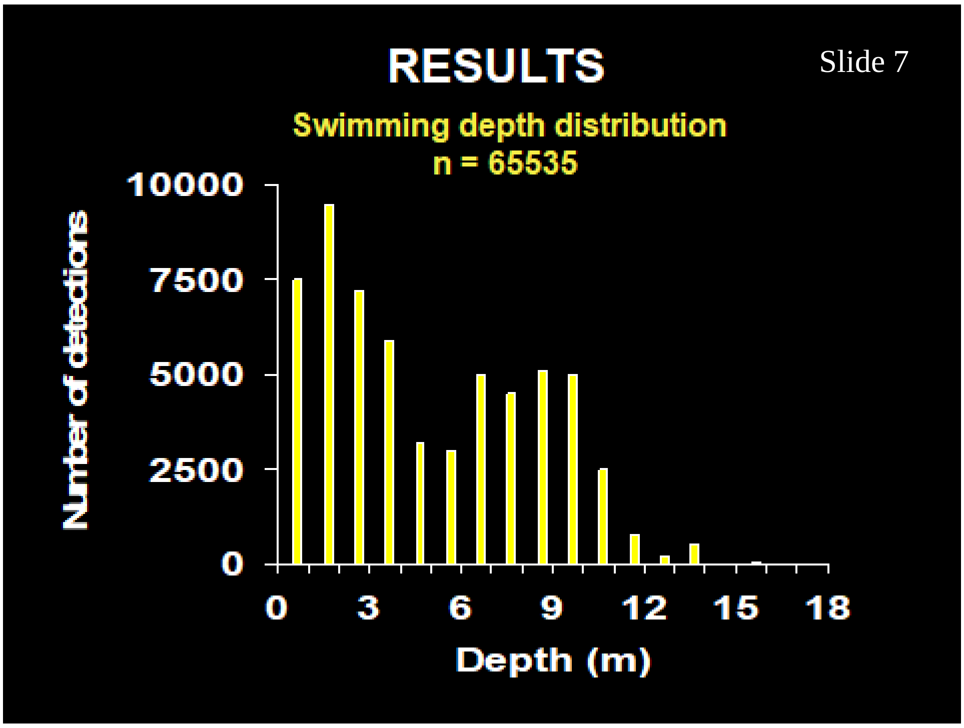
- Acoustic transmitter equipped with a pressure sensor (Vemco VR16-1H)
- 62 mm long, 16 mm diameter, 6 months battery life
- Automatic receivers (Vemco VR 1)

Slide 6 shows the study area in Motuoapa Bay, one area known to have a strong population of catfish due to the abundance of shallow water and weedy bottom. There were 3 listening stations (red stars), and we tagged about 25 catfish. We left the listening stations recording for one year and then downloaded the data.

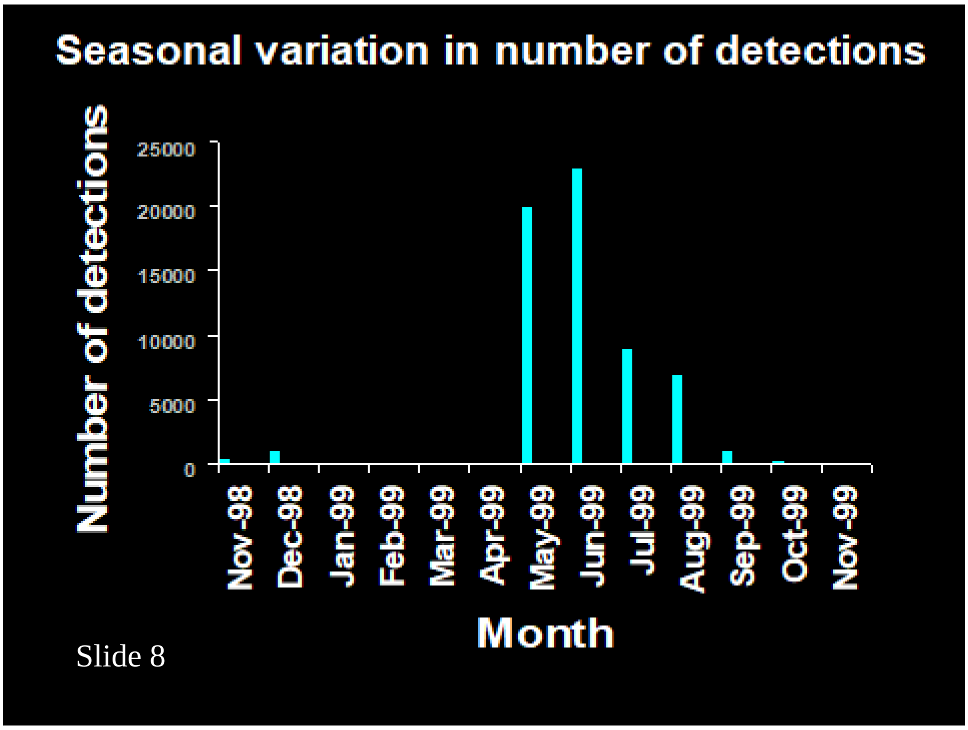
Slide 6



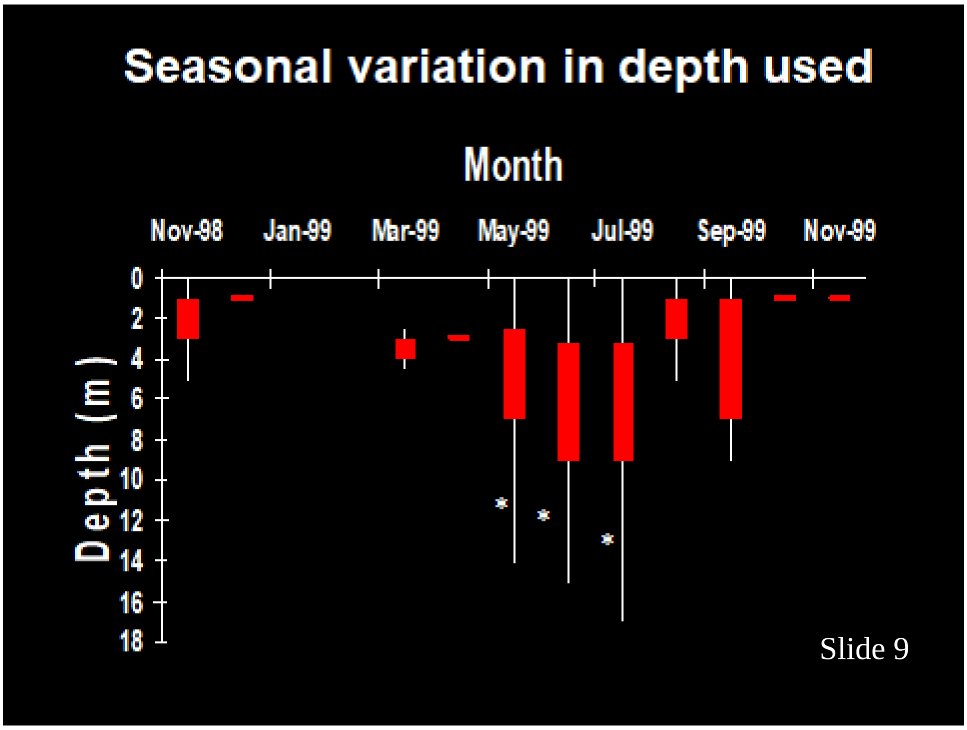
Slide 7 (next page): Immediately we found that catfish spend most of their time in shallow water. We did not get any signal from water deeper than 17 metres even though the listening stations could record in much deeper water. That was good news because Lake Taupo is like a bucket; if you cut through a bucket the edges are very narrow and then it gets deep very quickly. These initial results reinforced that we can be confident that catfish will not invade the pelagic zone of Lake Taupo.



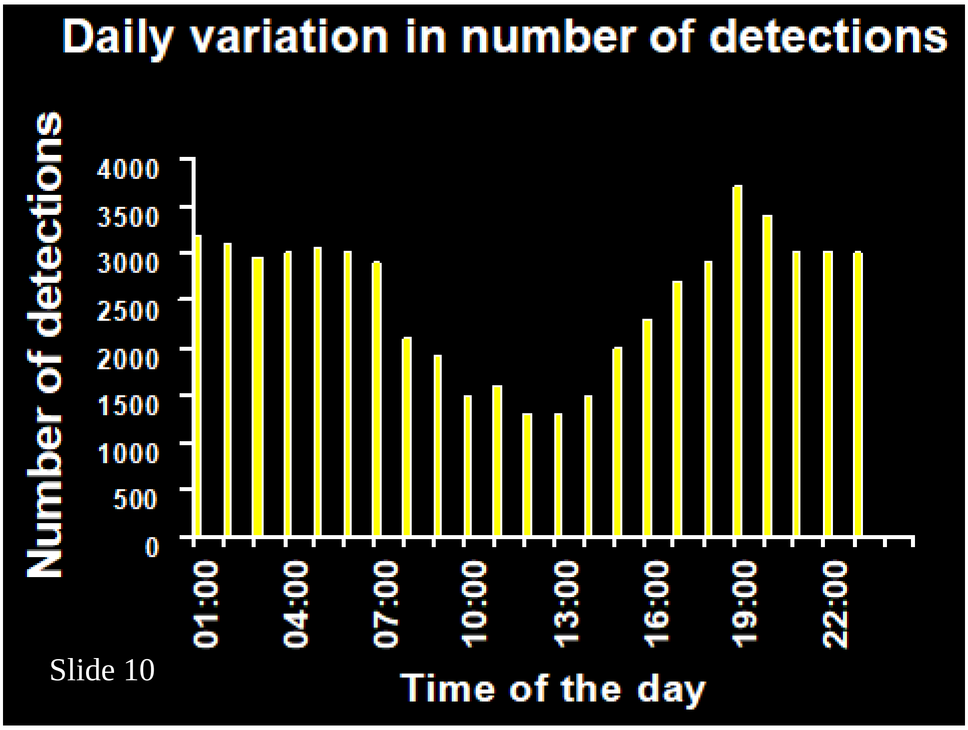
We also looked at the seasonal number of detections to assess when catfish are particularly active. (Slide 8) During summer they were difficult to locate, they were not where we tagged them and away from our listening stations. However, by April they returned to the Motuoapa Bay where they stayed until August. These movements in and out of the bay indicate when and where is the best time to target them.

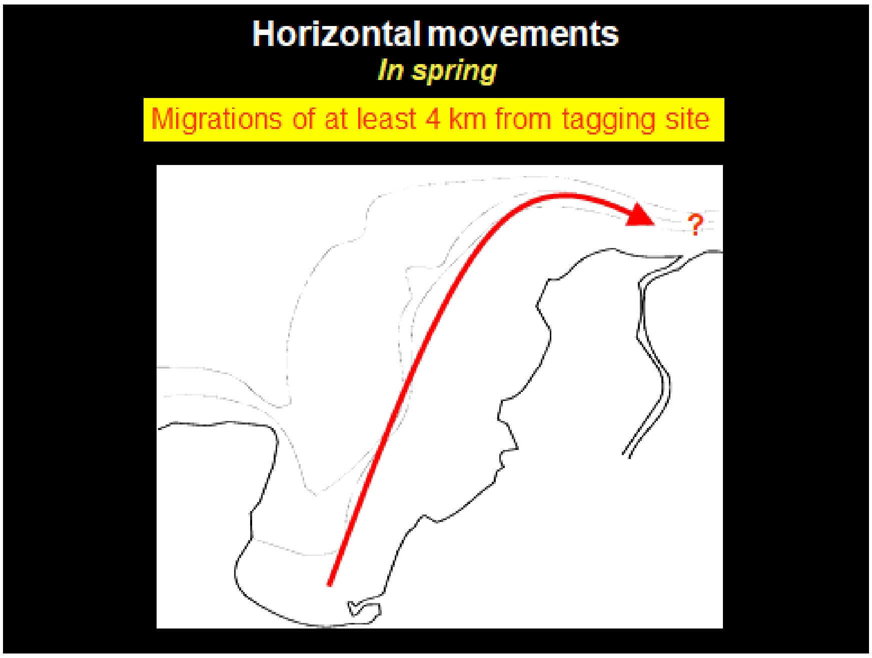


Let's have a look at what depths catfish generally swim in Lake Taupo. (Slide 9) Generally in winter catfish are in slightly deeper water than during the rest of the year especially in summer and spring. This indicates where to find them at different seasons.



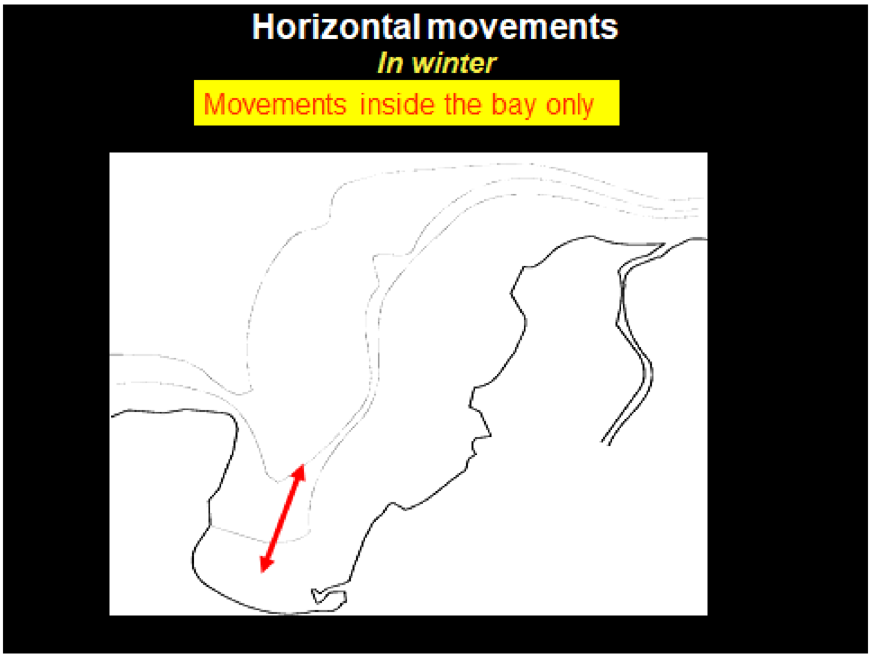
Looking at the daily variation we found that the fish were very active throughout the night but become much less active from dawn onward. (Slide 10)





Because we did not see them in summer we were wondering where they went. One possible explanation is that they go out of the Motuoapa Bay in spring but we could not know exactly where because such movements were unexpected and we did not have enough listening stations to monitor a more extensive part of the lake.

However, we detected catfish close to the mouth of the Tauranga/Taupo River which is about 4 kilometres north from Motuoapa Bay where they were marked. This shows that they can make substantial migration. From another subsequent tagging re-capture experiment that we did in Waihi Bay we found that these fish can move between Waihi Bay and Motuoapa 15 kilometres away.



In winter they park in Motuoapa Bay and do not move much. The overall horizontal movement of bullheads suggest that the most effective way of targeting them would be to stop their migration in and out of the bay.

In Conclusion

- Catfish in Lake Taupo are mainly found between the surface and 17 m deep
- They are unlikely to colonise the pelagic zone of the lake
- They are active during the hours of dim light especially at dusk and dawn
- They change their swimming depth by series of dives and ascents
- They make substantial seasonal migration (spawning?) in spring
- They use deeper water and are less active in winter
- Fyke netting would be an efficient control method because of its selectivity for large catfish that are causing the main concerns.
- Fyke netting would be particularly efficient during spring migration.

It is important to target catfish which are showed to cause a real problem. For example, if it is identified that eating koura is the main impact of catfish then target the large catfish that are predating on koura. We saw that catfish need to be at least 250 mm long to deal to and eat koura. Koura do not wait to be eaten and our underwater observations show that they will put up a good fight and not be gobbled up easily.

However, there are still some unknowns about the possible subtle impacts that catfish have on the ecosystem of Lake Taupo. Research on the trophic chain in Lake Taupo by Simon Stewart, from University of Waikato cannot rule out the possibility that catfish may have an impact on traditional pelagic fish like smelt and trout when those traditional fish species need access to the literal productivity. If this is the case then it would be at this stage that catfish could compete with trout and smelt. I believe Simon is not going to talk about this but it is another path we would like to further explore before being absolutely 100% confident that we do not have a problem with catfish in Taupo. Thank you.

Don Atkinson
Very insightful looking at what is happening in Taupo. Unfortunately our lakes are far more vulnerable because they like shallow conditions and that is what we have in Western Rotoiti and Lake Rotorua.

KŌURA IN THE ROTORUA TE ARAWA LAKES AND POTENTIAL EFFECTS OF CATFISH

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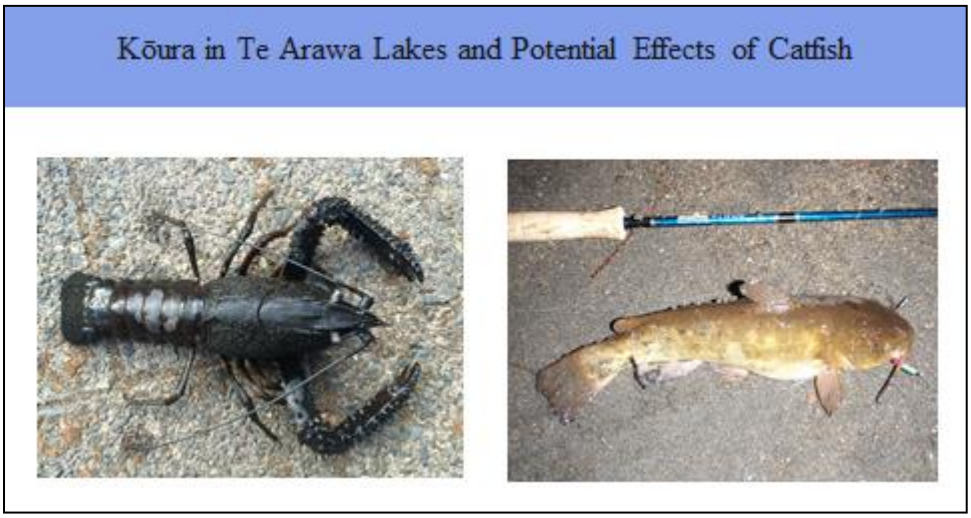
Ian is a self-employed freshwater fisheries scientist with more than 20 years' experience in freshwater fisheries consultancy, management, and research. He is a freshwater advisor to the Rotorua Te Arawa Lakes Trust and Tūwharetoa Māori Trust Board. Ian recently completed a PhD from the University of Waikato on kōura in the Rotorua Te Arawa Lakes. He is a member of the New Zealand Freshwater Sciences Society and International Association of Astacology. Ian currently resides at water-laden Lake Ōkāreka.

TRANSCRIPT

Tena koutou katoa

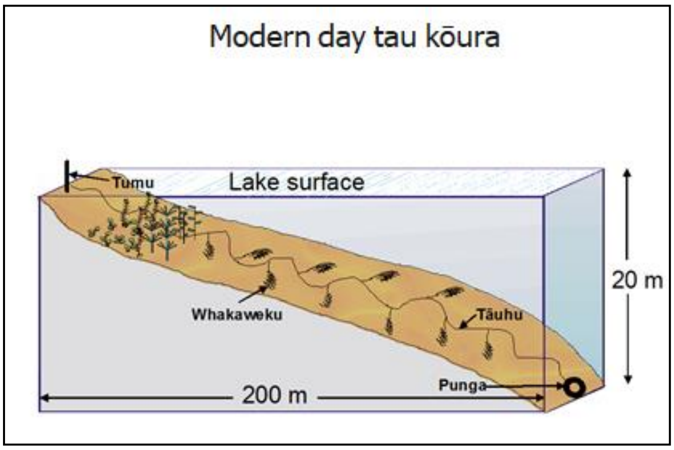
Welcome everybody to my presentation today on kōura in the Rotorua Te Arawa Lakes and the potential effects of catfish.



This shows the kōura, the northern species of freshwater crayfish (*P. Planifrons*), on the left-hand side, and the brown bullhead catfish on the right. That catfish picture was taken from one of our relations from Tūwharetoa, Kim Turia, and was captured fly-fishing at night at the Tauranga Taupō River mouth.

I would just like to acknowledge the following organisations - NIWA, the Bay of Plenty Regional Council and Andy Bruere in particular, the Rotorua Te Arawa Lakes Trust and Sir Toby Curtis.

I am going to talk about kōura and the novel sampling method we are using, then talk about the population characteristics of kōura in the Rotorua Te Arawa Lakes, including results from my PhD research, the Lake Taupō experience with catfish, which Michel Dedual has more than adequately described, and also future work.



The sampling method we use is called the tau kōura, a modern day take on a traditional Te Arawa/Tūwharetoa method. Bunches of fern bundles called whakaweku are put onto the lake bed and the kōura colonise them. We then retrieve and harvest them. There are a number of advantages over standard western methods.

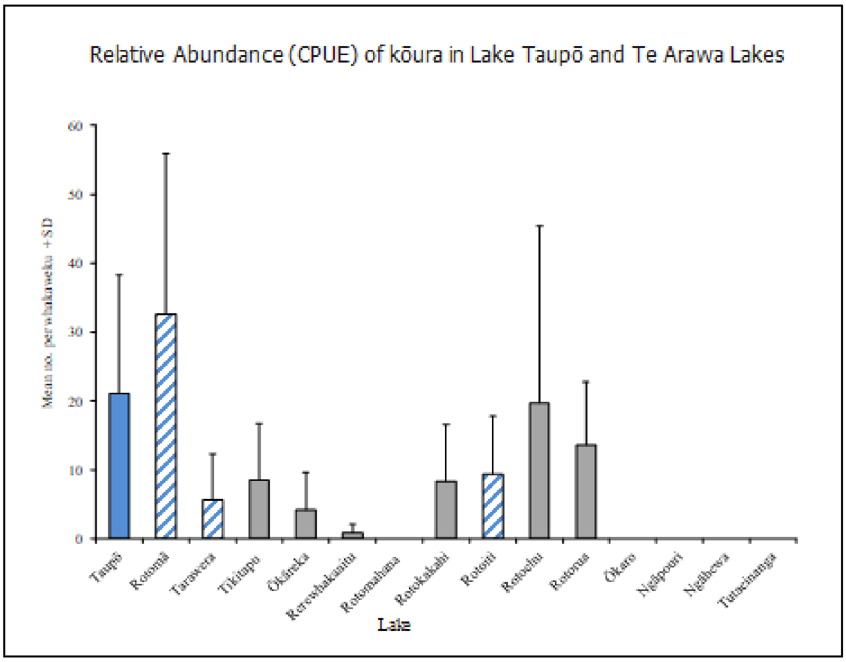
The bracken fern grows along the roadside. We collected 10 - 12 fern fronds, bundle them together with cable ties and make the ice-cream shaped whakaweku.

Below is a muddy, sandy bottom at Lake Tarawera. Kōura hang on to the whakaweku until it hits the air and then start jumping off. A kōrapa (landing net) goes underneath it to collect all those kōura jumping off.

At this point, I would like to acknowledge Willy Emery for sharing his traditional knowledge with us; he also designed the modern-day kōrapa. We would not be where we are today without his contribution.

Below - Willie Emery with a tau kōura being retrieved in Lake Tarawera

That fern bundle was in Lake Tarawera for about 2 years but in the more eutrophic lakes whakaweku only last about 6 months. After retrieval they are returned to the water and used on the next sampling occasion. We like to have two tau kōura, consisting of 10 whakaweku, per lake. The neat thing about this method, which no western standard methods do, is it collects kōura of all size classes; as small as a thumb nail right up to the biggest sized kōura. It also does not have sex biases inherent in other methods. Traps or nets generally only catch big males, no small ones and not too many females. It is a legitimate crayfish sampling method that is now being used in Europe and North America. The name tau kōura is the traditional Māori named and is acknowledgement to our tupuna.

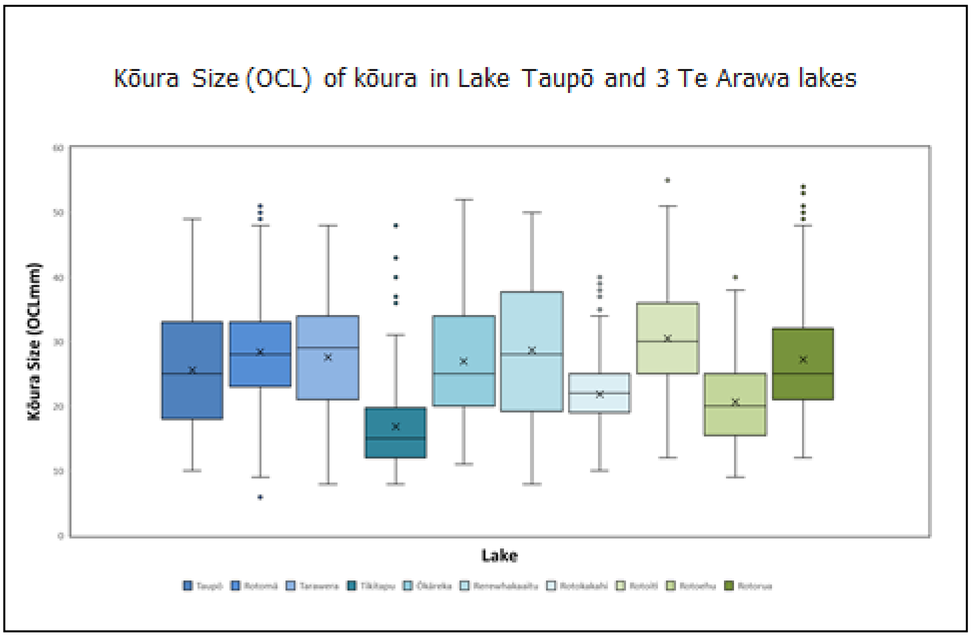


This graph shows the relative abundance of kōura in the Rotorua Te Arawa Lakes and Lake Taupō. The lakes are ordered along the X axis with increasing chlorophyll A concentration, the clean oligotrophic lakes on the left, moving into mesotrophic and then super eutrophic on the right. On the Y axis we have the mean number of kōura per fern bundle and as you can see there is no obvious pattern in regard to trophic state. It is notable in the super eutrophic lakes, which have very little dissolved oxygen for 8-9 months of the year, that there are no kōura at depth. There might be a few around the lake shore at the stream mouth or where wave action puts dissolved oxygen into the water but nothing at depth.

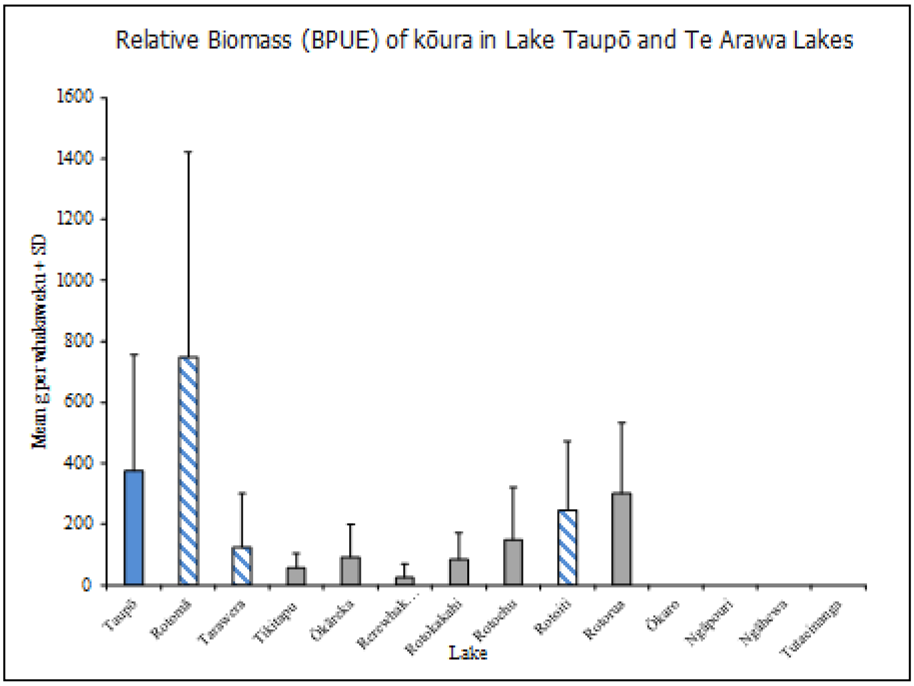
Lake Taupō has catfish but there are also still plenty of kōura. In the next slide Rotoma is a stand out. Lake Tarawera has few kōura at depth, we think that this is due to the eruption of Mt Tarawera in 1886 which put a lot of Rotomahana mud into the bottom sediments. Rotomahana mud is very fine and silty, not ideal for kōura. They prefer rocks. In addition, Joe Butterworth and I have only carried out one sampling at neighbouring Lake Rotomahana, and also did not collect any kōura at depth. There is also very significant geothermal input to that lake.

Rotoiti has good numbers of kōura and Rotoehu and Rotorua, which are eutrophic, also have good numbers. The sediments are good in these lakes, quite coarse with plenty of sand and pumice. They are also shaped like dinner plates so they are exposed to the wind and therefore their bottom waters do not deoxygenate like some of the other lakes.

The kōura size is on the Y axis and the lakes on the X axis in the same order as the previous slide, from Taupō to the super eutrophic lakes on the right. Good sized kōura are found in Taupō, Rotoma, Tarawera, Ōkāreka, Rerewhakaaitu and Rotoiti; if you want to harvest kōura to eat then these are the best lakes. Kōura were significantly smaller in Lake Tikitapu which this may be due to the low calcium concentrations in the lake. Interestingly, in terms of breeding season kōura in Lake Tikitapu appear to be out of sync with the other lakes.

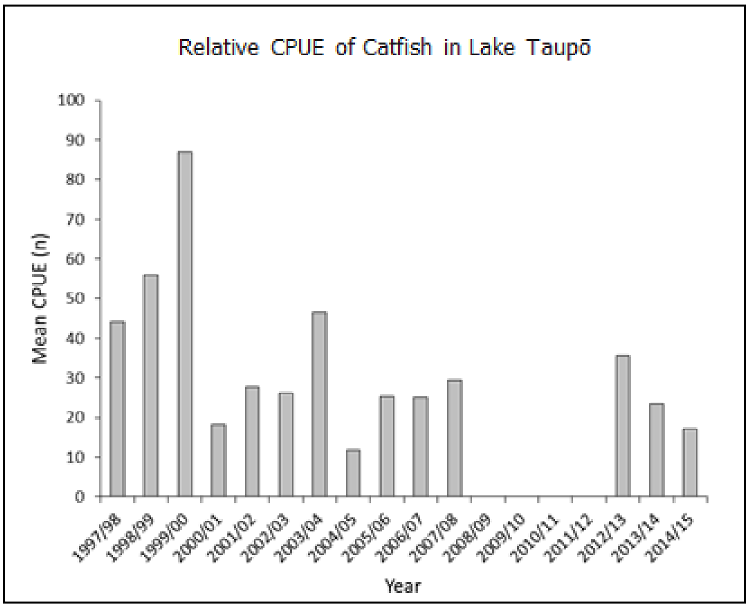


We also looked at biomass, which is the combination of average size and abundance, with Taupō, Rotoma, Rotoiti and Rotorua the standouts.



We have done a number of kōura surveys in Lake Taupō including Hiruharama Point, Motuoapa, Waihi and Pukawa bays. The stars indicate DOC's catfish monitoring sites. High numbers of catfish are found in Waihi Bay and Motuoapa.

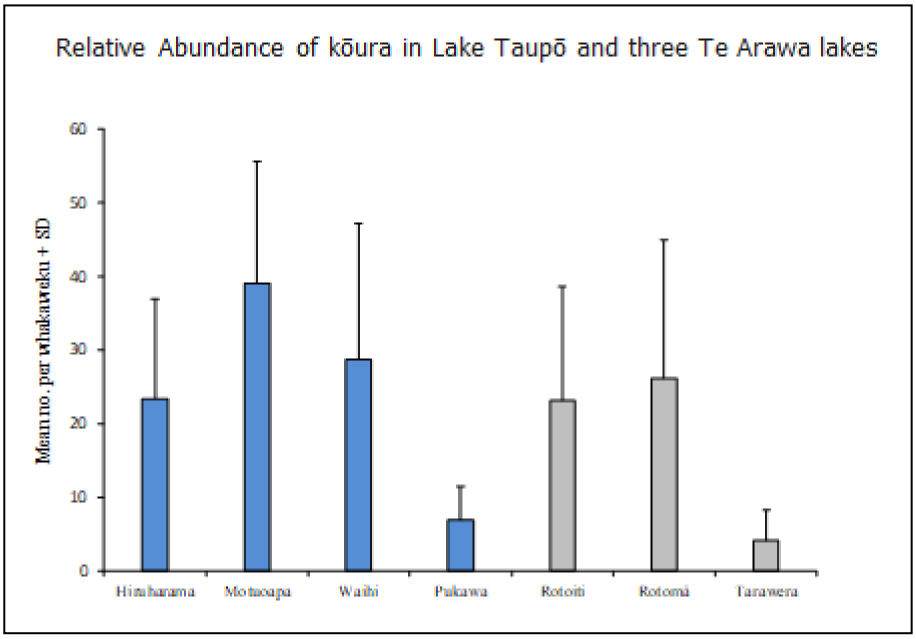
This is a summary of Michel Dedual's data and shows that the catfish population seems to have plateaued, but there are still plenty of catfish in Lake Taupō.



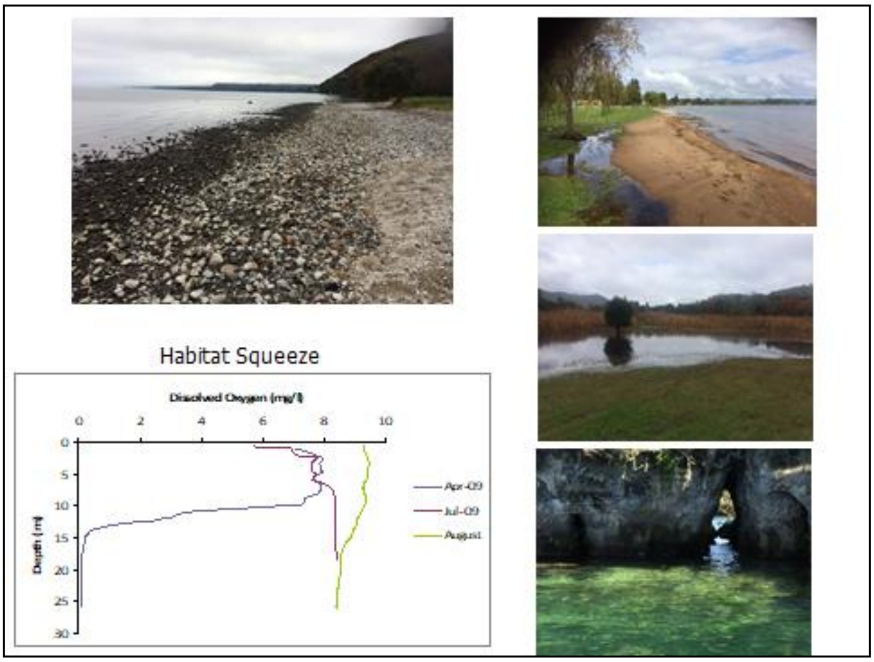
The juvenile life stage of kōura is the most vulnerable to predation. The Department of Conservation research in Taupō shows that most catfish are found in water depths less than 10 - 15m. In Lake Taupō, our tau kōura surveys caught kōura at water depths from 10m down to 35m. Therefore, there seems to be little overlap between kōura and catfish.

It should be noted that trout eat kōura as well but feed mainly on smelt and fish. This picture shows a kōura that was consumed by a catfish.

The next graph looks at abundance of kōura in various sites in Lake Taupō compared with Lakes Rotoiti, Rotoma and Tarawera, the big oligotrophic/mesotrophic Rotorua Te Arawa Lakes. Interestingly, Pukawa Bay in Lake Taupō and Lake Tarawera both have low numbers of kōura, this may be due to the fine muddy sediments present at these sites which suggests that bottom substrate may be more of a factor influencing kōura abundance than the presence of catfish.

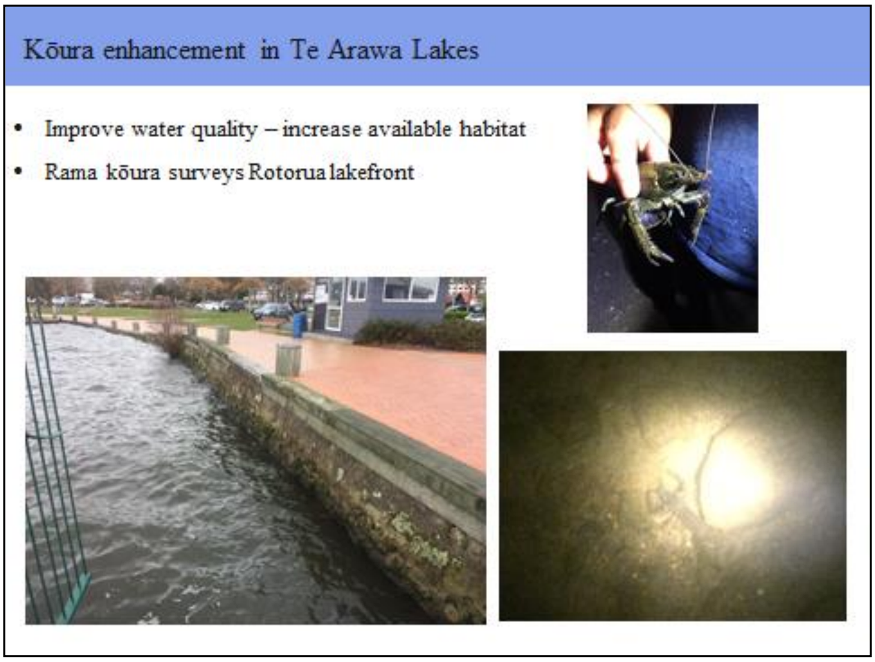


So, what is different about Lake Taupō? First of all there are lots of cobbles. The photo on the left (next page) is by the Waipehi Stream. The whole eastern side of Lake Taupō has greywacke gravels coming off the Kaimanawa Ranges. Top left is Lake Rotorua at Hannah's Bay with not one cobble in sight. The middle photo is a flooded Lake Okareka, raupo and mud. Nothing there. The bottom picture from the diving rock at Lake Okareka. Lots of bedrock but not many cobbles.



What is also good for kōura in Lake Taupō is that the bottom waters have dissolved oxygen all year round. Many of the Rotorua lakes stratify and their bottom waters deoxygenate for up to 8 months of the year. This graph from Joe Butterworth shows dissolved oxygen concentrations in Lake Rotokakahi. In autumn when the lake stratifies below 11 or 12 metres there is not enough oxygen for kōura. Kōura prefer dissolved oxygen concentrations greater than 5mg per litre. Once it gets below that kōura move into shallower oxygenated depths. In these kōura and catfish distribution will inevitably overlap.

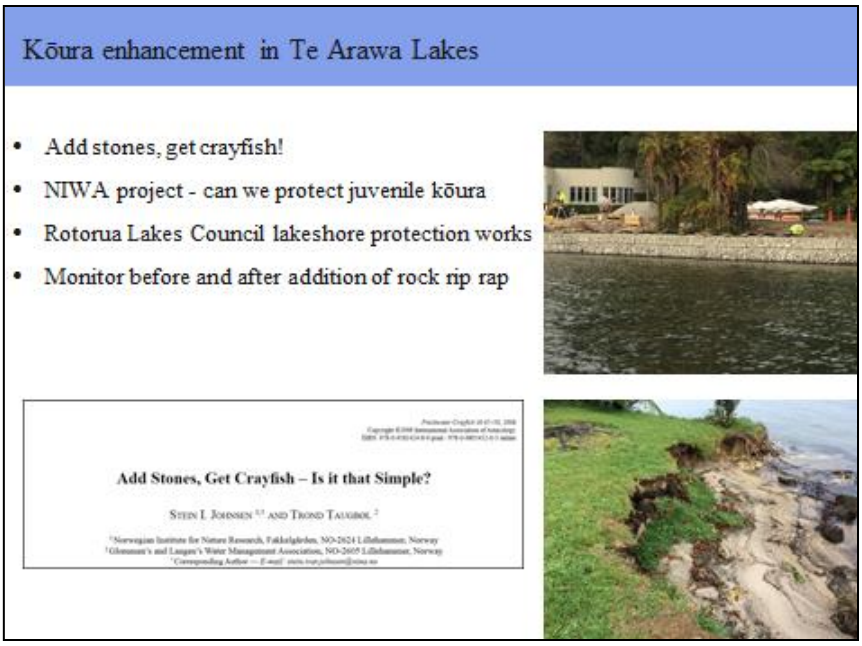
What can we do for kōura? Firstly, we need to improve the water quality and increase the dissolved oxygen concentrations at depth and thus increase available habitat for kōura. I have recently been doing some work for the Bay of Plenty Regional Council at the Rotorua Lake front where kōura are present in quite good numbers. Below shows one that



we caught almost right in the middle of town. We did night spotlighting surveys up and down the foreshore and counted over 100 kōura.

We found lots of kōura around rock walls but hardly anything near the timber retaining walls. It got me thinking about what we could do now that catfish are here. Can we do a pre-emptive strike and provide some habitat for juvenile kōura, which is the most vulnerable life stage? Below is a solid rock gabion wall constructed out at Te Akau Point, Lake Rotoiti, which is perfect for little kōura to get away from catfish.

We have had a number of cyclones this year and at Hamurana, in Lake Rotorua, there has been considerable lakeshore erosion. The Rotorua Lakes Council and Bay of Plenty Regional Council are looking to protect the lake shore by adding rock structures; we intend to work with them to make these structures kōura-friendly.



There was a paper in Norway called, ‘Add Stones, Get Crayfish - Is it that Simple?’ Well, yes it is that simple in Norway because in winter when the lakes freeze over all you need to do is drive a truck full of rocks on to the ice, unload, them, drive home and wait for spring. When the lake thaws the rocks fall to the lake bed. Obviously, that is a lot harder to do in a Central North Island lake in New Zealand. That is why we are looking at lakeshore protection works comprised of rocks to give kōura a helping hand.

In conclusion:

- Kōura are still common in Rotorua Te Arawa Lakes and Lake Taupō
- Kōura prefer coarse lake bed substrates and it is especially important for juvenile kōura
- There is a little overlap in the habitat distributions of kōura and catfish in Lake Taupō
- The best thing we can do is improve water quality and add cobbles where it is practicable
- Stop the spread - **CHECK CLEAN and DRY!!!!**
- We can’t have catfish getting into other lakes

QUESTIONS

Prof David Hamilton: Just a quick question to Ian, the gabion baskets around the edge of the lake, how do they compare with the natural riparian vegetation that might have been there and the habitat complexity that might bring for the kōura?

Ian Kusabs: It compares pretty well in Lake Taupō as you can see from the slides but around Rotorua Te Arawa Lakes we have not got cobbles. What else can we do? There is plenty of mud and raupo. Gabion baskets would add to the diversity of lake shore substrates and cover for kōura.

Nicky Douglas, Rotorua Te Arawa Lakes Trust: My question is for Lindsay. The Rotorua Te Arawa Lakes Trust have established Komiti Whakahaere (management committee) and written a Mahire Whakahaere (Fisheries Management Plan) which is really around our taonga ika species in the lakes and when you did your presentation on eDNA you talked about how it could be used for native fisheries. I wonder how we might apply that technology in protecting and restoring our native fishery in the Rotorua Te Arawa Lakes?

Lindsay Chadderton: Essentially eDNA is used as a presence tool. There is a rough relationship between the number of detections and the amount of DNA in abundance but certainly there is no reason why you could not use the tool. It is probably most useful as an inventory tool to work out where the taonga species are. It can be used for any aquatic species. It comes down to what your goal is as inventory on the landscape.

Elizabeth Miller, Te Weta Bay: I know Te Weta Bay gives you a wonderful opportunity for research on catfish but I want to know is why not rotenone? If finance is the main reason how does this compare with the costs of ongoing management for decades to come?

Prof Brendan Hicks: We could use Rotenone. In fact we had an incursion response workshop on Tuesday where we discussed this. Rotenone is usually considered a whole lake solution which is completely out of the question for Rotoiti. In the US they did Lake Gallivant, which is 157 hectares, and cornered the entire world supply of rotenone which caused a massive spike. But it has been used in what they call cove operations doing a small part of the shoreline by netting off to stop the fish from escaping. Then rotenone can be applied on the shoreline and catfish would be good for this because they are in shallow zones.

The idea is to mix the toxin through the water and if there are weeds or raupo the bi-kill would be a second problem, catching a bunch of unintended species as well, anything that requires oxygen and water which includes kōura, smelt, trout and goldfish. The goldfish would not matter but there are species we do care about. The last problem is public perception of toxins in the water. It could be managed but it takes a lot of careful discussion.

Rotenone breaks down quickly if applied at high temperatures and is gone mostly within 5-10 days. It does break down and people use it in their gardens. It is derris dust after all. I do not know how wide spread its use is now. People used to put it on by the bucket load and ten times the concentration needed to kill fish. It is certainly an option and on the table, but not one of the first given that they are already out of Te Weta Bay.

What are the options with the cordon in place? Shane has a good handle on the site and if catfish are identifiable with water temperature then they could be spot treated. But it is hard to know how effective it would be and there might be some community opposition to poisons in the water.

Elizabeth Miller: We have already got a cordon across the bay. I am not sure whether part of the research could be a biodiversity survey in Te Weta Bay? Is it a good kōura habitat? It is a bit muddy. I don't know. The kōura people could investigate that as a wonderful part of the research.

Natasha Grainger: There is one note of caution and that is that catfish are incredibly tolerant. Of all the species that can be taken out by rotenone, catfish are one of the tough species.

Gary Coker, a local conservator and keen fisherman: My question is regarding catfish in Lake Rotorua. We have seen it widespread in Rotoiti and in significant numbers in Te Weta Bay. What is the likelihood that they will spread through the channel and into the warmer waters of Lake Rotorua? Is the climate better for them there? Is there a food supply? Are we likely to see that in the future?

Prof Brendan Hicks: Certainly we considered that when we did our boat electrofishing survey. We went into Lake Rotorua specifically around the Ohau Channel entrance to see if there were any fish. We did not find them but it was not an effective tool considering that we only caught one in Te Weta Bay where there were plenty at the time. They do migrate and they do use flying water. It is probably not their preferred habitat to get to by fighting up against the current. But it does not mean they won't and that is the big fear, getting into Rotorua and finding a considerably better habitat.

Gary Coker: Is there any monitoring of catfish under way within Rotorua considering the fact that they are difficult to find?

Prof Brendan Hicks: No that we also discussed on Tuesday. It is a reasonable concern but costly to do the netting. They are of such low abundance around Rotoiti with nil on a number of sites. We are monitoring Okere Inlet and getting low numbers there.

Cr *Tipene Marr - Rotorua Te Arawa Lakes and Toi Moana, BOPRC:* How has the eradication gone? The burning question. We hear a lot about how to monitor and all that. Are you on top of them?

Michel Dedual: We did not make any attempt to eradicate them. We have been approached by people who wanted to get rid of them but with the size of Lake Taupō it is a biblical exercise that nobody could achieve. Because the concern was the predation of kōura by larger catfish we have suggested establishing a 2 or 3 people job to target the larger fish with a programme of netting, adjusting the mesh size accordingly. I think that controlled catfish in a system has to be one that pays for itself. Putting money in all the time is not going to work. On the other hand a few people can make a living by marketing the catfish which are popular with the Asian population in Auckland and Wellington. To me that seems an eminently sensible approach.

Cr Tipene Marr: Just taking the big ones and leaving little ones would be a job for life too. A bit like farming.

Michel Dedual: Yes but you get rid of the problem that you identified.

Cr Tipene Marr: I was also interested to hear about the protocol for bird diving. Thanks.

Natasha Grainger: Years ago we did national surveys and had problems catching dabchick particularly in this region. We developed some protocols for the regional wide surveys and it is about sitting on nets, setting them away from bird areas. But I know that Shane Grayling had more trouble doing an intensive survey and he would be the best to answer this.

Ian McLean: My question is for Lindsay. We know we have catfish in one of the 12 lakes and have not seen them in any of the others. What would a surveillance programme to detect catfish or any other species look like?

Lindsay Chadderton: That is a valid question and on Tuesday we talked about the need for broad delimitation surveys across the lakes. We have a set of tools that are reliable. Natasha talked about protocols with standard nets. The method is there and we could move relatively quickly towards a high throughput sequencing type of approach taking multiple water samples across the lakes. That is where to head which is probably more cost effective and sensitive. Catfish are one of the easier fish to catch. Council is considering undertaking surveys across the lake and I would encourage them to keep it up. The key is to look at lake habitat as well as likely points of introduction and targeting the sampling around those.

SESSION 3 : THE LAKE WEED MENANCE

SESSION CHAIR – Mayor Steve Chadwick

LAKE WEED AND THE ROTORUA TE ARAWA LAKES THEN AND NOW

Tracy Burton
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tracey.burton@niwa.co.nz

Tracey is a scientist in NIWA's Freshwater and Estuaries Centre with more than 15 years' experience in submerged vegetation management, with a focus on the use of aquatic plants as indicators of lake ecological condition. She has carried out biannual surveys of the submerged vegetation in the Rotorua Te Arawa lakes since 2002. Her current research looks at proactive management strategies for the prevention and spread of freshwater invasive species.

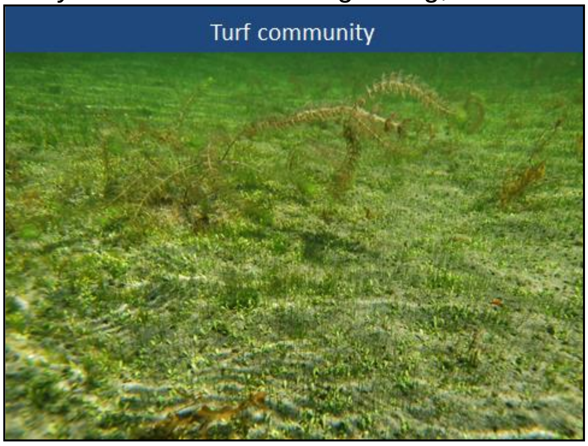
TRANSCRIPT

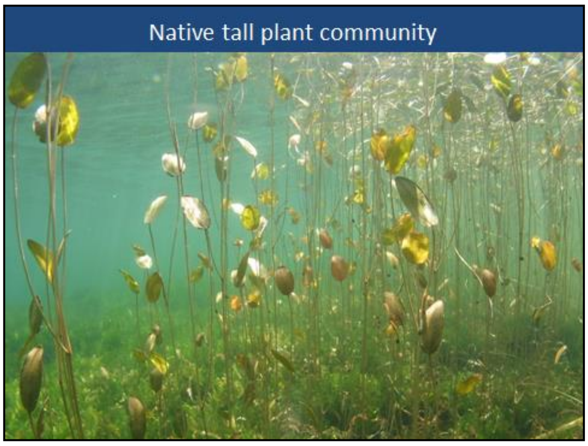
Kia ora katoa kotou. This afternoon we will be looking beneath the surface of the Rotorua Te Arawa lakes at the submerged aquatic plants that grow within them – the good the bad and the ugly. We will have a look at the special native aquatic plants that occur naturally in the lakes, familiarise ourselves with the weed species that have invaded them and look at how these weeds have (and are) changed the natural condition of the lakes. We will also look at how submerged plants are being used to report on the condition of our lakes and what these plant communities can tell us about the state of the lakes yesterday and today.

To gain a better understanding of our lakes, let's begin by going for a swim. But not just an ordinary swim, one that requires your imagination. So, grab your swimwear, don a pair of fins and a snorkel and join me for a swim in the Rotorua Te Arawa lakes prior to the arrival of any alien invasive weeds over a century ago.

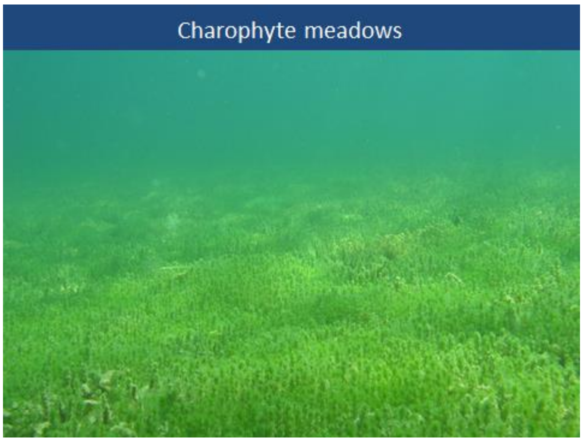
Arriving on the edge of the lakes in our time machine 100 years ago, many of the lakes would have looked similar in places to what they look today – beautiful and unspoiled by land use changes. In sheltered areas, the first aquatic plants we would have seen were those in the 'emergent zone'. This zone is made up of a variety of wetland species and include our tall sedges, rushes and grasses. They tend to be tall growing and can occupy the lake margin from just above the water line and can grow down into the water to a depth of around 2 metres.

When looking for a good spot to swim however, we would want to avoid fighting our way through the emergent zone and find a more exposed site around the lake where access to the water would likely have been easier. Once on the water's edge, let's start walking into the shallows and at around ankle to knee deep we would come across our 'turf' or 'low mound community'. There are around 26 species that contribute to this community type and they all tend to be low growing, less than 10 cm, and give the appearance of a grass-like turf or attractive carpet. Many of them are morphologically similar and are often referred to as our knife, fork and spoon communities because of the differing shapes of their leaves, and Deborah Hofstra will look at this community in more detail. This turf community is also able to tolerate short-term exposures out of water so can survive changes in water level.

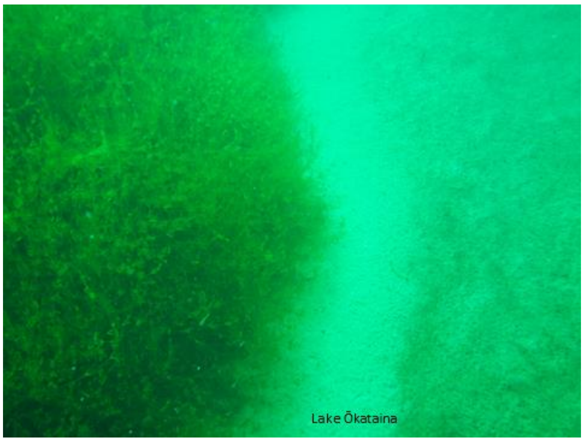




Next at around a metre depth, we will need to don our mask and snorkel and start swimming. As we continue to swim down the profile we would next likely see growing towards the surface our tall native plant community. This includes our pondweeds (*Potamogeton*) and milfoil (*Myriophyllum*) species that are most often seen growing through other native plants, like the turf or charophyte communities. The key thing to note with these taller growing native species is that they are not problematic, they have an open growth habit that allows light to penetrate through them and do not have much of an impact on the plants like the turf or charophyte species growing below. They can grow down to around 6 metres. This photo is very representative of most lakes in the area at that time.

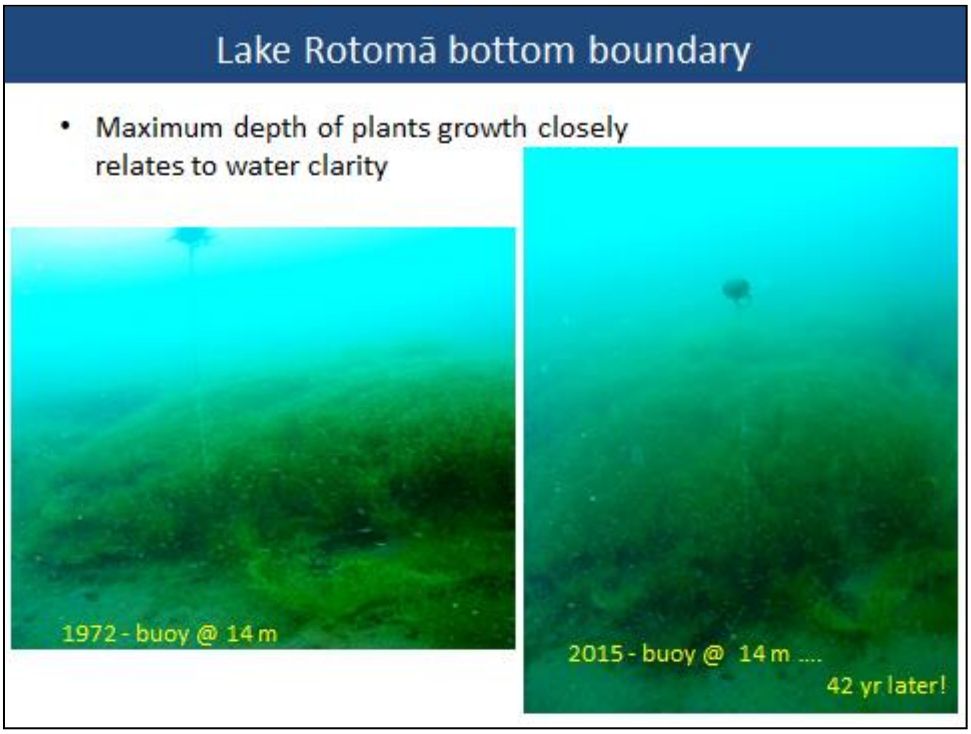


By now during our swim, we would also have seen our native charophytes. Charophytes are in fact macro-algae and are closely related to land plants. They are distinctive in that they can form beautiful bright green dense meadows, up to a metre tall down the profile. Looking down on them from the surface, it would seem like we are floating over a grassy meadow (or mini underwater pine forest) that covers the lake bed and they play many important roles to the lake ecosystem.

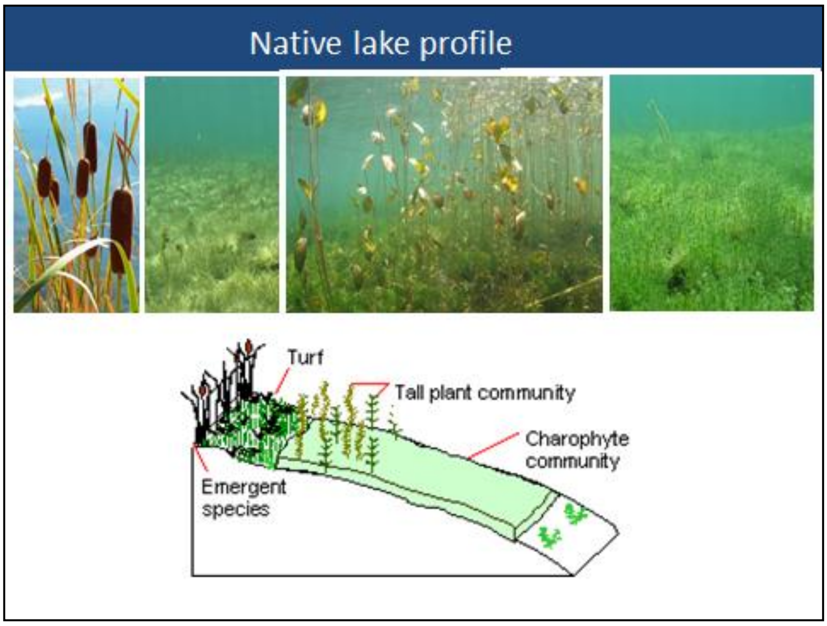


To reach the bottom depth limit of the charophytes, we would need to change our snorkels for scuba. This photo, looking down from above, shows the bottom depth limit of a charophyte bed and you can see how the meadow comes to quite an abrupt stop. The maximum depth to which plants can grow to directly reflects the water clarity, which is just how much light is still available to them. A hundred years ago many of the Rotorua Te Arawa lakes would have been expected to have had charophyte meadows extending to beyond 20 metres in depth.

The photo below shows a marker buoy that John Clayton placed at the bottom boundary of the charophytes at one site in Lake Rotoma in 1972. At that time, the bottom boundary of the plants was 14 metres, and in 2015, 42 years later, this marker was still present showing the bottom boundary of charophytes had stayed the same. This indicates just how stable the water clarity of Lake Rotoma has remained over the last half decade.



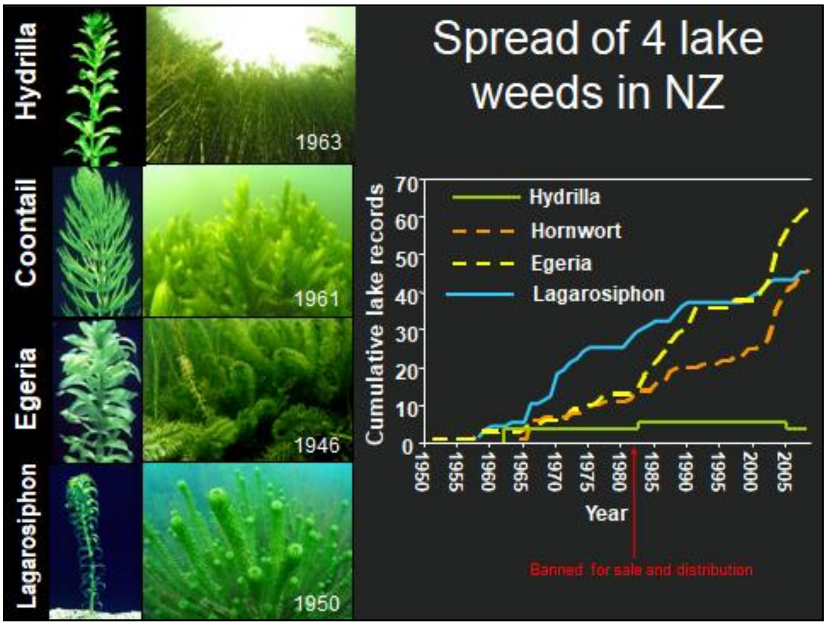
To summarise our swim, the next slide is a profile of the main components of the native communities that we just swam through. It shows the emergent zone growing around the lake margin, but only in sheltered areas, the turf community and charophytes, and the taller growing native species growing amongst these species in the middle section.



Returning now in our time machine back to the present day– unfortunately our lakes are under attack! Alien invasive weeds, species that have originated from other countries, have had spectacular success in invading the Rotorua Te Arawa lakes. Dense tall weed beds now occupy much of the littoral zone, particularly between 2 to 8 metres, and few lakes still retain all of the components of their natural native plant communities.

The Rotorua Te Arawa lakes contain four of New Zealand's worst submerged weeds shown below in order of increasing weed impact from left to right. Elodea and Lagarosiphon are both wide spread through both islands.

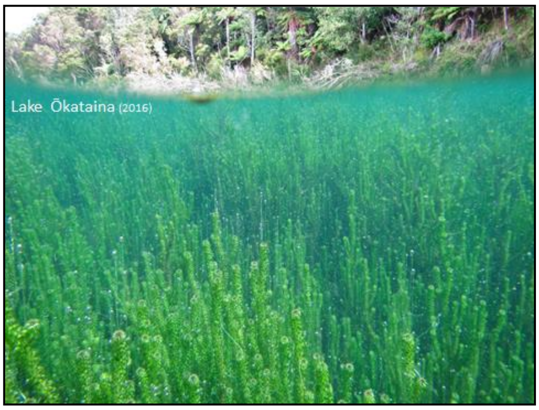
Egeria is known to be widely naturalised in most of the North Island and in Marlborough, with a few sites known elsewhere in the South Island. Hornwort, New Zealand's worst submerged plant species, is wide spread throughout the North Island. It has also been found in a few sites in the South Island but it has not been seen there now since 2008 so it is hoped that hornwort has now been eradicated from the South Island. Thankfully the Rotorua Lakes do not have the final weed shown here – hydrilla. Hydrilla would have an even bigger impact on our lakes than hornwort and has only been found in four small lakes in the Hawkes Bay Region. After 50 years of active management the hydrilla in these lakes is now considered under full control and it is hoped that is on its way to being eradicated.



The graph emphasises the rapid spread of these lake weeds in New Zealand since the 1950's, despite these species being banned for sale and distribution since 1982. All of these weed species reproduce vegetatively which means they are spread very easily from the movement of small vegetative fragments. The key vector in the movement of weed fragments is people, either through deliberate means, from ornamental ponds, release from aquariums into other water bodies, or through accidental spread from contaminated trailers, boats and fishing nets.

Elodea was the first oxygen weed species to invade the Rotorua Te Arawa lakes. It is likely to have first established in Lake Rotorua during the 1930's, given that the Ngongotaha trout hatchery had this weed in their hatchery around this time and that the ponds were flushed annually into the Ngongotaha stream which flows into the lake. Elodea is easily recognised by the arrangement of its leaves in whorls of three and is the only oxygen weed that can now be sold and distributed in New Zealand through the aquarium trade. It is the most benign of the weeds so does not tend to grow as densely nor occupy the same range as the worst weeds.

Lagarosiphon was likely the next weed to arrive in the region. By the mid 1950's it had been found in Lake Rotorua and by 1957 it was also present in Lake Rotoiti. It is a hardy plant that anchors to the bottom sediments with thick brittle stems and roots, and can form dense weed beds up to 5 metres tall and down to a depth of around 6 metres. It is recognisable because of its distinctive curved leaves that appear around the stem in a spiral pattern. This photo taken in Lake Okataina last year shows the extent of lagrosiphon around the margins of the lake and the impact it has had on native plant communities. At some sites it is surface reaching and extends down to the bottom limit of plant growth.



Egeria first appeared in Lake Rotorua in 1983. It is denser and leafier than the other oxygen weeds, with larger leaves usually in whorls of 4-5. It is bottom rooted and can form dense surface reaching beds up to 5 metres tall and down to 8 metres deep. It also is the only one of these oxygen weeds to have conspicuous white flowers that can be seen on the water surface during summer.

Hornwort is New Zealand's worst submerged weed species and was first noted in Lake Rotorua in 1975. It has stiff dark green leaves that are finely divided with small teeth, making the plants rough to touch.

Hornwort forms dense surface reaching weed beds and can grow down to more than 10 metres. As it has no roots these dense weed beds can be prone to drift, and on steeper profiles can continue to slump down into deeper water further smothering out native vegetation below, as has been the case in Lake Tarawera.

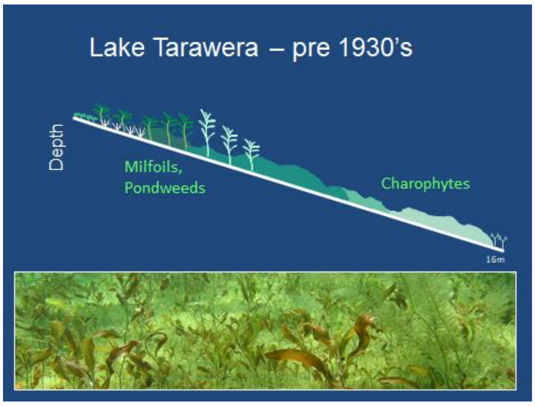
The problem with invasive species is that they have no natural enemies, such as plant-eating insects, and can spread and grow more quickly than our native aquatic plants, causing major damage to our freshwater habitats. As well as smothering out our native plants, including native seed banks, dense invasive weed beds can restrict the movement of water, cause flooding, block irrigation and drinking water intakes, destroy habits for native fish and wildlife, decrease water quality and can restrict recreational activities such as boating, fishing and swimming.

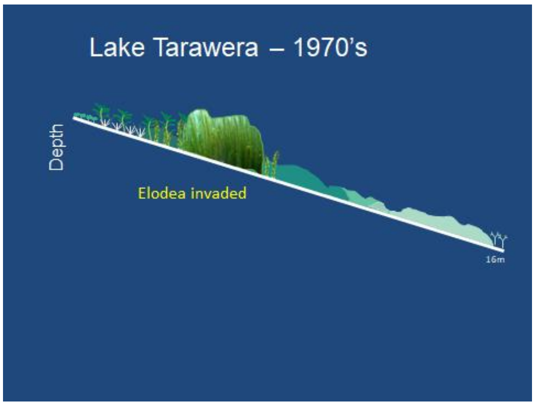
The negative effects of these weed beds are obvious when looking at them from underneath. The base of the beds are like virtual desserts consisting of highly flocculant smelly sediment. The sediments in these areas are too loose to support kōura or kākahi, and can become deoxygenated, particularly at night.

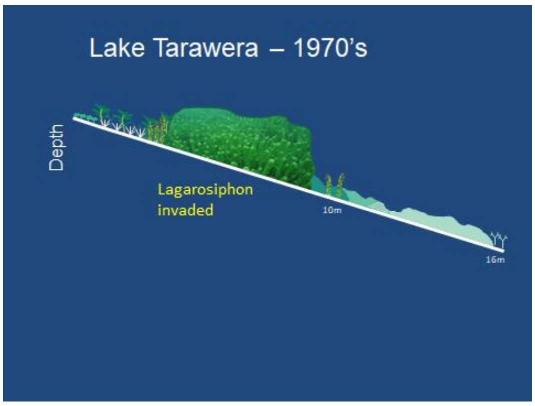
From the surface of the weed beds, the problems are even clearer. Photos show the weeds interfering with boating and swimming activities on the lake.

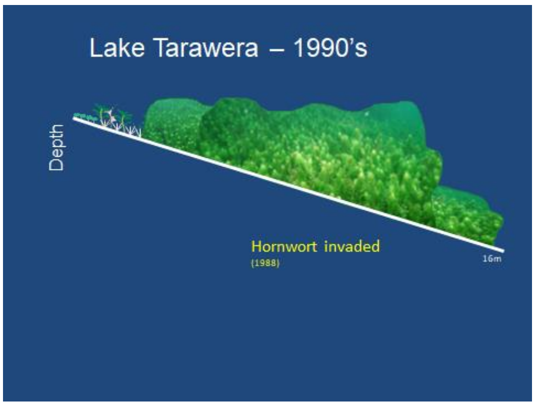
Weed rotting and smelling after being washed on shore is not something the community or tourists want to face when they head down to the lake.

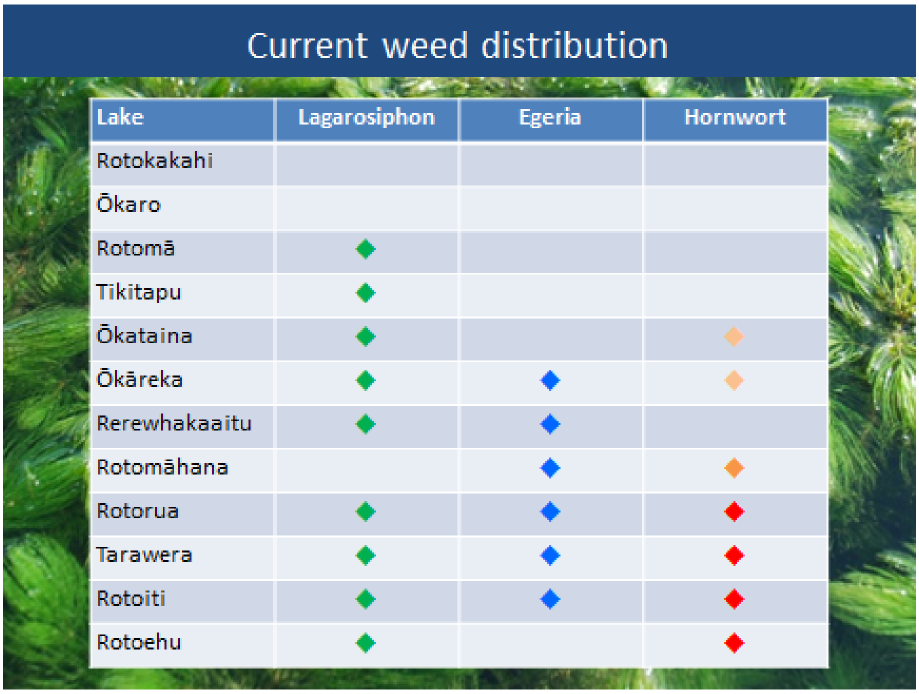
The sequence of slides below shows how weeds have changed the underwater landscape in Lake Tarawera, but these changes are representative of the changes that have occurred in other Rotorua lakes as well. In Tarawera in the 1930's, prior to any invasive weeds, the lake contained a healthy and diverse community of native submerged vegetation with charophyte meadows growing to around 16 metres in depth. In the 1970's elodea, and later lagarosiphon, invaded Lake Tarawera impacting on the middle zone of native vegetation down to around 6 metres in depth. Note that during this time native charophytes were still happily growing beyond the weed beds. Hornwort was first found in Lake Tarawera in 1988 and by the mid-1990's it had spread around most of the lake and had doubled the maximum depth of invasive plant growth smoothing out much of the native vegetation. By 2005 hornwort was responsible for the widespread displacement of almost all former deep water charophyte meadows.







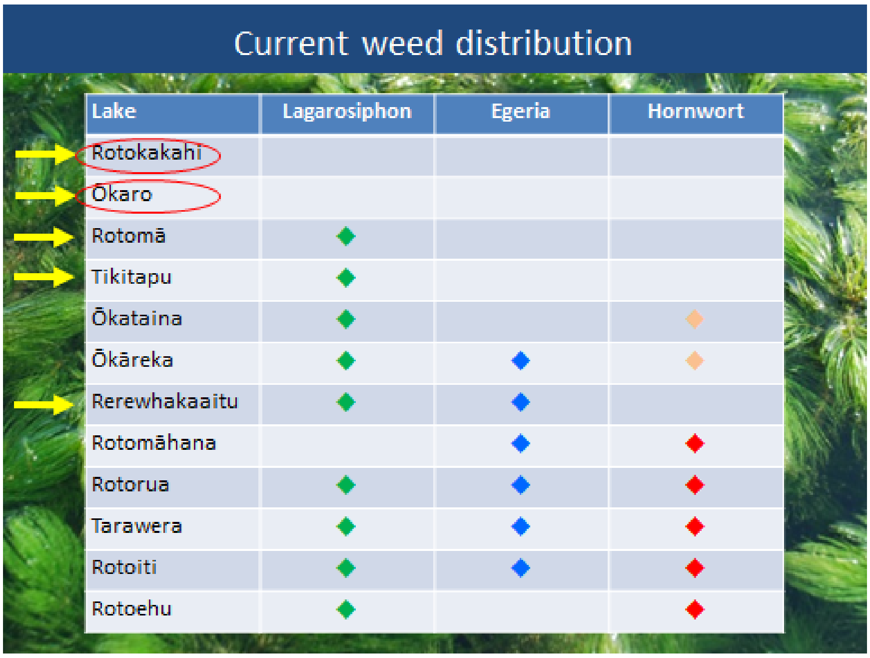




Current weed distribution

Lake	Lagarosiphon	Egeria	Hornwort
Rotokakahi			
Ōkaro			
Rotomā	◆		
Tikitapu	◆		
Ōkataina	◆		◆
Ōkāreka	◆	◆	◆
Rerewhakaaitu	◆	◆	
Rotomāhana		◆	◆
Rotorua	◆	◆	◆
Tarawera	◆	◆	◆
Rotoiti	◆	◆	◆
Rotoehu	◆		◆

So where are these weeds now? This table shows that lagarosiphon is now present in most of the lakes with a few exceptions being lakes Rotokakahi, Ōkaro and Rotomāhana. Egeria is in six of the 12 lakes and hornwort is well established in four lakes (Rotorua, Tarawera, Rotoiti and Rotoehu). Hornwort has also been found in lakes Rotomāhana, Ōkataina and Ōkāreka where it is being managed. In Okataina hornwort is currently found at only 1 of 12 sites where hornwort was previously recorded. No hornwort has been found in Ōkāreka for several years. There are still lakes that have not had hornwort (Rotokakahi, Ōkaro, Rotomā, Tikitapu and Rerewhakaaitu).



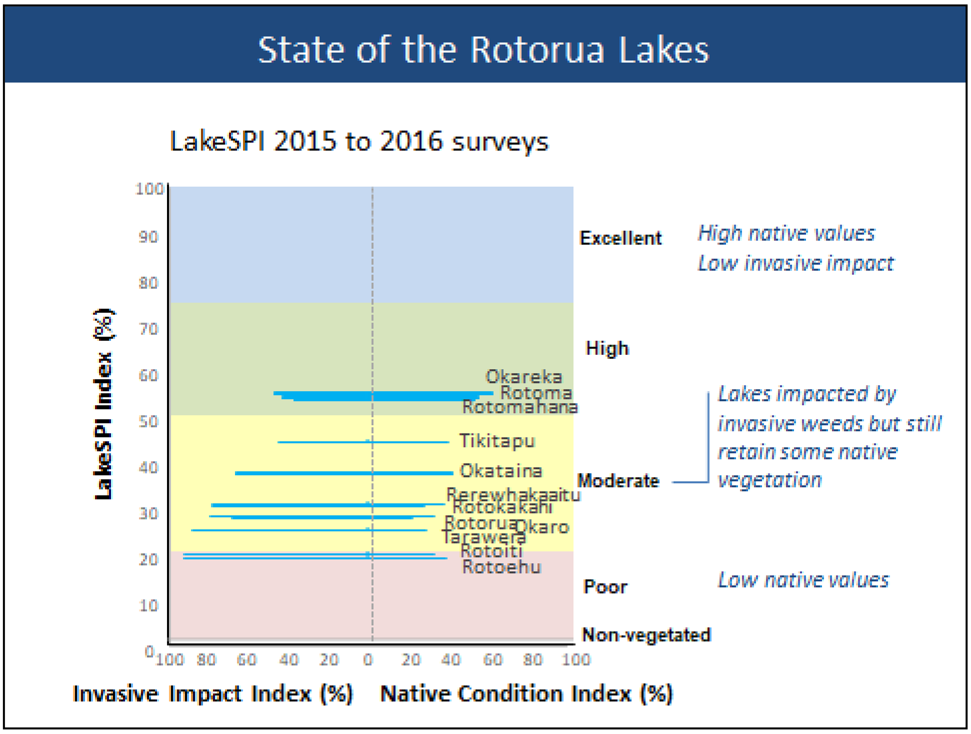
Current weed distribution

Lake	Lagarosiphon	Egeria	Hornwort
Rotokakahi			
Ōkaro			
Rotomā	◆		
Tikitapu	◆		
Ōkataina	◆		◆
Ōkāreka	◆	◆	◆
Rerewhakaaitu	◆	◆	
Rotomāhana		◆	◆
Rotorua	◆	◆	◆
Tarawera	◆	◆	◆
Rotoiti	◆	◆	◆
Rotoehu	◆		◆

Lakes Rotokakahi and Ōkaro are the only two lakes that remain free of off the worst invasive species. Although Lake Rotokakahi is widely impacted by elodea it does not have the worst species. This is primarily attributed to its restricted public access due to its sacred status to Te Arawa. Okaro is also free of the worst species but has a more restricted depth range on account of its water clarity.

Submerged plants are being increasingly used as bio-indicators to help assess the health of lakes. They make great indicators because they are non-mobile, cannot swim away, and are easy to see and identify because of their size. Because they are in the lake system all year round they can reflect environmental condition over an extended period of time, and also bring a focus to the littoral zone where greatest public interact occurs.

In the Rotorua Te Arawa lakes we have been using LakeSPI, or Lake Submerged Plant Indicators, to assess each of the lakes biannually since 2005. It provides three indices or scores that allow lake managers to assess and report on the status of their lakes and to monitor changes occurring within them over time. Because the LakeSPI method can be applied to historical data, which dates back for the Rotorua lakes to at least the late 1970's, we now have a really good picture of how the lakes have changed over the time. LakeSPI report cards for each of the Rotorua Te Arawa lakes are available at www.lakespi.niwa.co.nz.



For the purpose of ranking and discussing LakeSPI results, lakes are categorised into five main categories indicating overall lake condition: excellent, high, moderate, poor and non-vegetated. The LakeSPI indices for the lakes ranged widely from 19% to 55%. While most lakes would have once been categorised in excellent and high condition, representing those lakes with high native values and low invasive impact, only Lakes Rotomāhana, Rotomā and Ōkāreka fall into this group. Most of the lakes fall into the moderate group of lakes that are representative of those lakes that are impacted in varying degrees by invasive weeds but still retain some native vegetation. Lakes Rotoiti and Rotoehu however fall into the poor category reflecting the extent of invasion and dominance of hornwort in these two lakes.

It is not all bad however. While many of the lakes are showing a decreasing trend in lake condition, others are showing signs of improvement due to management initiatives being carried out on the lakes.

I would like to finish by thanking my colleagues at NIWA who will also be presenting this afternoon. Thank you also to the Bay of Plenty Regional Council who funds the survey work on these lakes.

Thank you.

LAKE BIOSECURITY – LOCAL ACTIONS AND RESULTS

Hamish Lass
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hamish.lass@boprc.govt.nz

Hamish is a Biosecurity Officer for the BOPRC. He co-ordinates the freshwater biosecurity programme for the Rotorua Lakes. His talk is on the BOPRC freshwater biosecurity programme local actions around the Rotorua lakes.

TRANSCRIPT

Thank you, I keep my biography short and sharp and probably should add that in a cruel twist I was born the year hornwort first invaded Lake Rotorua. I have been working from the Rotorua office for 11 years as a biosecurity officer focusing mainly on freshwater biosecurity.

Today I will go through our freshwater biosecurity programme. We have five main work streams:-

- Aquatic pest awareness programme (communications/ behaviour change)
- Weed Cordons
- Surveillance
- **Incursion response**
- Aquatic Pest Co-ordination Group

I have highlighted the incursion response because that is my main topic.

Our Aquatic Pest Co-ordination Group is made up from partners that have a management role around the Rotorua Lakes. This APCG group meet twice a year and talk about research, information sharing, work planning, shared coms and issues that we have. A hot topic is the spray programme around the Rotorua Lakes.

Tracey Burton from NIWA covered the freshwater invasive species in her presentation so I will only add to this quickly. This slide shows some of the invasive freshwater species that are present in New Zealand. Lagrosiphon is present in 9 Rotorua lakes, hornwort is in 7 lakes, hydrilla is not in any lakes but there have been infestations in other regions in the North Island. Egeria is in 6 lakes and there are no koi carp present in any Rotorua lakes.

Communications/behaviour change is really important work in our programme. Behaviour change is hard to do but we have some awesome communications people within Council that come up with good slogans - such as '*Clean your prop and trailer'* - using short sharp messages. It is all about telling people what the behaviour is that you want them to undertake i.e. too clean/clear their boat and trailer of lake weed. These are some of our summer giveaways and signage to tell people what to do, such as **Check, Clean and Dry** before going from one water way to another.

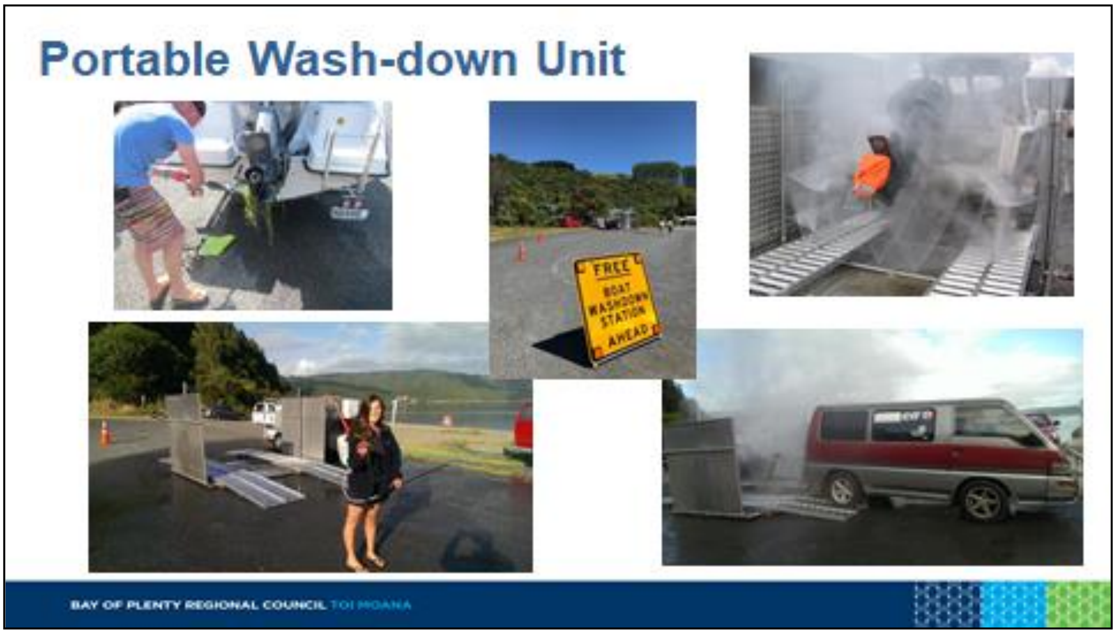
An important part of the programme is summer students. For 13 years we have employed two summer students who do a brilliant job. They talk to lake users about the issues, which a lot of lake users do not know. The students hand out giveaways such has prop flags, fish bags and floating key rings for when keys are lost over the side of the boat. The giveaways are designed to be useful to the lake user in some way.

The students collect data enabling us to target different areas and events over the summer with our messaging. This slide has two graphs, the top one relates to a question that the students asked the lake users over the summer period "*was the vessel checked or cleaned before launching their boat*". The blue line on the graph is 'Yes' and the data over the years is reasonably positive showing that we are going in the right direction. The red line is 'No' and going down which shows our communications programme is working well. The students produce a council published report at the end of the summer.

A big issue here in Rotorua is that there are large numbers of lake users travelling between lakes which are the main vector for lakeweed transportation. We have weeds in some lakes that are not in others and they can be situated in close proximity to each other.

We have a portable wash-down unit managed by a contractor. It is the only one in New Zealand made by the same company that built the wash-down at Sulphur Point boat ramp in Tauranga. It is set up at events, can be put anywhere and is a good education tool. When parked up it is a big piece of machinery and very noticeable. People ask questions, relating to lake weed management, and while carrying on the conversation they get their boat cleaned for free. We have intercepted hornwort at Lake Rotoma through the wash-down unit which sprayed it off.

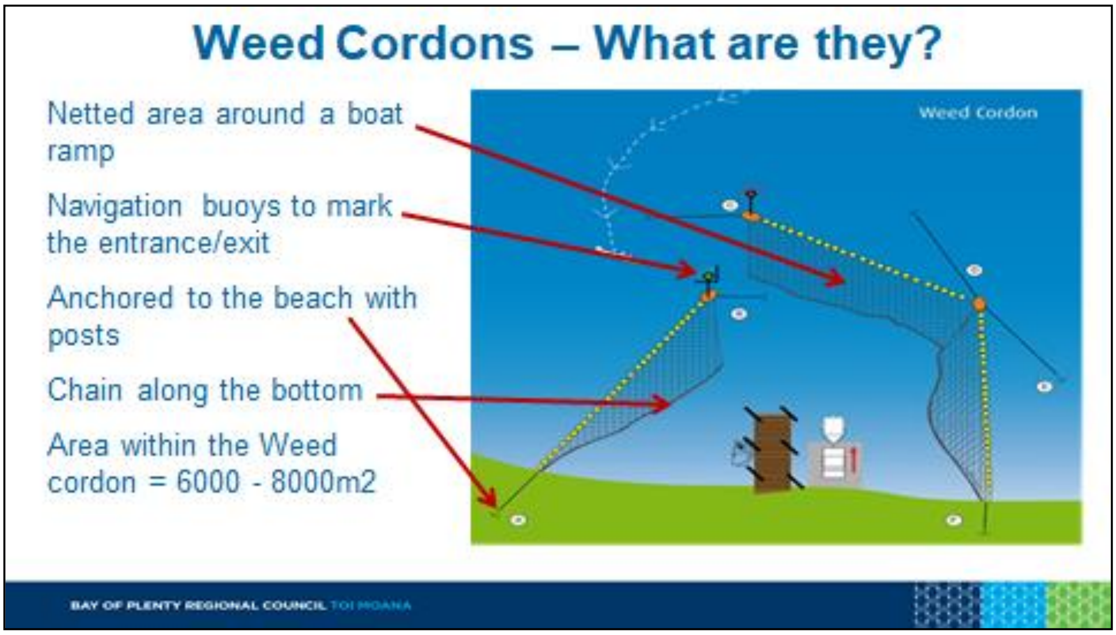
We undertake a lot of surveillance and have our own dive team consisting of 6 people available within Council. We also use contractors that we use as Biosecurity divers within the team. We use underwater scooters for our surveillance these are a brilliant adaption to our team because they cover large areas and allow less fatigue with the diver operating



the scooter. We also do beach searches, spot dives, manta boarding. We do surveillance in 8 lakes, Rotomā, Ōkataina, Rotokakahi, Tikitapu, Ōkāreka, Ōkaro, Rerewhakaaitu and Rotomahana, these lakes are chosen because they are our high value lakes with the least amount of pest weeds. Within those lakes we determine high risks sites that are the vector points such as slip ways or boat ramps. However now we are at the point of checking everywhere looking for aquatic pest plants and fish such as catfish and koi carp.

We've been doing surveillance for about 15 years. In a recent NIWA review of our surveillance programme they stated that overall we were using best practice. Our surveillance programmes have had consistent personnel involved, getting better and better. This slide is the Lake Ōkataina surveillance overview which shows we check everywhere apart from spots where we know there will be plants growing, such as sheer drop rock walls or depths down to 40 metres. When we find a pest plant we stop and put a surface buoy, which is attached to the diver, so we can mark exactly where each plant is for control purposes.

Weed cordons are a weed management tool set up in 9 different locations in 7 lakes around the Rotorua lakes and are a netted buoyed area acting like a fenced off containment zone around a boat ramp or bay. Navigation buoys are at the entrance so boaties know where to go in and out. They have posts on the shore to hold the cordon in place, chain along the bottom. The average cost of a weed cordon is about $40,000 to install. They have been working very well; research showed they were around 80% to 85% effective for keeping fragments in. Theoretically when somebody drives in with a trailer that has not seen all our signs or talked to our students or knows what they need to do, if all the fragments come off their trailer and boat, they will be encapsulated within that fenced off cordon area.



Weed cordons have been installed at Lakes Rotoehu, Rotoiti, Ōkataina (2), Rotomā (2), Otamangakau, Rerewhakaaitu and Ōkāreka.

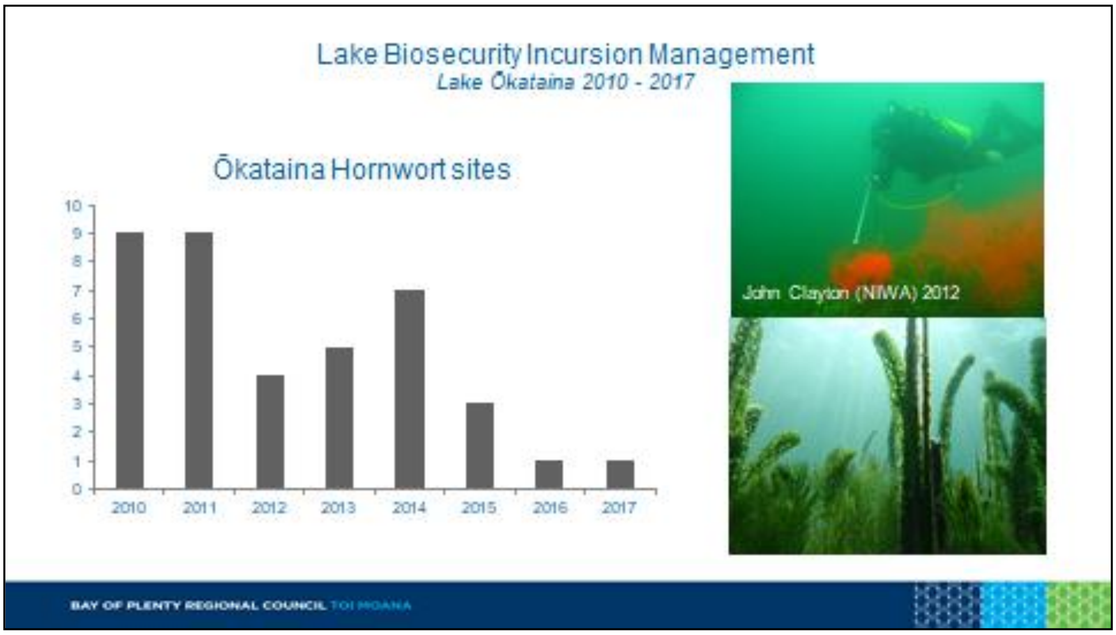
What do we do when we have a new incursion? We develop an incursion response plan which will include:

- Eradication plan
- Ongoing surveillance
- Containment using a weed cordon
- Prevention of human assisted spread
  (Sec100 and Sec130 Biosecurity Act)
- Increased public awareness

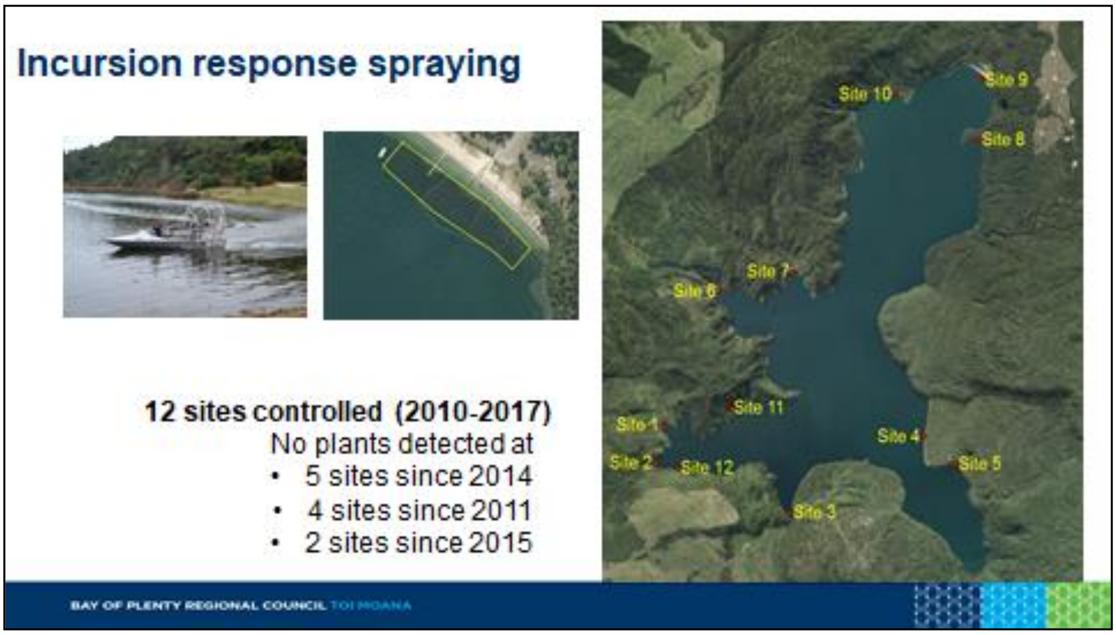
In 2010 at Lake Ōkataina an incursion of hornwort was detected by Council and NIWA staff. We initiated an incursion management plan which had three options, do nothing, which was not really an option, containment or eradication. We had the incursion management plan signed off by Council. It was decided that we would set our target for eradication. We undertook a delimiting survey in early 2010 as a result we detected 9 sites with hornwort present. These sites were sprayed with excellent results seen. In August 2010 we installed a containment weed cordon at the southern end of the lake where the main infestation was found, thus blocking the whole area off. We also installed a weed cordon in 2011 at the boat ramp to protect that area.

There has been progress over the last 8 years; we did surveillance, found sites, more surveillance, found more sites, surveillance again, each time finding less and less, and now in 2017 there is one site left.

We have had some highlights. In 2012 John Clayton did an underwater gun and hose spray using the aquatic herbicide Diquat. At this site plants were detected in 8 to 10 metres. We also used an Airboat to control these plants. We went there in March this year and spent a good day delimiting this site. We found no plants as a result of the spraying. This is a great result.



The last 7 years have been encouraging. Over the entire programme of surveillance work we have found 12 sites. We have not detected any plants in 5 of these sites since 2014, four more of the sites since 2011 and two of the sites since 2012. The incursion response spray programme is funded by LINZ and Bay of Plenty Regional Council.



In the future, we will use summer students again, they do a great job, and people know they come around and talk and have free stuff so everybody loves them. We are buying an underwater ROV, which will be here next week. It will open up another area for more surveillance at different depths. It will be useful for other things too, a water monitoring adaption and a sediment adapter to take samples. More summer surveillance this year and we will continue to work with our partners, a valuable piece of the programme.

Thank you.

DEOXYGENATION IMPACTS OF LAKE WEED

Dr Max Gibbs and Clive Howard-Williams
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Dr Max Gibbs is a water quality scientist who has worked for NIWA and predecessors for 52 years. He has spent the last 44 years studying lakes and estuaries around New Zealand, and has been a member of the Bay of Plenty Regional Council Water Quality Technical Advisory Group (TAG) since it was formed in the 1980s. Max was instrumental in identifying the hydraulic coupling between Lakes Rotorua and Rotoiti in 1986, which lead to the installation of the Ohau Channel diversion wall, completed in 2008, to improve the water quality in Lake Rotoiti. Today he is talking on the deoxygenation impacts of lakeweed in Lake Rotoiti and whether decomposition of the lakeweed is slowing the recovery of the lake.

TRANSCRIPT

Kia ora and good afternoon. This talk came about from a series of questions that were asked at a TAG meeting in May 2016. These included:

1) What are the consequences of invasive weed growth?
2) What is the succession of species invasion and will it get worse?
3) What are the risks associated with these invasive weeds spreading?
4) What are native aquatic species of the littoral zone and their values?
5) What are the impacts of the associated water clarity improvements on weed?
6) What are possible control measures/options/experience/typical costs and challenges?
7) What are the current BOPRC monitoring programmes?
   (i) Lakes SPI; what does this mean? Incursion monitoring?
   (ii) How do we compare with other regions? Can we improve?
8) What are the agencies involved and their current actions?

I will really only address the first two questions.

What are the consequences of invasive weed growth? A potential consequence is the possibility that these weeds might be altering the geochemical and oxygen dynamics in Lake Rotoiti.

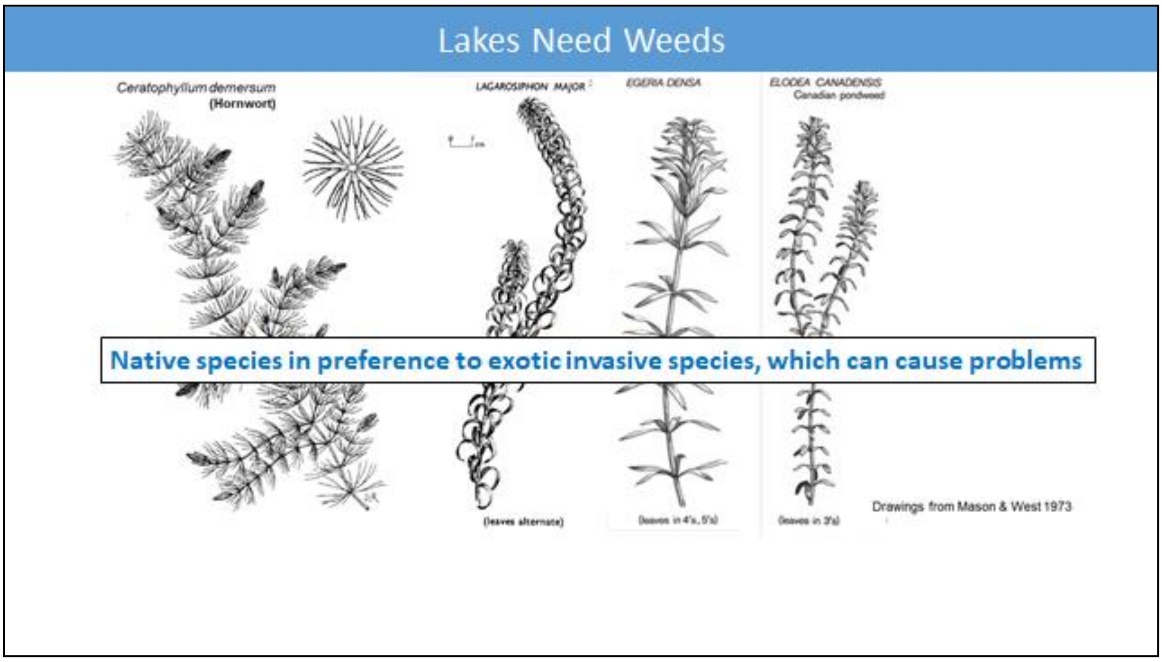
The LakesWater Quality Society asked the question, ‘Can the slow recovery of the anoxic hypolimnion be attributed to decay of the weedbeds that have established around the periphery of the lake?’

A good question and I hope that I can answer it. Lakes need weeds and Tracey Burton has shown you the sort of aquatic weeds that we have in the lake. We require native species in preference to exotic invasive species because they cause problems.

The littoral zone, the band of vegetation around the edge of the lake is very important. What is it that aquatic weeds are doing that native species are not? It can be summarised as:

1) Nuisance value to recreation, (boating, swimming, access, aesthetics)
2) Altering geochemical and oxygen dynamics (unquantified)
3) Effects on mahinga kai (unquantified)
4) Reduced native biodiversity
5) A range of other things too

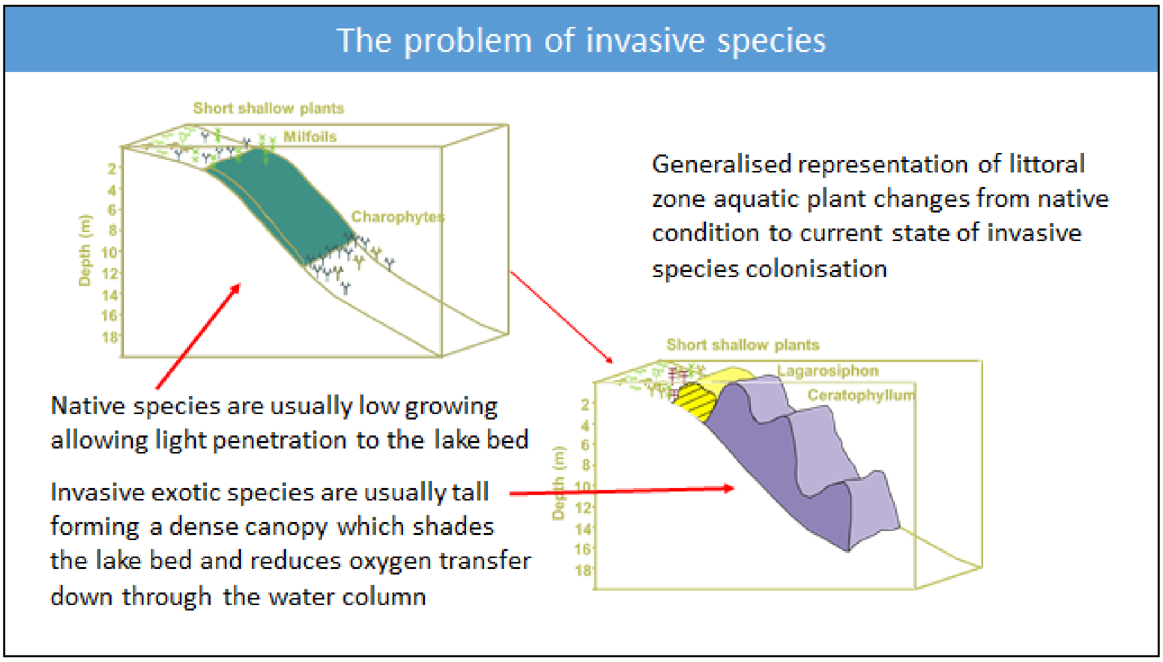
What is the succession of species invasion and will it get worse? Lake Rotoiti would always have had a valuable littoral zone of aquatic plants and in places such as Okawa Bay there would have been high density and biomass of these, probably more than wanted. In general the biomass of aquatic plants in Lake Rotoiti has increased as a result



of a succession of invading species such as elodea, lagarosiphon, ceratophyllum (hornwort) and egeria. The littoral zone plays a very important role in the lake ecosystem health.

Even in large deep lakes such as Lake Rotoiti where the littoral zone itself may be less than 10% of the lake area it plays a very important role. High environmental variability in the littoral zone means high biodiversity and complex ecosystem structures which is what we want.

We want a range of habitat, native and exotic species, which can support the other biota within the lake. In the littoral zone they form the interface between the land and lake with nutrient sediment attenuation. They provide food for herbivores and bottom feeding scavengers and filter-feeding animals. They form a substrate for other plants (epiphytes) and animals. They form a breeding substrate and shelter for vertebrates and fish. They provide a rich feeding ground for fish-eating and plant-eating birds and they have the capacity to settle out fine settlement from the water column and sediment groom and maintain the clarity of the lake. They also impact on lake oxygen and the biogeochemical cycles.



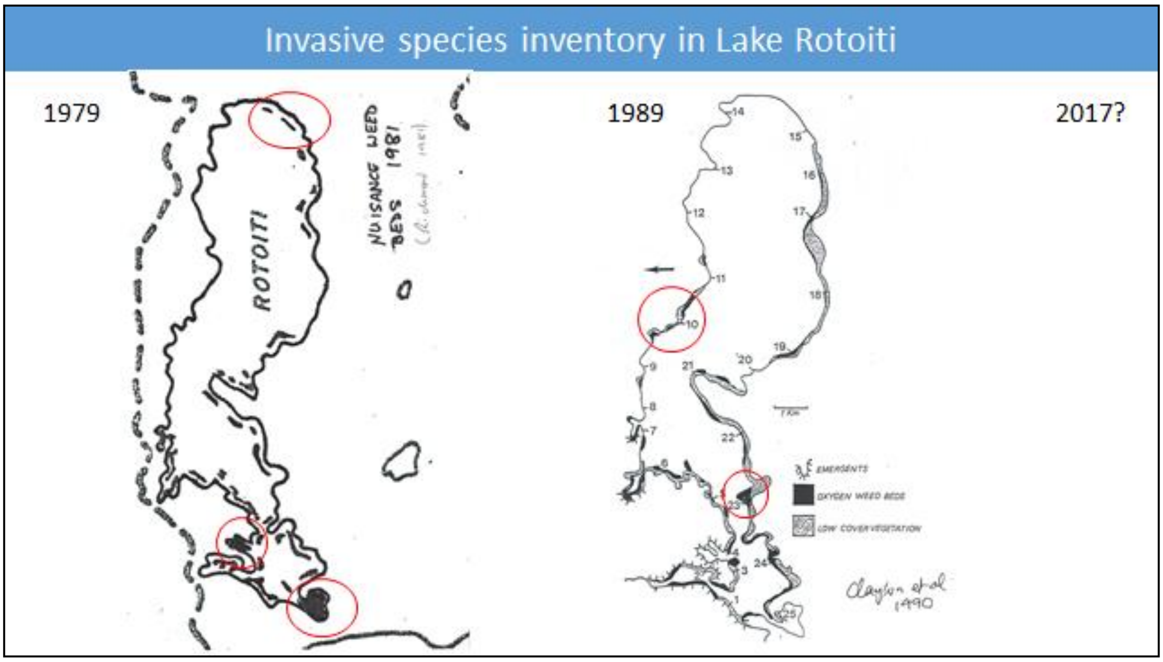
This is a generalisation for the littoral zone aquatic plant changes, from a native condition to an invasive condition. The native species are usually low growing allowing light to penetrate. Invasive exotic species are usually tall and form dense canopies that shade out the lake bed and reduce oxygen transfer down through the water column.

Comparisons between native and exotic invasive species show that:-

- Native weedbeds are generally low growing and may extend further down the littoral profile than invasive species, to deeper water, depending on water clarity
- Native weedbeds have a lower biomass than weedbeds of exotic invasive species which grow up to the surface and form dense canopies that shade out the native species

- The density of the exotic weedbeds reduces water movement through the beds and reduces oxygen transfer into these weedbeds allowing hypoxic zones to develop
- These hypoxic zones coupled with their higher biomass, means that when exotic weedbeds collapse they have the potential to affect the oxygen concentration in the lake as that biomass decomposes

Surveys of Lake Rotoiti in 1979 show various areas where they first found the invasive oxygen weed beds. The circles in 1979 indicate areas of oxygen weed and the elodea in Okawa Bay features prominently. The survey in 1989 shows other areas where oxygen weed was found and in 2017 there is not much change. What is noticeable is that the weed beds extend in a very thin border around the edge of the lake.

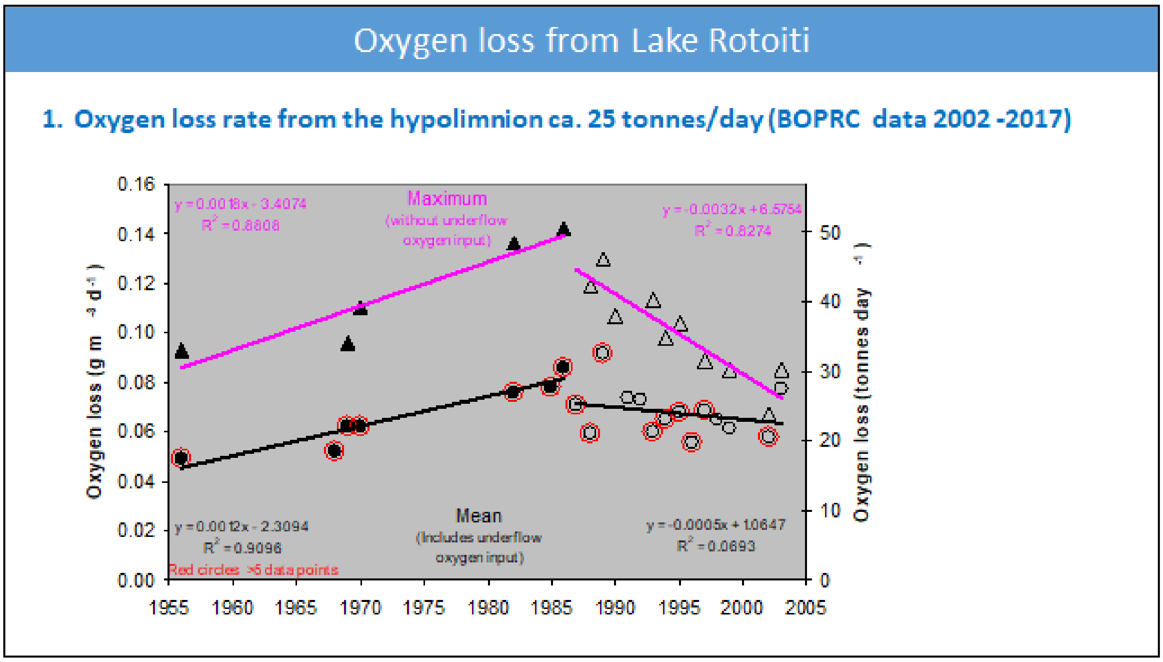


There was little change in the distribution of invasive weeds between the 1970's and 1980's suggesting that their habitat maximum had been reached. Exotic weeds such as lagarosiphon and egeria are not able to colonise water deeper than about 6 metres.

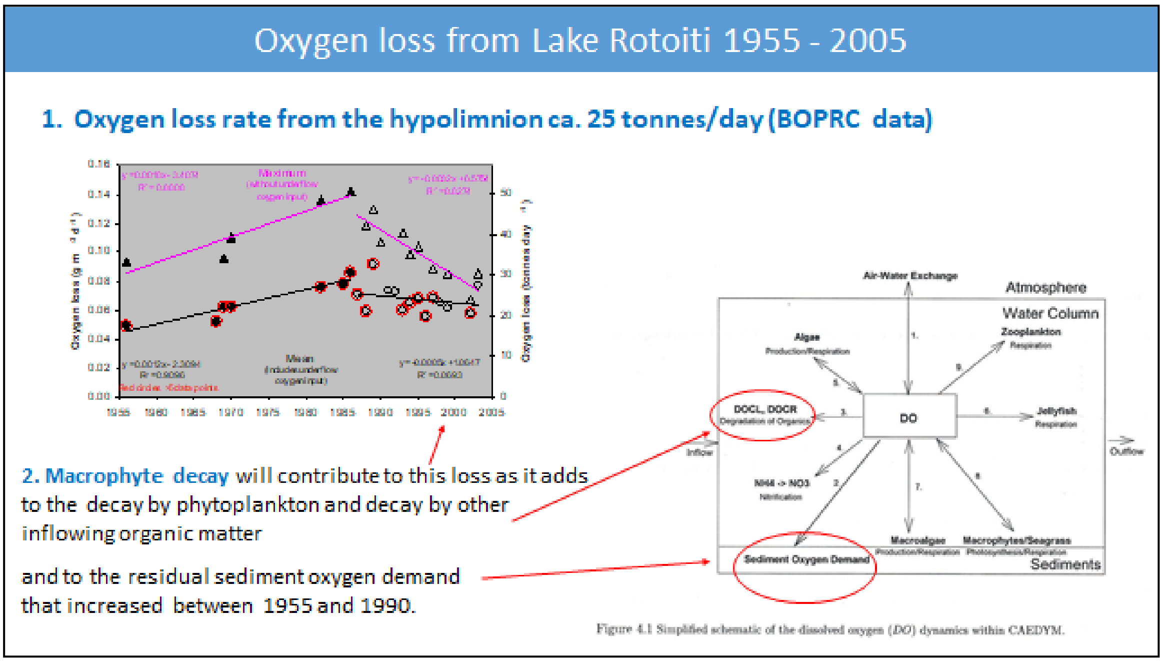
Elodea can grow down to 11 metres. Clive Howard-Williams put forward a hypothesis that there is very little additional space for new weedbed development in Rotoiti, but there is a caveat to that. As the lake gets clearer light penetrates further and weeds can move further down, but there is still a limit to how far they can go.

So changes in the weed beds will be related to changing proportions between lagarosiphon, elodea, egeria and ceratophyllum, rather than changes in the total area around the lake. This means that the plant biomass is likely to be relatively static between years and that is important for doing the calculation that we want to do.

Going back to the LakesWater Quality Society question - 'Can the slow recovery of the anoxic hypolimnion be attributed to decay of the weedbeds that have established around the periphery of the lake?' The next slide calculates what is happening with the oxygen loss from Lake Rotoiti. From work I have done since 1980 it would suggest that we have a loss of oxygen of 25 tonnes per day and if we look at the Bay of Plenty Regional Council data from 2002 to 2017 that value has not changed.



The Dyresm/Caedym model below on the bottom right corner includes a component for decomposition degradation of organic material. The macrophyte decay, or the weed decay, will contribute to this loss as it adds to the decay by phytoplankton and other inflowing organic matter and to the residual sediment oxygen demand that increased between 1955 and 1990. The steams carry organic matter down the sides, coming into the bottom of the lake, the lake turns over nutrients growing algae which precipitate to the bed of the lake and that consumes oxygen from the hypolimnion**.** The weed beds collapse, they roll down to the bottom of the lake and decompose and consume oxygen.



What is the actual amount? An initial estimate of the contribution of weed decay in Lake Rotoiti oxygen consumption is:-

- Lake area 3435 ha; Dense (exotic?) weed bed area 225 ha (6% of total lake area); Lake weedbed biomass 2250 tonnes (@ 1kg (dry mass)/m^2) or 10 tonnes/ha)
- Production/Biomass ratio 1.2/1 (*Howard-Williams* 1986 for *Potamogeton pectinatus* *see also Vollenweider 1974*)
- Therefore, annual amount of weed that can be decayed = 2700 tonnes
- Total oxygen consumption over decay period for submerged macrophytes ca. 400mg O_2/g (dry wt) decayed (400 kg O_2/tonne dry wt) (*Bianchini et al. 2016*)
- Total oxygen consumption for the whole lake weedbeds annual production is

  2250 t x 400kg = 900 t O_2 or **2.4 t/day**.

The total oxygen consumption for the whole of the lake weed beds annual production comes down to an equation that says we end up with a bottom story of 2.4 tonnes of oxygen per day. That is what the weed beds contribute to the deoxygenation rate in the bottom of the lake.

In answer to the LakesWater Quality Society question, 'Can the slow recovery of anoxic hypolimnion be attributed to decay of weed beds that have established around the periphery of the lake?' The short answer is, 'No,' which should be reassuring because we do not want that to be a major component, otherwise we are sunk.

Assuming the total biomass of the weedbeds end up in the hypolimnion, which is not likely, oxygen consumption due to decay processes, may contribute about 10% to the total oxygen loss from the lakes' hypolimnion. Based on the course figures that I have been using this is an overestimate and a static calculation.

Oxygen consumption is a dynamic process and depends on climate variabilities. In warm years there is more consumption than cold years. This calculation would be better modelled using the Dyresm/Caedym model of David Hamilton's team.

In conclusion, I would like to acknowledge that the material in this talk was drawn from a number of sources, research on Lake Rotoiti in the 1950s (Hilary Jolly), mid-1970s (Geoff Fish), my own research from 1980 on, the NIWA aquatic plant team surveys, and research and monitoring by colleagues from BOPRC and University of Waikato

I would like to thank the Bay of Plenty Regional Council for providing the oxygen profile time-series data and co-funding studies with NIWA that have enabled this lake research through the Ministry of Business, Innovation and Employment research programme. I would like to thank MBI for their contract funding as well, thank you.

THE RESTORATION OF NATIVE AQUATIC PLANTS

Deborah Hofstra
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Dr Hofstra is a scientist in the Freshwater and Estuaries Centre of NIWA. Deborah leads government funded and commercial projects that focus on research solutions for aquatic plant management including the rehabilitation of native plants and the management of invasive weed species. Collaboration with international colleagues has included projects on aquatic weed control, macrophyte growth and physiology under different environmental conditions, and most recently a review of management for invasive aquatic plants.

TRANSCRIPT

I am very pleased to be here today because I have the privilege of speaking about a good news story, that being the restoration of native aquatic plants instead of weeds. I will start by looking at what native aquatic plants look like, touch on species and communities, and talk about their benefits. You have heard some of this already from Max and Tracey, but we are now going to look at actions for restoration and then move on to outcome examples.

To start with I would like to share some statistics to show the current state of freshwater in New Zealand. We have 88 native aquatic plant taxa, of which 40% are endemic – the remainder are in Australia or elsewhere - and 36% are at risk of, or threatened with extinction, including 7 nationally critical taxa. The primary causes really come down to habitat change and pest species which have altered native freshwater ecosystems, contributing to their decline.

When we talk about native plant communities there are 5 different zones or communities within the freshwater plants that can be categorised as:

- Emergent plants
- Short growing turf plants
- Tall submerged plants
- Charophytes
- Deep water bryophytes

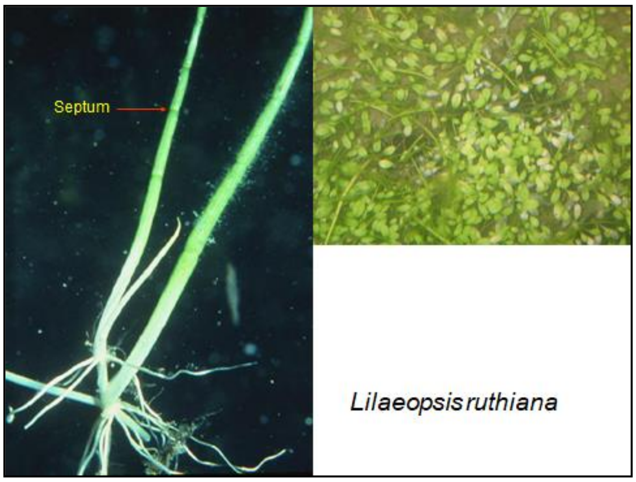
The deep water bryophytes are not relevant to Rotorua. Emergent plants are the ones most familiar because they are seen, as the name suggests, emerging out of the water. Slide 1 shows tall erect plants like the *Typha orientalis* (raupo, or bulrush) in the top left, sprawling emergents or floating leaf plants at the bottom of the slide.

The short growing turf plants are where the biodiversity lies. They occupy the first couple of metres within the water depth, with the exception of *Isoetes* that can grow a little bit deeper. We will spend more time focussing on that plant later. Most of these turf plants grow on moderately exposed shorelines. A few pollinate underwater or are self-pollinating and many flower when they are exposed above the water. Typically, they are referred to as the 'knife', 'fork' and 'spoon' plants because of the way the leaves look.

Short growing turf plants come from a range of different families. This slide helps those unfamiliar with freshwater plants, to recognise some families that are familiar from the terrestrial world, such as buttercups, ferns and daisies.

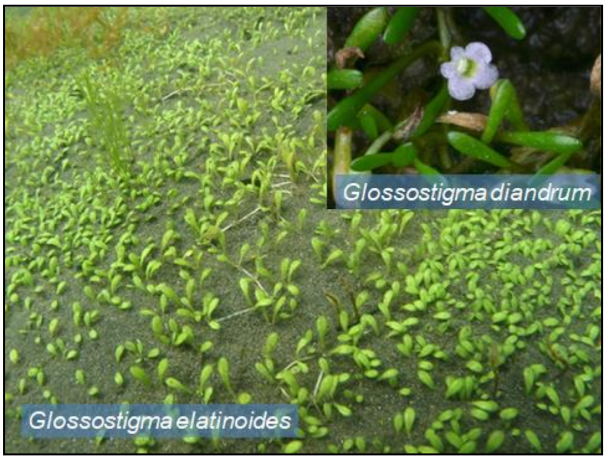
Asteraceae (daisies)	Juncaceae (rushes)
Apiaceae (carrots)	Juncaginaceae
Brassicaceae (cabbages)	Lobeliaceae
Centrolepidaceae	Marsileaceae (ferns)
Crassulaceae	Phrymaceae
Cyperaceae (sedges)	Ranunculaceae (buttercups)
Elatinaceae	Ruppiaceae
Haloragaceae	Tetrachondraceae
Hydatellaceae	Zannichelliaceae
Isoetaceae	

Slide 2 is an example of an underwater plant, thought of as a 'knife' species because it has a simple blade. *Lilaeopsis ruthiana* is easily recognised by the septum (indicated on the photo). You can see it grows with other native aquatic plants in a low growing turf community.

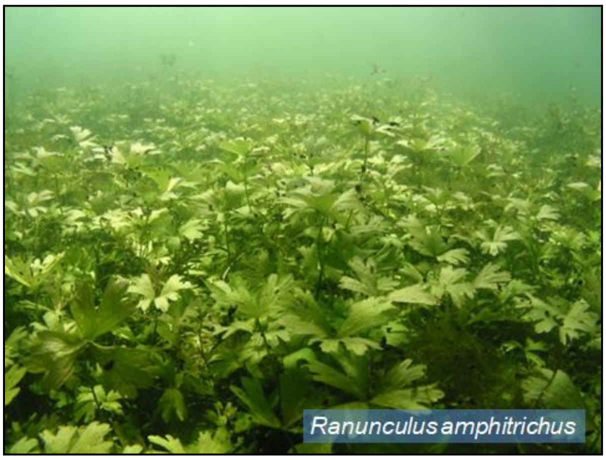


Slide 3 *Limosella lineata* also falls into the 'knife' category. This picture visually highlights the macro-invertebrates, that can be abundant on submerged aquatic plants. Those little brown dots are all snails.

Slide 4 shows two different species of *Glossostigma*, a 'spoon' in terms of the leaf shape, and it shows what that form or growth habit looks like. It is dense enough to see a few little white lines along the sediment, stolons, where different plants join up together and helps to bind the sediment in place. The lake substrate can still be seen, - quite a contrast to Tracey Burton's picture of big black dense invasive weed species. This is, by comparison a very open habitat.



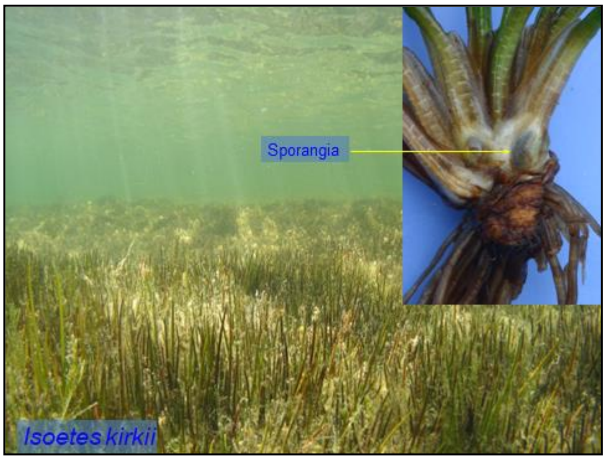
Slide 5 is another example of a low growing turf species, similar to the previous one but a different species altogether. In contrast the *Ranunculus* (in the next slide 12) may be more familiar in appearance to some *Ranunculus* species in the terrestrial world.



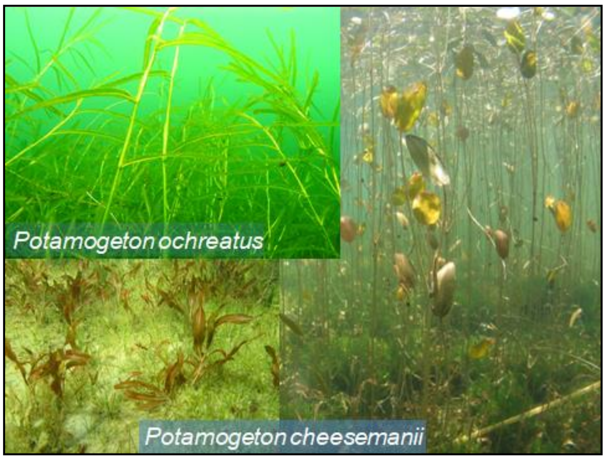
Slide 6 - Note again all those snails; they are just little black dots, but the photo illustrates that habitat is provided for macro-invertebrates**.**

Slide 7 – *Pilularia* is a plant in the fern group – as illustrated in this photo by the koru form of the new 'leaf'. In the top left photo, the plants look a lot like a lawn of grass in the shallow water zone.

Slide 8 - The last plant amongst these examples is *Isoetes*, which grows a little deeper than the others. It can grow down to about 6 metres and forms quite dense swords which you can see in the picture.

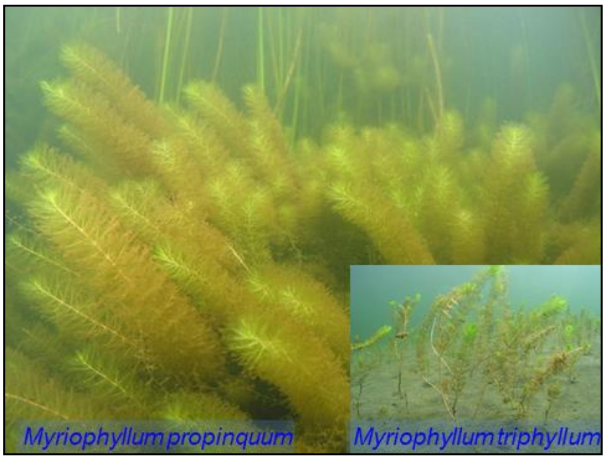


The next group are tall submerged plants within which there are 13 different species, but we will focus primarily on *Potamogeton, Myriophyllum* and *Ruppia*. These are the ones most often displaced from water depths of one to five metres when invasive weed species establish in a lake.



Classic examples in Slide 9 are *Potamogeton ochreatus* on the left hand side and *Potamogeton cheesemanii,* at the bottom, which can have different forms. One is submerged and short with a bronzy leaf and then as it approaches the water surface it has a more oval shaped, slightly tougher leaf.

Slide 10 Two species of *Myriophyllum* are of interest, one is *M. propinquum* and the other is *M. triphyllum*. They have a feathery growth form by contrast to the others we have seen.



You will now recognise that there is wide diversity of form within native aquatic plants which is key to keep in mind.

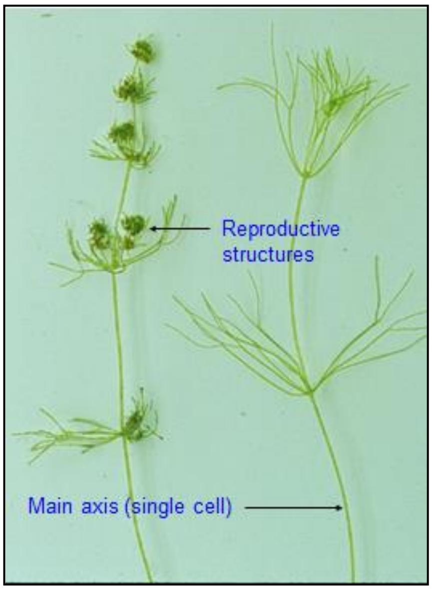
Slide 11 is a bed of *Ruppia*, quite different again in form, but occupying the same water depths as the pondweeds and the milfoils.

Slide 12 is *Utricularia australis,* of historical interest for the region. It was in Rotomahana before the Tarawera eruption, but has not been found since, and is nationally critically endangered.

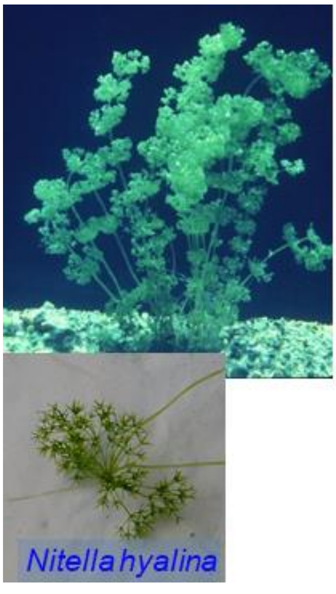
Charophytes are the final group of plants that I wanted to introduce to you, and the ones that form beautiful meadows. They are a type of macro-algae and close relatives of land plants. They are relevant for the Rotorua lakes. There are 5 species of Chara and 3 occur in the Rotorua Lakes. There are 12 species of Nitella and 7 are here in the Rotorua lakes. They develop best in clear lakes forming deep water meadows - 24 metres in Lake Ōkataina and 35 metres in Lake Wakatipu in the South Island.

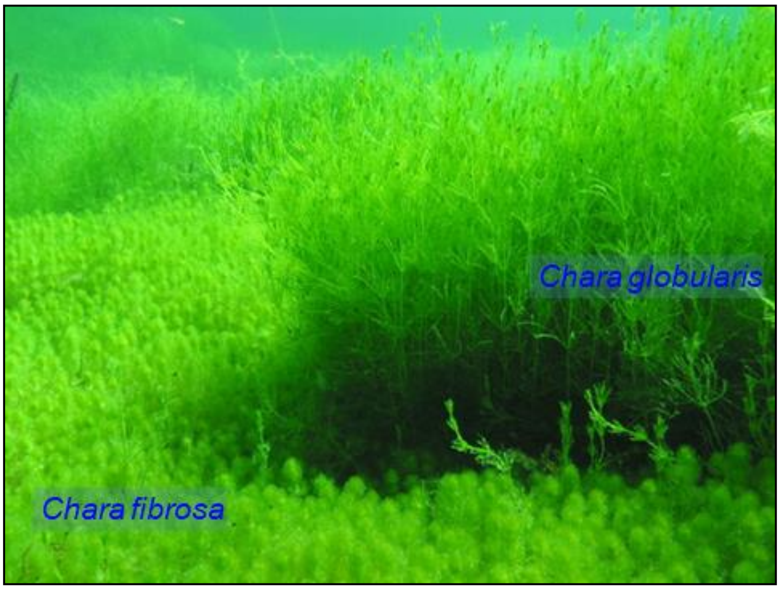
This picture is of oospores. When we talk about native plants we often talk about seeds and seed bank. A major difference between most submerged invasive weed species and native plants is that the latter have a seed bank, the invasive weeds thankfully do not. However rather than seed, charophytes have oospores, functionally the same but different in the terminology that is used.

Slide 13 *Nitella opaca* is important because it is only found in Rotorua and Central North Island lakes.



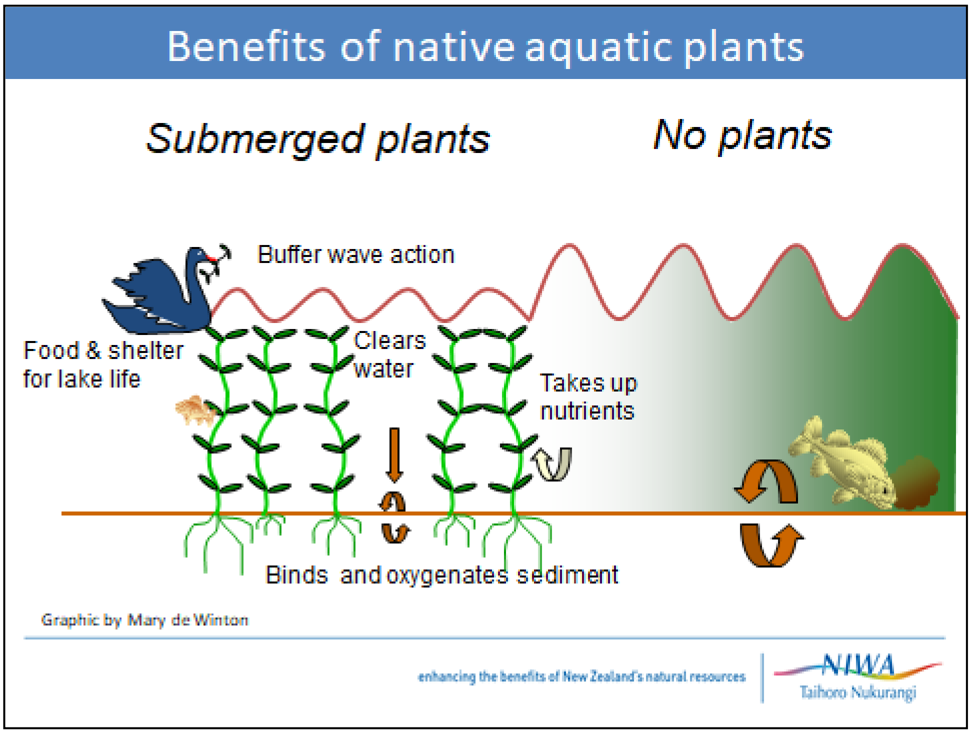
Slide 14 also shows examples of *Nitella*, note again the variety of form between these species, one that is more open and the other tighter clustering branches.



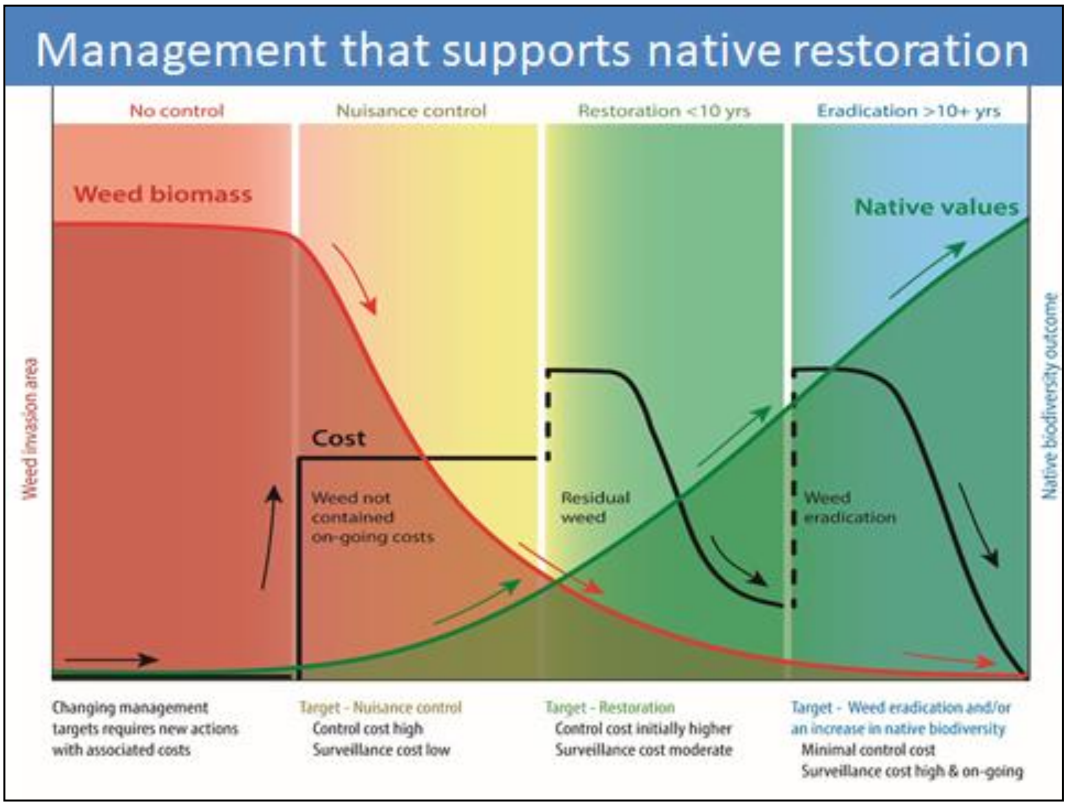


Similarly, these Chara, (Slide 15) seen within a lake, show the diversity and height between different species, again providing variety in habitat.

What are the benefits of native aquatic plants, why should we care whether or not they are in our lakes, and are they weeds? This diagram (Slide 16) highlights the contrast between an aquatic system with macrophytes in the littoral zone and one without. It comes down to the key functions the plants have. One of those functions is the binding of sediments which is important for water clarity. Plants help bind the sediments in the wave wash zone in the shallows which reduces turbidity and minimises the resuspension of sediments. The plants naturally buffer the wave action which also means helping to keep the water clear. They also provide an important habitat food source for water fowl and macro invertebrates and a refuge for fish as well.



There is a well-recognised relationship between structural complexity of the habitats that we have in our freshwater systems and the abundance of different taxa. Structural complexity relates to the diversity of the plants and to the diversity in their form. It relates to the fact that there are still exposed rocks or stones and a lake substrate in and around the base of those plants. That diversity of habitat and structure is what underpins the diversity in the macroinvertebrates, which is really important when it comes to food webs and lake health.

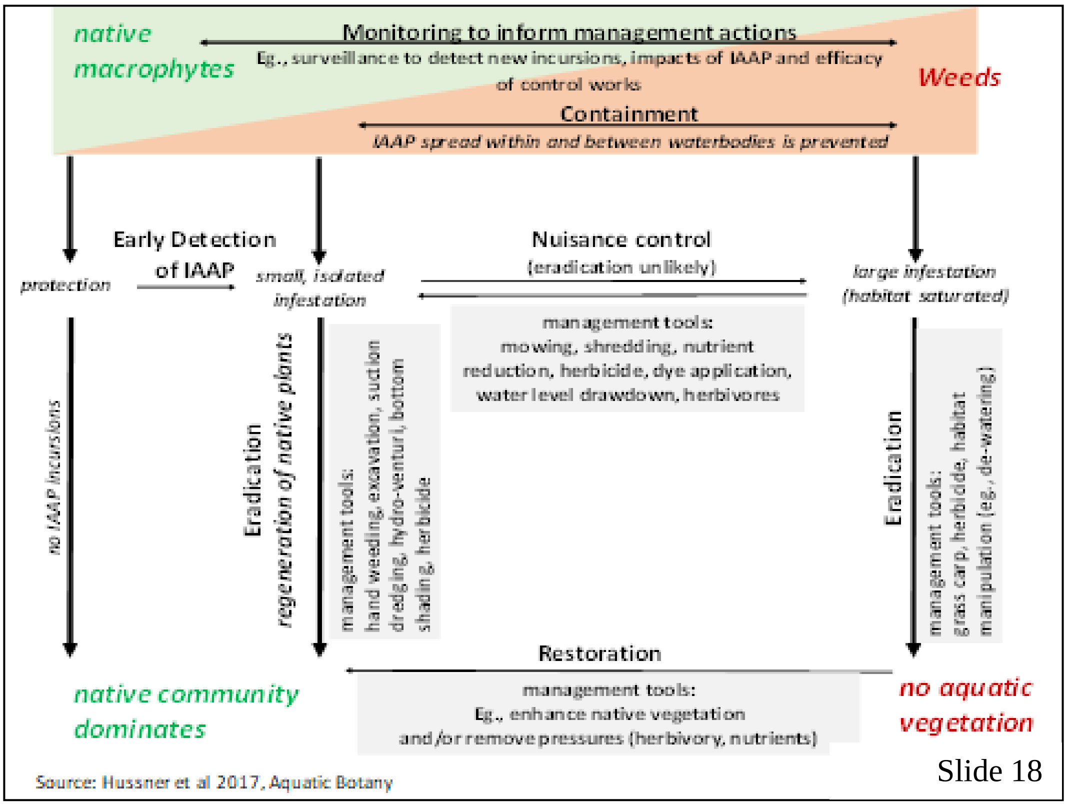


Why should we care whether plants are in our lakes and what they do? Slide 17 illustrates the concept that a high amount of weed biomass (on the left) results in very low native values. The contrast is also true, (the right) that management actions to reduce weed biomass provides the opportunity to improve the condition and diversity for all native plants and fauna. It is an simplified diagram for what we need to support native restoration and the kind of management undertaken.

Slide 18 is the same as the previous slide but more complicated, because it includes the strategic thinking required for native plant restoration and recognises that invasive species management is an essential part of native biodiversity restoration. The colored banner at the top represents the state of the ecosystem and highlights that when you have high native plant biodiversity you do not have weeds. On the right (of the diagram) high weed biomass means the natives are not doing so well.

If you cast your eyes to the bottom of that diagram, on one corner the native community dominates and the other there is no aquatic vegetation. The good news for the Rotorua region is that its lakes are primarily operating on the left. In other words the monitoring and surveillance work that Bay of Plenty Regional Council is doing ensures that when it comes to restoration there are still native plants to restore from, as opposed to a degraded

Waikato lake with no native plants, where more intensive efforts will be required for restoration. The arrow at the bottom, underneath 'Restoration' indicates some different actions for native plant restoration, but it is essential to have something to work with.

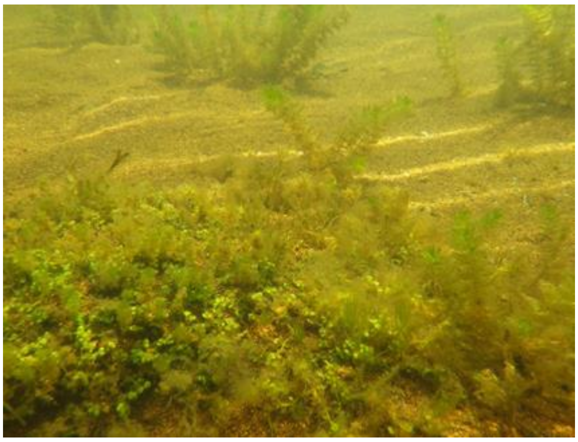


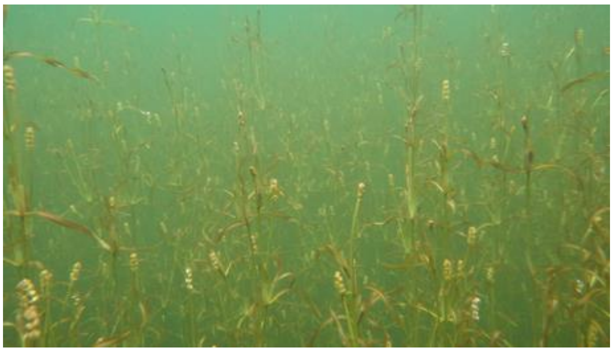
We need a strategic approach, and to recognise that invasive species management is an essential part of native biodiversity restoration. You cannot restore native plants if you have done nothing about the invasive weed species. Not only invasive weeds, but pest fish are a big problem too. It is important to act early because prevention is much easier than restoration. Surveillance activities are important in informing the management actions that can be undertaken. Restoring native plant communities is then about matching the tools and restoration goals – it is about recognising and working with the unique characteristics of the native species present, and an appropriate approach to weed removal. Examples include selectivity and benthic barriers.

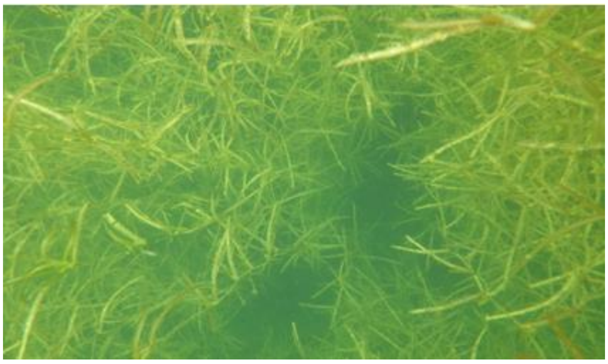
Slide 19) Lake Okareka is the first example. It was in a highly ecological condition. Hornwort was found there in April 2012.

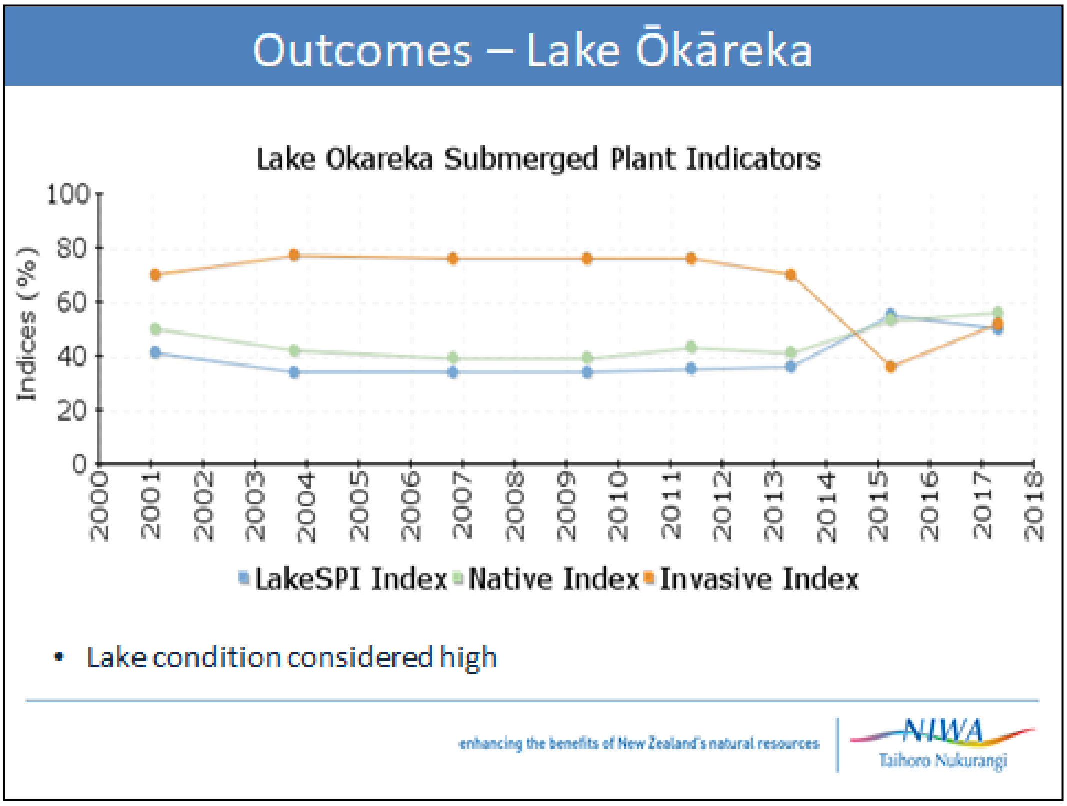
(Slide 20) Surveys were undertaken in 2013 by the Bay of Plenty Regional Council who located the areas of hornwort and a treatment programme was initiated. This was carried out by LINZ with Boffa in 2013, and the targeted areas were treated with diquat herbicide. There are no signs of hornwort in that lake now as a consequence of that programme.

These pictures show native plants flourishing and some are starting to flower. Even if nothing has been done to deal with the invasive weed, flowering is good as it indicates the plants will soon be setting seeds and replenishing the seed bank once more.





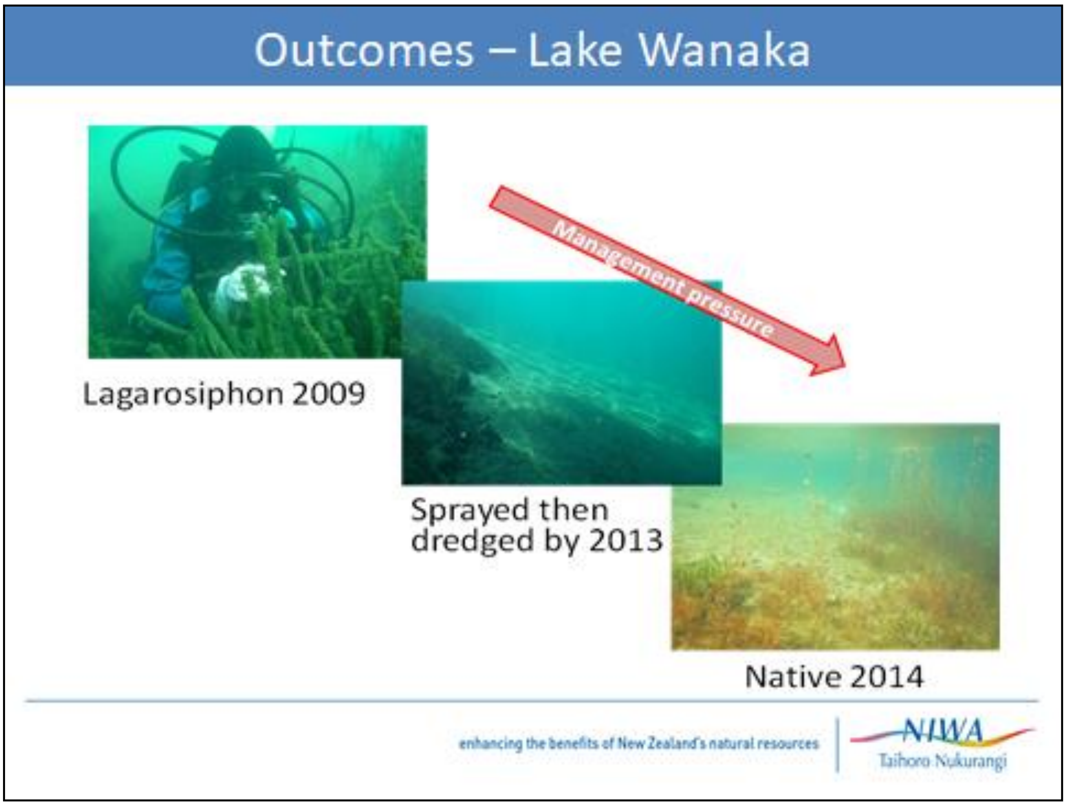




Slide 21 is a typical LakeSPI graph looking at ecological indicators in the lake and how they track over time. There are invasive species still in Okareka, lagrosiphon and egeria, but the dates show that when the hornwort work was done the invasive species index in the lake declined and the native plants improved. That is a good outcome for native plant restoration.

Lake Ōkataina has a similar story. (Slide 22) The weed beds were sprayed with diquat and in the bottom pictures there is recovery of native plants post spray.

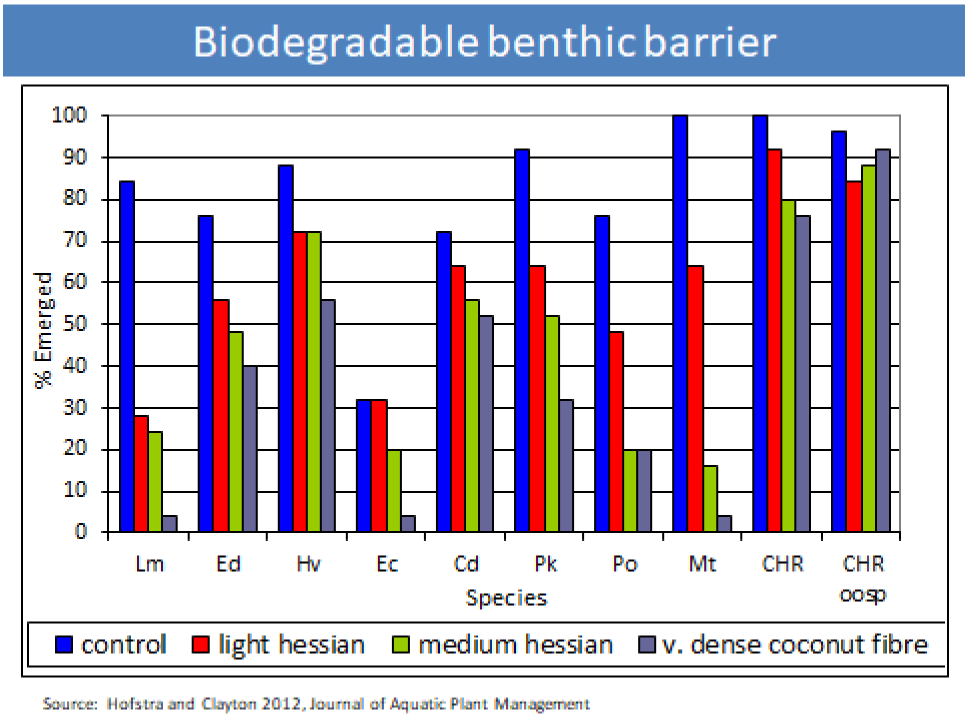
Slide 23 is the third example in Lake Wanaka, a different part of the country but similar successful outcomes. This is work that LINZ and Boffa are doing on the lagrosiphon programme over a relatively short timeframe. Lagrosiphon weed beds were dense and treated in 2009. By 2014 there was native plant recovery within those same areas.



Slide 24. The last example focusses on *Isoetes* which has been declining in the Rotorua region. We know that plants occur in different lakes throughout the country, and there are some quite distinct tetraploid plants in the Central North Island. Recently, in the South Island, we have seen that *Isoetes* also grows through hessian which can be used as a thick barrier to smother weed species.

This idea originally came from a colleague, Joe Caffrey, who found it helped with native charophytes recovery. (Slide 25) We then looked at different products we could potentially use, and also the density of those products.

Slide 26 shows the results. The right of the graph shows our native charophytes were responding positively, for example the blue lines were quite similar to the other bars. In other words the emergence or response of our native charophytes through the hessian benthic barrier was comparable with no barrier being present (the control). This provided an opportunity for a different way to deal with invasive species, in particular lagarosiphon on the far left of the graph.



Mary de Winton took this photo (Slide 27) recently in the South Island, of the work that LINZ and Boffa have undertaken. The hessian went down a couple of months ago, and the little green blades are *Isoetes* growing through it. This could be another tool used to deal with invasive weed species that supports native plant recovery.

In conclusion, restoration and enhancement of native biodiversity is possible. Preventing water quality and clarity deterioration is really important. Biosecurity threats and incursions need to be addressed. There can also be gains for native biodiversity from biosecurity actions. The strategic approach to freshwater biosecurity and biodiversity is very important to maximise all those beneficial outcomes across the board.

I would like to acknowledge other contributors to this presentation. There are a lot of photos by members of the Aquatic Plants Group at NIWA and conversations with colleagues that debate science from which new ideas are drawn. As I mentioned, the biodegradable benthic barrier idea came from Dr Joe Caffrey in Ireland and I have also included information from the LINZ and Boffa work in the South Island.

Thank you.

QUESTIONS

Cr Tipene Marr, Bay of Plenty Regional Council: A question for you Deborah, are you taking seeds from the bottom of the lakes in case it does end up like Waikato?

Deborah Hofstra: No we are not. From work that Mary de Winton and John Clayton have done in the past, we know that native seed banks will decline under those invasive weed species. The treatment of invasive weeds that temporarily reduces that weed biomass, or gets rid of it, even for a couple of seasons, still provides the opportunity for native plants to replenish their seed banks. As long as that is happening there is no need for seedbank sampling. I think that keeping everything in situ with less disturbance is the better way forward.

Cr Tipene Marr: One more thing what is the Maori name for those things? It is great having a scientific name, but there were a few basic weeds that it would be nice to know the Maori name.

Deborah Hofstra: Thank you, yes I will take that on board and change that for the next time, thank you.

Nicki Douglas, Te Arawa Lakes Trust: We know that kākahi, the native mussel, are a good filtration system for water. We also know they cannot survive on sludgy lake beds, could they survive on top of a hessian layer?

Deborah Hofstra:
That is a very good question and something we have thought about as well. There is a desire to look at other ways of dealing with invasive weeds and one of the questions is - What would happen when covering large areas? What kind of macro invertebrates, including kākahi, would survive with that? We have also noticed when dealing with weed beds for other reasons (projects not described in this presentation) that weedbed removal can improve the habitat for kākahi. I agree with you, they do not like mud, they prefer sandy open substrates, the kind you saw under those native plant communities, that is where kākahi will be. Under the dense mounds of invasive weeds we saw earlier in the day (presentation by Tracey Burton) will be dead kākahi. We would love to get together for some further testing of biodegradable benthic barriers and figure out how they would work for kākahi.

Craig Morley, Te Ohomai: Apart from people, what other vectors may be spreading these invasive aquatic weeds? Birds, for example, or any other non-human ways to spread these weeds?

Deborah Hofstra:
For those major weeds we have talked about like the *Ceratophyllum demersum*, (hornwort), *Lagrosiphon major, Egeria densa*, it is simple, people.

Cr Dave Donaldson, Rotorua Lakes Council: Deborah you talked about lake drawdown being a management tool for the enhancement of native species. I wondered how important fluctuating lake levels are. We have sustained high lake levels this year with many wet weather events, is that a good thing or a bad thing for native plants?

Deborah Hofstra:
Management techniques, whatever they are, be it herbicides, drawdowns, hessian benthic barriers, all need to be assessed on a case by case basis. Lakes are all different

depending on water depth, species compositions, what is going on in each lake, so lakes need to be assessed individually.

Don Atkinson, LWQS: Question for Max, I would like to dig down further into your answer in respect to Lake Rotoiti and the oxygen demands, I would like you to consider the consequences to western arm, west of the pylons. What would your answer be where we have got the large rafts of weed in bays where the weed cover is not of 6%, but probably in excess of 60%. And then consider periods of relatively quiet hot warm conditions of summer when we have not got any mixing from the greater lake. How would that impact your answer for those particular sections of the lake?

Max Gibbs: Different set of conditions, it is not stratified, it is not a hypolimnion, but the weed collapse in these shallow arms, Okawa Bay, Te Weta Bay and so forth will consume all the oxygen, the lake will go anoxic and that will have a major effect locally. You have another situation in Lake Rotoiti which is not common in many of the other lakes in the Rotorua area and that is that you have an internal seiche on the Thermocline in the lake.

The seiche sets up an oscillation of the water column as an internal wave on the thermocline whereby the surface water flows in one direction above the thermocline while the bottom water flows in the opposite direction below the thermocline. This means that there is a very large volume of oxygenated water pushed into the western basin and associated bays on the east-west cycle. This flushes the water from the bays back into the eastern basin. On the west-east cycle, oxygen depleted water from just below the thermocline in the eastern basin flows into the western basin displacing the surface water back into the eastern basin.

With respect to the effect on the oxygen concentrations in the western basin and bays, the seiche will cause a fluctuation between fully oxic (saturated) to about 70% saturated (from memory of my measurements in the 1980s) locally. The oxygen loss from the weed decomposition in the bays off the western basin (including Te Weta and Okawa Bays) is included in my calculation for the whole lake. It will be a greater effect locally, say, up to 15% rather than the average of 10% or less across the whole lake. The seiche effect is very complex in this lake and needs modelling.

Session 4 : WHOLE-OF-LAKE WEED STRATEGIES

SESSION CHAIR - John Gifford, LWQS

STRATEGIES TO MANAGE AQUATIC PLANTS: TOWARDS SHARED UNDERSTANDING

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Mary is a Freshwater Ecologist at NIWA, Hamilton, with more than 30 years of research experience on management of submerged vegetation. During this time Mary has worked on (and in) over 155 New Zealand lakes. Research interests include the biosecurity management of invasive water weeds, the enhancement and restoration of native submerged plants, resource survey, management of aquatic plant data and its application to research questions, and the taxonomy of New Zealand charophytes (freshwater algae akin to seaweeds).

TRANSCRIPT

Tena koutou katoa.
I am the first of three presenters this afternoon who are going to focus on aquatic weed management. I have the title *Strategies to Manage Aquatic Plants - Towards Shared Understanding* and I know what you are all thinking, 'Strategies' is not the kind of buzz word of the century but I am hoping to convey why we need agreed strategies, specifically an articulated strategy for lake weed management.

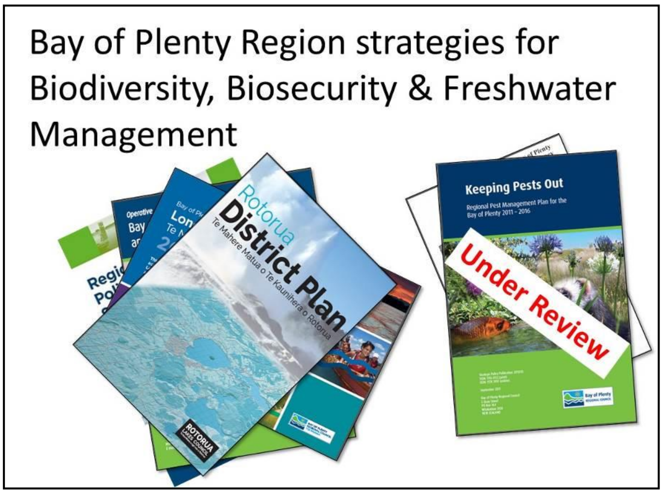
What is a strategy? It is a plan of action designed to achieve a long-term or overall aim. To me it is an important mechanism for communication between different parties towards a shared understanding, and it is essential where there is a shared resource or a 'commons'. I will introduce the strategy landscape for the Rotorua Te Arawa Lakes and answer why a specific strategy for managing aquatic weeds is needed (Slide 1). I want to introduce the important components of a strategy and summarise the progress on strategies for aquatic weed management plans in these lakes, which are being put together by the Bay of Plenty Regional Council and Land Information New Zealand. (LINZ).

The 12 Rotorua Te Arawa Lakes face the usual consequences of a 'commons', a shared resource for communities, Iwi and individuals, regulated by agencies acting in their interests. It is also a group of lakes which have a number of different management agencies working on various issues and sometimes these responsibilities are quite fragmented. There is definitely a requirement for a shared vision and plan of action for these lakes and I want to consider one for the aquatic weeds.

What is the strategic landscape for building a strategy for aquatic weed management? They say, 'Think globally, act locally', and New Zealand has an international responsibility to meet commitments as a member nation for a number of agreements on biodiversity and biosecurity. These include being signatory to the Convention on Biological Diversity which is a response to global biodiversity decline. There are other conventions too, looking at protecting our indigenous biodiversity through effective pest control: the International Plant Protection Convention 1951 and the Plant Protection Agreement for the South-East Asia and Pacific Region. Last year New Zealand became a signatory to the Honolulu Challenge on Invasive Alien Species.

All these international strategies and plans filter through to New Zealand and cause us to devise our own strategies and policies (Slide 3). There is recognition that our unique flora and fauna needs protection, which has led to our national biodiversity and biosecurity strategies. There is also a draft strategy for threatened species, which is under review at the moment. The National Policy Statement for Freshwater Management, recently amended, regulates the way our natural resources will be managed.

These policies and strategies all drive through to another layer of local management in the form of regional and district plans and strategies.



- The Bay of Plenty Regional Policy Statement preserves the natural character of lakes and their margins and protects areas of significant indigenous vegetation.
- The Bay of Plenty Regional Water and Land Plan states that aquatic plant pests are not to be introduced into the beds of streams, rivers and lakes.
- The Bay of Plenty Regional Long term Plan includes Rotorua lakes activity where focus is on nutrient management.
- The Rotorua District Plan manages the recreational use of the Rotorua lakes and rivers to avoid, remedy or mitigate adverse effects on visual, cultural, social and environmental values of water bodies.

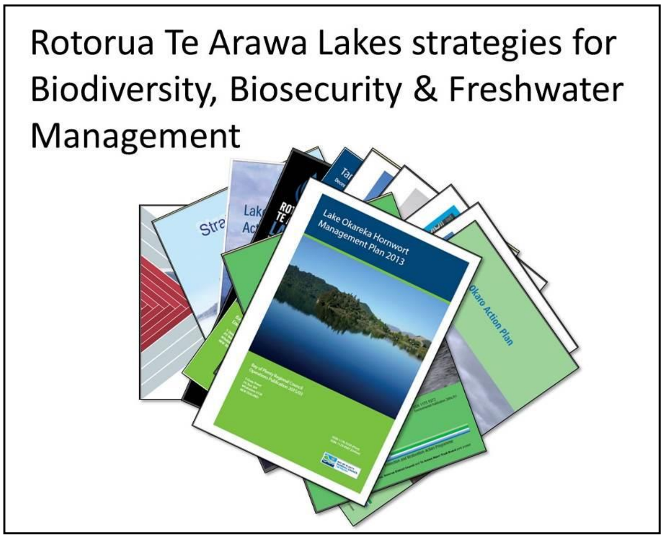
Probably the regulations which are most relevant to aquatic weeds are these two, both of which are under review:-

- The Conservation Management Strategy for the Bay of Plenty

- Rotorua Pest Management Plan which states that the control of *Egeria densa*, lagarosiphon and hornwort is required in certain of the lakes and LINZ is the responsible agency.

Of primary consideration is co-governance by Te Arawa as owners of the lake beds, or tribal entities as private owners of two lakes. While pest plants are recognized as impacting on the health and wellbeing of the lakes in the Te Arawa Cultural Values Framework, management of aquatic pests is the responsibility of the Crown under the Te Arawa Lakes Deed of Settlement.

Strategies are also focussed on the lakes themselves. There is an overall strategy document for the lakes, and 9 of the 12 Rotorua Te Arawa Lakes have action plans to put strategy into action (not Rerewhakaaitu, Rotokakahi, Rotomahana). These plans justifiably have focused on water quality, with mentions of lake vegetation management being few, restricted to biosecurity considerations for Ōkataina and Ōkareka, and Rotoehu as a weed source. The recreational strategy acknowledges the impact of weed on recreational activities, the role of lake users in spreading of new weeds, and potential for weed management activities to influence recreational use.



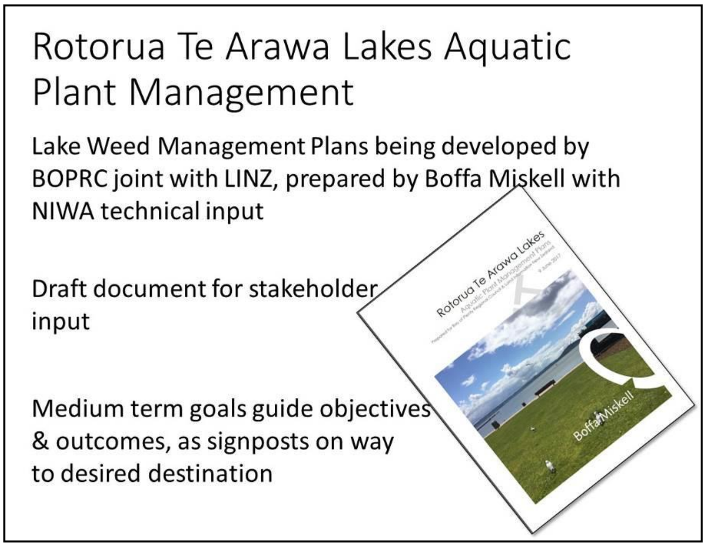
The Ōkataina Action Plan refers to implementation of a plan to eradicate hornwort and annual progress updates, with encouragement of boat checks for weed before launching. The Ōkāreka Plan gives consideration to submerged weeds through surveillance requirements. The Rotoehu Plan gives consideration to the lake as a potential source of hornwort.

A pile of strategies have been developed and available online, but do they address aquatic weed management or provide a plan of action to deal with lake weeds? I do not think they do by themselves.

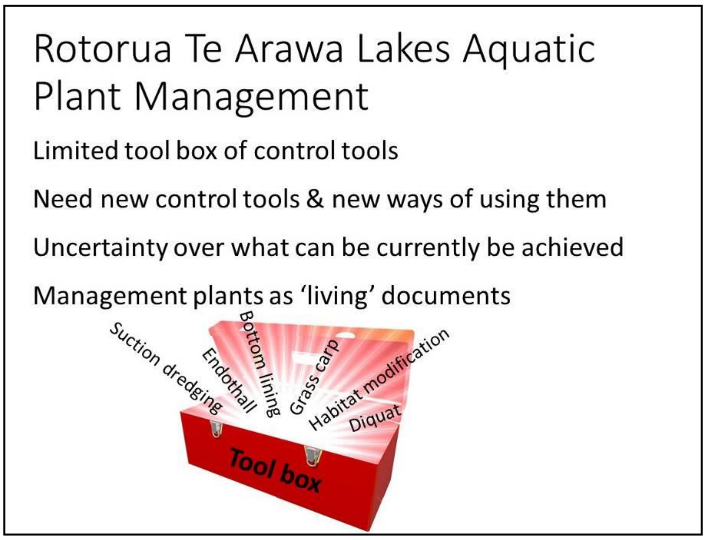
Obviously reducing elevated water nutrient concentrations will not prevent weed problems. We only need to look at our pristine South Island lakes. The photo below of Lake Wanaka showing a big bed of lagrosiphon yet it is a pristine lake with clear water and low nutrients. In fact elevated nutrients may reduce weed problems. The other photo is a picture of hornwort growing in an algal dominated lake. The light limitation is quite severe for this plant and could restrict where the bed is growing. If we alleviate those algal blooms by controlling nutrients, the weed beds could grow deeper, bigger, faster than ever before.

There has been a recent emphasis on swimmability with a public outcry about the condition of lakes and rivers in New Zealand and the demand for better defined standards based on the risk to bathers from bacterial infection or toxic algae. But add weeds like hornwort in thick beds and you do not have swimmable water, you have hornwater. Obviously something like this is not going to be swimmable and in fact could pose a hazard to swimmers and users of that resource.

In 2015, the Lakes Water Quality Society symposium identified the need for a strategic approach for weed management. In response, the Bay of Plenty Regional Council and LINZ are developing the Rotorua Te Arawa Lakes Aquatic Plant Management Plans, which are being prepared by Boffa Miskell with technical input from NIWA. It is still a draft 'living' document and going through the feedback process from stakeholders so it is not a done deal yet. This plan suggests medium-term goals to guide objectives and outcomes, to act as signposts on the way to a desired destination. We do not have all the answers so it will be important to stage this work.



For aquatic weed control we have a limited toolbox of control tools. We need new ways of applying those tools and at the moment there is uncertainty about what we can achieve with our current tools. Aspirations may be fine but can we get there with the toolbox we have? It is really important that those management plans for aquatic weeds are kept as living documents, updated as progress is made or as new initiatives and weed control options become available.

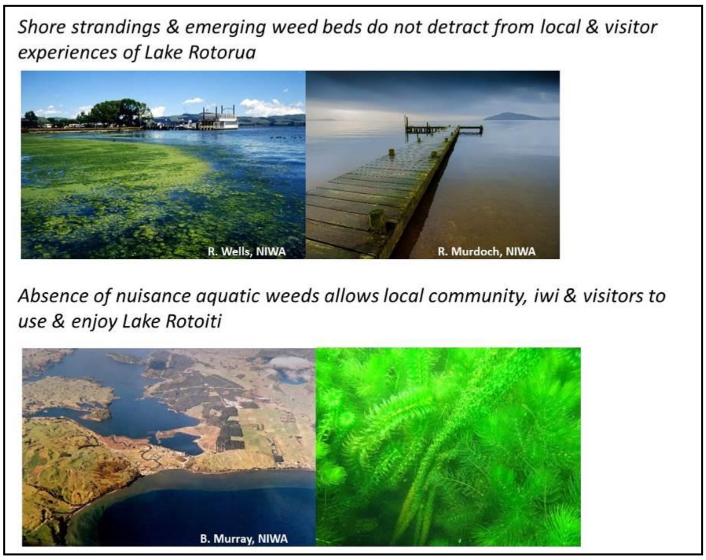


The management plans reflect a number of different strategies depending on the water body and the situation. These strategies represent a spectrum and start off with biosecurity at one end. We can protect water bodies by preventing weed invasion using such things as the weed cordons (see Lake Biosecurity – local actions and results). There is also a need for those lakes already invaded by bad weeds to prevent weed being exported and introduced to other water bodies. It is important to keep boat ramps and jetties clear of weed which is the main point of contact for boats being hauled out of lakes. There is also a need to minimise the weed bed contact with lake users so that their gear does not become contaminated and then moved off to another site.

In the middle of the spectrum is amenity and utility and the first action listed, minimise weed bed contact, is shared with biosecurity. Lake users do not want to have their fishing and swimming experiences ruined by massive weed beds. It is entirely compatible for amenity and biosecurity to have the same aims. Amenity and utility aim to minimise drift on shore and this might be to treat a weed bed which is the source of material coming to shore or maintaining access to key areas such as popular beaches or jetties. No one wants to fight through a weed bed to use that facility or utility area.
Biodiversity takes everything to a new level, trying to achieve what cannot be achieved with just an amenity and utility focus. This is about preventing new competitive weeds

from establishing in lakes. It is also about removing high cover weed beds allowing native plants and a diverse array of native plants to recover. This spectrum of aquatic weed strategies applies across all the Rotorua Te Arawa Lakes depending on their situation.

Looking at the medium-term goals of the draft weed management plan for the lakes starting off with Rotorua and Rotoiti. This goal is recognising that the shoreline strandings of weeds that have occurred in the past are something we want to avoid for both lakes. There are big weed beds which interfere with enjoyment of the lakes and should be controlled in some way. These lakes are also a source of weeds for other lakes as they contain the worst weeds already. The picture on the bottom right shows three of the four aquatic weeds in Rotoiti.

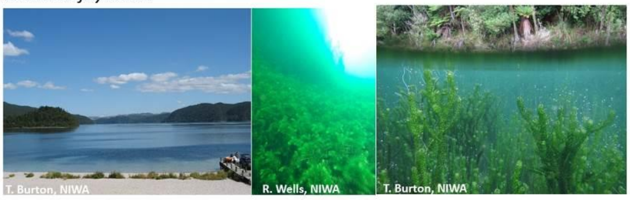


For Rotoehu it is important that the weed management strategy does not interfere with current nutrient mitigation works in the form of hornwort harvesting. Instead the focus would be in the northern arms of Lake Rotoehu to see what could be achieved from weed management and how far weed management can take those systems.

It is important that hornwort is kept out of Lake Rerewhakaaitu. It does have weed issues which need to be managed for visitor and lake user enjoyment.

Ōkataina and Ōkāreka lakes both have the incursion response for hornwort so it is important that this work continues. Eradication of hornwort and suppression of other aquatic pest plants and improved biodiversity allows the local community, iwi and visitors to use and enjoy these lakes.

Improved biodiversity of the Lake Ōkataina enhances local community & visitor enjoyment.



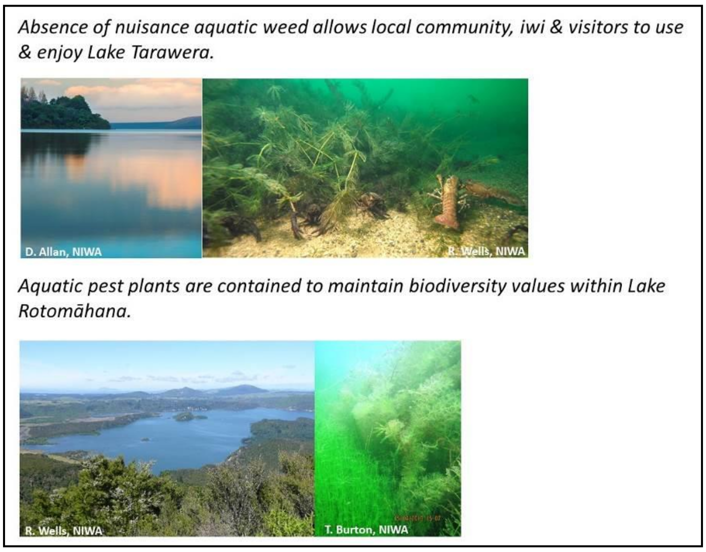
Eradication of hornwort & suppression of other aquatic pest plants allows the local community, iwi & visitors to use & enjoy Lake Ōkāreka

Lake Tikitapu is recognised as a national venue for water sports and it is important to keep it in that condition. At the moment we are very fortunate that the weeds that grow there do not have a big impact. The unusual water chemistry of that lake actually reduces the impact of weed so we want to keep it that way. The benign weed elodea is present in Lake Okaro and it is important to prevent other weeds, especially hornwort from establishing there.

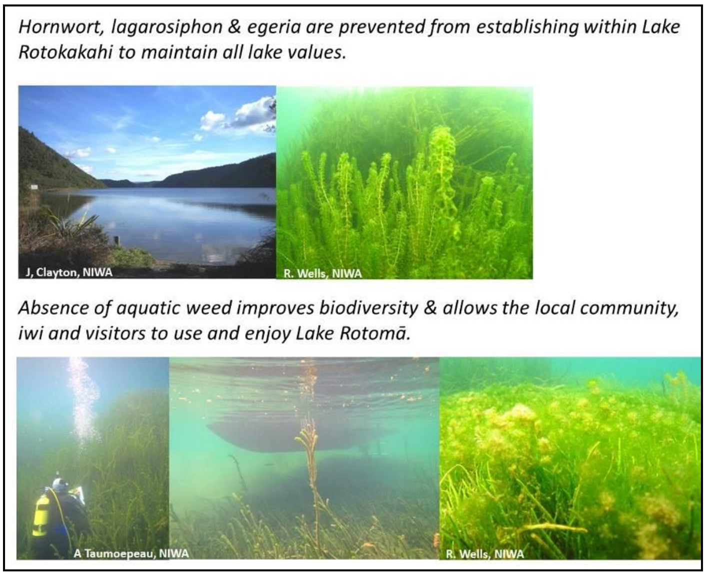
Local, regional & national events in Lake Tikitapu are not impeded by aquatic pest plants.

Lagarosiphon, hornwort & egeria are prevented from establishing within Lake Okaro

For Lake Tarawera it is important that the big beds of hornwort and their impact on lake users is minimised. Lake Rotomahana is a less utilised lake and there may be scope for focussing more on biodiversity values.



Lake Rotokakahi is privately owned by Iwi and is a real gem. It does not have the same weed issues as there has been less use and less transfer of weeds to this lake and it is important it is protected in its current state. Lake Rotoma is probably in the best condition of all the lakes and is least impacted by weeds. It is important that hornwort is kept out of that lake and it is preserved for the future.



How do we achieve these goals? Over the last few years I have been fortunate to be involved with designing and developing management plans for weeds in a number of lakes around New Zealand, work initiated by LINZ. There are some commonalities and I want to share with you the key elements for an aquatic weed management strategy.

Firstly, it is important that lake communities and their users see what kind of benefits can be achieved by undertaking weed management in a strategic way. There needs to be clarity around the costs and actions to control weeds. It is imperative that the best and safest tools are used, with no concerns over their use. All control works must be advised and any inconvenience to lake users minimised. It is really important the community is engaged and informed.

Proactive steps taken to prevent weed transfer depends on the community being on board. They are the ones who need to check their boat and make sure they are not transporting weeds and other pests. Finally the progress must be communicated back to lake users to keep them engaged.

Once benefits can be seen to be delivered for lake users and they are on board, there is little more to delivering on a strategy. Below is a set of components for strategic weed management plans for the agencies who must have freedom to operate. It is important that any weed strategies are aligned with existing strategies, such as the Rotorua Pest Management Plan and that plans are kept updated in a 3 to 5 year review. There must be annual planning and reporting undertaken and monitoring of the outcomes, which is often a step forgotten about. It becomes too hard or expensive but without knowing what the outcomes are, there is no feedback on how successful the programme is.

The Bay of Plenty Regional Council carries out efficient and effective surveillance for new weeds, which is great to see. The plan needs to be responsive to detection of new weeds, not only do they need to be looked for but the response must be ready to jump on them in the early stage to make progress. The last point is the need for research to improve the surveillance monitoring and control works because without that continual improvement, we are quite limited in what we can achieve in a weed control strategy.

In conclusion, my main messages are:-

Main messages

Lakes, as ‘commons’ require shared vision, articulated in strategies/plans

Existing strategies for lakes did not address aquatic plant management adequately

Management plans for lake weeds need to be ‘living’, updated as progress is made, long term gains made

Current tools and unknown outcomes may limit aspirations for lakes

Research advances needed for more effective tools

I would like to thank my NIWA colleagues for input and all the photos that I have stolen off them. I would like to acknowledge Kieran Miller at Boffa Miskell, who has been the main writer architect of the management plans and Greg Corbett at Bay of Plenty Regional Council for his input and approval to use this information in this talk. Also the Bay of Plenty Regional Council and LINZ as the lead agencies for the aquatic weed strategies now underway and funding for our Freshwater Biosecurity Programme and also NIWA's SSIF funding.

Thank you.

BEST PRACTICE TOOLBOX FOR WHOLE OF LAKE WEED STRATEGIES

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Paul Champion is the Programme Leader of Freshwater Biosecurity at NIWA, working there for over 20 years. He specialises in risk assessment, developing strategies for the prevention of aquatic weed spread and protection of unimpacted water bodies, and designing and implementing eradication programmes for aquatic weeds. He also has experience in wetland ecology and conservation needs and management plans for nationally endangered aquatic and wetland plants. He previously worked with the Ministry of Agriculture and Forestry (now MPI) coordinating eradication programmes for nationally important weeds.

TRANSCRIPT

Good afternoon everyone. I will talk about work I have been doing on the Regional Council's best practice toolboxes to provide management for a whole of lake weed strategy. It is a two year MBIE Envirolink funded project initiated in October 2016. The purpose is to gather together information held within regional councils and other organisations that manage aquatic weeds. It is endorsed by the Bio managers and the Surface Water Integrated Management Groups in regional councils.

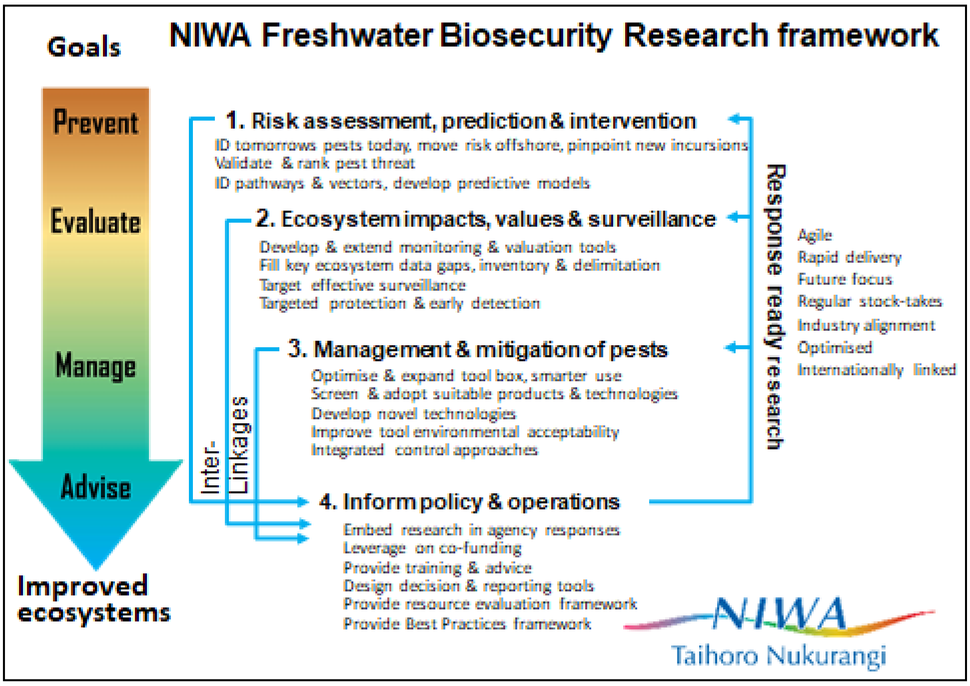
By the end of those two years we will have three tools:

- the strategic analysis tool (2016/17)
- the incursion detection tool (2017/18)
- aquatic weed control tool (2017/18)

There needs to be a strategic focus for aquatic weed management with best practice for weed surveillance detection and control programmes. Nationally these tasks are carried out in an ad hoc way. The Bay of Plenty is one of the better regions as far as a concerted programme. (Hamish Lass paper).

The strategic tool project includes collation of information received from regional council staff who undertake or oversee the management of aquatic weeds. The feed-back from field operations and new advances from research will continue to increase the efficiency and effectiveness of these activities into the future. It has potential application for all water body managers and central government agencies, for example, irrigators and power companies that rely on hydro power.

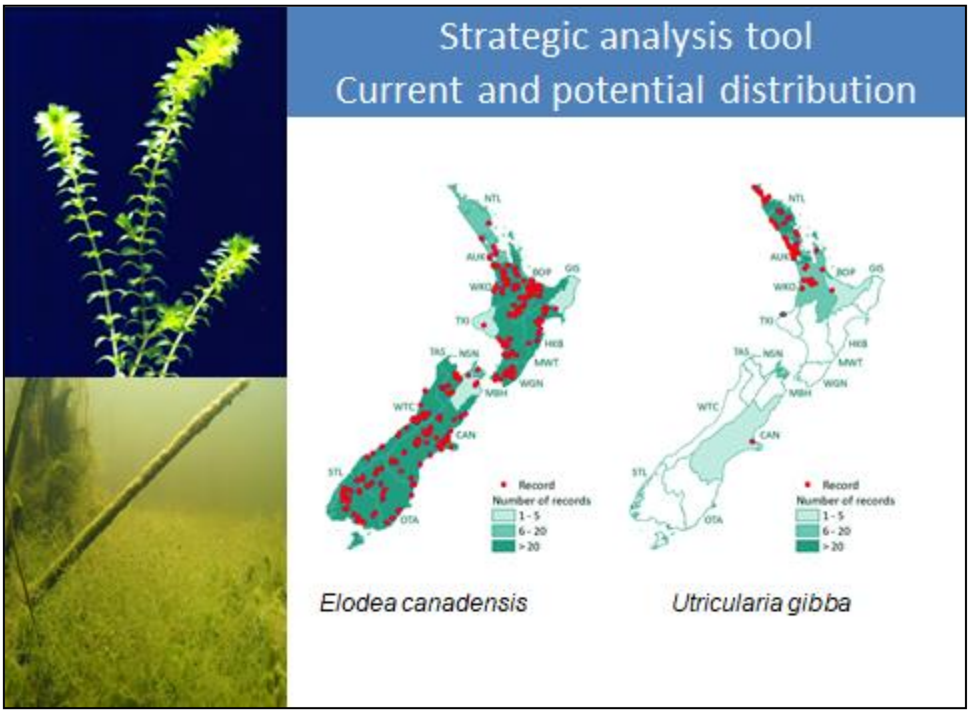
Our research programme covers three areas of research from prevention strategies through to management strategies, risk assessment prediction and intervention. We look



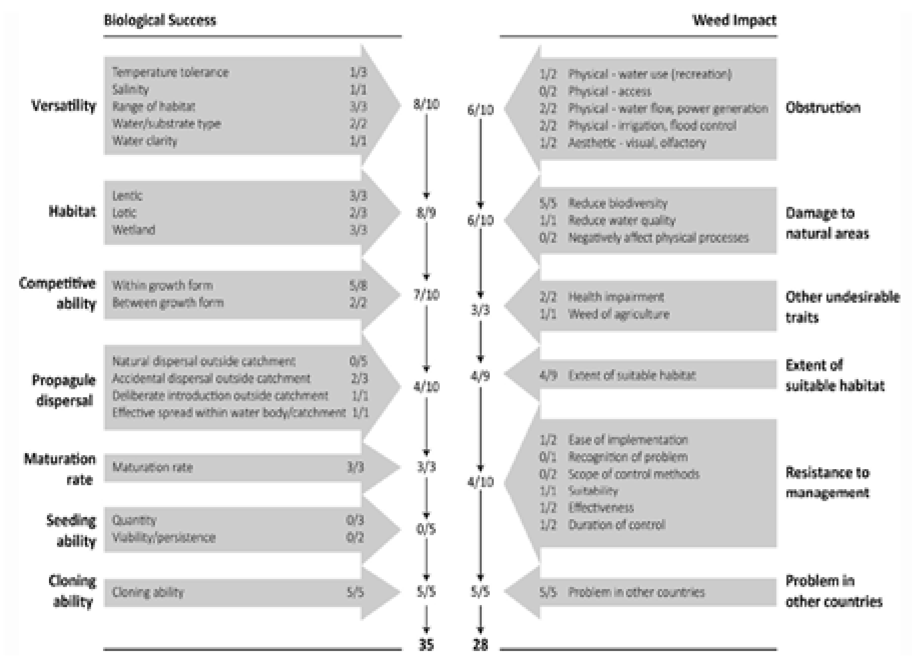
at species either already in the country or yet to be introduced to New Zealand, what risk they pose and the pathways by which they could be introduced and spread. We predict what systems are likely to be impacted, those of highest value, and how to target effective surveillance enabling water body protection and allowing early detection. By far the biggest part of NIWA's research, currently and historically, is focussed on control tools. The fourth part of our programme is making sure that the information is available to all management and policy agencies and this best practice framework fits this part of our research programme.

The Strategic Analysis Tool

This first best-practice tool is for strategic analysis, providing the rationale for aquatic weed control by evaluating the desired outcomes from management. There are several components - what are the problem species or potential problem species, where they are found now, where they could spread and what risks do they pose? We have developed an Aquatic Weed Risk Assessment model to assess those risks (Champion & Clayton 2000). Finally, the National Policy Statement on Pest Management (2015) outlines the classifications of control aims they recommend for use in Regional Pest Management Plans.

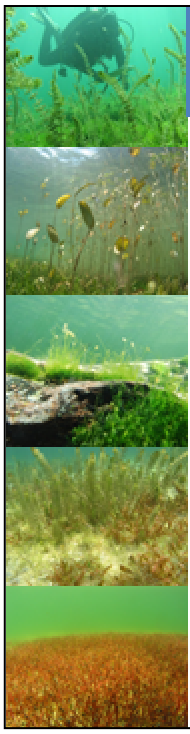


This provides two examples of pest species and where they occur. *Elodea canadensis* is widely spread throughout the country, introduced in the 1860s; it was deliberately spread around with the liberation of trout. Northland is too warm for trout so there is not much elodea there. Conversely there is a new weed *Utricularia gibba*, bladderwort, detected up north around the turn of this century. It was discovered in 1999 and over the next decade, (in 7 years) it had spread right throughout Northland, Auckland and into the north of Waikato. This year (2017) we found it for the first time in Taranaki. Unlike most submerged weeds, it is spread by waterfowl. There is one pond site in Rotorua and an aquarium site in Canterbury.



Alligator weed: weed risk assessment score (Champion & Clayton 2001)

This is the Weed Risk Assessment for alligator weed (*Alternanthera philoxeroides*) which is a major weed in the Waikato system and coastal Bay of Plenty. John Clayton and I worked on a model that outlines biological success and weed impacts of aquatic species (Champion & Clayton 2000). All generic weed risk assessment models rank most, if not all, aquatic plants as potential major weeds with no separation between them. The Aquatic Weed Risk Assessment Model looks at the range of suitable habitats, how competitive they are, how they disperse and their reproduction; all biological data. Then there are the weed impacts; obstruction, damage to natural areas, existing distribution and how much they could spread, resistance to management and finally whether they are a problem in countries with a similar climate.



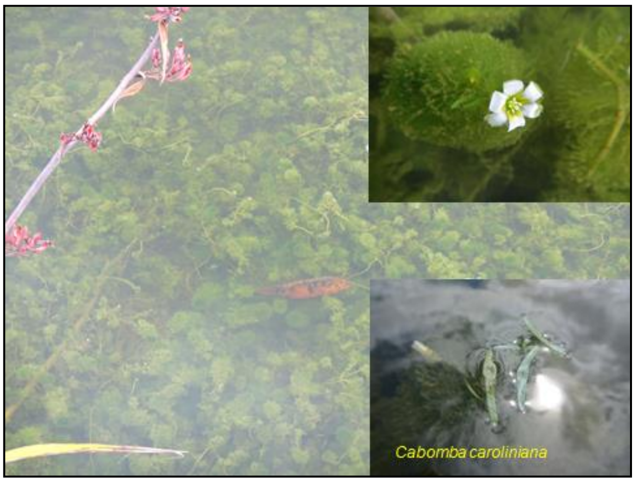
Strategic analysis tool

Weed risk assessment

Species	Common name	AWRAM score	Status
Phragmites australis	phragmites	75	NIPR
Hydrilla verticillata	hydrilla	74	NIPR
Zizania latifolia	Manchurian wild rice	68	NIPR
Ceratophyllum demersum	hornwort	67	NIPR (SI)
Eichhornia crassipes	water hyacinth	67	NIPR
Egeria densa	egeria	64	UO
Alternanthera philoxeroides	alligator weed	63	UO
Lagarosiphon major	lagarosiphon	60	UO
Potamogeton perfoliatus	clasped pondweed	55	eradicated
Butomus umbellatus	flowering rush	54	eradicated
Utricularia gibba	humped bladderwort	54	UO, unmanaged
Cabomba caroliniana	cabomba	53	UO, NIPR?
Vallisneria australis	eelgrass	51	UO, site led
Elodea canadensis	elodea	46	Site led
Potamogeton crispus	curled pondweed	44	Site led

The Strategic analysis tool generates a score and gives the top 8 aquatic weeds in the country. The ones with the solid blue lines are submerged species. The worst weed is *Phragmites australis*. The three weeds causing problems in the Rotorua Te Arawa lakes; hornwort (*Ceratophyllum demersum*), egeria (*Egeria densa*), lagarosiphon (*Lagarosiphon major*), are amongst the top 8 worst weeds in the country.

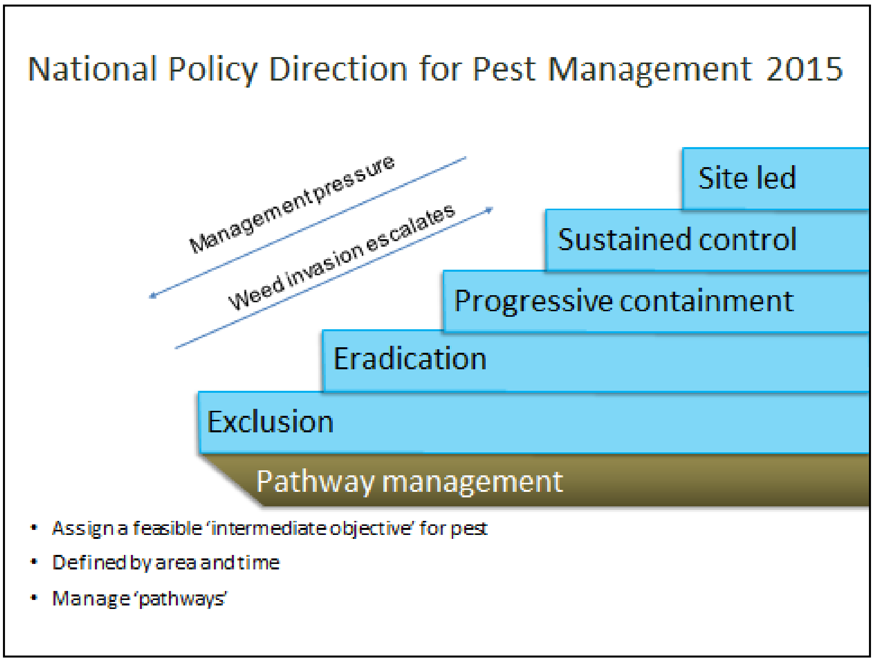
The next slide shows six species that have Natural Interest Pest Responses with these programmes managed by the Ministry for Primary Industries (MPI) targeting eradication. Hornwort was targeted for eradication from the South Island in 2008 and has been achieved. Hydrilla (*Hydrilla verticillata*) is targeted for eradication nationally. No plants of this species have been found in the last two surveys (two years) in any of the water bodies for the first time.



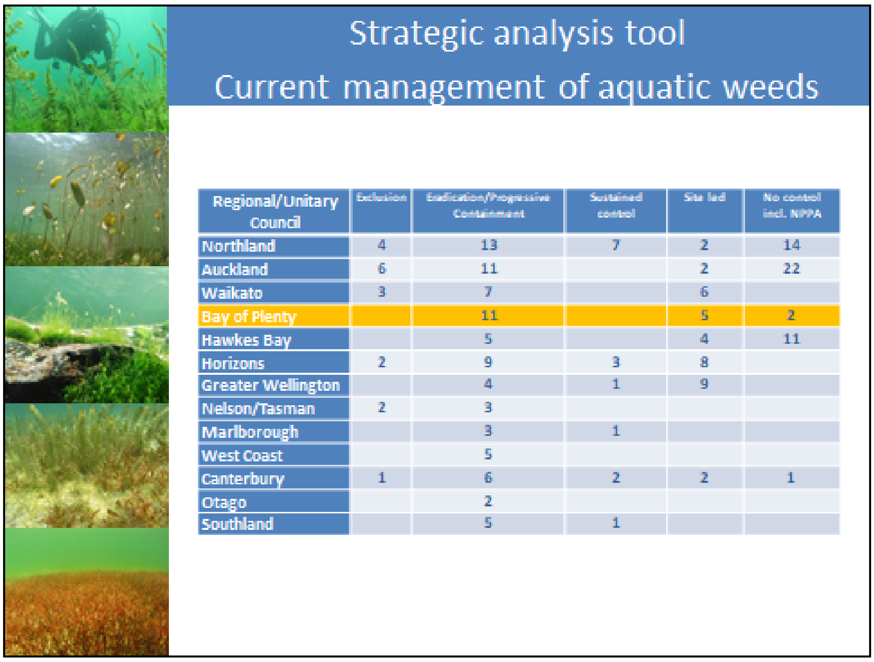
There are up and coming weeds. This is *Cabomba caroliniana* with a Koi carp (*Cyprinus carpio*), a photo from Paremuka in Henderson. This is the first field sign of this weed in New Zealand. In Australia, it is a weed of national significance but it has been in the aquarium trade in New Zealand for around 50 years prior to the detection of this site. MPI have now declared this plant an unwanted organism so it is no longer traded legally.

There are other species like this pond weed *Potamogeton perfoliatus* which have been eradicated from New Zealand and hopefully will never threaten us again.

MPI provides some common language in the National Policy for Pest Management 2015. There are four immediate outcomes in a set of conceptual steps on a management pathway which could go up or down depending on the pest's status or the goal of management and their ability to amend strategies. The scale of the strategy application maybe a contained water body, or a site within a water body, or even on a catchment scale. Firstly exclusion - no new pests coming into the region. Next is early detection and these new pests going into an eradication programme. Progressive containment is similar to eradication, working towards that aim but over a longer time period. Sustained control is about amenity control and site-led management is protecting special areas from the impact of weed species.



We surveyed all the regional councils about the aquatic plants they manage and the Bay of Plenty were similar to the Northern North Island area with 11 aquatic species targeted for eradication from the region and five site-led species, many of which are being well managed in several of the Rotorua Te Arawa Lakes.



Regional/Unitary Council	Exclusion	Eradication/Progressive Containment	Sustained control	Site led	No control incl. NPPA
Northland	4	13	7	2	14
Auckland	6	11		2	22
Waikato	3	7		6	
Bay of Plenty		11		5	2
Hawkes Bay		5		4	11
Horizons	2	9	3	8	
Greater Wellington		4	1	9	
Nelson/Tasman	2	3			
Marlborough		3	1		
West Coast		5			
Canterbury	1	6	2	2	1
Otago		2			
Southland		5	1		

The Incursion Detection Tool

This came from the strategic tool identifying regional threats and prioritising a framework for surveillance; where to look, how often, the risks and pathways. There is no point identifying threats and not doing anything, so detection leads to an incursion response.

The incursion response sequence starts from pre-planning to when containment actions are established.

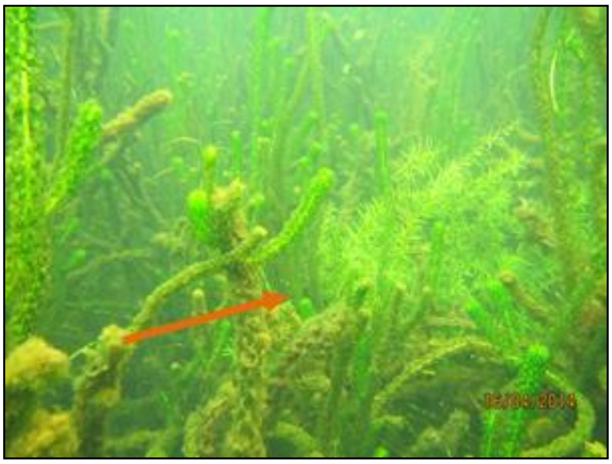
Human Dispersal - Human activity is the only mechanism of spread for many aquatic weeds. Contaminated boats and trailers, nets, association with ornamental ponds and aquaria, and even some control tools like weed harvesters are good weed spreaders as well as weed managers.

Pathway Management - The number one priority is to prevent. Hamish Lass's photo below shows weed cordons installed at boat access points to the lake that focus the detection of any new incursion to within this netted off area, which therefore reduces the surveillance zone considerably.

Decontamination - Check, Clean, Dry is a message everyone should be aware of. It came from the Didymo campaign. Last month Tracey Burton did a project funded by MPI to see if those protocols hold for other aquatic pests including lake snow, pond snail and our three worst weeds. They were all treated in all of the recommendations that are on the MPI website. The only treatment that effectively killed all of these plants was using water that you can actually get out of your immersion heater at home, which has to be 55 degrees and more, and that was absolute control of all of the species tested.

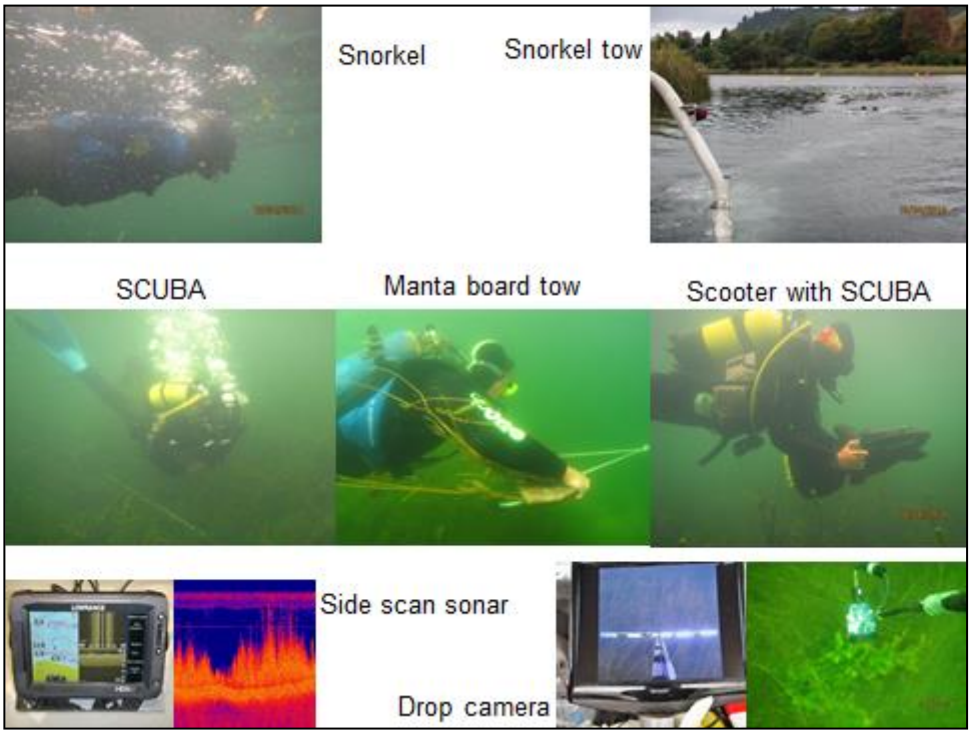
In the United States they use wash-down facilities similar to the one that Hamish showed us but using hot water. The other successful method is freezing but there are not too many freezers big enough for boats.

NIWA were contracted by the Bay of Plenty Regional Council to do a complete assessment and validation of their surveillance practices. The trials focused on new and existing surveillance techniques and methods capable of detecting new invasive weed species of concern in the Rotorua Te Arawa lakes. The most feasible methods from our review were tested in trials carried out in Lake Okareka which followed on from recent issues with hornwort detection that challenged surveillance detection capabilities and compromised timely management responses.

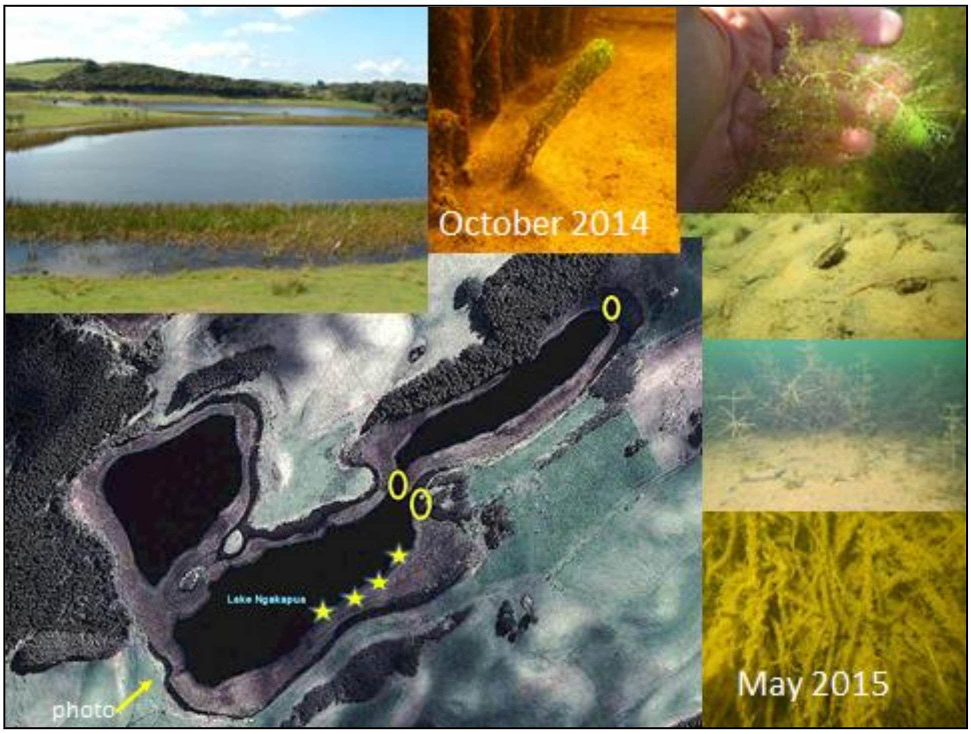


There were 6 trial sites, 12 divers and the detection targets were totara tree branches. This photo shows a totara branch looking very much like another aquatic weed.

They used a range of techniques including snorkel and diving either with scooters, manta boards and remote sensing. Detection was dependant on visibility. We found that the Bay of Plenty surveillance activities are consistent with best practice.



Below is an incursion response example in Lake Ngakapua in Northland. NIWA carries out an ecological assessment of high value lakes every 5 years with the Northland Regional Council and annual surveillance where there is a high incursion risk. Lake Ngakapua was seen as low risk but lagarosiphon was detected in April 2014. A year later endothall was used and removed the target weed, but retained all native vegetation/fauna including big beds of kākahi and an endangered bladderwort which were unharmed throughout the treatment.



The Aquatic Weed Control Tool

The control toolbox looks at the physical, mechanical, habitat manipulation, chemical and biological control approaches including:-

- the species effectively controlled by each option (including eradication, on-going control, spread prevention)
- recommended approaches (e.g., in the case of herbicide control: rate, additives, application technique)

It also looks at the legislation affecting the use of those control methods, ensuring legal constraints to their use are followed. Finally monitoring of control to record effectiveness of control, off-target impacts and to improve the approach is included.

This slide shows the range of control options available at different phases of weed invasion. In the case of Lake Rotoiti aquatic weeds have essentially occupied all available habitat, so the only options are harvesting, bio control using grass carp and herbicide.

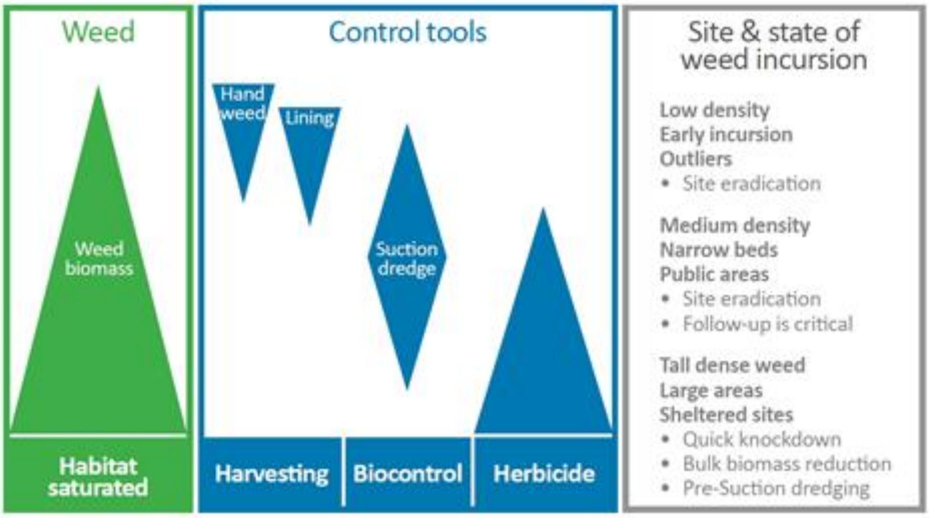
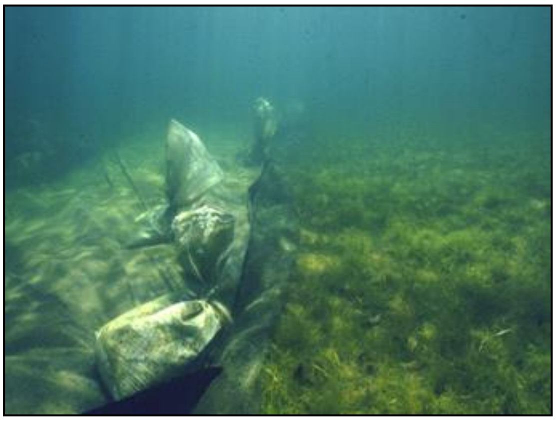


Fig. 8.1 Key factors for consideration when selecting an appropriate weed control tool. Weed biomass (green, left), site and state of the weed incursion (grey, right) determine the selection of control tool or tools (blue, centre)

Control tools

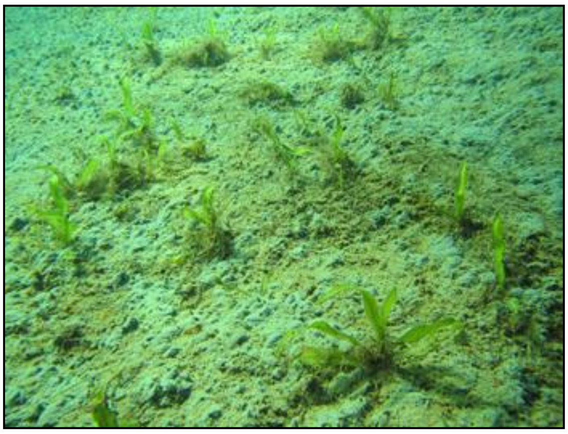
Hand weeding is very effective when you get an early incursion and have good underwater clarity.

Bottom lining – This is at Rosie Bay, Lake Waikaremoana, where lagarosiphon was covered with opaque material. Until recently we thought this method was restricted to very small infestations.



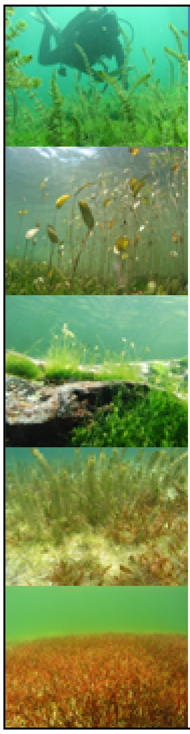
Suction Dredge – Up another scale to remove weed, using a suction dredge guided by a diver.

Hessian matting - Boffa Miskell have been trialling the technique that Deborah Hofstra talked about. There is a cost saving by laying big areas of hessian matting compared to suction dredging.



There is a bonus if native species like these pond weeds (below) grow through the weft of the hessian whereas lagarosiphon has a much thicker stem and will not penetrate through the mat.

Harvester - in one of the Waikato River hydro lakes.



Nationally eradicated species

Species	Common name	#	UO	NPPA
Butomus umbellatus	flowering rush	1	No	No
Eichhornia paniculata		1	No	No
Menyanthes trifoliata	bogbean	2	Yes	Yes
Nymphoides peltata	fringed waterlily	2	Yes	Yes
Pistia stratiotes	water lettuce	2	Yes	Yes
Potamogeton perfoliatus	clasped pondweed	2	Yes	Yes
Typha latifolia	greater reedmace	1	Yes	Yes
Zizania palustris	annual wild rice	1	No	No

We have eradicated a number of species nationally. Hopefully they will never be reintroduced back into New Zealand. The problem is when you get rid of a problem it is out of everyone's sight and if biosecurity is effective, nothing changes. When there is a big problem at the bottom of the cliff that is when everyone gets upset. Biosecurity is about stopping things before this happens.

I would like to thank all of the team at NIWA Aquatic Plants Group - Angus and Don McKenzie who were involved in setting up the Envirolink Fund, Darion, Randall, Andrew and Rachel, who make up the technical advisory group, Marcus Girvan from Boffa Miskell, who has been using the hessian and funding from the Strategic Science Investment Fund, NIWA's fund and also funded projects from MPI, Bay of Plenty and Northland Regional Councils.

Thank you very much.

CHEMICAL CONTROL OF LAKE WEEDS

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Rohan is a freshwater ecologist with 38 years in aquatic plant ecology and weed control research with MAF and NIWA. He has been involved with all forms of weed control: grass carp, bottom lining, hand weeding, mechanical harvesters and drag lining as well as chemical control. He has tested the new United States aquatic herbicides fluridone and endothall for use in New Zealand and was involved with the registration of Aquathol K in New Zealand.

TRANSCRIPT

Kia ora
I am going to talk about aquatic herbicides or chemical control and look at the range of aquatic herbicides that have already been tested or to be tested. We will look at diquat and endothall, address the knowledge and use gaps and give an update on endothall and then look at the future.

This is beautiful Lake Tarawera. The major threats to this lake and all other Rotorua Te Arawa Lakes are nutrient enrichment and invasive species. OECD figures state that New Zealand has led the world in agricultural intensification since 2004 and also led in nitrogen application and second place is 800% behind.

The issue of invasive weeds first arose to the fore in the 1950s and the public were desperate for a workable solution. It was the army engineers who tackled the problem first but it was soon passed on to the agricultural scientists at Ruakura. They looked for solutions in the literature and noted that the United States had been dealing with chemical control since the 1930s. Initially it was sodium arsenite which was quite expensive. In today's terms half a million dollars was spent on Hamilton Lake but in the Rotorua Lakes it proved to be hit and miss.

The second herbicide was diquat which has been our best solution for the New Zealand suite of nuisance weeds for almost 60 years. It targets the pest species we have here and fortunately has little impact on any of the native species.

We have continued to follow developments in the United States, testing their promising herbicides in our environments against New Zealand species. Below are the research facilities at Ruakura and Deborah Hofstra leads the project testing new aquatic herbicides.

We have looked at a number of aquatic herbicides since diquat, including fluridone, which was the first herbicide of choice in the United States from the 1980s. This herbicide did not have herbicidal activity on our weeds, they were tolerant of it. It was tested at Ruakura and in field tests in Okawa Bay in the 1980's, but the results were poor. It was interesting that in the United States their species developed tolerance to it after several decades. They moved to endothall as the herbicide of choice for their range of weed species.

Because of herbicide resistance there was a renewed search for aquatic herbicides in the USA and they brought a whole new range to the market. We are working our way through them as funding allows. We keep looking to America because each one costs about $800 million to search the health effects on people, the environment and other plants and animals. We are able to piggyback on their research.

Products approved by EPA for aquatic use in the USA include:

Contact herbicides

Flumioxazin

Carfentrazone

Systemic – ALS inhibitors

Penoxsulam

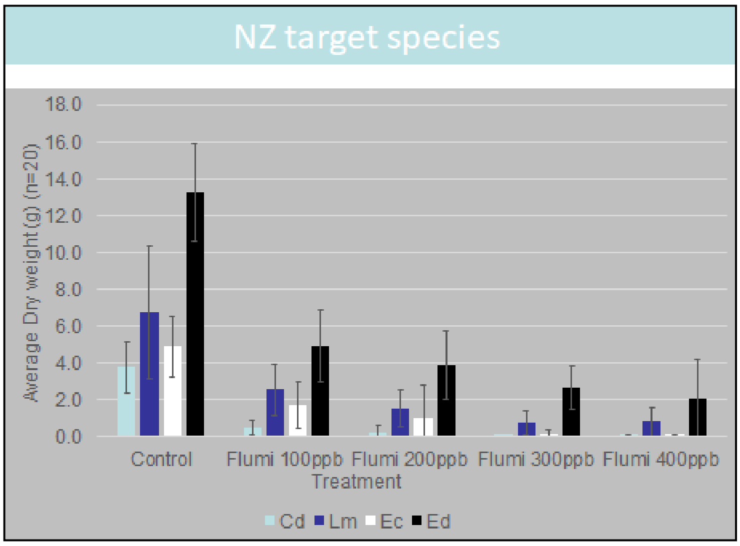
Imazamox

Bispyribac-sodium

Efficacy trials are also underway by SePRO

Procellacor

Deborah looked at Flumioxazin last year and has arranged for a visiting scientist to visit and engage with us in this year's research programme. Procellacor is the one to be looked at. We have a limited amount of money for the research so cannot do them all at once. Flumioxazin, works at very low concentrations and showed good results. It was effective on hornwort.



Diquat

- It has high efficacy for all target weeds in the Rotorua Lakes
- It has been the mainstay for weed control here for nearly 60 years
- It is very selective leaving native aquatic plant species intact
- It is relatively safe once diluted to herbicidal rates in water, and is rapidly lost from water.

It is in fact the only practical option for the larger scale weed control exercises in the Rotorua lakes. If we had a lot more money and more diquat we could get much better results.

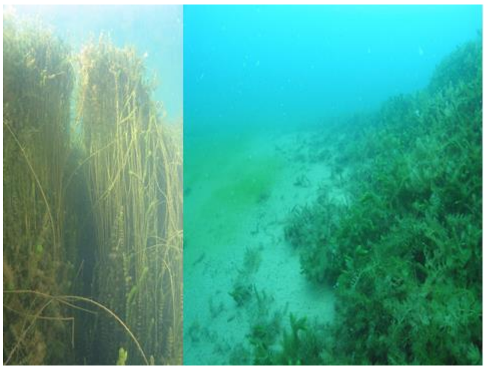
	NZ diquat	US Diquat
Swim	24h	no with holding period for swimming
fishing	none, 24h for a fish farm	no with holding period for fishing
drink	24h	1 - 3 days for drinking - 0.01dibromide (US drinking)
stock	24h	24 hours
irrigation	10days overhead, 24h flowing	1 - 3 days for turf; 5 days for food crops.
EEL	none determined	0.04 US MCLG (0.02 cation)
TEL	none determined	1 - 3 days for drinking - 0.01 (US drinking)
% treatment	up to 25% of water body	up to 50% of water body

30 L per ha diquat no allowance for depth

This compares the New Zealand and United States labels and highlights that our label has not been updated. We still have a swimming restriction, a shorter withholding period for drinking, a longer withholding period for irrigation, there is no tolerable exposure limit (TEL) or environmental exposure limit (EEL) set and there is a fixed application rate based on area treated (as you would for a paddock) with no accounting for depth of water diluting the herbicide or height of weed bed to treat, as there is in the United States label.

The herbicidal rate for diquat is one part per million and if applied at 30 litres per hectare, that rate treats only 0.3m depth of water. When treating a 3 metre tall weed bed, it is difficult to get a herbicidal dose as the application rate is about one ninth of the dose rate required.

For example, in the Otumutu Lagoon at Lake Tarawera, despite it being treated annually, the weed beds are surface reaching and obstruct boats leaving the boat ramp. Periodically the weed washes up on shore, stinky and decaying. Just below the surface are 3 metre tall weed beds that displace the native vegetation. Underneath the weed beds is an environment without light, often with little oxygen and the sediments are highly organic, forming a soft sludge due to the continual addition of rotting vegetation from above. You can feel the pre-hornwort, more consolidated, soil horizon below. This sludge is an inhospitable habitat to most benthic fauna.

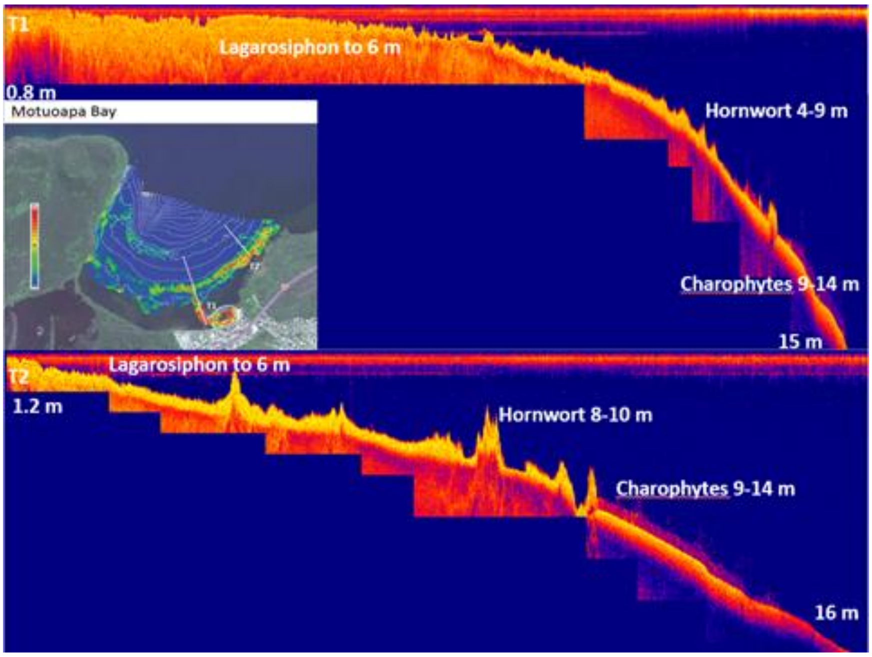


At 30 litres per hectare, and using the aqueous formulation, diquat does not penetrate the deeper cooler water the weed beds are in. A fully funded research programme enabled John Clayton to look at refining formulations to better target the weeds by adding gelling agents. Gel formulations were adopted and manufactured by ICI as PP100, Torpedo and Depth Charge over the years. Now he is considered the world expert on diquat in the United States. But New Zealand is really too small a market and these formulations have been withdrawn from the market. Applicators now have to add the gel to the herbicide themselves and viscosity is important to get right.

To illustrate that, on the left, we show the result of adding an aqueous formulation to water, it sits on top. We have added dye to highlight that. But if you add it with a gel you increase the density and sinkage rate, thus reducing drift and dispersion and ensuring that it gets down to the weeds.

Another innovation below looked at repeat treatments as an effective treatment with diquat and shows the weed bed has collapsed to the lake bottom. However, three to four months later there is much re-growth coming away from the stems. A second dose at this stage had a much greater long lasting effect, and over a year later the effects are still clearly evident with negligible recovery.

Repeat treatments were used in Okareka to virtually eradicate hornwort over a number of years (none seen since last treated). It cost $1570 per ha X 15.5 ha = $24,335, applied in November and May in 2016 and 2017. We ended up with native recovery. These very promising results could be extended to other lakes at a cost of about $3,500 per hectare. It showed the benefits of a much more intensive spray programme.



This submerged vegetation map of Motuoapa Bay, Lake Taupo, is generated by an off-the-shelf Lowrance fish finder and a web based US mapping service (cibiobase.com). The map shows the locations, depths and densities of weed beds in the bay. Monitoring can be this easy. Pre- and post-monitoring is required to record how effective herbicide treatments at different sites are and will remotely show the results of trying different options. There is an opportunity for community groups using fish finders to assist with weed management by recording before and after profiles of the weed beds.

Endothall

- No 1 aquatic herbicide in the USA.
- We trialled it in 1993.
- In New Zealand it has eradicated both hornwort and lagarosiphon.
- Registration started in 2000.
- It took 4 years to register, needing a consortium of Regional Councils and Agencies to finance it, and was available for use in 2004.
- It eradicated hornwort from the South Island in 2006.
- Waikato Region started using it in 2007 and it is part of regular drain maintenance there. It is now used in numerous other regions including Northland where two lakes have been restored by eradicating lagarosiphon.
- Resource Consent and EPA permission for the Rotorua lakes is still to come.

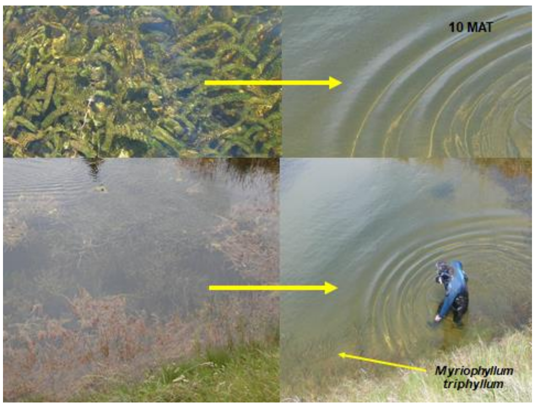
Here in the Bay of Plenty for the Rotorua Lakes we are still working on a resource consent and an EPA permission to use endothall. I have been provided technical information in support of this resource consent. However, at the moment we are also renewing the diquat consent and endothall has been put on the back burner to follow after the diquat consent. In New Zealand endothall is an option for aquatic weed eradication and has eradicated both hornwort and lagarosiphon in a range of situations to date.

	NZ Aquathol current	US Cascade
Swim	24h	none
fishing	3 days	none
drink	14d to 4.25; 25d to 5ppm	7d at 0.5; 14 d at 4.25; 25d at 5.0
stock	as above	no restriction
irrigation	as above	none on turf ornamentals and crops
EEL	or within 0.086	not specified
TEL	or within 0.28 (drink)	MCL 0.1
% treatment	to 25 % water body	not specified

Although relatively new, our endothall label is already out of date. There has been so much more research submitted to USEPA because it is now their number one herbicide. In the United States researchers have a senior scientist working very closely with USEPA to ensure they are fully informed and they had sufficient funding to get a re-assessment. The areas treated in the United States are very large and there is a very big market for making it economically viable for industry to fund it.

The changes in the label were so marked for Aquathol K that it has been re-named Cascade and relabelled. They now have no swimming restriction, no fishing restrictions, no stock watering restrictions, and irrigation restrictions lifted on turf, ornamentals and crops. We have a 24-hour restriction on swimming, a 3 day restriction on fishing and irrigation restrictions.

When we started using it here we found that in some situations it was more active than we thought. We initially trailed it at 0.1ppm on lagarosiphon which is 50 times less than the maximum label rate. After 53 days there was no green tissue, there was a whole lot of brown stems, but no root crowns. It is recognised now as having systemic effects and these are being researched in the United States.



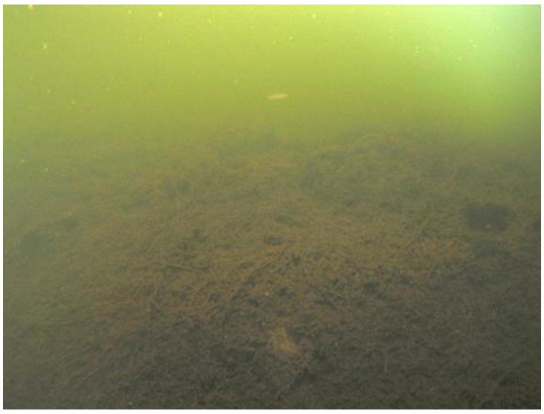
We did a large scale application in Lake Benmore, but we stopped looking for a result too early. We found that it needed 10 months for the treatment to fully work in that cool environment.

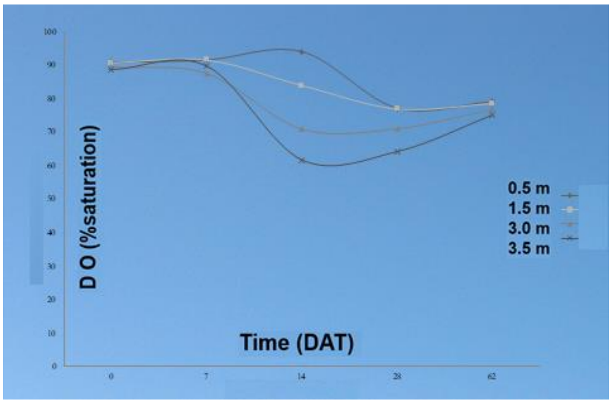
This is another good news story. Lake Ngakapua in Northland is 5-6 hectares and had scattered patches of lagarosiphon along its length. Northland Regional Council treated only 0.25 ha of the lake and in one treatment they eradicated the lagarosiphon. Lake Phoebe, Pouto (1 hectare) also had only one treatment and it took 6 months for all the lagarosiphon plants to die. Both lakes have now been restored to their native condition.

The Bay of Plenty Regional Council is going through the resource consent process. I was engaged to answer questions and do presentations to Iwi. The first questions are always about safety. That is one area where there is no knowledge gap. An adult would have to drink about 15,000 litres at herbicidal rates before a 50% risk of death. It compares very favourably with other products, such as a chlorinated swimming pool. Another question asked is, 'What if it were to get into a water supply?' The answer is that there is a 24-hour withholding period for drinking water stipulated on the label and a set-back distance to ensure adequate safety through dilution. If safe limits were exceeded then an alternative water supply needs to be provided.

Substance	Oral LD50 (mg/kg)	Use	Real life comparisons
Cyanide	1	Feratox for possum	About 7 tsp could kill a 70 kg adult
Strychnine	2	Omega bait 0.5%	About 5 tsp could kill a 70 kg adult
Nicotine	1-50	Cigarette (1–20 mg)	58 cigarettes or less may kill a 70 kg adult
Parathion	6-50	Insecticide	0.8 L could kill a 70 kg adult
Verapamil	108	Blood pressure 1 tablet = 120mg.	63 tablets may kill 70 kg adult 7 tablets may kill a 10 kg child
Chlorine	150-200	0.2 ppm used in drinking water 0.5-3 ppm used in swimming pools.	3,500 L of pool water drunk by 70 kg adult may be lethal
Warfarin	185	Blood thinner (1 – 7.5 mg pills)	Adult rate 5-15mg/day saves lives 70 mg/day for 6 days may kill adults
Coffee	192-355	64-272 mg /cup	49 cups may kill 70 kg adult
Diquat	214-420	Herbicide 1ppm for weed control	14,980 L of treated water may kill 70 kg adult or 75 ml of concentrate
Endothall	750		(>10,000 L treated water endothall)
Asprin	350-1000	Pain killer 300-500mg/tablet	84 tablets may kill an adult; 12 tablets (0.350 g) may kill 10 kg child
Salt	3000	Food additive	1 cup (210 g) may kill 70 kg person 3 tbsp (30 g) may kill 10 kg child

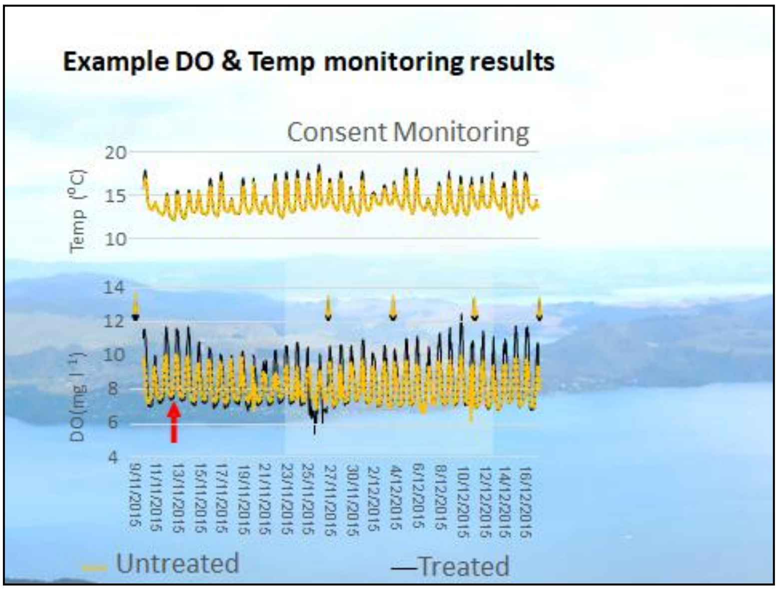
It is the environmental effects that are more difficult to give absolute assurances on. The effects of decaying weed on the aquatic environment are site and time specific. What does it do to the oxygen and the nutrients and what are the environmental implications? The next slide shows the oxygen levels in a 10 hectare lake (Lake Otamateoroa) which was full of hornwort. There was a reduction in oxygen but plenty still for the fish.





Looking at the nutrients, we had improving water clarity following treatment and no algal bloom. We had a reduction in both P and N following treatment. How can that be? There are nutrients in the plants and they are decaying. It does not have to go into the water. It can go into the sediment and that has to be the only explanation in this situation.

Consents are often given with monitoring requirements. In Marlborough the Council were required to monitor oxygen in the waterways following treatment in 7 systems. None were detrimentally affected by the effects of herbicide induced decay relative to the untreated sites.



If you do not control the weeds, what happens then? We have heard from Max about decay and its consumption of oxygen. There is this diurnal change in oxygen levels too because plants respire and they consume oxygen overnight and when they get really dense oxygen depletion occurs on a diurnal basis. Without treatment there can be severe impacts.

Without weed control, the weed beds grow and store greater quantities of nutrients, and will then senesce naturally. Weed beds can create anoxic conditions and sediment nutrient release by raising the pH to 10. This can cause the beds to die and be replaced with algal blooms until the bloom sinks to the bottom. It can 'flip' from one state to another as was occurring in Lake Omapere.

The cycle was broken in Lake Omapere by preventing weed beds re-establishing (using grass carp) resulting in lower nutrient levels and aerobic conditions since.

Future Directions

Social licence
Need to update EPA controls
Need latest tools and keep learning
Site specific strategies
Pre- and post-monitoring
Role for citizen science
Refine viscosity, better targeting
Endothall; get the consent and EPA permission for the Rotorua lakes
Determine best strategies, rates and formulations

Lastly, we always need to think of the social licence. In some areas of the country there is a strong anti-chemical lobby. It is important that people are informed of what the risks are from invasive weeds left unchecked, what the environmental effects of using herbicides are and what the benefits of using them are. I have been to a public meeting where, prior to it, activists circulated the skull and crossbones warnings of the chemical risk to health. At the end of the meetings there would be only two or three people not convinced and usually those people become accepting when they see the data. I have worked with Iwi, some have even put on their snorkels and flippers to look for themselves. They have usually been really supportive of what is going on. But we do need to be very aware we need to have a social licence to continue to use herbicides.

I just want to acknowledge the following:-

The aquatic plants team past and present
LINZ and Boffa Miskell
Geoff Angell – Aqua-ag
BOPRC
LWQS
NIWA SSIF funding

QUESTIONS

Cr Tipene Marr: I am probably one of those people that is anti-chemical and I felt you are fairly well brainwashed. Just because it is good in America, how good is America at doing things? We have Monsanto and DuPont seeding plants that do not die with Roundup. We know it is happening. You sound blasé about how we use these chemicals. You cleaned up Ngakapua Lake in Northland but only a small lake and it did not look very lively after all the chemicals. It looked pretty black to me. The 10 hectare lake you talked about and said you would have to drink about 15,000 litres of water to be affected but we are all different people with different bodies. Someone might drink 1 litre and become cancerous or sick. You cannot say 15,000 litres to get affected. As I say, because it is good in America does not mean to say it is good for us.

I look at the root of the problem. Why are these weeds growing? I did see Mary de Winton's photograph of Wanaka, lovely clear water but it does not always mean lack of nutrients. There is farmland around Lake Wanaka as well and therefore nutrients which are one of the things that help weeds grow. They have got plenty of stuff to feed on. I think it is the bigger picture in New Zealand without heading down the line of just nuking everything, chemically.

Rohan Wells: Very good comment. I am sorry to have been blasé and to have glossed over it. It would have been good if you could have been at two of the hui that I ran or at a previous LakesWater Quality Society meeting where I had the opportunity to spend an hour to run through and explain this. It is very hard to go into all details in such a brief period of time.

We do get the chemicals here and look at them from the New Zealand perspective and what can be achieved. One of the things that impressed me most on the hui that we had down at Utuhina, was one of the Kaumatua stood up after the meeting and said, 'You guys brought these poisons to our lake'. He was referring to the weeds as poisons. Then he said, 'Now you want to add more poison to our lake'. He said, 'I appreciate how well you have explained it and I accept that we need this other poison.'

It is unfortunate and I will make myself available if you want to go through it in much closer detail. People do have concerns and this is the kind of opportunity that we need to talk with community groups to give people confidence that it is a workable option. These herbicides are so specific, not just to plants but to these particular weeds. If you go on your golf course, there is sure to have been a chemical on the putting greens to ensure that they are weed free.

I am sorry, conceptually to some people it is an anathema to put a poison into a waterway and I can totally see that. The consequences of not managing the problem is what is going to manifest itself around the corner, and unlike a lot of water quality issues, if you have a weed in a water body it is not just going to sit there, it is going to multiply. We are trying to protect lakes by stopping invasions in the first place. It is a series of choices about what you are trying to achieve.

Tipene Marr: Is it going to kill them or will they grow back again. Some of those photos you showed, where you had repeated the treatment still showed stuff growing up again. We would just go on and on forever.

John Gifford, Chair: That was with diquat, which is only giving you a chemical control of the top of the plant and the endothall that Rohan was talking about is an eradication option. It kills the roots of the plant of lagarosiphon and hornwort so there is a difference. Not all of these things act in the same way.

Tipene Marr: And they become resistant and then we go for something that is stronger and it just goes on. No, we have got to stop the nutrients.

John Gifford, Chair: One thing we should keep in mind is that rather than just focus on the chemical side of things what we have heard this afternoon is a broad range of strategies that we can potentially use from a strategic approach, the different toolboxes and obviously chemicals are one part of that whole toolbox mix.

Warren Webber, LWQS: Rohan, I was encouraged to hear some of that data on endothall. Diquat has always been our fall-back position and has been very gentle on native plants. You did not mention how endothall affects native plants? Could you also comment on the impact of the size of the waterbody. Is endothall only going to work in shallow and small lakes or have we got something that has true application to the littoral zone of our larger lakes?

Rohan Wells: In terms of efficacy for invasive species, endothall is limited to hornwort and lagarosiphon. It does not affect the egeria or the elodea. We have looked at it on 34 other native species, and the only ones that it has some effect on is the milfoil, Myriophyllum triphyllum. It does not have a Maori name that I know of. It was affected marginally and had a full recovery and then of course it had much more habitat so it really expanded its range.

Size of water body - we have had limited experience with endothall. We have eradicated lagarosiphon and hornwort from 8 or 9 water bodies to date, the largest being 6 hectares. Two months ago it was used in Lake Ianthe because lagarosiphon is invading the West Coast lakes now. We would like to eradicate it with one treatment. If this endothall breaks down into water and carbon dioxide, if we can eradicate it with one treatment and do not have to do it again, that is what one would consider ideal. Nothing residual and eradication of the plant, lake restored, that would be great. If you pull it out by hand, even better.

Lake Ianthe is a much larger lake. Next week I am going down to have a look. That is more of a similar scenario to our Rotorua Lakes. Lake Ngakapua in Northland was a 6 hectare lake and we only treated 0.25 hectare and achieved eradication so can we scale up? There are so many more questions that we want to know around its operation. Is it a useful tool? So far it has exceeded expectations by a long way.

John Green, LWQS: Can I make a comment? Having lived on Lake Rotoiti for over 15 years, diquat was only ever going to be effective for knocking back hornwort and year after year, after year, after year, after year, we have hornwort coming back and causing problems. Tipene, I would like to take you for a ride on Lake Rotoiti and show you just what a problem it is.

I am a little bit worried about who makes the decisions and how we are going because on the one hand LINZ is responsible for sorting out the weed problem. It is not Te Arawa, but obviously the Bay of Plenty Regional Council has a role. Rohan, what you are saying to me is that we have taken 24 years to get endothall into our lakes yet it is used currently around the rest of New Zealand. You have eradicated hornwort in the South Island and had no problems. Why don't we put the whole thing on the table? We want endothall. We want it now. We want it sprayed to kill hornwort. Rohan says the EPA (registration) costs a huge amount of money, $800 million, and they have put a lot of science into research. Surely we are entitled to piggyback off their work and costs as an efficient approach to our approval processes.

Is this a silver bullet? I suggest it is because certainly diquat is not and you have demonstrated that you cannot get the concentrations of diquat down to the root system. Endothall is about getting to the roots and killing hornwort forever. I would suggest we stay on that track. There will be people who do not like poisons. We have to address that as part of the process but please get endothall approved and then get it working. Otherwise we will be here for another 50 years because nothing else is happening. Our Society originally started as a weed society – that was over 50 years ago.

*Brian Stamp, LWQS***:** We have 4.5 million people and different regulations throughout the whole of New Zealand. They have resource consents in the South Island to use it and yet up here we have to get a resource consent. Why isn't it the same for the whole of the country? We have rules in this country but every council has different rules to the one next-door. They should all be the same. I think Central Government should be setting a standard. I just cannot understand why they are all different. I was on LakesWater Quality some years ago and pulled out because it took so bloody long for anything to happen. Endothall has been around for yonks.

Tipene Marr: Okay so where has it been done successfully? Wanaka is it? What lake has it been done and dusted and we will go down in six months' time and have a look.

Rohan Wells: In Southland we tested it in 8 different water bodies and eradicated it from 7. In the South Island hornwort in Centennial Lake in Timaru we gave it one treatment and eradicated it from there. That was the last site of hornwort in the South Island. It was a system with a flowing stream as well. It took us one year to get approval to use it.

Someone from audience: Have you tried something the size of Rotoiti?

Rohan Wells: No we have not. As I said, we are going to look at Lake Ianthe next month but it may not be useful on a much larger scale. If we do not try we will not know. We are scaling up slowly and looking at the results and refining the tool as we go. When it was used in Lake Benmore, at our initial look a month later, we thought it had not worked. But going back about 18 months later it had. Lagarosiphon had all gone from the treated area.

Tipene Marr: How big was Benmore?

Rohan Wells: Not out of the whole lake - the area that was treated. The scale of treating something like Lake Benmore is massive. I am not making any promises. I am giving you the information that I know and so far the largest lake that we have eradicated it from is 6 hectares and we only treated 0.25 hectare. Even if it is only useful in a smaller scale it could be used on site specific areas maybe in Okawa Bay. We will see what benefits we can get. This is a decision that the community can make. This is why we go to hui, to involve people. I am not making decisions for the community. I can show you lakes. I have taken plenty of Iwi to see lakes and I can show you photos. I am happy to sit down with you and show you much more detail if you are interested.

Warren Webber, LWQS: This is not a question. It is more a comment. I am looking forward to the trialling on larger water bodies. We have seen all afternoon that weed exists in the littoral zone of the lake. We do not have to treat the whole lake, in fact nothing deeper than 15 metres. We only have to treat the side of the lake. I am looking forward to the application of endothall on large water bodies and see the proof of the pudding. I commend you for the work you are doing. Thank you

Ann Green, LWQS: We have lived or visited Te Weta Bay since 1994 and every year we got the letter to say there is to be spraying, sometimes twice a year. When considering the cost of using something like endothall, included in the calculation should be the costs of all those years of using diquat. I suggest that the cost would be equivalent, or maybe even better using endothall just the once.

ANNUAL MAYORAL SPEAKER FORUM : SUSTAINABILITY

Facilitated by Warren Webber, LWQS
Mayor Steve Chadwick has been a committed environmentalist and supporter of sustainable development for a long time. She was approached by Ian McLean from our Society when she first became MP for Rotorua in 1999 with concerns about the dire state of the Rotorua Lakes' water quality. At that time the councils were not responsive to the call for more action, but Mayor Graham Hall and Regional Chair John Cronin were interested enough to accompany Steve to Wellington to propose a collaborative programme, funded by the Crown, Regional Council and District Council. However, Environment Minister Marion Hobbs sent them packing, with instructions not to return until both councils could work together. They took this to heart and agreed to collaborate; in the event securing $72 million from the Government for the clean-up of the Rotorua Lakes. Thank you Steve for being very much at the fore of making that happen.

Mayor Steve Chadwick
Welcome everybody. Anaru Ririwai Rangiheuea also came to that meeting, and afterwards we realised that we did not 'cut the mustard' - a very good message. Today the LakesWater Quality Society symposium has shown the rest of the country what can be done when you work together in a collaborative model. We always knew we were on an amazing journey and we still have a long way to go.

In 2015 we were proud to be New Zealand's first city to become a signatory to the United Nations Global Compact Cities Programme, a United Nations initiative to encourage businesses worldwide to adopt sustainable and socially responsible policies about environmental sustainability. We need to know that we are connecting with the very best researchin the world. We have linked our Global Compact Directorate with Local Government New Zealand and asked other mayors to join. Then we will get consistent models of measurement, ensuring that we make beneficial incremental change to our environment.

It is my pleasure to introduce our speakers tonight:

Sir Rob Fenwick, a conservationist and businessman with a diverse background in resource recovery, bio-diversity, heritage conservation, science and Iwi governance. He co-founded Living Earth and led the passage of the Waste Minimisation legislation in New Zealand. He established the New Zealand Antarctic Research Institute for climate change research and led the restoration of heritage buildings in Antarctica. He founded Predator Free New Zealand and the campaign to save the kiwi from extinction. He is a director on two national science challenges and chairs the panel reviewing the New Zealand fishery system.

Rod Oram has 40 years' experience as an international business journalist working for various publications in Europe and North America including the Financial Times of London. He is a valuable commentator on the state of the environment in New Zealand, contributing regularly to Nine to Noon on RNZ, Newsroom.co.nz and the Larry Williams programme on Newstalk ZB. Rod is also a frequent public speaker on business, economics, innovation, creativity and entrepreneurship, in both NZ and global contexts. For more than a decade, Rod has help fast-growing New Zealand companies through his involvement with the ICEHOUSE, the entrepreneurship centre at the University of Auckland's Business School.

Eamon Walsh is a final year student and sustainability leader at John Paul College in Rotorua. He has a keen interest in environmental issues and aspires to a career in medicine.

Question, Warren Webber, LWQS: *What are some of the new innovative ways of managing land without resorting to environmental national standards, rules or regulations and thereby enforcement. Can we do this in a more enlightened way?*

Sir Rob Fenwick: This is an area that Rod has a lot of expertise. The whole environmental effort rests with local government and leadership of mayors like you, Steve. Currently there is a lot of discussion about the responsibilities of central government but most environmental problems impacting our daily lives are the responsibilities of local government. It is excellent that you and your Council get behind these issues.
The old carrot and stick argument comes to the fore whenever we think about change without regulation. In particular, the question is about the correct use of land with minimal impact on the environment. With no regulation there has to be the threat of regulation in the background and an incentive for change. The most obvious one in the farming community is changing markets. Farmers have only recently had to come to terms with significant emissions and nitrate loading issues, changing their thinking very quickly. There are huge capital issues around changing farming activities.

I was impressed recently while visiting controversial farms near Taupo where a large forest was destroyed. The Landcorp managed Wairakei Pastoral Holdings has converted one whole farm from traditional dairy to sheep milk, and the transformation is extraordinary. Sheep use half as much water, a fraction of the compaction of soils, far less nitrate loadings on ground water and emissions are a fraction of a cow herd. Most importantly, the product produced has much greater value than milk powder and greater health benefits. Ask yourself, we used to have 70 million sheep in New Zealand, now we have less than half that. Is sheep farming for dairy a better land use outcome? That is a huge market shift and answers your question of a preferable land use without regulation.

However, change will not happen by itself. It needs incentives from local and regional councils to encourage the process and should not be by regulation alone. There are glimmers of hope, but ultimately how we use our land is the responsibility of regional councils under the Resource Management Act.

Rod Oram: I would like to build on what Rob has just said. There will always be a need for a solid framework of rules and regulations. However, we also need to remind ourselves that technology, business economics and societal values move faster, at an accelerating rate, than we can keep up with regulations. Regulations lag the real leaders in the field.

A couple of years ago the Productivity Commission did a survey of senior civil servants asking, 'How fit for purpose was the legislation under which their ministry worked?' The answer was two thirds of it was not fit for purpose. Legislation was behind the issues, and this in a parliament renowned as one of the fastest in the world for passing legislation through when it wants to! We need a far greater collective sense of responsibility so when we are at the leading edge of change we make good decisions, possibility in the absence of, or ahead of regulation.

I had the privilege recently of delivering the Salmon Lecture to the Resource Management Law Association. It was 'Reinventing Paradise - From Rules to Reason, From Economics to Ecosystems'. If we keep the rules but also develop a collective sense of what is reasonable, and account for things in the ecosystem, rather than a narrow economic one, that will take us a long way towards a far greater rate of change, and give more confidence in the changes we do make.

Mayor Steve Chadwick: Our Council is looking at innovation and talking about the impact of natural capital and what is the best land use for this catchment. We might come up with a better solution than rules and regulations.

Question, Mayor Steve Chadwick: *What are your views on natural capital?*

Sir Rob Fenwick: The problem with capitalism is that we only focus on financial capitalism and that runs amuck from time to time. If we bring in natural and human capital, and add social capital, using systems that work with those four capitals, it would take us a long way down the road. The dominant one would have to be natural capital because it comes back to the ecosystem. Very good disciplines are emerging in this. Globally the accounting profession is getting its head around deeply integrated reporting. However, it will only work if we make sure there are no unexpected externalities. Everything must be on the table to understand exactly what the impact is, both positively and negatively, and who is responsible. Then we can start making far better decisions. Steve, it will come as no surprise that you are ahead of the rest of the country in this.

In November there is a symposium of CEO's of major companies in the public sector looking at new strategies around investment in natural capital assets for the country, to get some agreement on how New Zealand can protect and enhance the principle natural assets on which our economy rests, such as soils, sustainability of the fish stock, fresh water and the atmosphere. These are the ecosystems of which humans are a part, but we tend to make the mistake of thinking we are not. But human communities are so much a part of these ecosystems and we need to play a role in their protection.

Question, Warren Webber, LWQS: In the Rotorua area you will be aware that we have been first off the block in trying to allocate nutrient rights and reduce leaching rates. It has been a huge mission undertaken by a stakeholder advisory group to work through the issues. Other councils such as Horizons, Environment Canterbury and Northland have also been trying to work out their own solutions, and we have ended up with a mishmash of policy with no consistency across the regions. That is a dangerous precedent going forward. It was encouraging today to hear that a working group has been established to consider allocation mechanisms and it is badly needed. It is also complicated by the fact that soils vary in relation to nitrogen leaching. Why don't we focus on the nitrogen leaching capacity of soil as opposed to some other blunt instrument?

What thoughts do you have about the establishment of a central government coordinated working group to define consistent national policy templates for land use management?

Rod Oram: The answer is absolutely yes. I may not be hearing the Minister quite clearly enough or I may be too harsh, but when he made a comment that there were still limits to how prescriptive central government wants to be because of natural variation around the country, I believe that central government is not fronting up to the issue. There needs to be very clear strong guidelines and understanding across the country. Yes, flexibility allows local variation but it must be strong enough to be central to all Government's environmental work. It comes back to being an ecosystem. We are getting better; we now have an aquatic ecosystem view. The Hauraki Gulf is a classic example of the terrific work on a spatial plan through the sea change process. This is a first in the world to integrate terrestrial and marine spatial planning. But the whole thing has completely fallen over because the relevant councils have different agendas and cannot work together, and the government shows no appetite for stepping in to create the legislative mechanism which would make the very good integration of that ecosystem work.

Question, Warren Webber, LWQS: *For Eamon - How can we get more young people engaged in conservation and environmental projects, initiatives and organisations?*

Eamon Walsh: The answer comes in two parts. How do we light the fire inside our young people? This is something I think about as Environmental Captain of my school. How do we get students passionate about the environment? Firstly, is to integrate environmental issues into the curriculum. This is happening at John Paul College, and other schools in the nation, by making the environment part of science, because they fit hand in hand. This starts in Year 7 and goes up to Year 10 showing young people that science is all around us and related to the environment. Students go out from the lab, down to the Utuhina Stream to take water samples and the like, showing the practical application of science and how it fits with the environment.

The second part of inspiring young people is to connect schools with communities. That was done really well by the Bay of Plenty Environment Council a few years ago by holding a Youth Environment Forum, bringing younger students together in workshops about the environment. It is all about connecting schools and environmental leaders to talk about the same things and ensure we all go in the same direction. If we have those two things it will inspire young people to step up and take the mantel as the next generation.

Question: *Are there any thoughts of the Council investing more money into working with schools to create more programmes such as the Youth Environment Forums in the future?*

Mayor Steve Chadwick: We did very deliberately abandon a Youth Council because we got people like you Eamon, all with good parents, prefects that came and were all motivated. But I realised we were not touching the group in our community that I heard about today participating in one of the Regional Council's summer programmes doing surveillance work with our lakes. It is that interactive learning opportunity and engagement with real projects that is probably going to make a greater bigger difference than having forums.

I would take your lead on it if you got a group of young people together who came and said, 'This is what we would really love to do.' It is not one individual student's idea. The online feedback from our Vision 2030 showed that environment is top of most people's heads in our district.

How we get youth involved and linked is the next challenge. We have to engage very differently with young people. It is probably not a Youth Council; we need an engagement tool that is more interactive, where we get young voices. You are all good on your iPhones and social media. If we keep that connectedness going, and get the right lead from young people like yourself, that will guide us to what is best for our environment.

Sir Rod Fenwick: Steve, as a former Cabinet Minister you know that one of the failings of environmental education is that we do not have the teachers. If schools are part of the solution we need teachers who can teach about the environment. At present there is no priority given to that. That is a key to unlock potential.

Mayor Steve Chadwick: Very much so, and it is needed even before college. It should start way back with pre-schoolers. The Waste Minimisation Bill is a great lesson; it is about children and grandchildren telling us to get our act together. Put an efficient waste system and recycling in place. Young people demanded that when we asked their views. But they will not come to Council to give a submission; it is not their mechanism of engagement. For Council the secret is to find the right engagement tool.

Question, Warren Webber, LWQS: *Tomorrow we look at land pest issues in the Tarawera catchment. Feral deer, wallabies and wild pigs destroy the native bush understory in many of our lake catchments. The Predator Free 2050 programme does not deal with this threat. What would be your advice on a national policy to deal with the threat posed by these non-predators?*

Sir Rob Fenwick: Predator Free New Zealand 2050 is an interesting story. For over 100 years there have been exotic predators in New Zealand. Rats, stoats, ferrets, wild cats, pigs, and the like, have progressively destroyed our natural bio-diversity and we have managed them in different ways for a long time. These pest populations have now reached a high level, while the decline in our biodiversity has plunged to such a low level, that it really is our last shot before we lose control. Extinctions are now inevitable.

Jan Wright's recent report on the state of our birds suggests that 80 different species of our native birds are on the critical list, exacerbated over the last two decades directly as a result of the increase in the population of predators. We know we must act quickly before we lose these incredibly important species. Birds are the best indicators because they are the most visible, and New Zealanders have a long affection for them, but reptiles and insects are equally threatened.
This movement was initially started by the late great scientist Paul Callaghan who suggested that the concept of ridding New Zealand of all its predators to save our natural heritage would be as ambitious as putting a man on the moon. This inspired us to think differently, if we were able to combine the resources of everybody in the country, and new innovation in science and technology, it may be possible to roll back this tide of invasive predators.

I started the Predator Free New Zealand Trust with some generous help from Gareth Morgan and others. The purpose was to identify an army of volunteers throughout New Zealand, many already doing terrific work for conservation. There are literally thousands of conservation groups and tens of thousands of volunteers all over the country working on biodiversity and predator management, and many in this room. Conservation groups from Lake Okataina, Lake Okareka, the Tarawera Pest Control Group, the Land Care Group at Okataina, the Tikitapu and Kokako Groups run by Forest and Bird, are all throughout the Rotorua district and have signed up to the Predator Free New Zealand Trust. We can see you all doing this wonderful work and the gaps between, and clearly the opportunities to create a whole landscape approach to predator management.

It showed us that these groups were targeting completely different species of predators. Nobody knew what they were doing, or how successful they were. Some target rats and stoats, others possums and wild cats. It was an opportunity to bring together a collective strategy across all these people to elevate their capacity to a best practise standard, be even more effective, support ideas and show paths for funding support. So the Government launched Predator Free New Zealand 2050, a long term goal with some short term targets and attacking the problem on a landscape scale.

Your particular question relates to three species that are not in the first suite of targets and I noticed that you did not call them predators. Pigs can very quickly destroy a kiwi nest and are ferocious predators and very destructive. We need to be careful that this whole conservation movement is not an anti-hunting group because that has polarised communities. I was a hunter when younger and it is an important part of community life being able to hunt for pigs and deer. But there are some parts of New Zealand where they are very damaging and we have to get rid of them, in other places they are tolerable. It is a region by region process. The best wallaby is a dead wallaby anywhere. They are so destructive of the understory. In the context of 1080 we must be careful not to have a campaign against hunting. We need to look at it on a case by case basis.

Question, Warren Webber, LWQS: *Environment Canterbury claims that to meet national water quality standards for Lake Ellesmere nearly every dairy farmer in the Selwyn District would need to shut down, resulting in a $300 million annual loss in the District's operating surplus and a reduction in employment, de-population and bankruptcies. Similar compliance issues are faced by other districts with highly polluted water bodies including the Waikato peat lakes and here locally. What is your take on how councils and communities deal with such challenges?*

Rod Oram: I am a bit surprised that Environment Canterbury is so black and white about Lake Ellesmere, but if that is right, clearly the whole district needs to make a decision on whether they want the lake or not? If there is to be a lake then probably there has to be an alternative to dairy farming. But deep down I do not believe it is as black and white. There is a lot of progress in nutrient management and farming systems and it maybe that dairy farming in that district will not impinge on Lake Ellesmere at all. The challenge is to make sure that enough pressure is taken off the lake in the short term to enable recovery, whilst that farm evolution goes on.

Obviously there is some scope for public funding because people have made decisions to farm there in the absence of the knowledge that we now have. People who have made those decisions in past decades should not bear the entire cost of changing land use. But I am convinced that there is scope to dairy farm around the country, but in less intensive ways, totally unobtrusive ways would be my hope. It is about people in those intense situations being able to work together through that process over some decades.

Mayor Steve Chadwick: We would not have embarked on our journey for the lakes' water recovery if we did not have the LakesWater Quality Society, an advocacy group which saw the degradation of the lakes every day and felt that neither the Territorial Authority nor the Regional Council was taking ownership of the problem, so they got active. It was people power that really began that journey and they are still with us today. It worries me that the less populated parts of New Zealand, whose environment is just as important, do not have community voices with a level of influence to get change at the national level. I was a little back bencher and very nervous when we put the business case to cabinet for $36 million. Michael Cullen said, 'You can't do much with $36 million, let's double it.' That is how we got $72 million. He was right, it is now more than a $243 million programme. We need community voices.

Rod Oram: I would like to put one other really big issue on the table because this steers my thinking on direction for New Zealand's future as a food producer. The global impact of food production on the total ecosystem is severe. It is the second largest source of greenhouse gases and there are all the problems of land use change and thus degradation of land and water. So global food production is a total mess. We need to get to where food production has zero environmental impact in 30 years' time, and even better would be when ecosystems are restoring.

I thought the competitors to our farming model were still some time off but they are already here in cellular and contained agriculture such as growing produce under LED lights. They already have zero environmental impact, and like all new technology the cost curve is plunging fast. That is the competition. If we want to be pastoral farmers there must be zero environmental impact within 30 years. Of course at that point you would be able to farm around Lake Ellesmere.

Tipene Marr, Regional Councillor, BOPRC: Sir Rob talked about milking sheep. He did not include goats but that is where farming has to go, organic. We cannot keep on the way we are, water belongs to all New Zealanders and we need to get away from fertilisers. Organic sheep and goat milk gets five times the price, and both the Middle East and Asia are keen to buy. The Selwyn River dried up last year and we had the big drought in the summer. So what Sir Rob said is the answer. Farmers have to think differently or shut down. They get their resource consents and then the wash up from their farms goes into the rivers and streams and that water belongs to everyone.

Question, Nicki Douglas, Te Arawa Lakes Trust: *Tena tatou. I am here on behalf of Te Arawa Lakes Trust. I am also a conservationist, a vegan and I do not own a car. So I am very much about sustainability and adhere to the korero around agricultural sustainability. What are your views on the role of indigenous knowledge and values from a global perspective in terms of restoring the environment? We are keen to apply our matauranga and knowledge to the restoration of these lakes and our environment. Tena tatou.*

Sir Rob Fenwick: We have come late to this in the western approach to solving the problems of the last century, but there is growing enlightenment within the science community of the value of indigenous knowledge and Vision Matauranga in the way we look at the sustainable use of capital and natural assets. I chair a couple of national science challenges, one to do with the sustainably of our salt water fish stocks. It is all about ecosystem based management and indigenous Maori people have been part of that ecosystem for a lot longer than anyone else. They bring a lens to the values of the marine ecosystem that is much more profound than a western view. Knowledge and history and the way in which Maori people look at the value of the marine environment needs to be valued. It is not about either Maori or Pakeha, rather more about integration of this knowledge into long term sensible solutions.

The other national science challenge is biological heritage, specifically looking at biosecurity issues in the country. Again the Vision Matauranga aspect is hugely important and the value that indigenous people place on the flora and fauna that has been part of their ecosystem for so long is fundamental to understanding where it goes to the future.

Eamon Walsh: My perspective is that John Paul College is in a beautiful location right beside the Utuhina Stream. We work a lot with the Fordland community and especially the Iwi community that reside there. A few years ago they came over to talk and impressed on us the concept of kaitiakitanga, being guardians for the environment. As young people it is good to have people who have such strong values to instil in us the idea that we too need to use their values and look after the environment.

Sir Rob Fenwick: Extending the National Science Challenge further, I am involved from time to time with the Science for Technology and Industry and Vision Matauranga is in that too, which is quite fascinating because that is about new fields of technology for industry. It is trying to find a way to make that relevant in an indigenous way and making that a two way connection.

Deliah Balle, Te Arawa River Trust Iwi: I recently went to Monash University with a United Nations Global City Compact. While we beat ourselves up here about not having that spiritual and Iwi perspective, they have nothing. We talked about environmental sustainability on a world stage but the indigenous view was totally missing from the whole plenary. That was so strange to me. I believe that fabric is being woven well into our thinking here.

Question, Steve Chadwick, Mayor: *David, now you live in Australia, you might want to give a comment from your Australian Rivers Institute perspective?*

Prof David Hamilton: Times are changing and typically in a public meeting there is an acknowledgement to the owners and caretakers of the land. But there is still a lot of work to do.

Question: *My concern is around the responsibilities and mandate of regional and district councils. Warren mentioned the Canterbury Regional Council and the $300 million loss which, to be a little facetious, is perhaps used as a justification for doing nothing to encourage change. Lake Ellesmere/Te Waihora is a taonga to the Te Taumutu Runanga and one of our most diverse fisheries with 43 species of fish, one third of New Zealand's commercial eel catch and 167 species of birds. So there is more to consider beyond potential economic loss. What is the mandate of regional councils regarding environment versus economic impact?*

Rod Oram: I had no idea Lake Ellesmere was that amazing. To me there is no contest; it is the lake rather than dairy farming that takes priority. That is just the sort of decision which needs to be made at a local level, although nationally this lake could be designated as a place of national significance. Under the RMA places of national significance are vetted by the EPA rather than the regional council. Perhaps we should lobby for Lake Ellesmere to be considered at a national level. Clearly decision making authority should be considered on a case by case basis, but areas of national significance should be at the top of the tree.

When we hear those facts about the value of that whole Ellesmere ecosystem to the community, in social, economic and environmental terms, it is a complete failing that the continuing degradation of that lake has been allowed.

To give some credit, some years ago several groups including Fonterra, Ngai Tahu and Environment Canterbury committed to a process to save the lake. How it has got to its current state is a tragedy and a failure of the system. The RMA was set up to ensure that this should not happen, through a process designed to protect land relative to its value and significance, and it clearly this process has not delivered. Geoffrey Palmer was the architect of the RMA and said it was intended to have a whole suite of national policy statements to support the original document, but that has not happened. Inconsistences between one regional council and another have prevailed and created these diverse outcomes. Whether a national policy statement with an agreed suite of values on fresh water for New Zealand would have saved Lake Ellesmere who knows? I suspect alarm bells would have started a couple of decades ago which would have saved a lot of angst.

There is a call in the legal community and groups like the Environmental Defence Society (EDS), and many others, for a royal commission to work out what the next generation of environmental legislation should look like. That would be immensely helpful and a number of parties in the election campaign are calling for that. I argued in my Salmon Lecture for replacing the RMA with the ERA - the Ecosystem Restoration Act. We could improve the fundamental principles of the RMA to achieve the same effect, but it might be better to have a very big change so long as it was supported by case history and precedent so there was no relitigation of 20 years of environmental legislation. EDS has a 20 month project funded by the Law Foundation to work on that very issue and my hope is it would be an even bigger leap forward than the RMA was in 1991.

Mayor Steve Chadwick: I agree with you, we need a quantum leap. We keep blaming the RMA. How do we get the very best of expertise from regional councils working with local authorities with a national environmental body guiding us? We have gone down a pathway of reform of local government that just put us to war and have wasted millions of dollars. We have lost the ability to work in a relationship model that is most protective of our ecosystem. The tools that we work with are far too blunt. When a local authority does not like a regulation there is no other address other than in the Environment Court. It is not right.

John Green, LWQS: I am very interested in this conversation, particularly Prof Hamilton’s question which I do not feel you answered. Going back to the experience we had here in Rotorua in 2000 – 2003 it was the politicians saying there was no way to fix the lakes once they were in algal bloom. They did not worry too much about dairy farming, the environment would be fine. Ultimately Lake Rotoiti sorted us out in 2002/2003 with an algae bloom across the whole lake. Dogs were dying, people swimming were itchy, and the water was green and foamy. We had the local ratepayers AGM at the Ngati Pikiao Rugby League Club and 900 very irate, aggressive Rotoiti people turned up. No longer could the councils turn their backs on the Rotorua Lakes. I have been involved through the 15 year community journey with programmes of $235 million to sort out the lakes. Prof Hamilton was very instrumental in ensuring that everything was backed by science and the learning continues all the time. Working together, the Rotorua community has focussed on the real issues that count. Perhaps Lake Ellesmere never had such a proactive community around it?

In 2008 on a journey down to Wanaka passing through land that used to be pine forest and stony dry grassland farming sheep and cattle we were amazed to see how things had changed. The trees gone, green, green grass, thousands of dairy cows and kilometre long irrigators. Clearly an economic focus from Environment Canterbury despite the environmental impacts of these activities.

Why would you leave the decision making of land use in this country to politicians who are only there for 3 years? Their decision making cycle is not long enough to properly balance the environmental and economic considerations they are challenged with. You need an EPA, you need people who have the long term future of this country in their control and their understanding. We cannot allow the politicians to make short term commercial decisions for us. It simply does not work.

Rod Oram: That is the point John and the problem with the RMA without national policy statements that set a national standard for these really important issues. There is a coastal policy but not enough to set a bar that is non-negotiable. Looking at the Nordic countries, they have been infinitely more successful than we have around protecting their natural assets. They have non-negotiable standards on fresh water, on soil health, on biodiversity, on fish stock and coastal development. Then politics is at the margin and the basic standards cannot be breached, which means control has been wrenched away from the political milieu.

Warren Parker: My mind is on Houston, Bangladesh, poverty in South Auckland and increasing tourism. We are in a globally connected economy and I am not sure people understand what tomorrow will look like. You alluded to Sir Paul Callaghan, who seems to have become the default vision for New Zealand's future, and the importance of vision and aspiration and helping people to be able to engage in a future that is plausible and reasonable, in which a child in South Auckland has the same opportunities as a child in Southland or Rotorua.

Lots of capital is allocated into land and buildings and less into innovation and new jobs necessary as computers change the future. In this view we must have an ecosystem that is healthy. But it is not going to revert back to what it was like with a billion people on earth, it has to adapt to 9½ billion. I welcome gene technologies, I welcome innovation; plants four times more efficient, reducing methane from animals, and so forth. But could you both talk about creating a national version that is plausible, that we can get behind, support and work toward over several decades.

Sir Rob Fenwick: You are absolutely right and the risk for some of us old tree huggers is to get swamped in nostalgia and the way things were. They will never be the way they were. We need to look to people like my friend on the right (Eamon) for the world that they and their children will inherit. If we are going to protect New Zealand we must have a shared vision around what it stands for in the world and things within that are precious to us, where we can add value to products and why people want to visit us. It is these natural assets that we must protect, such as the biodiversity of fresh water and soil health. The current framework is failing us and the only way it can be restored is through a different framework, a leap forward that affects the values that we aspire to, not just based on narrow economic values, but including a holistic and ecosystem approach.

Rod Oram: Human society covers a range of people from those who are really visionary and progressive to those who are intensely conservative. For the last 9 years we have been led by conservative and short term thinking, and I believe it has squelched an awful lot of stuff in the country so I am very interested in the election debates going on now and whether there is a shift. Of course everybody tries to catch votes around the centre, but the question is whether that centre has been redefined. The increased interest around water with the public is a very good example and maybe things are changing.

Many people have an understanding of what they want, but I am haunted by the outcome of the work that Landcare Research did 10 years ago that came down to 4 scenarios. The vertical axis was from depleted resources to abundant resources and the horizontal axis was from an individualist society to a cohesive society. When that work was canvassed around the country a lot of people picked the independent Aotearoa scenario which was for abundant resources in a cohesive society. But scarily those same people feared that the way we were going would be with depleted resources in an individualist society, the new frontiers scenario.

The research found that it was as pervasive in school children and average citizens as it was amongst senior civil servants and politicians. There was a sense that we are not in control of our destiny because the vested interests are too strong and prefer the status quo because it suits them. Landcare has some new funding to revisit that work and I am intrigued to see whether the mood has changed. Do we now feel more capable of taking things into our own hands? I think that is the big change underway which is crucial to achieving what we want to achieve.

Eamon Walsh: Yes it is an issue that a lot of young people do care about and with the elections coming, we can vote. Young people are leaning towards parties that offer solutions to climate change.

Question, Mayor Steve Chadwick: *So Eamon, why are quarter of young people not enrolled to vote and yet the election is only 3 weeks away?*

Eamon Walsh: That is a huge issue. One of the main reasons is because they are not educated about the political landscape. Schools are now tackling the issue by teaching young people about what political parties are offering so they can make an informed decision. So often they do not know, nor do they think it is important to vote. We need a mind shift because it is incredibly important for young people to vote. We are a large part of society and obviously decisions that are made now will affect us in 5 to 10 years' time.

Max Gibbs, NIWA: I have a whole raft of questions but will stick to one. I am a practical technical scientist and always have been, my family came up through number 8 wire technology. My two fields of research are lake research and sediment tracking and training, conservation of soil for sustainable food production around the world. These fields may seem totally different but the sediment that comes off the land gets into the lakes and carries nutrients which cause pollution in the lakes, so the two fields actually work very well together.

It is the people responsible for what goes on around lakes that are not working together. In Lake Ellesmere some people try to restore the lake with certain conditions set up. Another group want to change the settings for the lake level to 1½ metres, the next group come along without consultation and open the gate so that it drops down to 0.6 metres. There is a lack of coordination between the various parties.

Question: *How do you get a community to communicate together? We have a perfect example here in Rotorua, the LakesWater Quality Society and the councils have done a fantastic job together, but how do you transmit that to other communities to coordinate their efforts rather than wasting money by one group doing a set of research and another group taking the benefits of that work away?*

In the absence of a stronger set of regulatory settings it is probably the random process of finding leadership. Here it is people like John Green, Steve Chadwick and others. When leaders coalesce around a great idea things change. That is how people power manifests itself in a random process. In parts of the country there has been an absence of it, or leadership has been vested in the hands of those that do not rank the values of the natural environment highly. It is a high risk game to wait for a leader to come along. Hopefully technology will help in communication and enable us to work together in a more collaborative way, which leads to new forms of participatory democracy.

We need a much greater common understanding about what we are trying to do and thus a common purpose. However, there is still an important case for a competition of ideas, because the moment we have 100% agreement we go to sleep and stop challenging ourselves. Are we on the right track? Are we making the right decisions? I am all for a greater sense of common purpose but it is important to have legitimate and well based competition for what we are trying to achieve.

Mayor Steve Chadwick: It has to come from outside the political domain, but democracy is the tool we use, its imperfect, it is not a popularity contest and it is hard. Fellow community board members and councillors would say we hardly inspire the right people to engage in politics, either at a local or national level. It is more and more difficult with media scrutiny and one has to be really brave to stick to lofty ideas, which come from outside.

Question, Sir Rob Fenwick: *Eamon would you consider politics?*

Eamon Walsh: No not for me, it is a dirty game, but we do need people who have strong morals who stand up for what they believe, people who care about our nation and for the things that matter, such as the environment, which is a pressing issue that will affect young people.

Question, Geoff Rice, AFOMA: Once you have been a doctor for 10 years Eamon, maybe you should be Minister of Health.

I will start by saying I am not a vegan, I love my meat, I love dairy, I probably eat all the other bad stuff too. I have owned thousands of cars because I am a retired car dealer. I am the elephant in the room when we start talking about predators, which tells me that we need to change our behaviour. We do not have a choice. Iwi are in the business of protecting our mana and that is our responsibility. Over the years I have watched producers grow more dairy to make more. I have been a kiwifruit grower, growing more trays of kiwifruit to make more. It was not that long ago when 90 million trays per annum produced by New Zealand was an impossible thought. This year we will produce 140 million and it could tip 200 million in the not too distant future. That is a huge mistake, if we are going to produce quality products we should go the other way - produce less, protect our environment and our land, create a better product, sell it to the right people and make more money.

Concentrate on quality, not quantity, your thoughts around that please?

Rod Oram: Yes absolutely, however we also need to be very mindful that cellular agricultural contained farming with its zero emissions in food production seems to be the overriding key issue. That is what we are going to have to meet. So yes to quality, but making sure we do not become some quaint back water of the totally natural because that is ultimately not going to work.

The other challenge is to change the incentives. Dairy farmers farm for capital gains, not for income, because drivers are there for that. We need to change those drivers as well as our societal values. Lastly, we still give away a great deal before ensuring that we have captured a fair proportion of the value, thus generating a value chain. A lot is captured down the value chain by other parties before the final customers. This requires a big change in our relationship with the end consumers, reinventing or inventing a parallel value chain closer to the end consumer.

The Primary Growth Partnership (PGP) is a joint venture between government and industry that invests in long-term innovation programmes to increase the market success of the primary industries. Unfortunately, almost half the funds have gone into the red meat industry which has not changed very much. Another big chunk has gone into the dairy industry, mostly to on-farm not downstream issues. We have continued to underinvest in that downstream activity.

Exactly the same concerns raised about the primary sector apply to the tourism sector where our quest for high volume at the expense of value is not only shrinking the margin for everybody but destroying the product on offer. It is a result of a de-regulated aviation industry that has allowed everybody to come to New Zealand as tourists with hardly any barriers to entry and no fee at the border. That may change with this election. Currently it is a pathway to self-annihilation of a wonderful industry, and the perversity of this quest for volume rather than value based growth is mad.

Could I just defend growth in one important way because it is a discussion that often comes up. People say to stop growing because of the damage to the planet. I say the human population is 7½ billion now, heading for 10 billion. We have already got several billion people on the planet seriously starving or underfed. Therefore, we need to supply a lot more to 10 billion people in due course. We will have to produce more but wealthy countries cutting back will not solve the problem even though we are already damaging the environment.

In very simplistic terms we need good growth where the technology, economics and values that drive the restoration of a healthier ecosystem sustainably provide us with more food. Concepts such as biomimicry, technology borrowed from nature, or the circular economy ideas reusing everything we make which is completely unmade, which is well beyond waste minimisation or recycling. This means reusing things down to parts per million, not just the natural input, but the compounds that we humans make. Conceptually we can have good growth delivering more for people as opposed to the very bad growth that we have now. Imagine a world that looks like that. However, we have an astonishing amount of work to do over the next two or three decades, working out what that means and how.

Warren Webber, Facilitator: Thank you Rod. We will draw things to a close because we could go on all night; it is an extremely intriguing and interesting discussion.

Mayor Steve Chadwick: Thank you everyone. There have been some wonderful messages and it is very affirming thinking of the Rotorua district in which we live with our spatial planning, looking at what is a sustainable population. Our community has said very clearly they do not want a boom bust growth. They want sustainable growth to about 100,000, and at present we are 74,000. We are looking at land use in the spatial plan to sustain that growth, with a connected, innovative community, looking after our forests, lakes and land.

Session 5 : THE EIGHT LAKES OF TARAWERA

SESSION CHAIR – Don Atkinson, LakesWater Quality Society

PREDATOR FREE NEW ZEALAND BY 2050 – BENEFITS FOR THE LAKES

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Martin is the Deputy Director General for Biodiversity at the Department of Conservation. Recently he has led DOC's 'Battle for Our Birds Programme' and the operational components of Predator Free 2050.

TRANSCRIPT

Morena. Tena koutou katoa
No reira tena koutou tena koutou tena koutou katoa

I am here today to speak to you about Predator Free 2050 and the benefits of this programme for the lakes. I am a new Deputy Director-General and only been in my role for 7 weeks and that is because the biodiversity business group that I now lead has only recently been formed. I am accountable for the delivery of the Department's science technical monitoring and reporting functions and this is the first time these functions have been brought into one business group within the department, which is enabling us to have a fantastic focus on our national biodiversity work.

I am delighted that my first opportunity to speak in this capacity is to this symposium, but there are a couple of things I should get off my chest to be really clear about before I start. The first is, I am from the South Island, and if I had to identify my mountain it would be Aoraki Mt Cook. I am used to man-made lakes that have pristine water, very little biodiversity around the edges and all the water runs out of them in straight lines, so fantastic lakes like Tarawera are something new to me, and a very different environment from where I am from.

The second thing I should admit is that I am not a scientist. Sadly, my background is as a lawyer. You need to know that, because as a lawyer I have the ability to sound compelling and convincing about almost anything without really knowing a lot about what I am talking about. So the science I am going to talk about today may not stand close scrutiny.

Included in my accountabilities is responsibility to coordinate the Department's response to the Predator Free 2050 initiative. That means for the work streams under our operational delivery arm, our partnerships group, and also under our communications team, I hold accountability to build the DOC component. This initiative is led across New Zealand. It is not an initiative led exclusively by the Department and I am charged with building the DOC component in association with the Predator Free 2050 Ltd company of which the Government is a shareholder with the Predator Free Trust, the Bio Heritage National Science Challenge led by Andrea Byrom as Director, and then key stakeholders, obviously key among them Iwi and also the NEXT Foundation.

It is important that I share a little bit of the Predator Free context so that we all start on the same page. On 25 July 2016 the Government committed to the goal of New Zealand being predator free, meaning free of possums, rats and stoats by the year 2050. The aim of the Predator Free 2050 programme is to deliver huge benefits to our threatened native species and for the social and cultural links that we have with our environment.

Paul Callahan said of a predator free New Zealand, 'It's crazy and ambitious but it might be worth a shot'. He also said this could be our Apollo programme. This gave my Director-General the most fantastic elevator speech whenever he enters the Beehive. He can get into an elevator and say, 'This is our moon shot as New Zealanders'.

Predator Free 2050 struck a deep chord with the people of New Zealand, reflecting our attachment to our species and landscapes. I can give you one specific example. I was invited to the launch of Predator Free Miramar about three weeks ago. In just one suburb in Wellington, there were 600 people who turned up on a rainy, wet, windy Wellington Saturday morning during kids' sports. There were presentations, sausage sizzles and the local supermarket sponsored traps that were built on site and handed out for free to the community. There are now only three suburbs in Wellington that do not currently have an organised predatory free community in place.

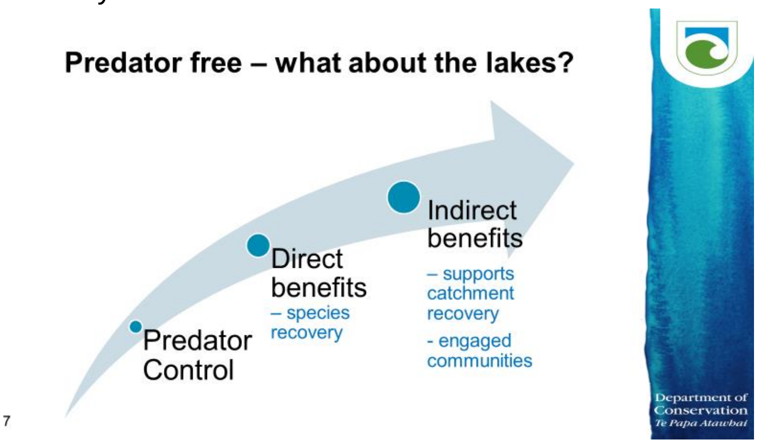
What are we all working towards, all these people turning up and grabbing traps? We have an initial framework as we start our work under the programme; that is the interim list of four 2025 goals. We want create an extra million hectares of land controlled through

Predator 2050 projects, in addition to the current baseline work that the Department does as well as the work of OSPRI and Regional Councils.

We are looking for a scientific breakthrough capable of eradicating one or more of possums, rats or stoats and this is why a link with the Bio Heritage National Science Challenge is so very important. We are also looking for areas of more than 20,000 hectares protected without fences. The maximum we currently have is around 3,000 hectares behind a fence, but the idea is that we remove the fences, eliminate and defend, and then scale up to 20,000 hectare blocks using natural and defendable boundaries. The fourth objective is removal of introduced predators from all offshore island nature reserves. There are about six left now that fit within that category, the biggest being the Auckland Islands in the sub-Antarctic.

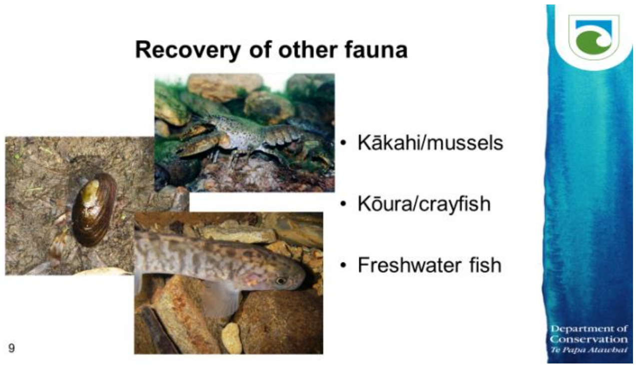
DOC has appointed a range of nine Predator Free rangers and I mention that today because I want to ensure that when you have the opportunity to connect with a Predator Free ranger you might look at the work that is happening in your community and maybe, with other community members, get involved. There is one in each of our regions and their job is to help communities to scale up predator free activities and coordinate community effort.

Daniel van der Lubbe is your local Predator Free Ranger. His contact details and profile are on the DOC website, so go for it. Think about what that predator free initiative might actually mean as far as the lakes are concerned.



Striving for the predator free goal means not only more predator control, or perhaps the development of new tools to deal with predators, but it also means a better alignment of existing efforts and a chance to leverage off each other's work to maximise the collective impact of the predator control work that we do. This will result in both direct and indirect benefits for our lakes and waterways.

The most obvious primary benefit is the recovery of bird life. We all know that predators are a major threat to native bird species, in forests and those that utilise lake ecosystems. Australasian Bittern, Scoop, NZ Dab chick and Australasian Crested Grebes are species that are iconic components of our lake biodiversity and highly vulnerable to predation. They often nest on the edges of lakes and on adjoining wetlands and are susceptible to all the usual predators including, obviously, rats.

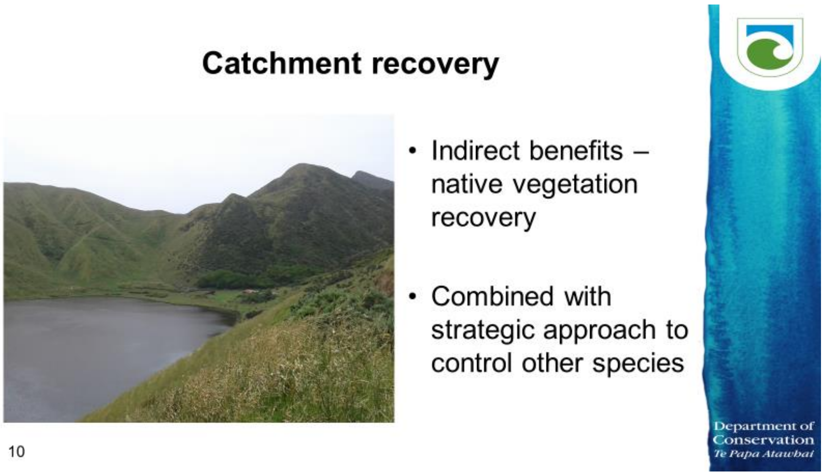


Recovery of other fauna is also a clear direct benefit. Predators are also a threat to some native species and large aquatic invertebrates such as crayfish and kakahi. We know that rats dive for freshwater mussels and there are various reports of fish predation including species like koaro. These freshwater species utilise habitats at the terrestrial aquatic interface and they are all very susceptible to ground-based trapping in that interface area.

There are also a number of indirect benefits and perhaps this is where the most exciting opportunity is. You will hear more from Jan Hania who is presenting on behalf of the NEXT Foundation this afternoon.

I want to talk about the indirect benefit in terms of catchment recovery as a whole. Control of possums, as well as having a benefit to threatened animals, will also assist the recovery of native vegetation. If combined with effective control of other species - deer, pigs, goats and wallabies - recovery of catchments will help to reduce sediment and nutrient inputs to waterways.

Under the Predator Free banner, DOC is now moving to predator control at landscape scale and identifying defendable boundaries beyond islands within which large scale work can be undertaken.



Fresh water is a big driver in DOC's collaborative landscape approach and the way we look at whole of catchments. A principle that we have identified internally to inform our predator free landscape scale investment is alignment with other programmes of work. We have used the MFE vulnerable catchment work as a guide to inform that.

One great example at the top of the South Island we supported Ngāti Koata with technical skills and assistance to enable them to be successful in restoring the wetlands at Moawhitu on D'Urville Island. If we can put predator free effort into catchment scale work it will ultimately improve the river and lakes that the catchment feeds.

Another indirect benefit that we cannot lose sight of comes from harnessing the power of community. The predator free announcement has taken off at the community engagement level and the way they responded really struck me, as opposed to something like the flag debate which was hard to get momentum or engagement from New Zealanders. People have picked up the Predator Free effort in their communities and it has been hard for DOC to keep up. Perhaps that is not a bad thing. Communities show their desire for enhanced conservation outcomes at their place and that is what they value the most.

The opportunity exists to lever off this new and active community to bring them into projects supporting catchment recovery. What has occurred to us at DOC over the past few months is that rather than being a conservation initiative with community benefits, Predator Free is a community initiative which has conservation benefits.

Can we make a difference? This is where my science might get a bit dodgy so bear with me. We are undertaking large scale predator control in a number of wetland systems often adjacent to lakes. It is too soon to say how successful these have been at reversing declines in threatened water birds but at Awarua-Waituna in Southland, fernbird numbers have been steadily increasing since predator control commenced back in 2010.

I want to mention a connection to the Department's freshwater stretch goal which is that 50 freshwater ecosystems are restored from mountains to the sea. We have started to shift our attention to working on vulnerable catchments including partnering with Iwi and Councils. The Department has also been directly involved in supporting a number of freshwater improvement projects such as Lake Inoke, Waituna Lagoon, Waipoua River, and Moawhitu Lake on D'Urville Island.

Here is a slide both Steven Spielberg and Peter Jackson would be proud of. It is obviously a little bit of a montage of what we would hope to achieve in a wetland system.

I want to acknowledge a couple of things. The first is that we are often asked about cats and whether we can achieve this vision without focusing on cats. We know cats have an impact on native lake birds. We target, as a department, feral cats on conservation land, but responsible cat ownership is a community responsibility as much as it is a conservation effort. It will be interesting to see as communities invest in Predator Free 2050 how they define what responsible cat ownership means.

The Department is involved in the National Cat Management Strategy Group providing input and we are also engaged in various RMA proceedings for new subdivisions that neighbour onto high biodiversity value areas looking at cat free subdivisions. It will be interesting to see how this conversation evolves over the coming years.

The second thing I wish to acknowledge is that we are only focussing the Predator Free banner on stoats, rats and possums. We do have other invasive animals - pigs, deer, goats and obviously wallabies, and these species directly contribute to erosion and obviously lake water quality. All I can say about that is that the predator free initiative is not diverting away the Department's efforts to control those animals, so this is work that will be in addition. We are not diluting or losing our focus on those other invasive species.

The third thing to acknowledge is that to achieve the predator free vision we cannot just do it through community effort with the current tools. The next interesting conversation for New Zealanders to have will be about the influence of gene editing, understanding the difference between gene editing and genetic modification and we have had discussions previously as a country around that. How do we have an informed discussion about the role that gene editing might be able to play in terms of dealing with our predators?

Is New Zealand up for a situation where over the next two to three years we invest in gene mapping of the stoat so that when that technology arrives in a few years' time we can turn off a gene? We can produce Trojan females who only produce male stoats and gradually that species is removed from New Zealand. The Department is investing quite a bit in understanding how we might be able to inform a debate and build the social licence needed to get to that point, and as a country we make a decision about where we stand on such issues.

In conclusion, DOC is keen to maintain the momentum already building as a social movement under the Predator Free 2050 initiative. There is no doubt in my mind there is an opportunity to enhance a number of existing work programmes and move to that landscape level. It is in that area that we will get the most benefits to the lakes.

Kia ora - thank you very much.

LAKE TARAWERA –
LAKE TARAWERA RESTORATION PLAN

Chris Ingle
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Chris is the General Manager Integrated Catchments for the Bay of Plenty Regional Council. This means he is accountable for delivering the deed funded lakes operations plus other lakes' action plans; he also delivers region-wide Biosecurity and Biodiversity activities, Rivers and Drainage, engineering and land management activities. Previously Chris worked for the West Coast Regional Council for 12 years, ten of those as CEO, and before that was a regional planner at Otago Regional Council. He holds planning and science degrees from University of Otago and has been with BOPRC since June 2016.

TRANSCRIPT

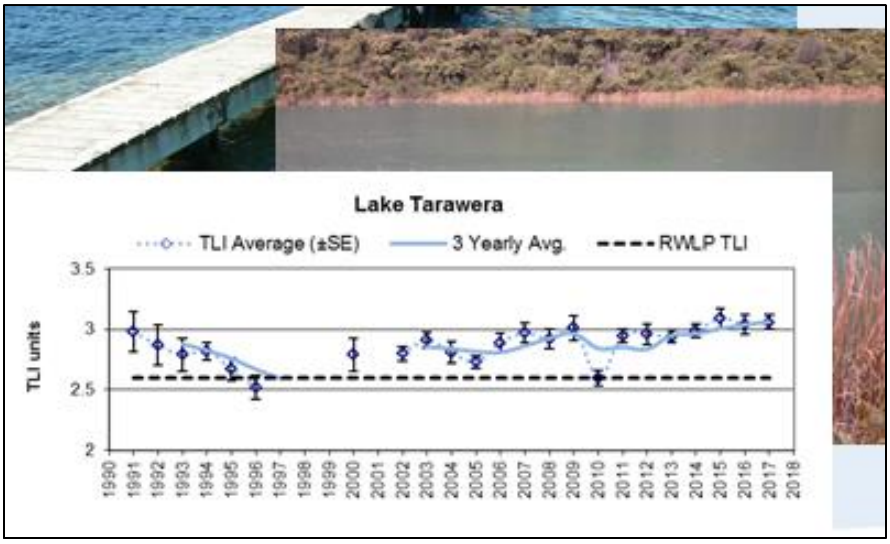
I would like to start by acknowledging the elected members from the Regional Council and the District Council who are here. The work we do together is quite complex and we still have a long way to go to improve lake water quality. I would also particularly like to acknowledge the Lakes Water Quality Society for organising today's events and giving us the opportunity to engage with wider community interest and science groups to look at what the future might hold for the lakes, and what part each of us can play in the solutions.

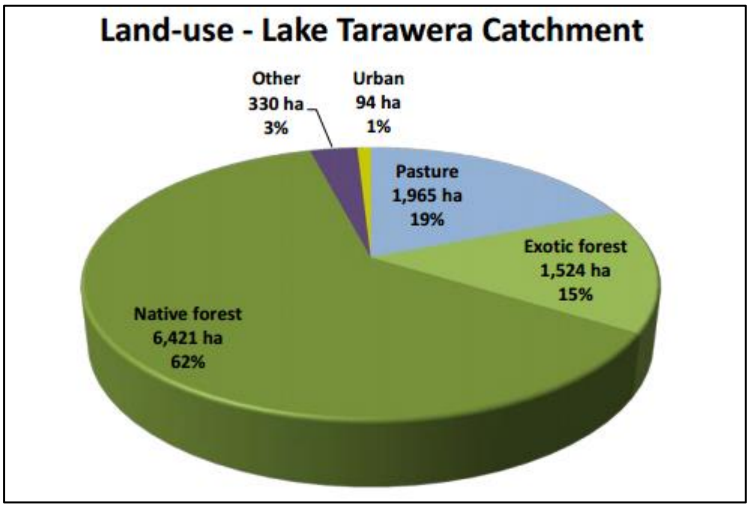
I am quite new in this role and, to be honest, I am still figuring out what the role involves and how this role differs from that of other general managers who have come before me.

I want to acknowledge that I am neither a specialist nor a scientist. I did an undergraduate degree in science but I have mainly practiced as a planner and then as a senior manager. I see my role primarily as connecting people to create opportunities for change or, in this case, help the Lakes Water Quality Society in harnessing science, encouraging and trialling innovative solutions that people have not tried before. Most critically to see if we can agree on a vision of where we want to go: and once the vision is agreed, my job is delivering the results in conjunction with Council's operational teams.

I have been asked to talk about the Tarawera Lakes Restoration Plan. The vision in that Plan is a lake where one can swim, recreate, fish, or do whatever else you want with confidence that the water will be clear, clean and fit for purpose.

Unfortunately it is not always like that. Sometimes it is clear water that we expect in Lake Tarawera but the reality is at times areas of the lake have an undesirable algal bloom with water discoloration from other lakes and streams that feed into Lake Tarawera. The Trophic Level Index (TLI) is an indicator of water quality. High is bad, low is good and the dotted line at the bottom is what we aim for. In the graph that blue line is heading in the wrong direction at the moment and we have to do something about this.





This pie graph summarises the immediate catchment of Lake Tarawera. Dark green is native forest, lighter green is exotic forest and pasture is blue and a little bit of yellow for urban land use around the edge of the lake on one side. It is dominated by forest of one kind or another, and that is good news because that type of land use does not produce a lot of nutrients except at harvesting time for exotic forest. The farming area is about 19% and not intensively farmed.

Lake Tarawera is at the centre of an eight lake complex, so it is not just the immediate catchment on which land use must be managed. These other lakes are variable in terms of their water quality status. Unlike other lake catchments, for Tarawera there is not going to be a simple solution derived from land management in the immediate catchment. We have a complex web of surface and ground water flows between these lakes. This makes management very difficult.

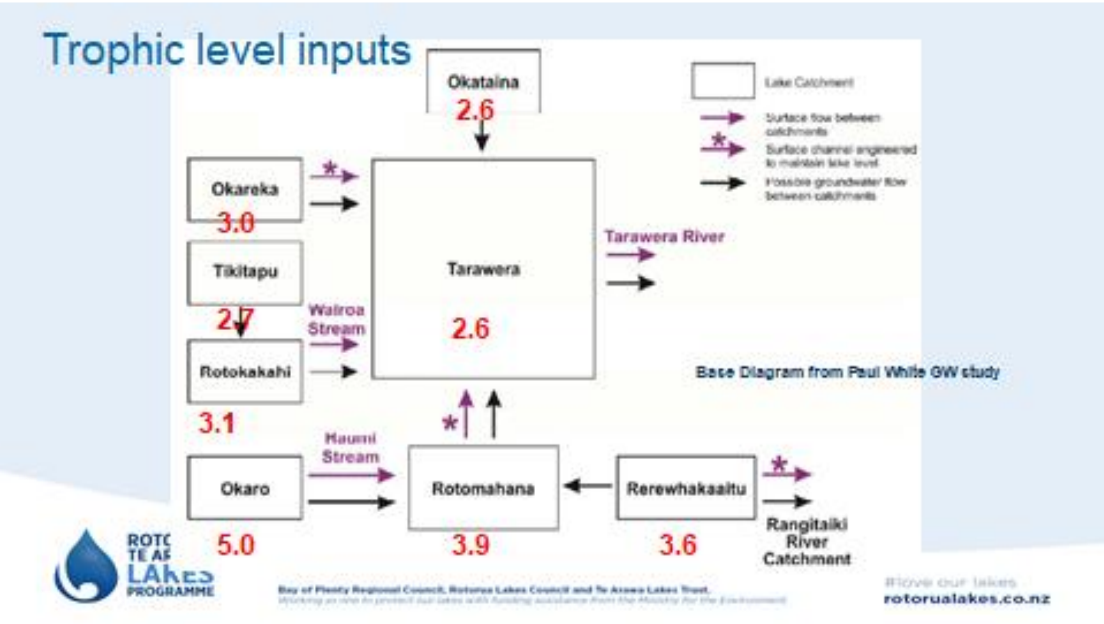
Andy Bruere and I have another problem which has been dominating our time in recent weeks and that is elevated lake levels. After the wet winter, Lake Okareka in particular is at unprecedented high levels and properties around it are at risk of flooding.

We are trying very hard to manage that lake level. There is no natural surface water flow from Okareka to Lake Tarawera. We installed a pipeline and started pumping the water down but it is only going down a couple of millimetres a day. With rainfall events like we had last night it is filling it up faster than we can pump out.

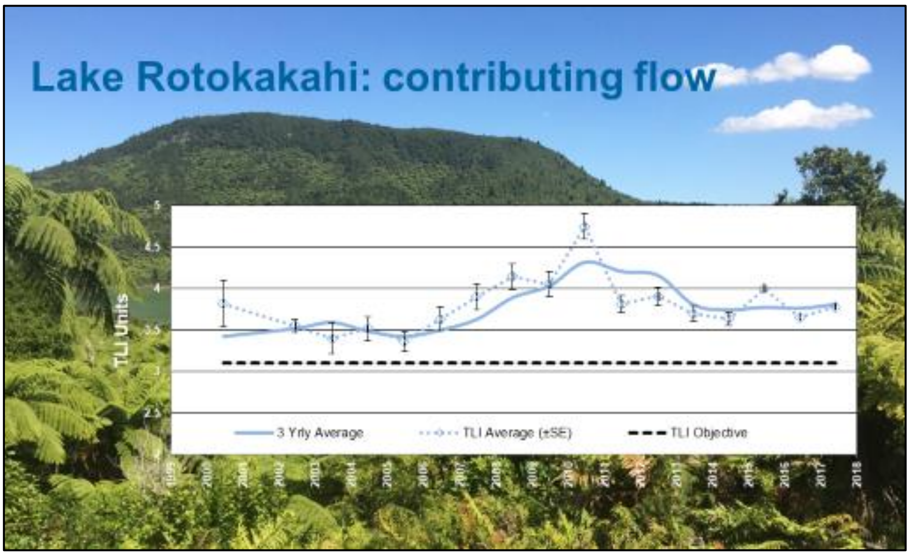
Load	Q (Woods) $m^3 s^{-1}$	Q (adj) $m^3 s^{-1}$	N load $t\,y^{-1}$	P load $t\,y^{-1}$
Tarawera catchment			66.87	4.47
Geothermal		0.4	6.30	5.00
Buried village septic	n/a		0.18	0.02
Okareka	0.49	0.49	3.40	0.11
Rotokakahi	0.5	0.5	3.50	0.19
Tikitapu	0.08	0.04	0.25	0.01
Rotomahana	2.62	1.31	9.10	1.27
Okataina	2.58	1.29	5.25	0.32
Total		4.03	94.85	11.37

This table, which a subsequent presenter will comment on in more detail, but it highlights the phosphate load into the lake. Geothermal inputs are something we cannot do anything to manage. Natural geothermal flows are estimated to bring in almost half the phosphorus and whatever we do, that quantum is always going to come into that lake. We need to be aware of that.

This is a slide from Paul White and his ground water study. The purple is surface flow and the black is possible ground water flows. I do not want to go into detail, I will let Paul do that, but the red figures show the TLI targets for each lake. We need to understand how the water quality target for Lake Tarawera will be achieved in the context of the land use within the contributing lakes and their catchment land uses. The first step is the development of a conceptual model bringing together all known catchment information.



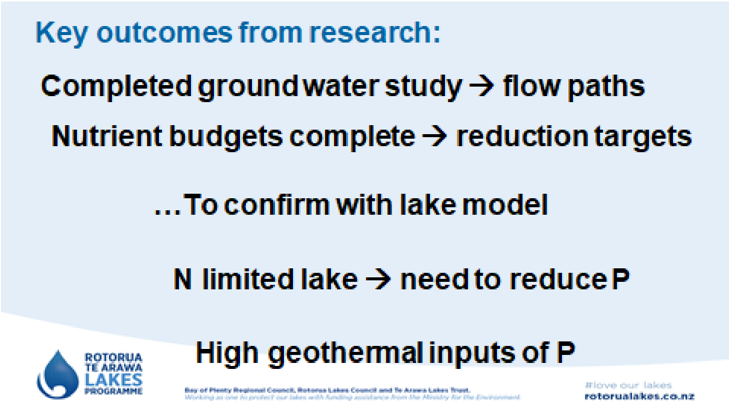
At Lake Tarawera we are aiming towards TLI 2.6 and it is currently over 3. There is a mixture of other TLIs there; for example 2.6 for Okataina. You will notice that the lakes at the bottom are generally a little higher in their TLIs because of the nature of the lakes, whereas Okataina, Okareka, and Tikitapu are around the same as Lake Tarawera. It will be interesting to see in the next phase of study and research how those interactions impact Lake Tarawera as the bottom catchment lake, and whether Tarawera can actually achieve a reduction in TLI, when some of the contributory lakes have higher target TLIs. The progress we make on the outer lakes will affect the speed at which we can achieve improvements for Lake Tarawera. There are still many unknowns.



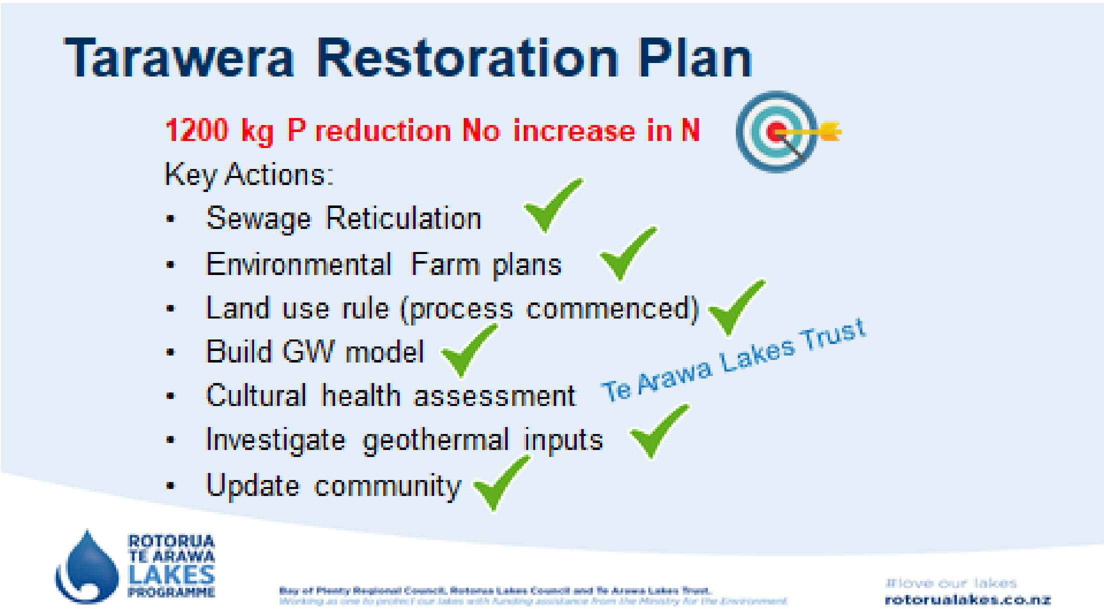
Lake Rotokakahi produces one of the contributing flows. I have picked on a couple of lakes because we have interesting information. This is the TLI graph and again the dotted line at the bottom is the target and the blue line is tracking the actual TLI – clearly we are not there yet and there are a number of fluctuations. We suspect that in the centre of that graph forest harvesting may have contributed to higher TLI levels at the time. There is work to do at Rotokakahi. We have started on an Action Plan but it is not yet complete.

Lake Okaro on the other hand, a farming catchment, has met its TLI target for 4 years, a good news story. Although looking at this year's data I have some concern because it has risen a bit showing that we are not in a consistent downward trend. The light blue line is the 3 year rolling average, to remove the confusion of different seasons and climatic variability. I suspect the very wet winter this year will affect nutrient levels in the lakes, by using the 3 year rolling average we see the longer term trends rather than the noise.

In Lake Okaro a contributing factor to achieving the TLI has been alum dosing. Positive land use change has been going on at the same time, and it is not clear which has had the greatest impact on the TLI. It has not been practical to have a control trial in place to test the steady state against an intervention. We have instead tried to put all actions in place as quickly as possible to improve the lake. Until we stop using alum we do not know whether the land use change, will result in long-term improvements in water quality.



These are key outcomes from the groundwater research that has been completed, which Paul White will expand upon. Lake models, nutrient budgets and targets will be required to determine the relative need to reduce phosphate and/or nitrogen. These discussions were played out in the Plan Change 10 hearings held recently for Lake Rotorua. Lake Tarawera has high geothermal inputs of phosphate that will be difficult to mitigate.



So, to the nub of my presentation, a summary of the actions on the Tarawera Restoration Plan. We have a bull's eye target, but we are not quite there yet. The key actions include sewerage reticulation, which has been boosted by a recent $6.5 million funding announcement from the Environment Minister. Rotorua Lakes Council is leading that work.

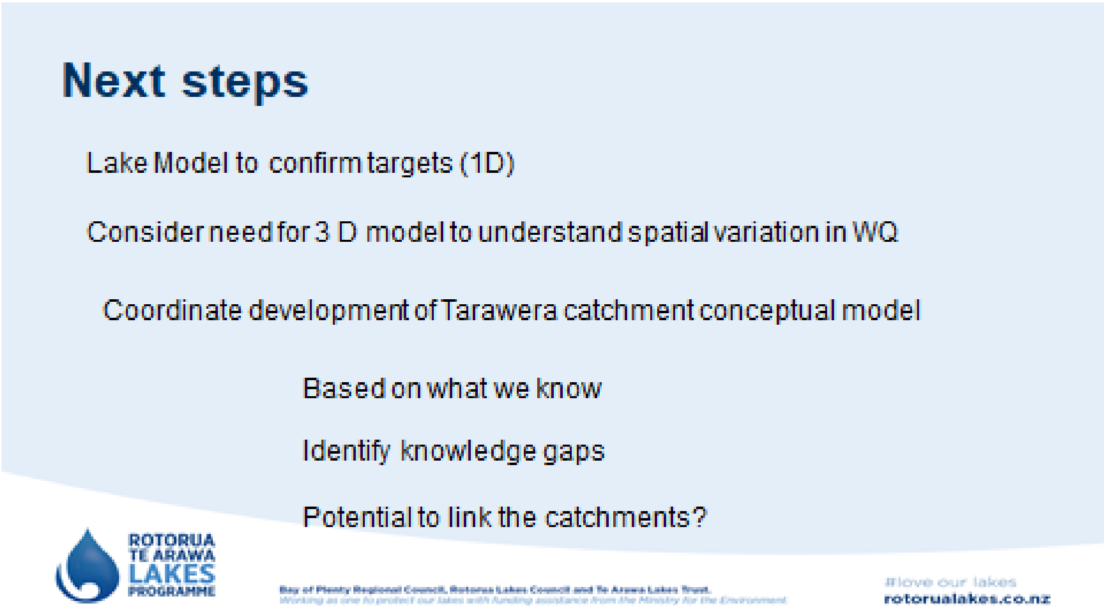
Chris Sutton is helping us with the environmental farm plans project and he is speaking later. They are well under way now in the wider catchment. Work started at Rerewhakaaitu in the early days has now spread out to the whole of the Tarawera catchment. Farmers will be working on that over the next few months; we have given it a tick because it has commenced, but I note that as with most of these targets, it is not yet completed.

The land use rule is an important action that the Regional Council will lead. The Regional Council recently agreed to bring this project forward as the next NPS Freshwater project off the ranks, so that's about to get under way. The actual plan change has not been drafted yet and consultation on that will happen soon.

The Ground Water model I have mentioned several times and that is complete.

The Cultural Health Assessment is also a very important part and Te Arawa will take the lead on that. There is a strategic partnership in place between the Te Arawa Lakes Trust, the Rotorua Lakes Council, Ministry for the Environment and the Regional Council which I assist with and that partnership approach works well.

An important part of the action plan is to investigate the phosphate coming into Lake Tarawera and what can be done to address that. The community will be kept updated as



part of this process, connecting people and bringing innovation in through forums like this one today.

So what are the next steps? We are working on a lake model to confirm our targets. A 3D model is needed to embrace scientific innovation coming in from the Water Quality TAG and elsewhere. We need this to better understand spatial variation in water quality.

We are also considering the development of a conceptual model for the lakes that feed into Lake Tarawera. We need to understand how it all works at a fairly basic level, identify those links between lake catchments and identify any glaring knowledge gaps.

Thank you.

GROUNDWATER STUDY – THE EIGHT LAKES CATCHMENT

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Paul is a Senior Scientist in groundwater resources at GNS Science and has worked for 37 years in New Zealand groundwater hydrology with current research including: 3D models of geology, groundwater flow and groundwater use, that are developed to inform regional council water allocation policy decisions; land use, groundwater quality and lake water quality; and the economic drivers of groundwater use.

TRANSCRIPT

Thank you very much. This talk is on behalf of my colleagues in GNS Science - Mike Toewes, Conny Tschritter and others, and my colleagues in Bay of Plenty Regional Council - Janine Barber and previously Dougal Gordon.

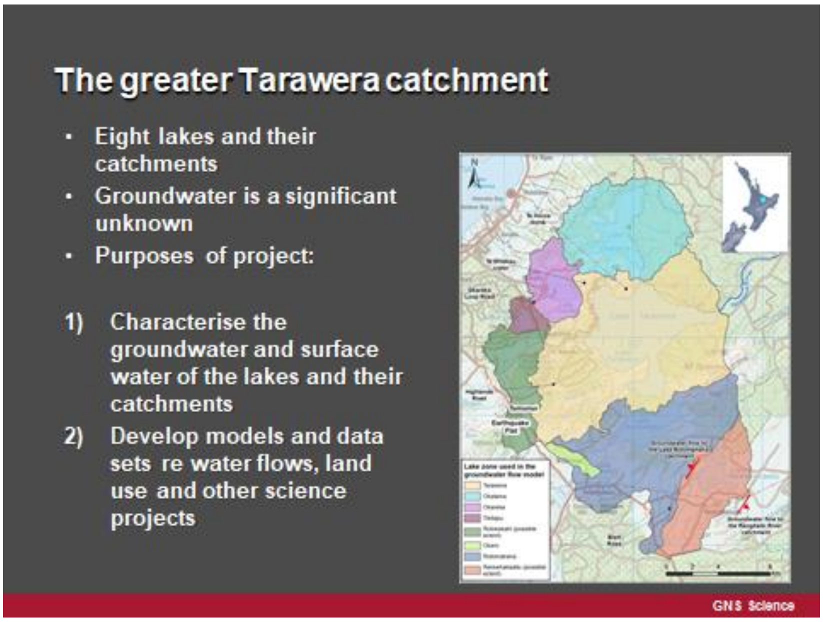
I would like to quickly romp over some of the science we have done since 2002 in the Greater Tarawera catchment, focusing on results. I hope to give people a flavour of what we think is going on in each of the 8 lakes in the catchment:-

- The greater Tarawera catchment
- Purpose of Tarawera project
- Overview of scientific results
  - drilling and some early results
  - geological model
  - catchment hydrology of the 8 lakes
  - groundwater flow
  - nitrogen generation and discharge to lakes and streams
- How results are being used

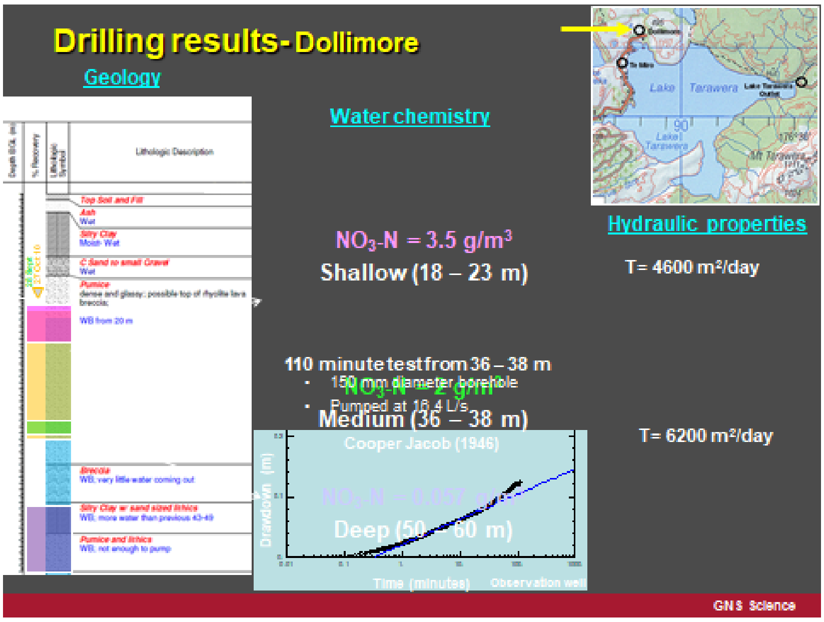
The following slide is the greater Tarawera catchment which includes 8 lakes. Tarawera topographically is at the bottom and rainfall will gradually make its way down to Tarawera from its surrounding area.

What areas are we talking about in the greater Tarawera catchment? Rerewhakaaitu and Earthquake Flat have been the subject of debate within our team and the Regional Council as to where water goes on the margins. Earthquake Flat is included in the Waikato Region and we have included it also because there is evidence that water does flow from this area towards the Tarawera catchment and to the Ōkaro catchment.

We have a situation similar to the Rotorua catchment where part of the Lake Rotorua catchment is in the Waikato region. The Bay of Plenty Regional Council and Waikato Regional Council seem to be working well together in having consistent planning rules around the Waikato part of the Rotorua catchment and possibly the same will happen here.



In 2011 we started the Tarawera Project, a drilling programme, as very little was known about the groundwater system of the area. It is important to understand the groundwater systems to these lakes and I will give a lake by lake potted summary in a few minutes.



The purpose of drilling is to understand the geology, what sort of rocks are down there and the properties in relation to water flow. We drilled three wells, the first being on the Dollimore property in 2011/2012. On the left of the slide is a geological log which is produced by a drilling and shows the most common sediment type which is pumice sand.

We do pump tests, pumping the well, the water level goes down in the well and we can analyse for the hydraulic properties of the rocks in terms of water flow. We came up with numbers, called transmissivity. These numbers are about ten times the numbers in the Rotorua catchment. The implication is that groundwater flows faster in the Tarawera catchment than it does in the Rotorua catchment.

Groundwater chemistry. We sampled for all the nutrients and various other bits and bobs from shallow, medium and deep depths. The results in nitrate nitrogen were:-

- 3.5 g/m^3 in the shallow zones, 18 to 23 metres
- 2 g/m^3 in the moderate depths, 36 to 38 metres
- Less than 0.1 g/m^3 in the deep

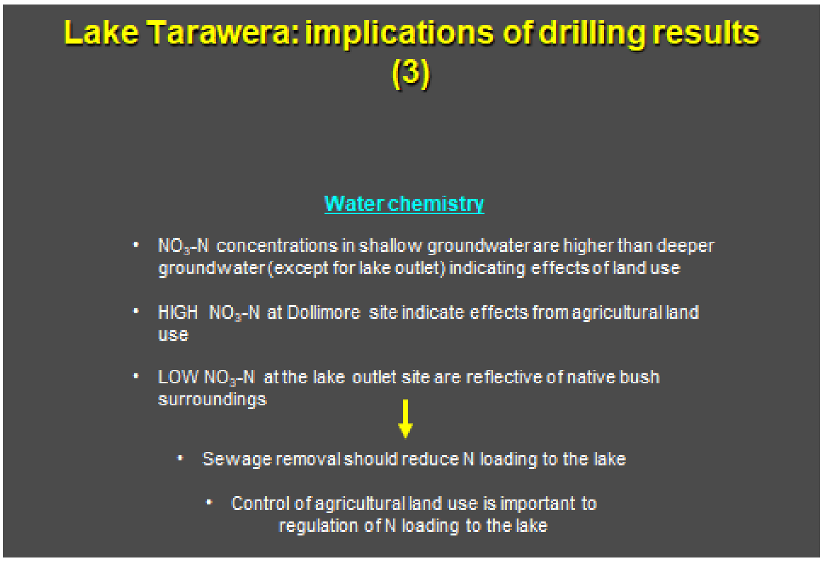
It is very common in groundwater systems to see a decrease of nitrate concentrations in groundwater. Is this number of concern? Yes, it clearly indicates the impact of human activities. That could either be septic tanks or farmland behind the Dollimore well.

Streams flowing into Lake Elsmere typically have a median nitrate concentration of about 3 ppm so this would definitely cause impacts on the nitrogen loading to the lake. In comparison, from a study we did around Lake Rerewhakaaitu in 2002, nitrate concentrations in groundwater around Lake Rerewhakaaitu are up to about 8 ppm and that reflects the intensive use around this lake.

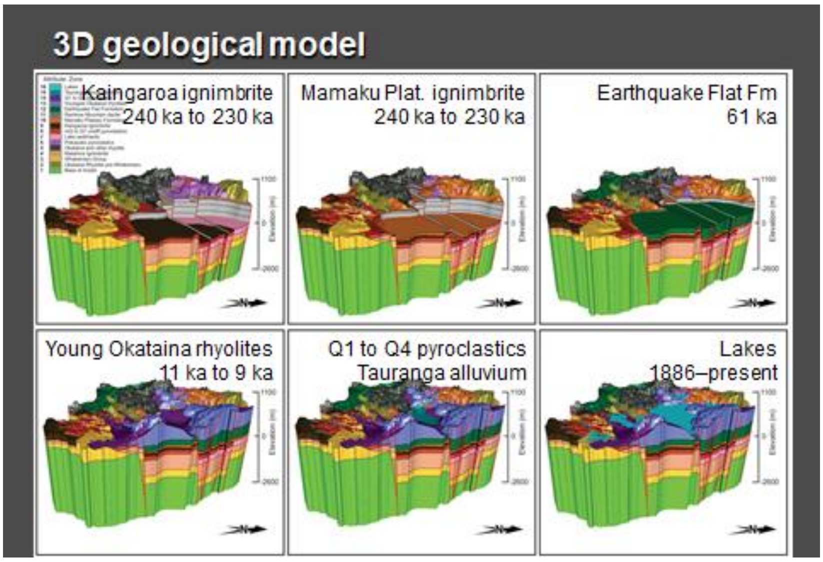
From the geology we found that pumice and ash are the most common lithology, aquifers are mostly unconfined, and confining layers are uncommon. This showed that there is little impediment to groundwater flow and that nitrogen from land use can generally reach lakes. In some of New Zealand's groundwater systems there are denitrifying layers but it seems that these do not occur in the Tarawera catchment and that is because the eruptive products are quite recent.

The hydraulic properties show that the permeability values (K values) range from 14 to 3100 m/day which is typical for volcanic sand and gravels, and they are greater than in the Rotorua catchment. The implications are that nitrogen will respond to land use change and that response may be faster than Lake Rotorua as I mentioned before.

Water chemistry and nitrate nitrogen concentrations in shallow groundwater are higher than deeper groundwater. Sewerage removal should reduce the nitrogen load into the lake. The control of agricultural land uses is important to the regulation of nitrogen loading to the lake.



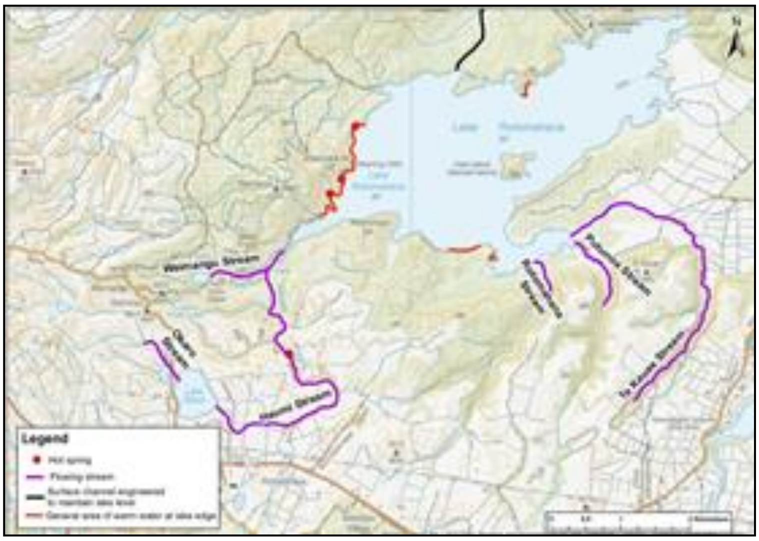
Groundwater can be dated using isotopic methods. We measured the groundwater age to be about 10 to 40 years. For Rotorua the age is about 40 to 180 years. That is consistent with the idea that groundwater is flowing faster in Tarawera than in Rotorua and means that it will respond faster to an increase in nitrate loading from the land and that reductions in taking out nitrate from the catchment will improve lake water quality over shorter timescales.



This 3D geological model represents the layers in the ground from the Kaingaroa plateau deposited from the Reporoa area 240,000 years ago to now. All these layers have different properties. Our drilling programme tries to understand the relevant properties of the key layers in relation to groundwater flow.

Above is a potted summary of some of the lakes, starting off at Lake Rerewhakaaitu. Work we did in 2002 with Dougal Gordon indicated that this lake was perched which answered an issue in terms of the management of that lake. I estimate that this catchment is probably the most intensively farmed in New Zealand. There is a lot of pasture, mostly dairy, and yet the lake is not as poor quality as you would expect if all the nutrients leaked into the lake. It looks like groundwater in the catchment is generally below lake level, which means the lake is perched. So the nitrate from land use seeps down into the ground travels in the directions of the Rangitaiki and Rotohama catchments, and mostly not into Lake Rerewhakaaitu.

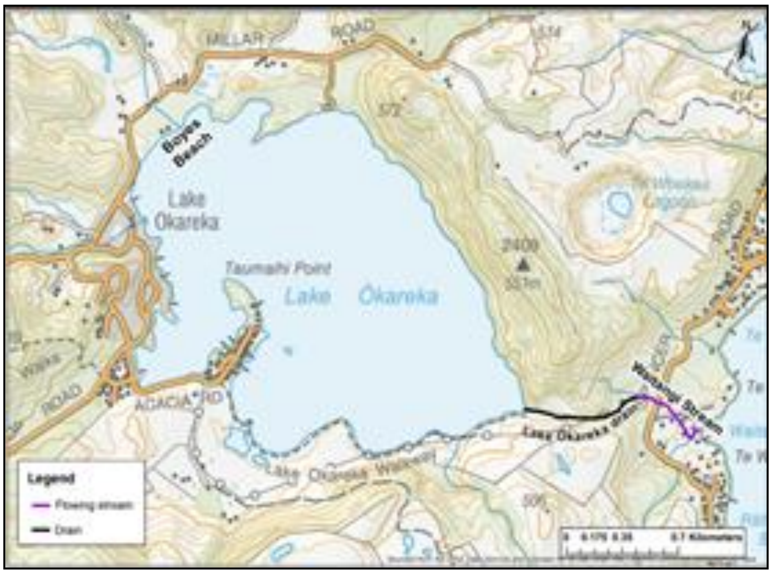
I have spent a lot of time trying to figure out where it does go but it looks like nitrate flow in the groundwater is split between going towards Rangitaiki one way and towards Rotomahana the other way. It is a bit tricky to figure out where the boundary is.



Above is Ōkaro and Rotomahana. The purple streams are permanently flowing and there is one flowing into Ōkaro and the Haumi Stream flows down to Rotomahana. The red colours are geothermal and there is geothermal activity around the lake. The black lines are engineered channels with one going out of Rotomahana. There is another permanent stream on the eastern side which is probably recharged with flow from the Rerewhakaaitu catchment. Ōkaro itself possibly gets groundwater from the Earthquake Flat area.

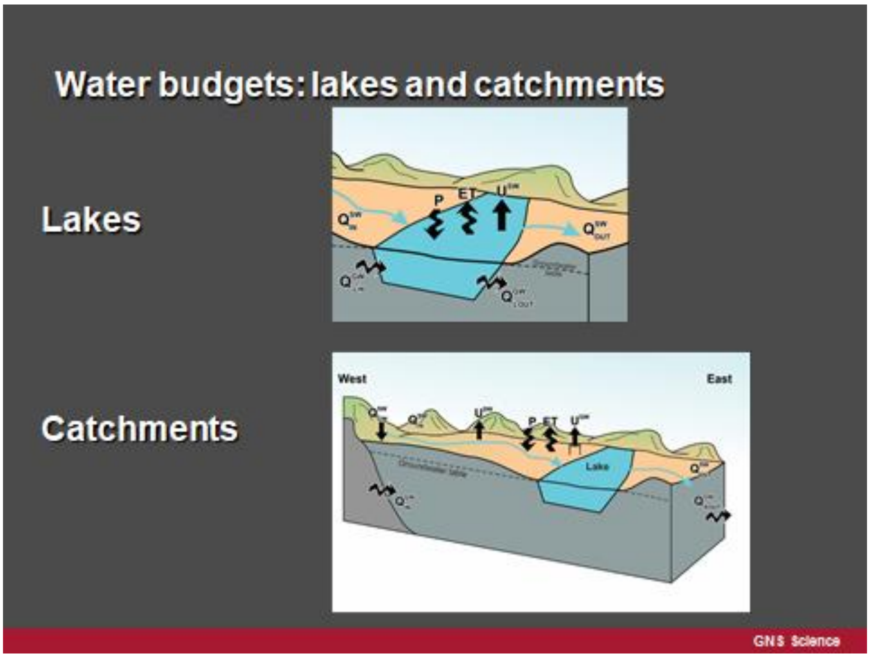
Above is Rotokakahi and Blue Lake. Neither of these lakes have inflowing streams. Therefore rainfall on the catchment all travels into the groundwater system. Generally, 50% of rainfall goes into groundwater. Rainfall in this area may be 1.5 metres, or something like that, per year, that means 700 mm a year goes into the groundwater system. That is a lot of water, aggregated for catchments.

This is Ōkareka which has no permanently inflowing streams and the lake outlet is an engineered structure.



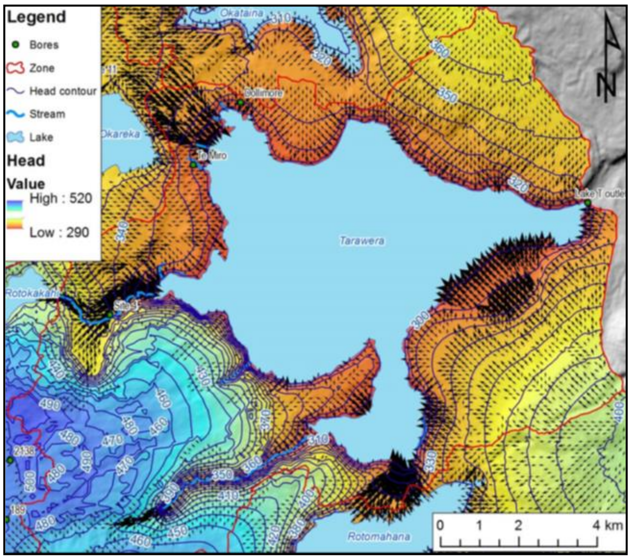
Ōkataina has a couple of little streams in the west and some sign of geothermal activity in the east.

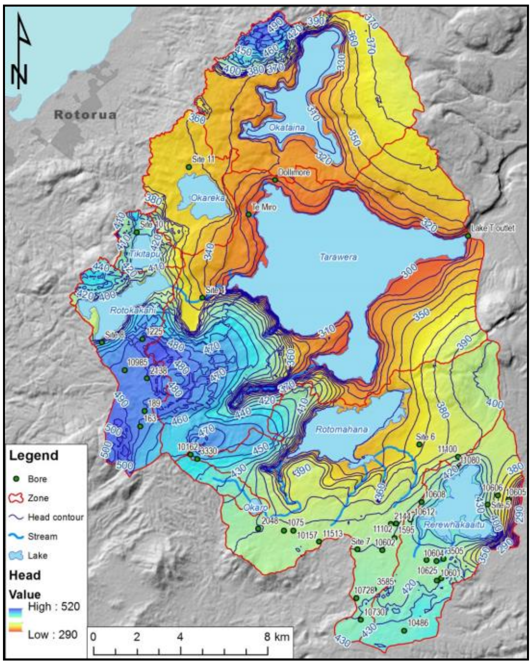
Tarawera is the most complex catchment. There are lots of springs around the lake shore, but not everywhere. For example, few springs are observed between the outlet and opposite Moura Point.

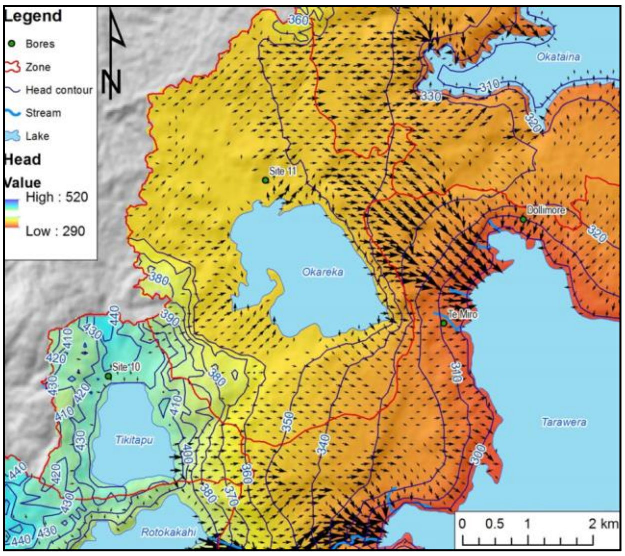


We did water budgets of the lakes to understand the inflows and outflows of each individual lake and the catchments. It is a bit tricky to figure out. One of the first things we did was to estimate properties of groundwater flows for setting up a groundwater flow model.

The next three slides are groundwater flow models. These contours are elevations of the water table. Like any contour map the groundwater table can be represented as an elevation map and we can figure out where the water is going. We can also understand how groundwater interacts with surface water, e.g. the spring-fed stream that crosses Spencer Road takes groundwater from the area between Tarawera and Okareka.

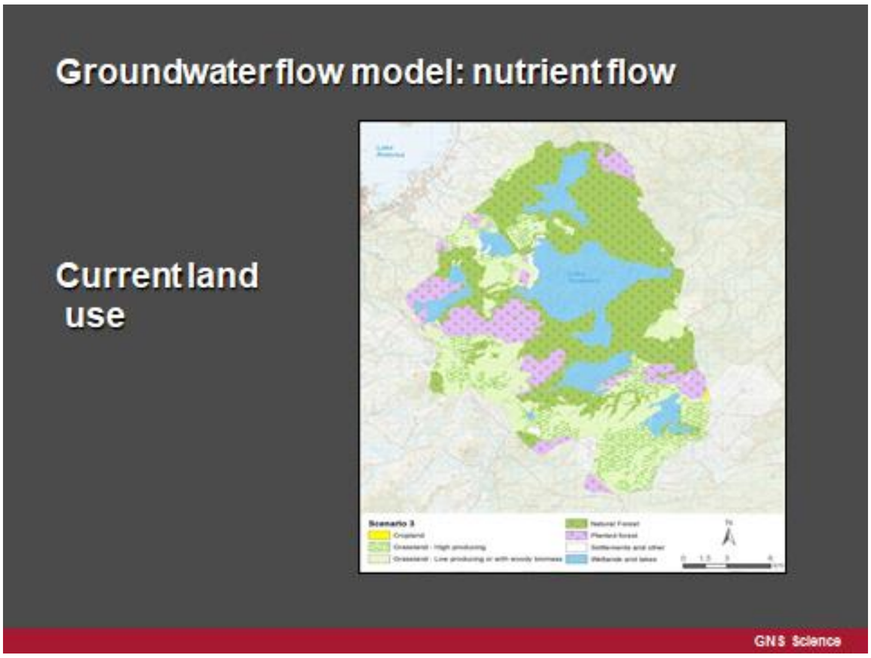






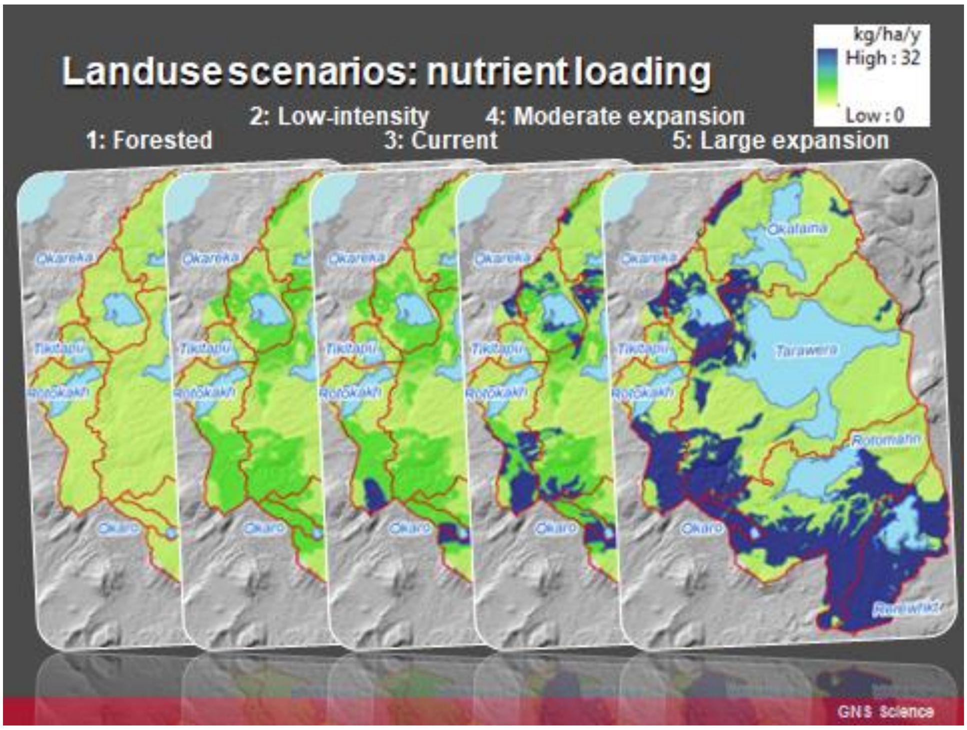
The Dollimore well is on the right slightly above centre of the slide

The computer can work out flow directions. You cannot quite see these details but these are all little arrows. The little arrows are then interpreted to figure out where groundwater is flowing to. The Dollimore well had quite high nitrates in the shallow part of the well. My interpretation of the cause of those would be land use in the area of the craters between Tarawera and Okareka. The arrows are swinging around and then coming down to the lake, so water would be recharged from back up this area. These maps are really important because they make the link between land parcels (and land use in the parcels) and receiving water bodies. We want to know, for instance, if groundwater is flowing directly to the lake or it is flowing to a spring fed stream and then to the lake.



With Alastair McCormack of the Bay of Plenty Regional Council (above) we looked at land use and nutrient flows, particularly nitrogen. The map from Landcare Land Resource Inventory (LRI) data set indicates native forest, exotic forest and pasture in different colours. We looked at what nitrogen could be generated from these land parcels and what the springs and lakes would receive. We looked at current land use, pre-development, pre-human, and a scenario of the likely future intensification. That is not dairy cows everywhere as it is infeasible to think of dairy cows on top of Tarawera. But what if the existing pasture areas were intensified a bit more?

The next slide is actually 5 different scenarios showing the nutrient loading maps translating land use into nutrient loading. Different land uses have different loadings, forest has less than sheep and beef, and others have less than dairy which has less than market gardens for instance. They show a whole lot of zones that we defined around the lake catchments and the green colour goes into blue as the land use becomes more intensified. From forested land use on the left to the current one on the right showing a large expansion in the intensification of farming in the whole catchment.



Following on from that in the slide underneath we looked at nitrogen loading from streams and lakes to understand whether streams are spring fed. In other words are they impacted by land use, particularly nitrogen, or are they not? For the Wairua Stream flowing into Lake Tarawera (Scenario 1, pre-development) we think about 3 tonnes a year was going into there. For Wairua Stream, (Scenario 3, current land use) it has about 5 tonnes of nitrogen per year flowing into the stream with groundwater. Scenario 5 (the most intensified land use) has this discharge increasing to 10 tonnes of nitrogen per year. Therefore, we would have to predict there would be significant water quality effects with such an increase.

Nutrient loadings calculated for many streams and all lakes, e.g.,

Surface water body	Nitrogen loading (tonnes N/year)				
	Land-use scenario				
	1	2	3	4	5
Wairua Stream	3	5	5	5	10
Lake Tarawera	73	105	125	151	211
Lake Okareka	1	2	2	3	4

GNS Science

The Lake Tarawera Scenario 1 (i.e. all forested) about 70 tonnes a year is going into the lake. Nitrogen discharge with Scenario 3 (i.e. current land use) is about 125 tonnes a year, but at its most intensified land use Scenario 5 is about 211 tonnes a year.

In comparison, Lake Rerewhakaaitu shows a very small increase in nitrogen loading from groundwater between Scenario 3 and Scenario 5. This is because the lake is mostly perched.

Chris McBride takes numbers like these and the flows that we calculate and estimates water quality impacts of land use intensification with his lake water quality models.

There are a few more uses as well. We have been looking at the potential effects of land use intensification on spring fed streams. There is a paper on Lake Rerewhakaaitu in the final stages of completion with a student of David Hamilton's and myself. Other lake models are progressing; Chris McBride is going to talk about these models next.

Thank you.

MODELLING THE EIGHT LAKES OF TARAWERA

Chris McBride
University of Waikato
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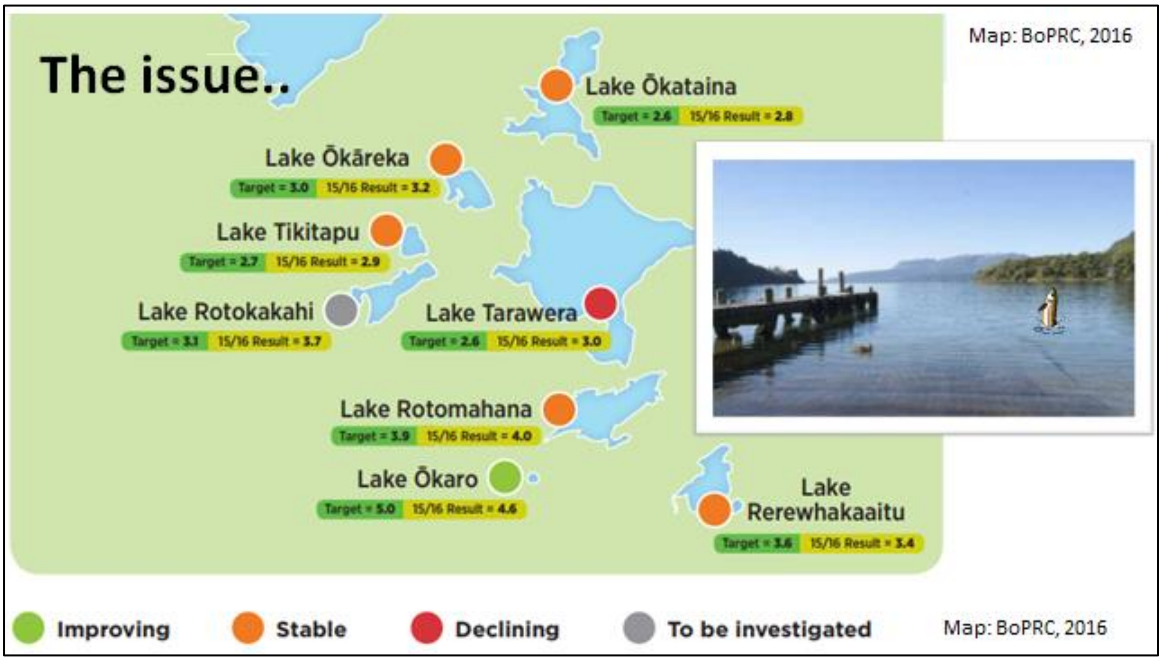
Chris began working on the Rotorua Te Arawa Lakes in 2003, studying food webs using stable isotopes. He has worked for Waikato University's Lakes Chair since 2005, developing and installing lake monitoring buoys, and undertaking lake modelling and nutrient budget studies.

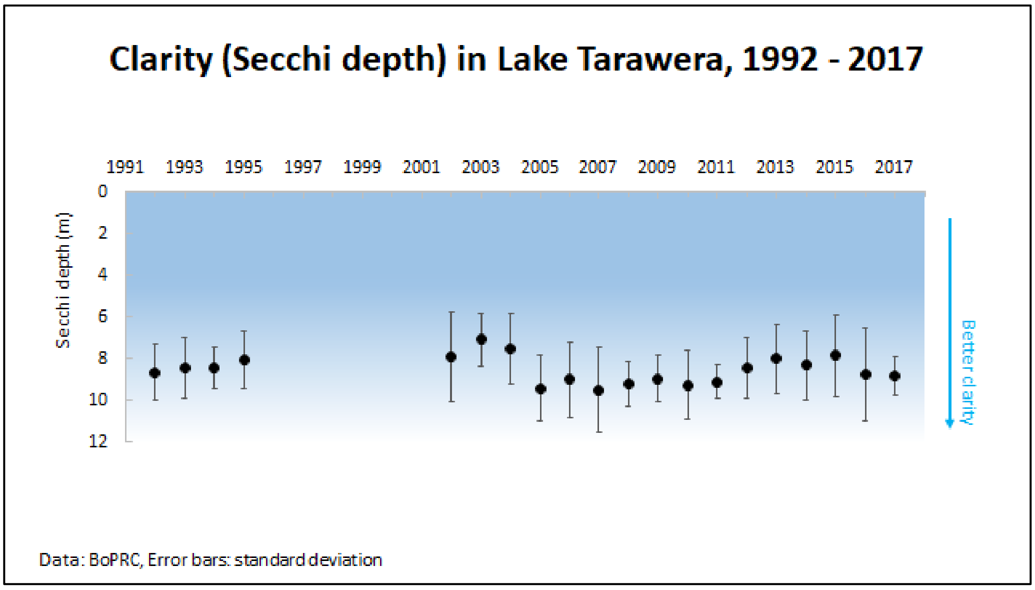
TRANSCRIPT

Thanks for a very generous introduction, and to the LakesWater Quality Society again for organising another fantastic symposium and for giving me an opportunity to present here.

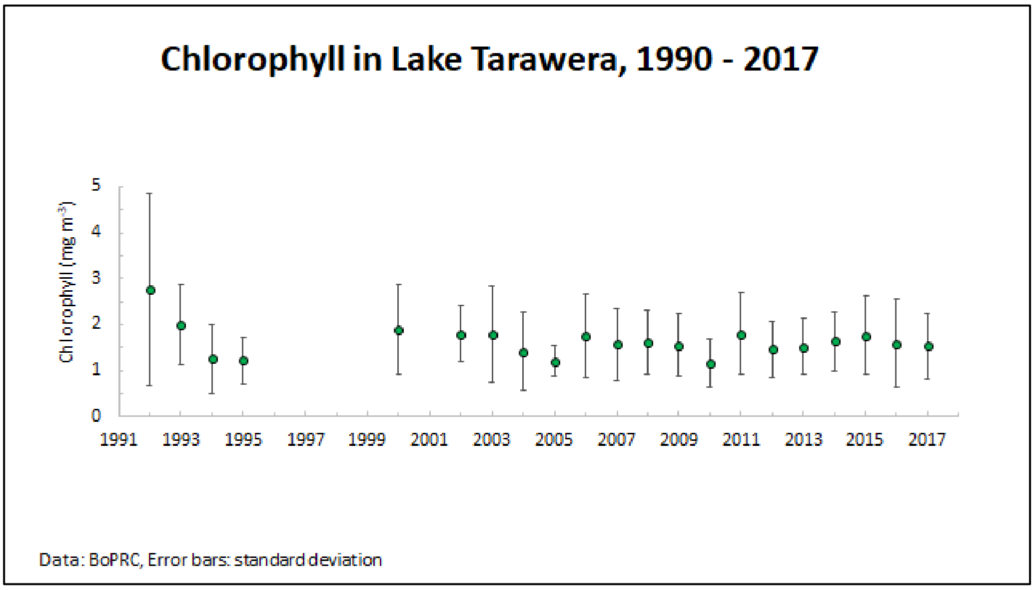
The work I am presenting today is on behalf of myself and the Waikato University team and also my collaborator Jonathon Abell, who is a former student of David's with our group. I am presently working towards a PhD, and some of this work will feed into that. Paul White has given a nice lead in to this talk and we will be leaning heavily on his great work. The project is to model water quality in Lake Tarawera and its response to climate and nutrient loading in particular. Obviously, modelling Lake Tarawera requires conceptualising and understanding the broader hydrological system, so that is a big part of this project too.



We are all well aware that Lake Tarawera can be a picture postcard perfect sort of environment, but in the most recent publicly available Lakes Water Quality Report it does stand out as a red dot on the map representing a declining TLI. That it does stand out as a red dot lake perhaps reflects the great work and success that we have had in some of the other lakes across the programme. Nevertheless that red dot is a little alarming and it is worth taking a deeper dive into some of the data behind that point on the map.

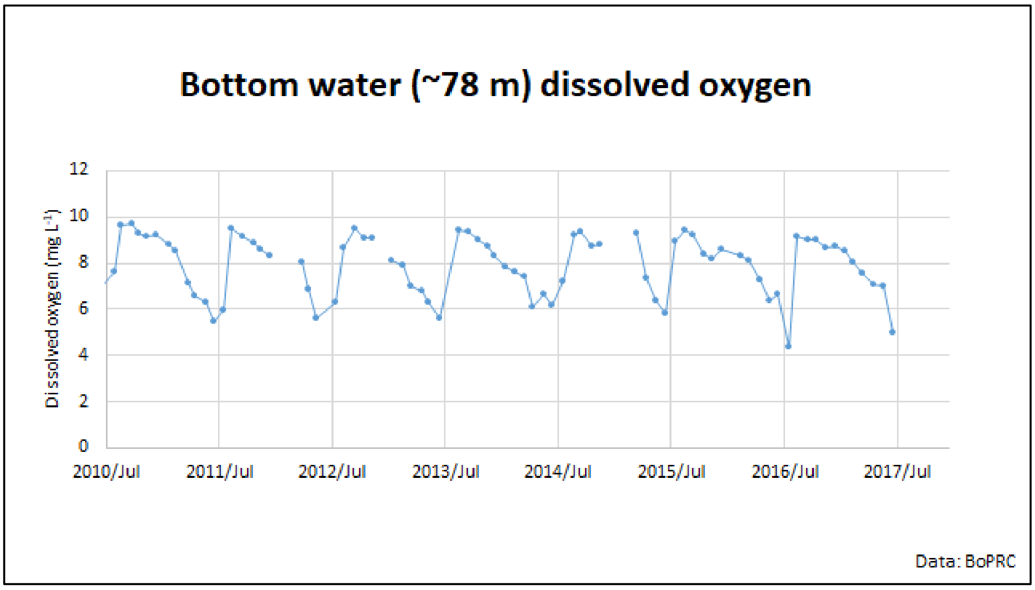


To follow on from the approach David took yesterday for the northern lakes in the region, we will look at the chlorophyll concentration and Secchi depth (which is indicative of water clarity). This is the long-term data set for Tarawera with values further down representing a deeper Secchi depth measurement, and better water clarity. There is certainly nothing too dramatic over recent years in any decline in annual average water clarity in the lake.



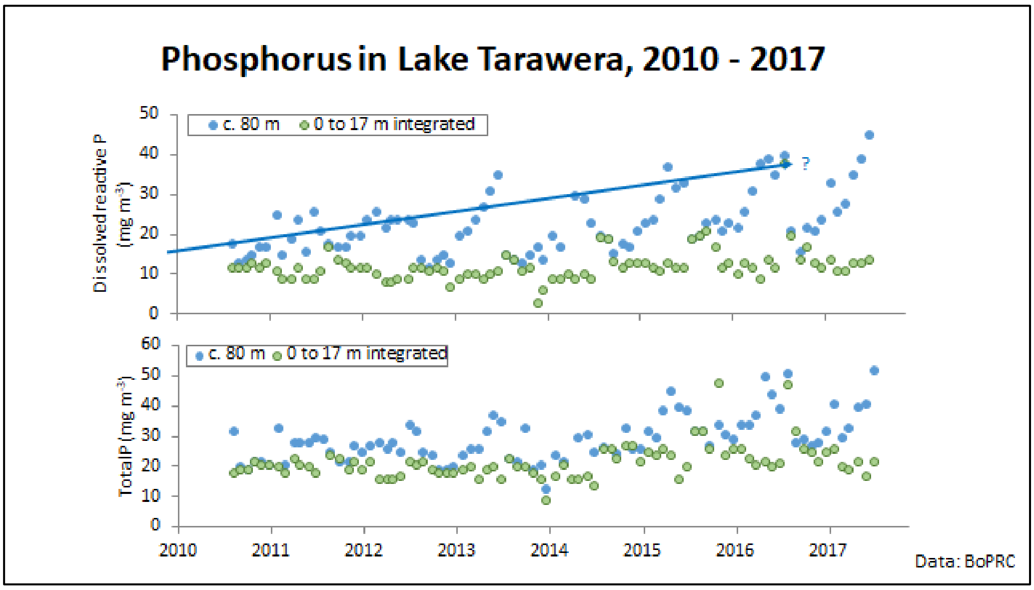
Likewise for chlorophyll, no dramatic rise over the recent decade or so in annual average values for the lake. So no dramatic changes, despite periodic anecdotal observations of blooms at the Hot Water Beach end, and also some green water coming in from Rotokakahi at times around the Landing.

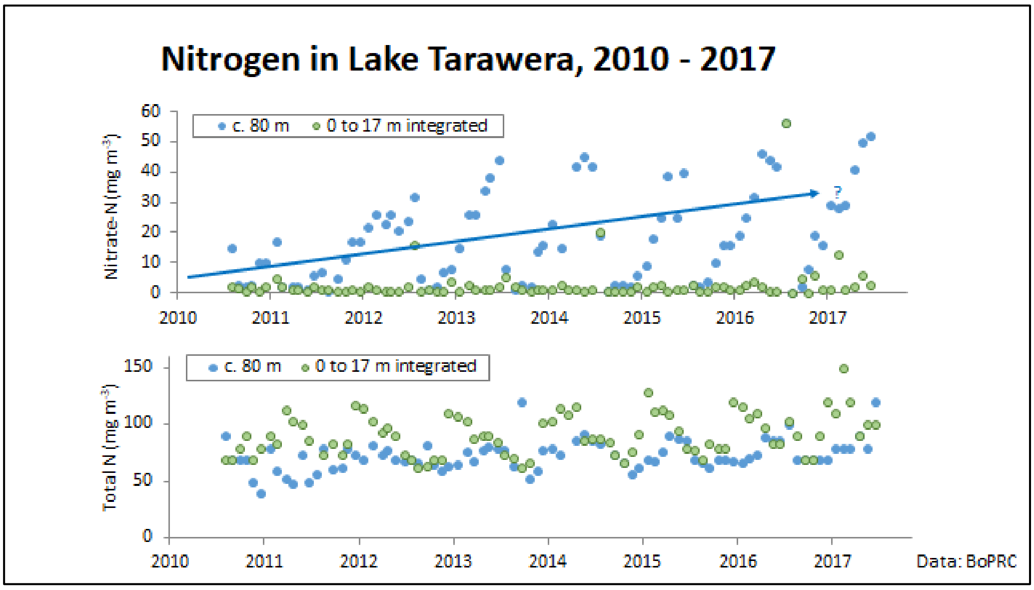
Again, in a similar plot to what David showed, (next page) bottom water dissolved oxygen in the lake looks fairly stable over the last 7 or so years, although maybe one month we did see some unprecedented low concentrations in bottom waters. When we get low oxygen concentrations in the bottom waters of stratified lakes, as David explained yesterday, that can lead to internal loading via release of nutrients that are stored within the sediments.



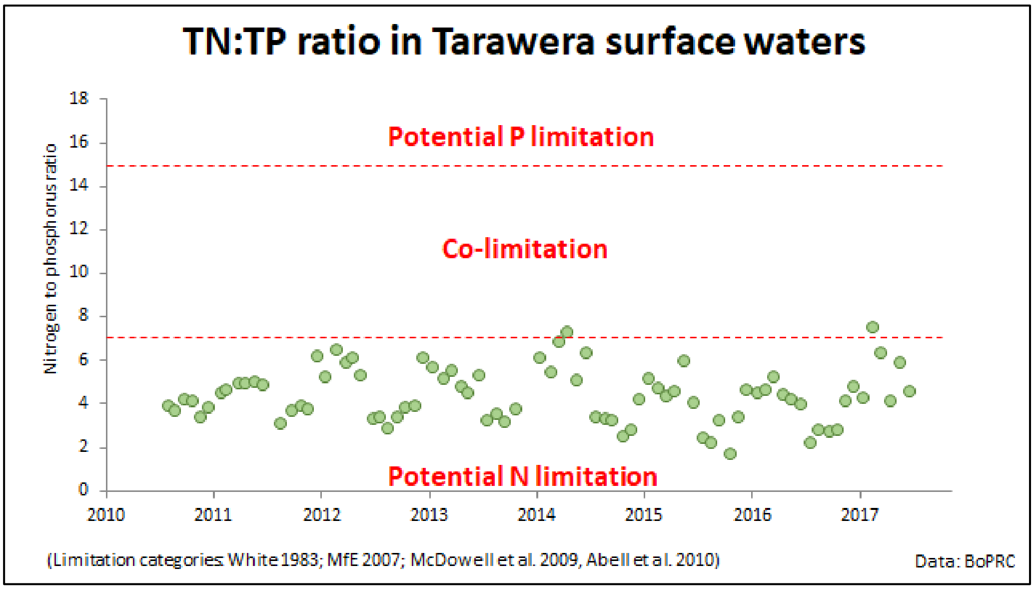
Below is the phosphorus data, dissolved phosphorus in the top panel and total phosphorus in the bottom panel, with blue dots representing bottom water concentrations over a 7 year period, and green dots representing surface waters. What we might be able to infer (with very non-scientific style regression lines), is some indication of an increase in bottom water concentrations over that last 7 year period, which is obviously cause for concern. Lakes can get into an internal feedback cycle with bottom sediments supplying nutrients to the water column, creating more organic matter growth and subsequent decay, then more deposition to bottom sediments. That kind of self-reinforcement is a critical aspect for managing and monitoring lakes.

There is a very similar pattern for nitrogen, (next page) with dissolved nitrogen on the top, nitrate and total nitrogen on the bottom, and an indication of an increase in bottom water N concentration and bottom sediment nutrient release. More research is needed to better understand these processes in Tarawera.



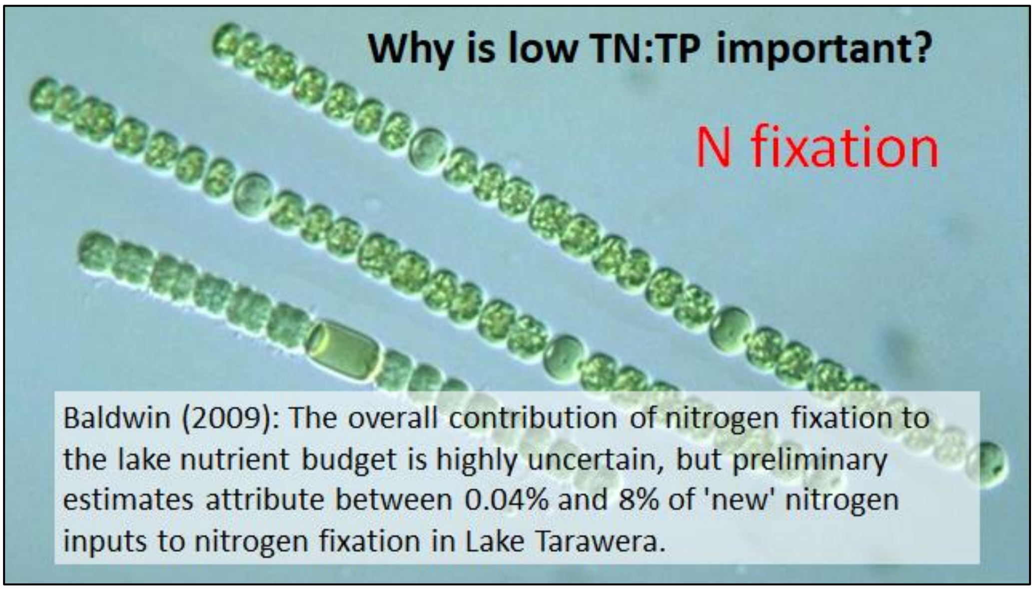


We can also look below at nitrogen and phosphorus levels in relative terms - as the nitrogen to phosphorous ratio. Chris Ingle mentioned how important this discussion has been in the Plan Change 10 process for Lake Rotorua, in terms of which is the most limiting nutrient for phytoplankton growth or algal production in the water of the lake. In the case of Lake Tarawera it is a unique and interesting system in that most of these values sit comfortably within the zone of what we would call ‘potential nitrogen limitation’. Nitrogen is likely to be a stronger limitation on algal production than is phosphorus.



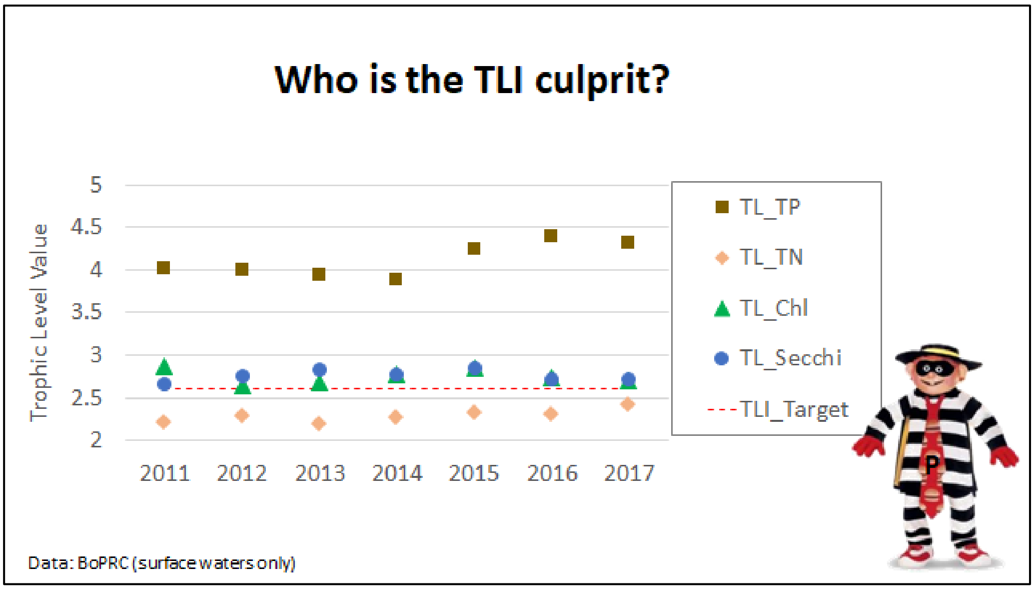
Why is that important? When we have a low N to P ratio this can favour the production of cyanobacteria due to the ability of some cyanobacterial taxa to fix atmospheric nitrogen. Those familiar with Lake Tarawera can be surprised by relatively dense flocks of cyanobacteria in the water column, when at other times the lake is very clear.

Amanda Baldwin, for her PhD research, studied nitrogen fixation in the lake between 2007 and 2009 and estimated that fixation might account for somewhere between almost nil and 8% of new nitrogen inputs to Lake Tarawera. Further to that we might expect that if



phosphorus inputs were to increase faster than nitrogen inputs then fixation may become a more substantial component of nitrogen input to the system, in a relative sense.

Taking all the four components that we have looked at - chlorophyll, nitrogen, phosphorus and Secchi depth or clarity, in the context of the TLI, we can plot these all on the same scale. The N to P ratio jumps out in this plot as something really quite interesting in that three of those TLI variables sit at or around the TLI target for the lake, but it is phosphorus that is most affecting the actual TLI for the lake.

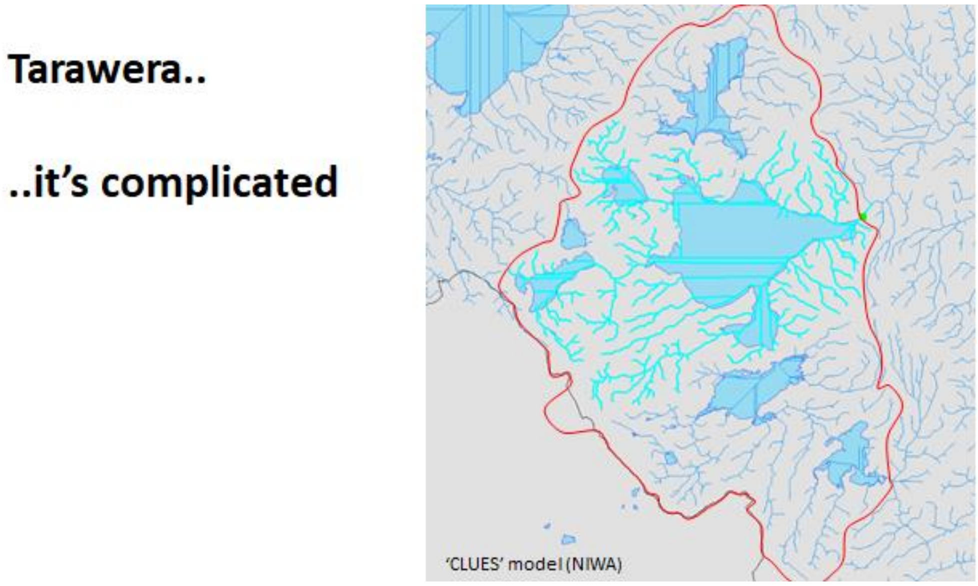


From this it might be tempting to think we only need to manage phosphorus. However, something really important to note is that, because of the oversupply of P, if we add any N to the system, we are likely to get a corresponding increase in chlorophyll and a reduction in clarity. So it becomes doubly important to manage both sources – this is now reflected in the Lake Tarawera Restoration Plan as a reduction in phosphorous in conjunction with nil increase in nitrogen.

Now that we have the context of broad water quality issues in Lake Tarawera, we can move onto the actual modelling project. The aims are multi-faceted. In the process of establishing these models we work to understand the system, the inputs, the hydrology and the nutrient loads. The aims of the project are:-

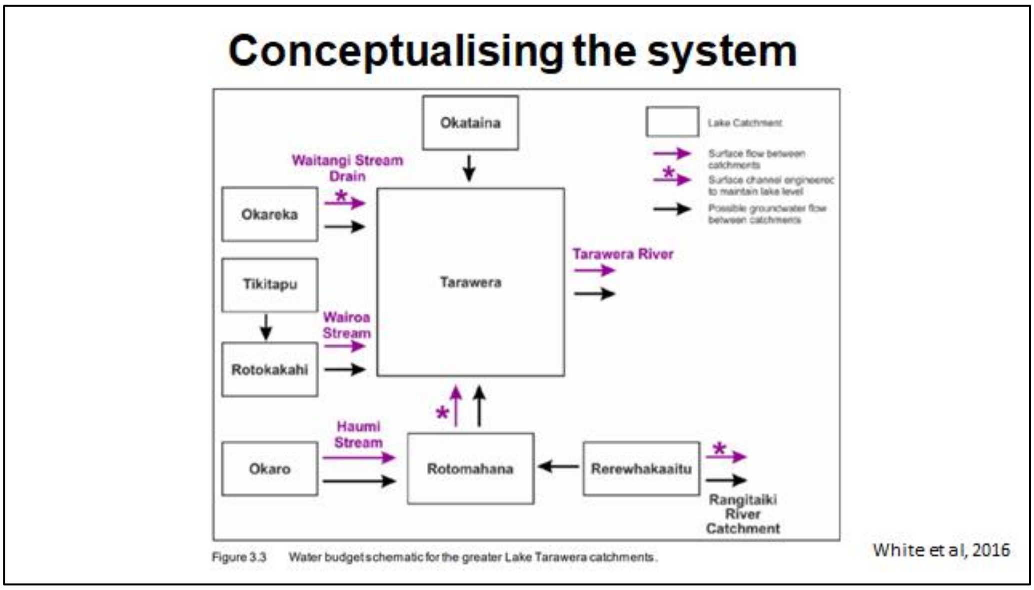
- Review and synthesise available budget information
- Configure a 1-dimensional computer model of Lake Tarawera, the DYRESM–CAEDYM model
- Validate the model using lake water quality data
- Simulate broad nutrient loading scenarios to understand how lake water quality responds to changes to nutrient loads (e.g., Δ P and N loads by 5%, 10%, 20%, etc.)

An intended outcome of this work is to identify sustainable nutrient load targets that will lead to, or achieve, the TLI target for the lake.

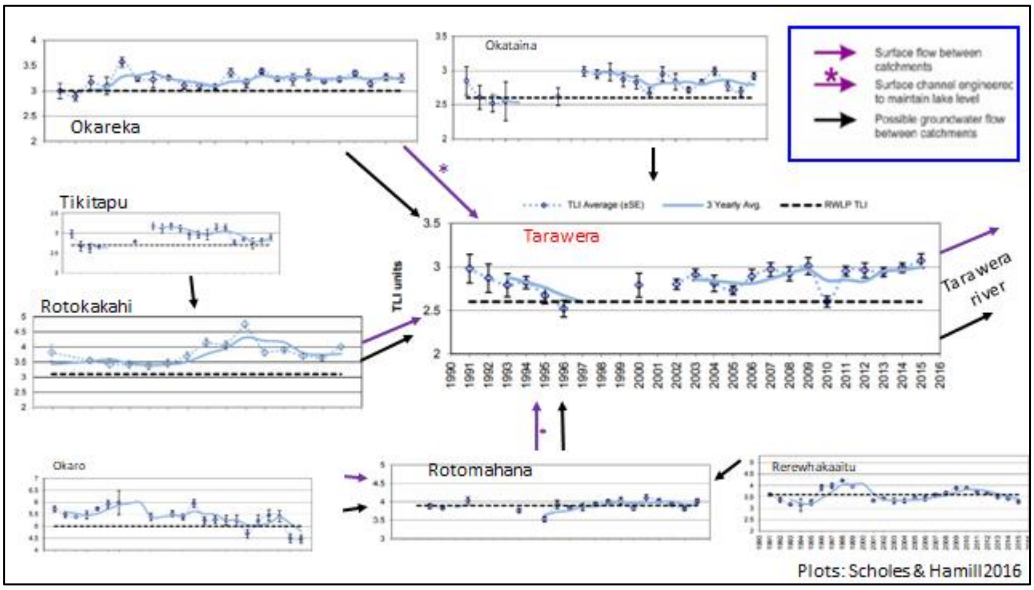


The modelling of lake water quality necessitates understanding and conceptualising the system. Paul White has done a fantastic job of this already, but I will reiterate that, as it is complicated. We have a number of lakes in the Tarawera system, some with surface water connections, which are shown by the connected blue lines in this CLUES model (NIWA), and some which have groundwater connections only.

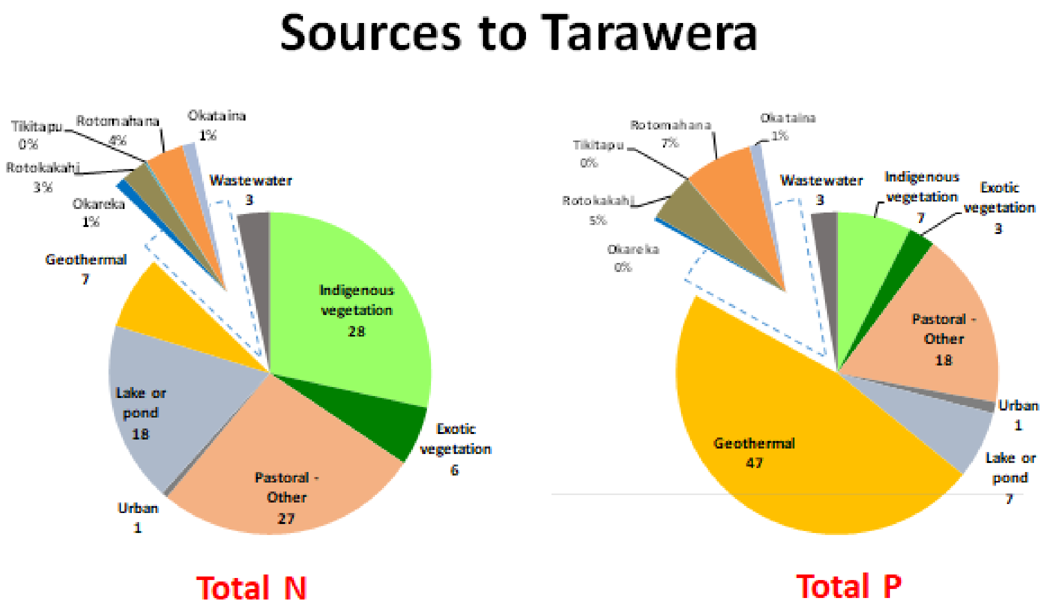
I am the third person to use the next slide, a great diagram that Paul White put together and we are all using it. It shows the connected lakes and the way that surface water and ground water connections flow between them.



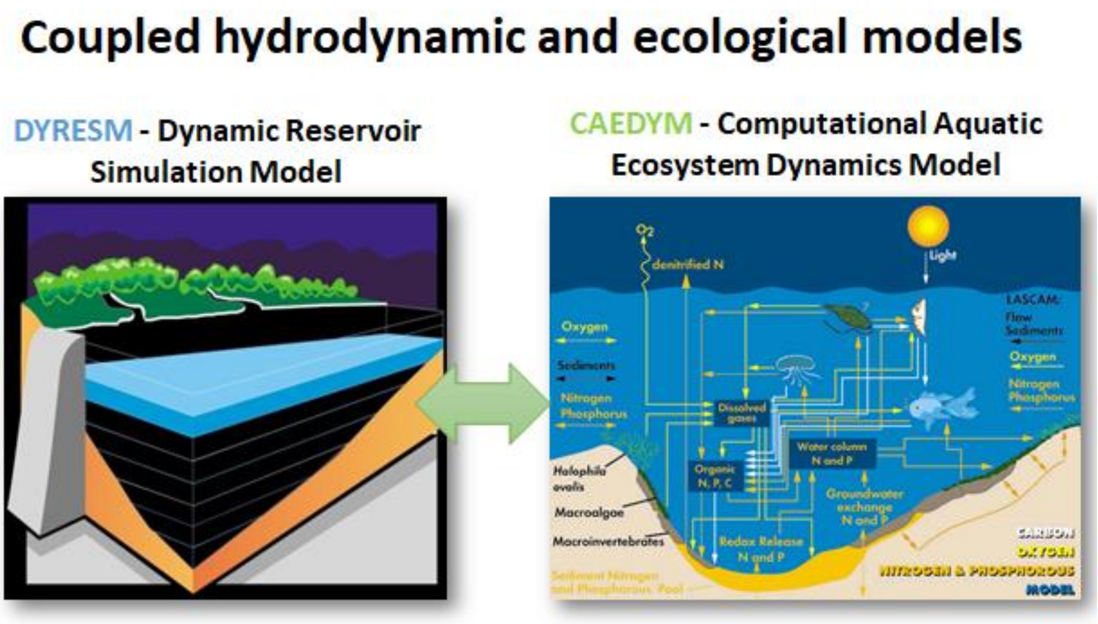
Expanding on that concept, I have replaced the boxes with TLI plots from each of those lake systems so we can see where gains might be made for Tarawera through approaching or achieving TLI targets in the other lakes. Looking at this plot it is tempting to say, 'Oh well, we can manage Tarawera just by hitting our targets in the other lakes', but unfortunately life is never quite that simple.



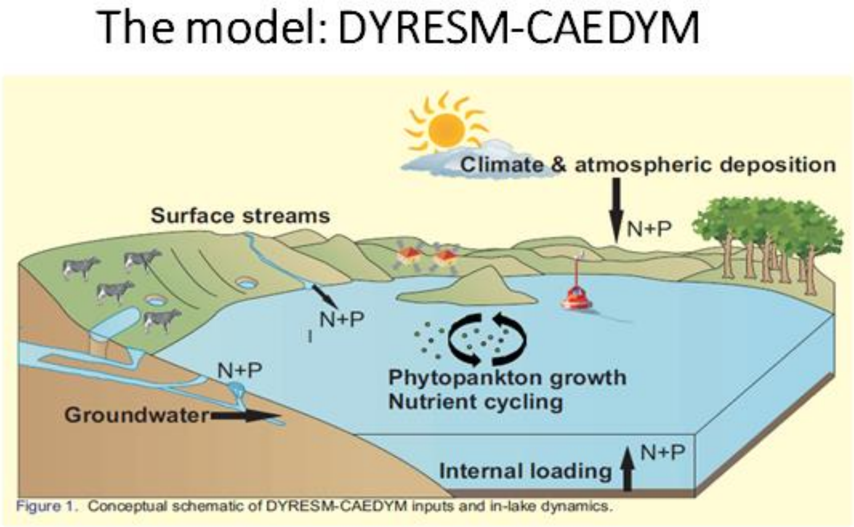
The pie charts on the next page show the nitrogen and phosphorus budget for the greater Tarawera catchment, including the smaller lakes. The zoomed out wedge of the chart represents inputs from other lakes, and is a relatively small contribution of both N and P to the system as a whole. Following on from Chris Ingle's comments, the geothermal load of phosphorus to Tarawera is potentially massive, but it is also worth noting that the yellow wedge is subject to a very high degree of uncertainty. I will touch on that again later. Nutrient budgets like those pie charts are a rather blunt instrument for managing the lakes. What we aim to do with this project is something a little more sophisticated.



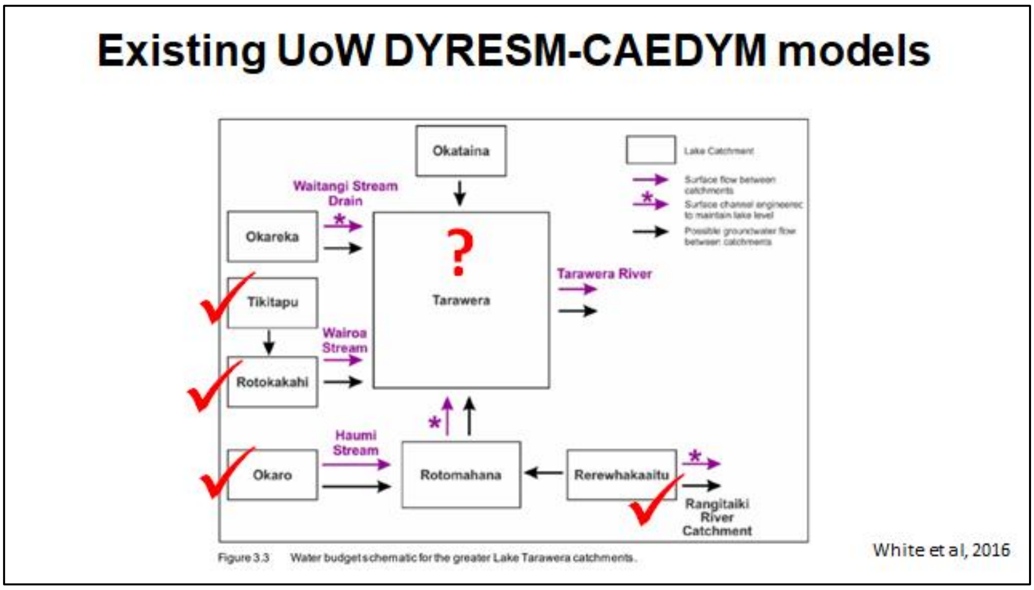
These are the DYRESM–CAEDYM models coupling the hydrodynamics of water movement with the biogeochemical (nutrient and biological) cycles in the water column. These diagrams can be simplified to show how the model accounts for all the various inputs - surface water, groundwater, climate, atmospheric deposition, phytoplankton growth and internal nutrient loading. The model represents all those processes to provide a best informed estimate of the water quality response to external forcing.



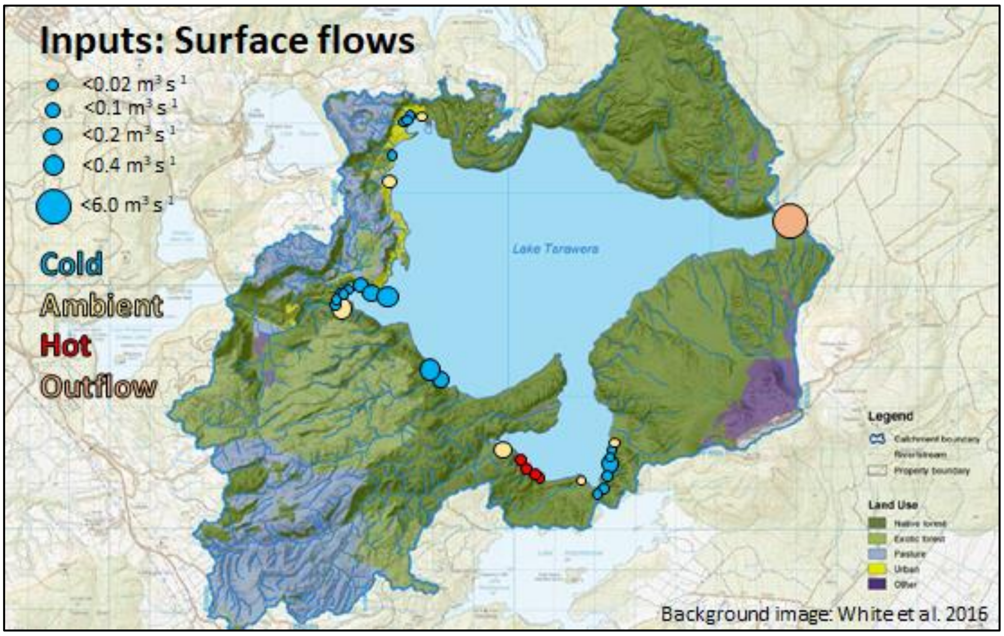
We have used the DYRESM–CAEDYM model (on the next page) across the Rotorua Lakes. For the greater Tarawera catchment we have models already established and published for Lakes Tikitapu, Rotokakahi, Ōkaro and Rerewhakaaitu. It is probably time to model the greater Tarawera catchment, the grandfather model of them all.



These models, with their multiple inputs, are data hungry. They provide a useful opportunity to aggregate all the data and knowledge that has been collected across this greater lake catchment into one tool, and use it to project water quality.

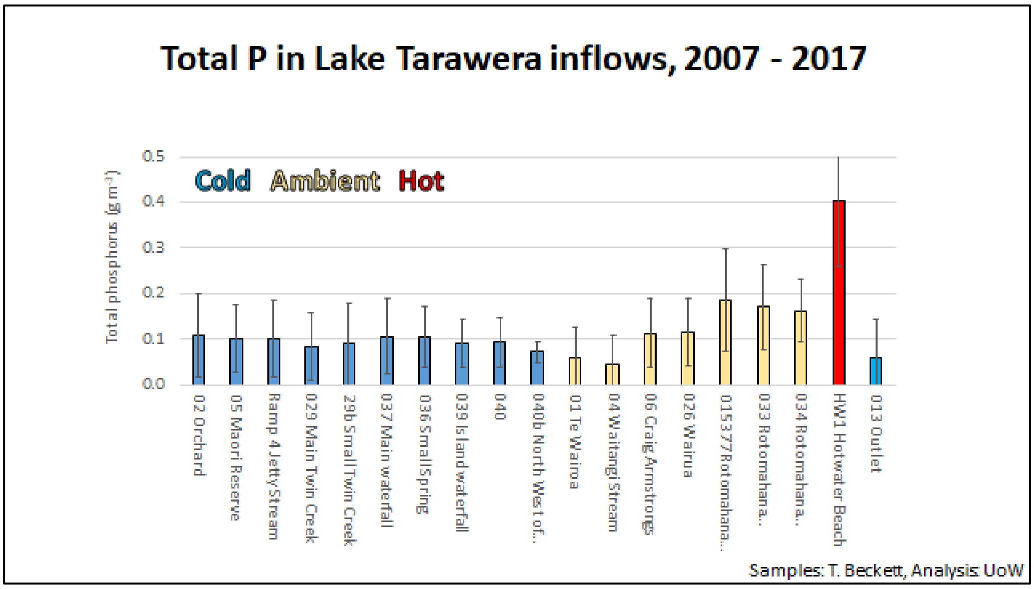


One of the primary inputs or data types we need is obviously water discharge and water quality inputs from the catchment. This is Matt Hamilton, a former student with us, who did some of the original nutrient budget work back in the mid-2000s. Since Matt's work we have been very fortunate to have the commitment of Terry Beckett, and some students as well, who have helped him to monitor the various inputs to the lake, quarterly since about 2007.

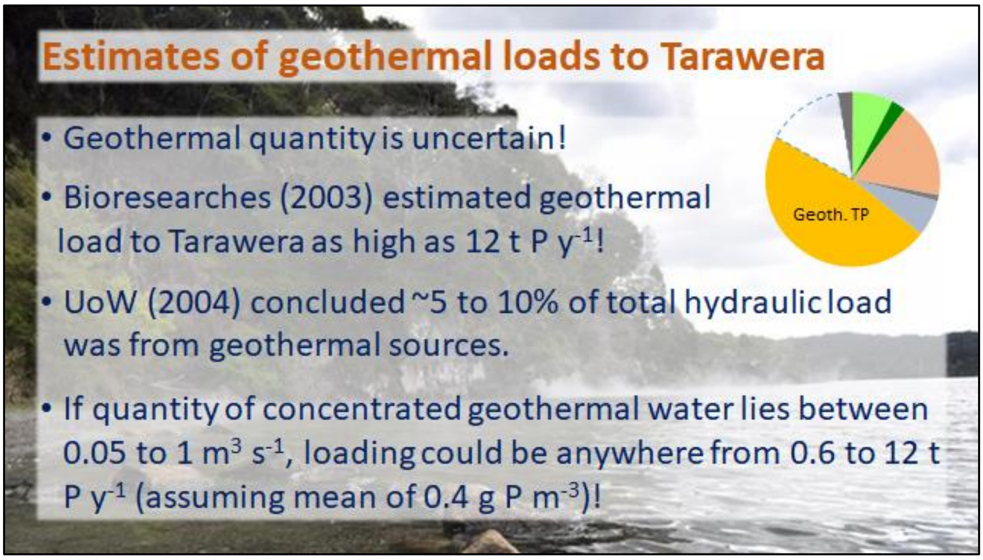


The dots on this chart represent categories of surface flow. The size reflects flow rate at those point sources and the colour indicates the type of flow. Blue is cold water, yellow is ambient temperature, basically surface streams, and red is hot geothermal loads which we will come back to later.

Terry has done a fantastic job of collecting samples for analysis at Waikato. From this we can calculate the long-term average nutrient concentrations for each lake input. This graph is for phosphorus; cold and ambient concentrations have moderate P concentrations. Ambient flows are a little higher, perhaps representing surface flows around some of the more intensively used land areas, but the one that sticks out is the very high P value in geothermal water, and this is the reason for the really large yellow wedge on the pie chart.

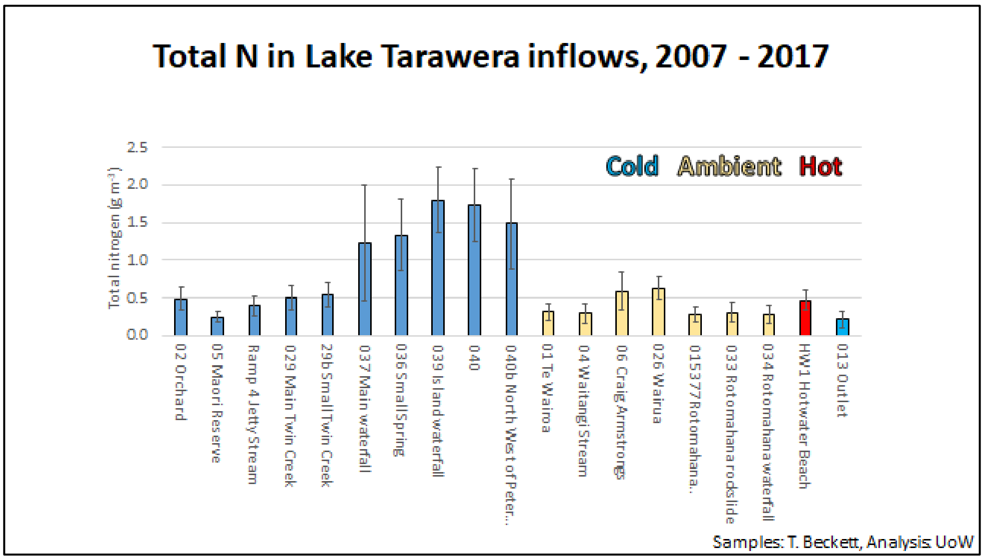


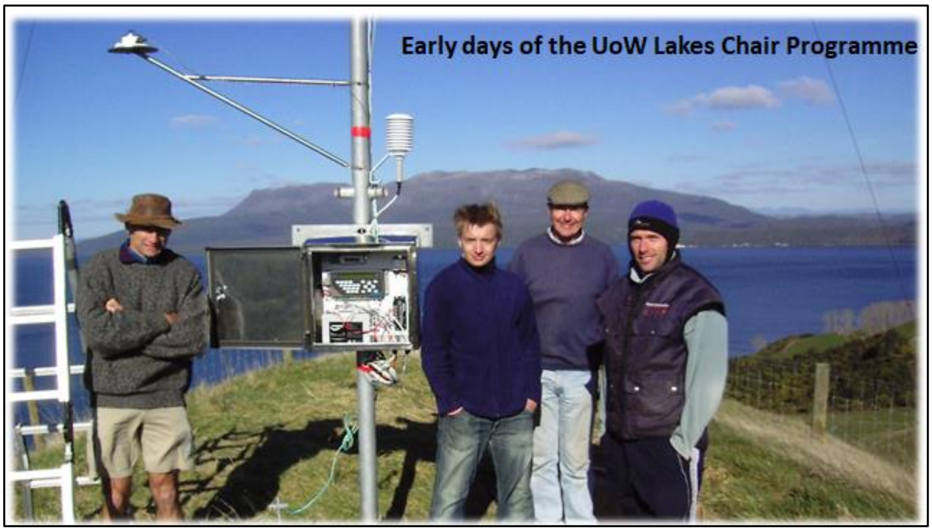
That wedge is subject to quite a lot of uncertainty. Although we have a good handle on what the concentration of that water is around the Hot Water Beach area, the actual volume is a lot harder to estimate because many of those inputs are diffuse and subsurface. Historical research in 2003 estimated the geothermal load might be as high as 12 tonnes of phosphorus, so that would be more than twice all the other P inputs combined.



A more recent study by Waikato University estimated that 5% to 10% of the total hydraulic load to the lake could be from geothermal sources. The 5 tonnes P estimate shown by the yellow wedge on the pie chart is based on a 5% geothermal water contribution, equal to slightly less than half a cubic metre of geothermal flow into the lake. This is one area in which we will do more work to tighten up our estimates of the volume of geothermal water going into the lake itself.

Switching back to Terry's monitoring data on inputs, looking this time at nitrogen, it is almost the reverse of P; there are quite high N inputs from some of the surface streams and springs. That follows logically from what Paul White described with the shallow ground water being N enriched up to approximately 3.5 milligrams per litre (grams per cubic metre).

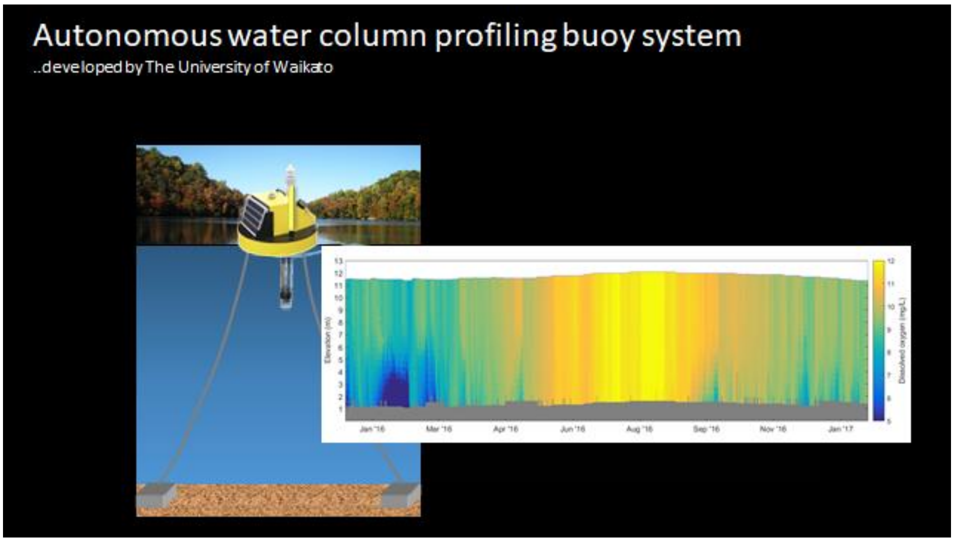




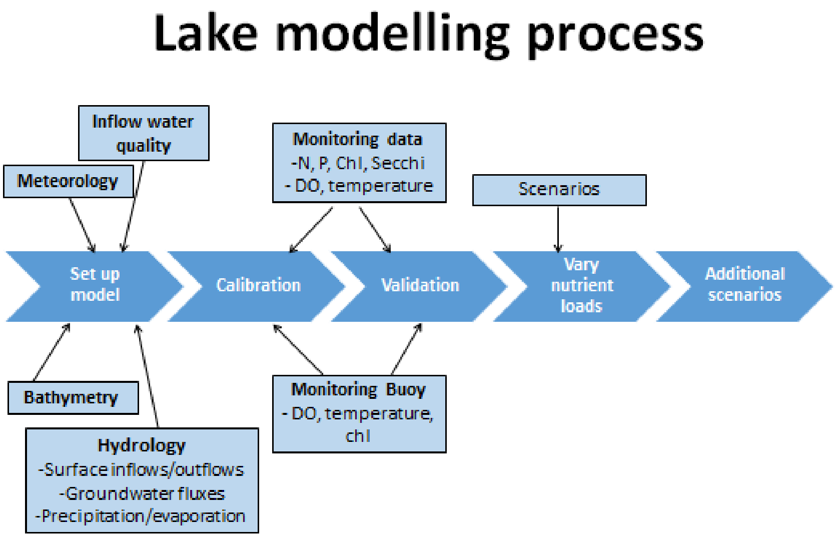
We have a nice handle on the water quality inputs in water quality of inflows to the lake. Another data type that we feed into the model is climate data. In the early days of the programme David Packman kindly donated a small space on the top of a hill on his farm where we could set up a weather station overlooking the lake. This has given us a good record of climate quite near to the lake for the last 10 years or so. You can see the Danish and British guys look pretty comfortable, but the kiwis are more rugged up. It was a pretty cold afternoon despite the sunshine!

Additionally we have high frequency lake monitoring buoys, which I have been quite involved with. These also have a climate station and right on the lake we have weather data as well as near real time water quality information at 15 minute intervals with occasional gaps. The Tarawera monitoring buoy has proved something of a problem child due to the depth and exposed nature of the site.

Over the last few years we have been developing these water column profiling buoys which use an automated winch to raise and lower a sensor package up and down through the water column. The advantage of this is that we can measure variables like oxygen, pH, chlorophyll fluorescence or water turbidity throughout the water column, rather than



just at one or two depths that we would be restricted to by a traditional buoy with fixed sensors. With this buoy we can generate nice plots and get a much better feel for the vertical dynamics in the system. That will be very beneficial for the future, particularly the 1D modelling, that we undertake. The data is from a year of uninterrupted recording from the prototype profiler buoy, which was deployed at Lake Rerewhakaaitu. Periods of oxygen loss from the bottom waters are evident in this plot. This is the type of data we will be generating for Lake Tarawera going forward.



This flowchart shows the process for the modelling project. There are no results at this stage but we will set up the model with the inputs that we have just considered. We then calibrate the model using the monitoring data that we summarised in the first five slides to optimise model performance and check that it reproduces the observations accurately. Then we will validate the performance of that model with an independent time series or separate time period of the monitoring data, so that we can have confidence in the model's projections. That will allow us to run scenarios, perhaps in two stages; firstly, some broad scenarios with broad assumptions, then more detailed, based for example, on Paul's White's modelling.

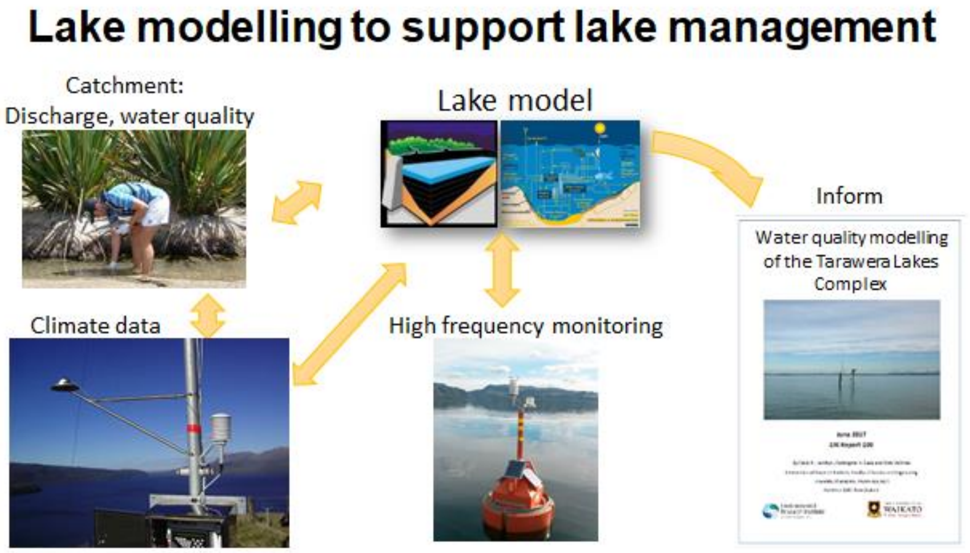
MODEL 'SCENARIOS'

- **Multiple simple nutrient load scenarios to identify sustainable nutrient loads that will achieve the TLI target:**
  - **e.g. 5, 10, 20% reduction in N and/or P?**

- **Additional scenarios, e.g.;**
  - **What if all tributary lakes met their TLI target?**
  - **Intercept geothermal loads?**

- **The lake model will provide a tool that could be integrated with future catchment modelling to understand how changes in individual sub-catchments will affect Lake Tarawera.**

Those model scenarios will have multiple simple nutrient load scenarios to try and identify sustainable loads that might achieve the TLI target. That might mean starting off by looking at 5%, 10%, 20% reductions for example in N and/or P to the lake. We could then use the model to run additional or more specific scenarios like, for example, what is the water quality outcome for Lake Tarawera if the TLI changed only in the tributary lakes. Or what if we were able to somehow intercept 20% of the geothermal P load, or similar.



As a longer term vision, the lake model might provide a tool that could be integrated into future catchment modelling, such as Paul White has completed with his MODFLOW groundwater study. This would help understand how changes in more specific parts of the greater catchment might impact the water quality at Tarawera.

The net result of that is we are bringing together the whole picture of monitoring and modelling, and using these tools to inform both the community and the process of management and implementation for the restoration plan.

In conclusion, Lake Tarawera water quality does currently exceed its TLI target and the TLI has increased over the period of 2000 to 2016, although there was a similarly high TLI observed in the early 1990s to mid-1990s. That is not to say that is where the water quality should be, because obviously water quality measurements in the lake only started relatively recently.

Nitrogen, chlorophyll and Secchi depth are roughly in line with the TLI target. However, phosphorus is a great deal higher and results in a low N to P ratio, which is a specific issue for consideration in Tarawera.

The hydrology of the lake is very complex and that presents a challenge for lake managers, but we do have this project under way to integrate the work that has come before, and try to identify sustainable nutrient loads to the lake. Our aim is that the model will prove to be a tool that can be integrated with other undertakings and other modelling endeavours, be they surface water catchment modelling, groundwater modelling, or other information from the greater catchment.

With that I will say thank you and acknowledge all the people below. You have been a great help towards getting this project going.

Paul White (GNS)
UoW Aquatic Team
David Hamilton (Griffith University)
Joseph Butterworth (JFB Environmental)
Paul Scholes, Alastair MacCormick (BoPRC)
Terry Beckett, David and Robyn Packman, and the Lake Tarawera Ratepayers Association

Thank you

QUESTIONS

Don Atkinson, LWQS: Chris, there is an enormous amount of work being done and absolutely fundamental going forward with solutions to the catchment. Is it now fully funded and when will it be completed?

Chris McBride: It is fully funded. I believe we are going forward with the 1D modelling project now.

Don Atkinson: The modelling project that is indeed funded and under way.

Chris McBride: I think probably it should be perhaps three months away.

Don Atkinson: That is very encouraging.

John Green, LWQS: A question for our pest man but he has gone. I was going to say that having run a ten acre property on Lake Rotoiti the pests are unbelievable. The key is to get care groups throughout New Zealand focussing on targeting those particular pests. We killed thousands of rats and possums over our time and we still could not get on top of them. It is a challenge.

Going back to Chris and Paul, I really enjoyed your presentations because you have shown us how complex the Tarawera lakes system is. What I find interesting is that Tarawera looks like it is the main problem and it is not so much those outside lakes. Their TLIs are slightly higher than the central lake but what impact does the volcanic mountain have? You do not appear to have focussed on that at all. Does the mountain have some input of phosphorus that has not been measured or identified? I am so pleased with the work you are doing and keep it going because it is clearly a very complex system. Thank you.

Chris McBride: What impact does the mountain have? If it explodes again there will be a pretty big impact I would imagine. It has definitely had a big impact in the past as you can see from a sediment core. When we constructed the nutrient budgets in the pie charts that I presented, they are based on broad export rate coefficients that we assume for different land types and based on whatever published literature we can find for losses from that type of land cover. It is accounted for in the nutrient budgets but probably there has not been too much detail yet so maybe it is something we could focus more attention on.

Gary Rushworth, Hawkes Bay Regional Council: A question for Chris. You mentioned briefly the core. The model did not seem to include a lot about nutrient legacy. I have been working on Lake Tutira and we collected cores to understand internal cycling of nutrients. Is that part of the model?

Chris McBride: Yes. The diagram I presented was very much a simplification of what was represented. There are hundreds, maybe thousands of processes represented and it does not explicitly include release of nutrients from sediments and sediment legacies but it is part of the model.

Gary Rushworth: How would you rank its importance? Obviously it will vary from lake to lake. Is it something that New Zealand Scientists need to understand more about? How does it rank in terms of knowledge gap?

Chris McBride: Absolutely, particularly the impacted lakes and those that stratify. The internal loading is a really important source of nutrients to the water column, as much or even more so, than external sources. It definitely needs to be considered in any system that is impacted or may be impacted.

John La Roche, LWQS: My question is related to alum dosing in Lake Ōkaro but equally in Lake Rotorua. The mechanism of alum dosing is that the aluminium sulphate forms a flock with the turbidity in the water that then settles out. It is certainly removing phosphorus and nitrogen by tying them up in the turbidity, but that flock forms a blanket right across the base of the lake that would not deteriorate very quickly. Are you investigating what happens from alum dosing on the floor of the lake and what is the long term effect of having a blanket of inert aluminium sulphate or aluminium hydroxide across the floor of the lake?

Chris McBride: I could comment quickly and then defer to Max Gibbs who is the expert on this. As part of the Lakes' Programme, we have ongoing studies taking sediment cores and monitoring aluminium concentrations in the sediments of both Lake Rotoehu and Lake Rotorua. We have just completed a follow-up study to that.

In terms of accumulation in the sediments there is some aluminium sulphate detectable mainly around the points of insertion of those dosed inflows but it is not dramatic. There may be some subsidiary effects in the long term accumulation preventing further release of alum into the water column. If the dosing were to be stopped, over time that layer would be buried in deeper sediments as organic matter settles onto the lake floor.

Max, have you anything to add or correct or anything else?

Max Gibbs: It is pretty much what you said. The idea of alum capping is that it resets the sediments, forms a very thin blanket, perhaps a couple of millimetres at the most, and that sequests everything out of the water column at the time that it was applied. It also stops anything coming up from the sediments below. The lake is then reset, no phosphorus in it. Whatever happens from the catchment will cover it.

Overseas these layers get buried deeper and deeper into the lake and that legacy material is held within the sediments rather than recycling. The alum process gives a chance to reset the lake and gets the lake water quality improving, which we see in Lake Okaro.

Andy Bruere, BOPRC: I have a question for Chris. You talked about the uncertainty of our estimates of the phosphorus input from geothermal. Do you think there is a possibility that those geothermal inputs might be changing and increasing? That is something that we have not experienced before.

Chris McBride: It is certainly possible. It is outside my domain, and probably Paul White would be much better placed to respond. It is something we definitely need to look into as part of the study assessing what the geothermal quantity might be. Part of that picture is how it might be changing through time, which is especially important because it is such a large fraction of the inputs to the lake. We need to understand that if we make changes in Tarawera and the other lakes, how might that affect natural variation of phosphorus inputs from geothermal sources.

Max Gibbs: John Green raised a very important point about the influence of the mountain. In Lake Taupo we know that there is a hydrothermal vent at the bottom of the lake which was discovered by GNS. We have been monitoring it since about 1975. We can pick up the chemistry difference from this vent. We know that it couples with eruptions in Mt Ruapehu and the southern mountains and with large earthquakes across the system. Has anybody looked to see whether there is an equivalent vent at the bottom of Lake Tarawera rather than just at Hot Water Beach?

Chris McBride: Perhaps we should. Perhaps another way we could look at this is following up on Matt Hamilton's mid-2000 study that I mentioned, using sodium as a tracer for potential geothermal inputs. Maybe we need to do a follow up study on that as well.

Fred Stevens, Rotorua Lakes Community Board: I have been living at Tarawera for over 30 years now. We have never been able to get a straight answer to, 'Did we have a Tarawera Action Plan?' Several years ago it was demoted to a Tarawera Restoration Plan. My understanding is that an action plan has more statutory weight. The reason we were told it was put back to a restoration plan was because they are waiting for more data. From what Chris McBride said it sounds as though works are being undertaken at the moment. I just want to ask Chris Ingle when are we likely to get the Tarawera Restoration Plan put back to a Tarawera Action Plan?

Andy Bruere, BOPRC: Thanks Fred. First of all, the reason it was called a restoration plan was because when the nutrient budget work was undertaken there were no identified sources of nutrient, particularly phosphorus, which we could reduce to meet the reduction target required to make a sustainable land use change around the lake. So they decided to call it a restoration plan. We will convert that to an action plan when we have identified nutrient sources and actions that will definitely meet those targets. In terms of timing it is reliant on this modelling work and on the farm environment plan work and then on the work that Chris McBride talked about with conceptual modelling.

Giving you a timeframe is probably a bit like a politician's promises at the moment, it is likely to be broken. I would prefer to say we will work through that work and see what information we have to achieve those reductions. It is a watch this space, sorry.

Fred Stevens: It still does not answer my question but thank you.

Chris McBride: You mentioned statutory weight, but I do not think either of them has any statutory weight. The name of the action plan or whatever we call it is semantics really. What you are looking for that has statutory weight is the Regional Plan and the Regional Policy Statement. We have just made a decision to start that Regional Policy Statement process of identifying outcomes for water quality in these lake catchments which is coming up quite soon. We have to get Council go ahead on a few things and sort a few more but once we have changes to the Regional Plan that will have effect on land use in the catchments.

Bob Armstrong, Gisborne Point, Rotoiti: As a long standing member of the LWQS, I am intrigued not only with the information that has been gathered but also the method of gathering it, particularly the three wells, which we saw drilled around the shores of Tarawera. Two of the wells were on an area where inlet water would obviously be coming in, but I noted with interest that the third well appeared to be at the outlet. Could I ask why that was chosen and if so what valuable information was received from that particular well?

Paul White: That well was sited for two purposes. The first one was a water budget purpose trying to understand the inflows and outflows of Tarawera. It has been observed that the surface flow at the bridge by the camp ground is about 3 cubic metres a second less than the flow below the falls, so downstream that river gains a substantial amount of water.

The first question was where is that water coming from, could it be coming from the lake? David Hamilton and I supervised a Masters student maybe ten years ago, Nicolas Gillon. He did an interesting project with options of inflows and outflows to and from Tarawera. Our best guess was about 2 cubic metres a second was missing in the water budget, so it looked as though the increase of flow at Tarawera Falls came from the lake somehow. So we sited the well there to intercept geology that was capable of transmitting about 2 to 3 cubic metres a second from the lake. That is important to the lake model because there is 2 to 3 cubic metres a second that we need to make the whole budget work and we had to see where it was going.

We drilled a couple of wells, one about 90 metres deep and the other about 80 metres, and intersected the same geological material, fractioned rhyolite, which is at the Tarawera Falls. It had sufficient hydraulic properties to be able to provide 2 to 3 cubic metres a second. There was some other work done but I think the problem is more or less solved. That flow is probably coming from the lake bed somewhere.

The second purpose of having the well there was to have it in a pristine catchment. The other wells on the western side were purposely drilled in the town to see what impacts of land use in the catchment behind the wells were having on the shallow and deep ground waters. That was demonstrated by the Dollimore well that I showed the results from. A relatively pristine catchment showed that the nitrate concentrations are much lower, consistent with native forests.

Session 6 : THE EIGHT LAKES OF TARAWERA

SESSION CHAIR - Warren Webber, LakesWater Quality Society

I would like to begin this session by acknowledging the huge amount of work that Ian McLean has put into this Society. He was the Chair of the Society from 1999 when it changed its name from the Lakeweed Control Society to the LakesWater Quality Society when it recognised the issues were much wider than just weed. He drove the founding principle for these symposia which was the need to bring evidence based science to the water quality problem. We must not deal with folk lore and anecdote. If we are going to solve this, we need good evidence based information. I just want to thank you for that, Ian. Thank you.

Ian McLean
Thank you, Warren. Warren and I are the only two members of the original committee who are still on this committee. There are others here who made a big contribution early on, including Nick and Elizabeth Miller and Mary Stanton who has been supportive throughout the years. It started almost accidentally and has had great support from a lot of people and been a wonderful team effort, well worth doing. Thank you very much for your kind words.

THE CULTURAL PERSPECTIVE:
LAKEWEED AND PEST ANIMALS

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Nicki Douglas is the Environmental Manager for the Te Arawa Lakes Trust. Her focus is to ensure that Te Arawa values are known and provided for in decision making as well as active participation by Te Arawa whanau, hapu and iwi. Nicki has spent the past 15 years working for the Department of Conservation in a variety of operational and strategic management roles.

TRANSCRIPT

Kia ora, tena tatou

I have been with the Department of Conservation for about 15 years now and worked in Rotorua for 11 of those 15 years in various roles. I was lucky enough to be the Operations Manager for Lake Tarawera so I have a very strong association from a practitioner perspective. Practitioner is probably the key word for me. Most of my korero today will be based on experience and practice in working with communities and that is my area of expertise. I will talk about collective impact. It does say that I am talking about lake weeds and pests and I will mention them at least twice.

What is collective impact? It is a cool model developed by John Kania and Mark Kramer in the United States and describes groups of people coming together for a common cause, sorting a common agenda or goal and then putting things in place to achieve it. That well describes what we are doing here around these lakes. I want a wider discussion about some of the elements of collective impact that we might address in a different way. As a practitioner I often look for improvements from frameworks and then apply those in our work.

I want to acknowledge Ken Raureti. He was going to run this session today and asked me to step in for him, so it will be a different kind of conversation, but I will give you some insights into the cultural perspective. I also want to acknowledge Sir Toby Curtis, the Chair of the Te Arawa Lakes Trust, for being here this morning, Ken Kennedy for his mihi whakatau and Cr Tipene Marr, Rangitihi Tuhourangi. I speak about his papakainga so I want to acknowledge all of you in the room today. Kia ora.

Let's talk about complexity. The symposium theme is complex lakes and system restoration. This slide is the Cynefin Framework which is a decision making critical thinking model that helps us make decisions about where we might put our time, effort, and resources into issues that we deal with. What is the problem to solve? Is it a simple problem? Is it a complicated problem? Is it a complex problem or are we in complete chaos?

During this symposium I have heard a lot about science and evidence based decision making which is phenomenal. What we thought complex ten years ago when the Lakes Programme was set in place has changed. The strategy was developed and we moved from complex into complicated because of all the work being done. In saying that though, dealing with those problems, together with urgency and in the social, cultural, and economic environment, it brings us back into the complex.

Looking at the complexity, we have to be agile. It is an emergent space learning as we go, trying something, and if it fails we try again. We have to recognise that sometimes that is okay. When we can solve a problem quickly we should do that effectively. That is how I think about complexity. What type of problem am I trying to solve?

What is the role of Matauranga Maori and of Te Arawa to actively fulfil their role as kaitiaki in the collective impact model? Kaitiakitangi is a form of collective impact and Te Arawa see themselves as an integral part of the system of nature and people, as part of us, and we describe that in the context of 'Mauri'. The life force that exists in any living object also exists in us and we give and take mauri to each other.

The cause and effect of kaitiakitanga and mauri in the collective impact model is if I take something, I replace it. It must be protected for future generations. Mavis Mullins is Business Leader of the Year and talks about decisions made today must be right for our mokopuna in the future. It is about those ahead of me, and asking permission from our creator to take things, and that creator is within the context of our cultural framework.

Every single hapu, whanau and Iwi member sees themselves as part of their system and acts within the bounds of that tikanga, (culture) and therefore as a collective make a significant difference in a positive way to the environment by living by that tikanga, by those cultural practices. Individuals, groups, and collectives all have an impact on our environment.

The Lake Tarawera network is made up of 8 lakes and I thought we should show you them. This is Rotomahana.

These are the five conditions of collective impact:

The common agenda

From a cultural perspective the outcome, or the common agenda, that we ask for in the Lakes Restoration Programme can be expressed in our own whakatau.

> *Te ma o te wai e rite ana kia kite nga tapuwae a te koura*
> *The footsteps of the koura can be seen because the water is so clean*

That is a goal and if we attributed that to our broader goals of water quality and having clean lakes, those two things line up. It is about the common agenda expressed in a cultural framework.

Shared measurement

For collective impact to work we need to collect data from everybody who is involved, and that is happening. But what is the data missing from the cultural framework that can inform and give indicators towards those outcomes?

Te Arawa Lakes Trust has gone through a refreshed strategic planning process and developed a set of indicators that are meaningful to our people. An indicator would be that mauri is restored, the water is clean. Another indicator would be the abundance of kōura and other taonga fisheries that we collect for our cultural practices.

How do we measure our ability to move closer to those things? Can we have measurements in the programme that reflect Te Arawa values and demonstrate to Te Arawa whanau, hapu, and Iwi that we are moving closer to that goal?

Mutually reinforcing activities

Collective impact means that the goal is the centre and everybody's contribution matters as long as it contributes to the goal and that can be demonstrated and have a measurable difference. The centre is the goal and everybody being valued and seeing their role. For

Te Arawa what are the things associated with this Lakes Programme work that make a real difference to our outcome and the values we attribute to these taonga.

Continuous communication

It is clear to me just how much institutional knowledge and information is being shared among the parties in this programme. To get a collective impact model working well, those parties that are the coordinators must spend a lot of time together. Something that needs to be done better in the Te Arawa Lakes Trust role is to communicate with those undertaking active Kaitiaki roles.

What am I doing on the ground and how is it making a difference to the goal? How do we tell that story and communicate with the wider public? It is important to keep the flow of information between those who are active and those keeping the goal going so they know what their contribution is, how it might need to shift, how their measurements demonstrate the impact they are making and how they might change what they are doing to make a better difference. We probably do continuous communication well from the centre but doing more outside may need some attention.

Backbone support

This is about having an organisation, and the Lakes Programme is well supported by agencies that play a crucial role. It is about connecting to the wider network.

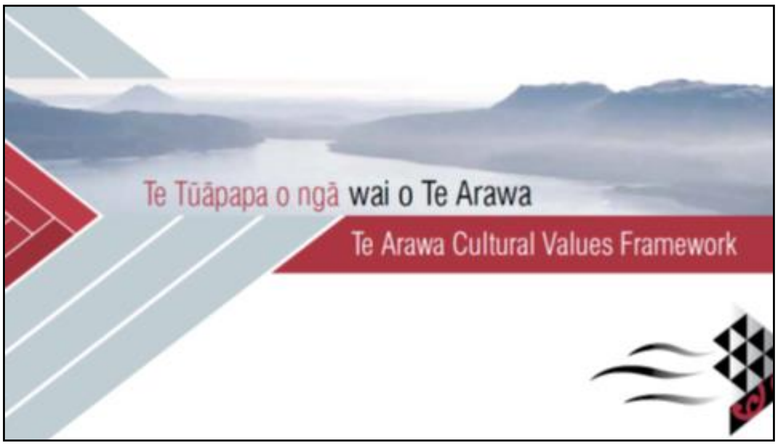
Tarawera and the Lakes Programme is a good example of a collective impact model. I seek the presence of Te Arawa values in that model and some improvement around how we could address that model and put our hands up to be party to that.

I want to congratulate the Rerewhakaaitu Farmers' Collective for their work around the Rerewhakaaitu Action Plan. When I left Rotorua in 2013 conversations had been going on for a couple of years. Coming back to see the commitment and dedication of that Collective is fantastic. Kia ora.

I was heavily involved with the Ruawahia 2B pine removal operation on Mount Tarawera which Ken would have talked about as he holds that project close to his heart. He talks about it being mana maunga mana tangata, bringing back the restoration of that maunga into its natural state being a representation of the return of their people to that maunga.

The terrestrial efforts, community pest control efforts, the conversations that our whanau at Okataina and Rotoiti have about pest control. We all know the pest control issues and the damage to the understorey. Possums, wallabies, deer, rats, mice and stoats, browsers at every level of the ecosystem, that forest needs some serious attention. I was inspired by our Rotoiti whanau taking on that challenge and having that conversation amongst themselves and with their people.

Aquatic pests. I went to an amazing workshop run by Shane Grayling and Lindsay Chadderton was there. I learnt so much. The last thing I want to see is catfish near the complex Tarawera system, what damage they could do. Ian Kusabs mentioned yesterday that kōura do not like Tarawera, they like other lakes. I want to ensure that while we are protecting the values in the other lakes, and if we can improve them, they will make a significant difference in Tarawera.



How does a cultural values framework work with collective impact? What is it?

It starts with water - wai, and is about the relationship of water coming from our gods. We call it waiariki. The tears of Ranginui come to Papatuenuku. Kingi, Sir Toby's poem, was not translated yesterday but he said in his tauparapara that we express our relationship with water through our activities. How it makes us feel, how clean we feel, our spiritual response to water, the way if feels on our skin and then how clean the water is itself.

Wairua is the spiritual connection the way we think about our relationship with the water, the species that live in it and what this means to us, that we eat them and that we also feed them by protecting them so we ensure that we only take them at certain times of the year. We use cultural practices to keep the numbers in manageable lots and then Waiata. How do we actively express our role in those lakes? By restoring wetlands by doing our stream restoration. Those are the footprints of our people that made their way to the lakes using those streams and those pathways. For us it is about how would we express that?

Iwi management plans for the environment play a key role because they are somewhere to go. We can all look at them and see the values of those people in those places. It brings to life the stories and the attributes of the people associated with that place into the public domain and gives us some clues about how we might work with those people who hold that place so dearly to get the solution that we might be looking for.

Capacity building - We have seen a lot of research. I had a conversation with Ian Kusabs yesterday evening about research that we might drive from the Te Arawa Lakes Trust perspective in terms of Matauranga Maori I have been at the Trust for 4 months and have met ten graduates; science bachelors, masters or PhDs, who are Te Arawa living in Rotorua. That is a massive opportunity for us in tapping into their expertise and giving them the opportunity to flourish here in Rotorua. They can offer this programme something that may not have been done before, or in a new way.

Value Te Ao Maori is another principle of this framework. It is about managing the whole system, taking an holistic view. We talk about social, cultural, environmental and economic well beings. The approach that Maori take is to look at all those well beings and address them through their role as Kaitiaki, managing the whole system, land to lake, stream to sea and connecting them up.

A quick summary

- How close are we to a collective impact for Tarawera?
- Acknowledging the level of complexity and taking stock of what is complex?
- Are the outcomes expressing everyone's values and aspirations?
- Are there other ways we could express those outcomes?
- How are we measuring success?
- What story do we tell about this?
- Is it making a difference for whanau?
- How is each party making a contribution to the bigger picture?
- How are the parties connecting for effectiveness and wider benefit?
- Who is taking care of things?

He pena pena he roki roki he rakai whenua
To save to manage we will all be wealthy.

Kia ora

THE IMPACT OF 1080 ON AQUATIC ECOLOGY

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Alastair Suren is a freshwater ecologist working for the Bay of Plenty Regional Council in Whakatāne. Prior to this, he worked at NIWA Christchurch where he was involved with a wide range of research and commercial work looking at flow-biota interactions, the impacts of urbanisation on streams, and wetland ecology. While at NIWA he also led research examining the effects of 1080 on freshwater ecosystems, and on the fate of 1080 in catchments.

TRANSCRIPT

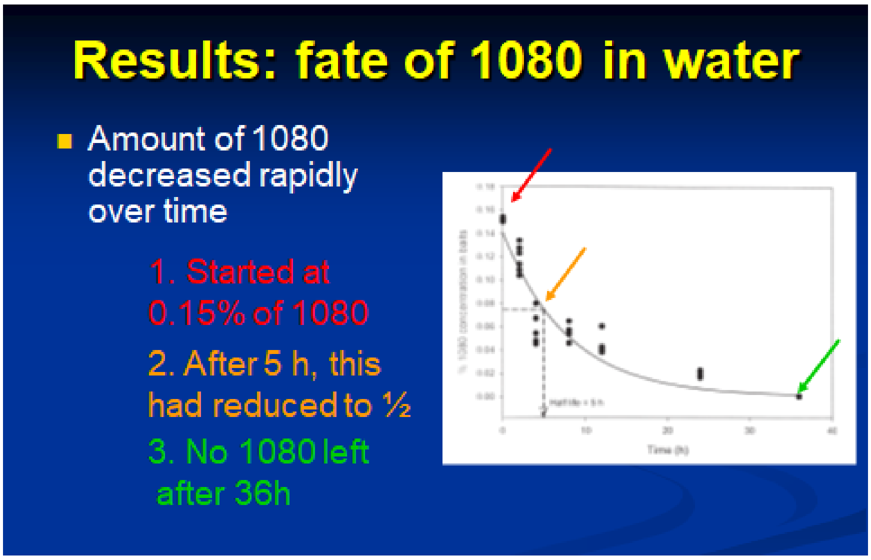
Kia ora everyone. I was at NIWA in Christchurch before coming north to the Bay of Plenty Regional Council. I became involved with the following studies as a result of what could best be described as a low-key assessment of a 1080 drop on the West Coast with the West Coast Regional Council. Following this low key assessment, I approached the Animal Health Board to conduct some more robust studies to answer the very important question, 'What effect does 1080 have on aquatic ecosystems?' I eventually did five studies while at NIWA, which were all funded by the Animal Health Board, and it is these studies that I will now discuss.

These studies essentially build on previous work, and answered questions such as:

- What happens when 1080 baits land in streams?
- What effect does 1080 have on stream life (fish and stream insects)?
- What effect does 1080 have on kōura?
- What is the fate of 1080 under rainfall – do streams become contaminated?
- Does 1080 enter soil and groundwater?

Within New Zealand, 1080 is the only pesticide allowed to be applied aerially. However helicopters simply cannot avoid flying over streams during these aerial operations. Although some regional councils implement buffers around their bigger rivers, most of the smaller ones have no such buffers, and it is these small streams that baits can, and do, land in. For example, the slide here shows a small stream in the Lewis Pass area with a 1080 bait in it.

The question is, then what happens to these baits? I wanted to see how quickly 1080 leaches from baits once they have landed in a stream. At NIWA, we do a lot of work with flow and ecology. We had a flow tank which could circulate water at 20 cm per second around the tank. This velocity is typical of an average mountain stream. I placed baits in the flow tank and measured the 1080 levels over time at 1 hour, 2 hours, 4 hours, 8 hours and 12 hours to find out how much 1080 was in the baits. From this I could easily calculate the time it takes for 1080 to leach out of the baits.



The graph shows that overall the amount of 1080 in the baits decreased very rapidly over time. You can see time is shown on the X axis - 10 hours, 20 hours, 30 hours and on the Y-axis is the 1080 concentration. We express the amount of 1080 in a bait as percentage weight of 10u0 per weight of bait. We start off at 0.15% weight of 1080 per weight of bait. As you can see after 5 hours that decreased to half the concentration, and after 30 hours there was no 1080 left. You can see the rapid exponential decay and then it tapers out over time.

Once it leaves the baits, with all this water flowing past, the 1080 chemical is diluted to extremely small quantities, often below detection, and is simply washed away. It is probably the only time I would be happy to say, 'dilution is the solution to pollution'. We also know that because 1080 is a natural product, it is broken down by bacteria, although this rate of decomposition is slower in colder waters such as in the South Island.

Most Regional Councils and the Health Department require operators to monitor water quality after a drop for signs of 1080 contamination. The Ministry of Health has set guidelines to ensure that no 1080 contamination of drinking water supplies exceeds 2 parts per billion for safe drinking.

Landcare Research lab tests have shown no significant or prolonged contamination of surface waters with 1080 after drops, and they analysed over 2,400 samples. This is an impressive result, especially when considering that we can detect 1080 to a degree of 0.1 parts per billion.

To give you an idea as to how sensitive the test is to detect 1080, let me explain what 1 part per billion is. Imagine 1 gram of something put into a single 10-tonne dump truck. Then imagine that you have another 99 more 10-tonne dump trucks driving past. Thus 1 gram amongst those 100 10-tonne trucks is 1 part per billion. But we can detect 1080 down to 0.1 parts per billion: that is 1/10th this amount. So, if we cannot detect 1080 in water at concentrations of 0.1 parts per billion, it raises the philosophical question that if we cannot detect it, is it still there? Obviously I do not have the answer to that question because everyone's philosophies are different, but the point I am trying to make is that the tests for 1080 are incredibly sensitive, and yet the vast majority of results have returned an absence of detectable 1080 from water sampling.

Once I had shown that 1080 leaches from baits relatively quickly, and that it is often diluted to below our ability to detect it, I then had to answer my second question, 'What was the effect of 1080 on stream life?' I examined the effect of 1080 on fish and invertebrates in five streams near Greymouth that flowed into the Grey River near Red Jack's Creek. These streams had very small discharge as I wanted to minimise dilution. They were generally no more than 1-2 metres wide, and mostly quite shallow. Their average discharge was less than 100 litres per second, which represents very small streams where dilution would be minimal.

I wanted to simulate a worst case scenario of a lot of baits landing in a small area. As part of earlier work characterising the degree to which streams become contaminated with 1080 baits, I walked up a number of streams in operational zones where 1080 was being applied aerially. The most number of baits I counted up a 100m section of stream was 8, so I put in ten times that in one location in the small streams I used for this experiment. This was to ensure that I was creating a big loading to see if that worst case scenario could affect fish and invertebrates.

I monitored fish and invertebrates survival above and below the baits. The fish species targeted were longfin tuna, upland bullies and koaro. I put these fish in separate cages, at 2 sites above the baits, and 2 sites at increasing distances below the baits. I then looked at survival 1 and 4 days after the introduction of the 1080 baits. I did not run the experiment for more than 4 days because there would be no 1080 left in either the bait or the water by then. I was thus only interested in short term acute effects. I also collected water samples to measure how much 1080 was in each stream after I added the baits, and to confirm that all the 1080 had disappeared by day 4.

I only assessed the effect of 1080 leaching from baits, and not of animals consuming baits. Some people might think that is a big weakness to the study, but I did this because all our native fish are predators, and would not eat cereal bait. Fish are visual feeders and feed on things floating in the water column or at the surface of the water, or moving along the streambed. They will swim by a bait and simply ignore it. This behaviour is why Landcare Research had to force feed tuna 1080 bait in a study they did to assess whether tuna were affected by 1080.

Most invertebrates would also not consume baits. They are so small that they could not consume a whole pallet. Although an individual animal might crawl onto a bait, only those invertebrates such as caddisflies or stoneflies that have mouthparts to allow them to actively 'shred' and bite into decaying leaf litter would ingest parts of a 1080 bait. Furthermore, any consumption would only be by those animals that directly encounter a bait, and I was looking at the effect of 1080 leaching from baits on the entire community that would be potentially exposed to the 1080.

Did 1080 affect the invertebrate community below where I introduced it? From my water sampling, 1080 concentrations were found at only very low concentrations, about 0.2 parts per billion, which lasted for only a short period of time, After 24 hours, no more 1080 was detected. This result again emphasised that dilution is really important in reducing the effects of 1080.

The invertebrate community was dominated by caddisflies, midges, mayflies and stoneflies. We found absolutely no effects to biotic metrics that we calculated that described aspects of the invertebrate community. Although we found a slight significant difference with one metric above and below the 1080, I regarded this small difference as not ecologically significant. It must be emphasised that there is a large difference between statistical significance and ecological difference. For example, if we record the temperature on one day at 23 degrees, and on another day at 21 degrees, that is statistically different. However, would we really feel that difference, and would it affect us?

There is a big difference between statistical differences and ecological differences. The subtle statistical difference in only one of the many metrics that was used to describe the invertebrate community was not regarded as ecologically meaningful. All the other metrics displayed no consistent differences above and below the 1080 baits, as would be expected if the 1080 leaching from the baits was killing invertebrates. Because of this, I could confidently say that we did not observe any adverse effect of 1080 on the invertebrate community – even at the very high doses that we exposed these animals to.

We also recorded no fish mortality, suggesting that fish are tolerant to dissolved 1080. The USEPA have done some work on toxicity of 1080 to fish, and regard it as 'practically non-toxic' to the fish they used, one of which was fingerling rainbow trout. This lack of toxicity simply reflects the different metabolism animals have. Thus, dogs are very sensitive to 1080, whereas fish and other cold blooded animals are very, very tolerant, simply because their physiology is different.

From these results, I concluded that 1080 leaching from submerged baits had no detectable biological effects on fish or invertebrates. This reflected mainly the huge effect of dilution and also the fact that these animals are naturally tolerant to 1080.

What about kōura? Kōura are big enough to consume 1080 baits, and if they do, what are the implications? Will they die? So I did a study to look at that.

This study was run in a stream simulator at NIWA Christchurch, with water flowing through a pool and riffle area. I added kōura, invertebrates and leaf litter for food and left them alone in the simulator for about a week to acclimatise. I placed 10 kōura in the riffles and 10 kōura in the pool, each in separate cages. After 1 week, I placed a single pellet in each cage at dusk, because kōura come out to feed at night. Again, I wanted to simulate a worst case scenario of a pellet landing in an area where a koura would encounter it in a very short time – to minimise the time that 1080 could leach from the bait.

I also did not give any bait to another 8 kōura placed in the flow tank. These animals acted as control to see if they could absorb 1080 through their gills or their exco-skeleton. I then monitored the behaviour of all koura over time and measured their tissue for signs of 1080 after 1, 2, 4 and 8 days. After those times I randomly selected replicate kōura, euthanized them, analysed the viscera (or guts), the stomach and the muscles for signs of 1080. I always collected water samples as well.

What did I find? The highest 1080 concentration was only 1.1 part per billion, despite putting 20 baits in the simulator with a discharge of only 5 litres a second. Again this low concentration highlights the importance of dilution. I also found that kōura consumed the baits. Indeed, one individual ate almost half the bait, which I thought was quite interesting, but no mortality was observed, and their behaviour seemed unchanged. I did not interview them because I can't, but they looked and behaved perfectly okay!

What is important to note is that over 1, 2, 4 and 8 days the 1080 concentration in the koura viscera and muscles decreased, suggesting that kōura metabolised and excreted the ingested 1080. This is a well-documented physiological response of many animals which consume sub-lethal doses of 1080: they metabolise and excrete it. I was happy with these results as they confirmed the results of other studies of 1080 on other animals, in terms of the ability of animals to consume sub-lethal doses of 1080 and metabolise it.

I also found no 1080 in the control animals. That strongly suggests that 1080 contamination of koura flesh can only arise by direct consumption, and not by animals sitting in water where baits may have landed. This result also suggests that 1080 cannot enter via the gills or the exco-skeleton.

The conclusion from the koura study showed that they are unlikely to become contaminated due to their small home range, the presence of other food which they might prefer to eat and the rapid leaching rate of 1080.

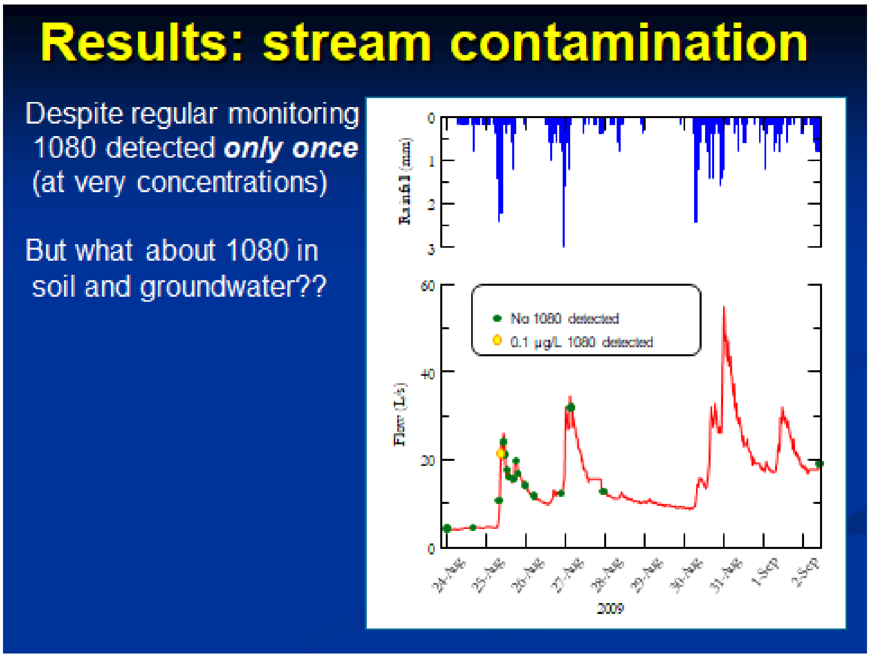
Some people are also concerned about what happens after a drop of 1080 and it rains. Does the 1080 leach out and contaminate streams? This lead me to my fourth study, which was done in a small sub-catchment that was excluded from a larger aerial drop done by the Animal Health Board a few weeks prior. It was not until heavy rain was forecast that 1080 was aerially applied to this small sub-catchment.

I did this work with a hydrologist at NIWA Christchurch, and we were examining the chances of 1080 contaminating surface water if 1080 was applied immediately before rain. Because the majority of the area had been subject to an aerial 1080 application a few weeks prior to our experiment, we assumed that few (if any) baits in the sub-catchment would be consumed. 1080 was aerially dropped 1 day prior to forecast rain, and we monitored a small stream, every hour for 12 hours after the start of the rain to see if we could detect 1080 in the stream. We continued the monitoring at increasing lengths of time for up to 9 days after the rainfall event. We had lots of coffee during this time as well!

These photos show the very steep country, well forested with black and mountain beech. You can also see the size of the very small stream, which was only about 5 litres a second

at base flow. Again this was done as we wanted to minimise dilution, and give us the best chance of picking up a 1080 signal.

What did we find? This graph shows the date the 1080 was dropped, at that second dot. We also collected a water sample prior to the drop to show an absence of 1080 prior to the drop. The rainfall is shown on the Y axis, and when it rained the stream flow increased. The one yellow dot on the graph is the only time where 1080 was detected, at 0.1 parts per billion. Every other sample we collected was below this detection level. I am not saying that there was no 1080 in the water, but I am saying that we simply could not detect it, even at 0.1 parts per billion. That is the limit of detection.



So, despite this very intensive monitoring during a rainfall event we detected 1080 in stream water only once, and at a very low concentration.

Finally, what about soil and groundwater, do they become contaminated? This question led us to the last study that looked at the fate of 1080 when it leaches from a bait in the catchment. Where does it go? Does it move into the soil and groundwater and eventually end up in the stream? To help answer this question we had 4 goals:

- to quantify the 1080 transport in overland flow
- to understand 1080 movement into the soil
- to examine whether 1080 enters groundwater
- to monitor 1080 concentrations in stream water

We wanted to quantify the importance of all these different pathways of 1080 and look at how long 1080 stays in the environment. We designed a somewhat ridiculous study whereby we placed 2 kgs of 1080 bait into a small area (0.4m^2) of hill slope. This huge amount was applied to such a small area simply to allow us to detect the 1080, and thus determine where it goes. Remember, we were interested in assessing the movement of 1080 from baits, into the soil water, the groundwater, and the stream water; not how realistic that movement was. For some context, aerial applications normally apply 1080 at about 2.5 kilograms per hectare, so the application rate we used was 50,000 times more than operators are allowed to apply. We then did lots of monitoring of water flowing across the soil or entering the soil, groundwater or stream. We applied the baits just prior to forecasted heavy rainfall, and collected samples throughout the rainfall period.

We ringfenced an experimental area by driving metal sheets into a slope up a steep sided valley about 25-27 metres away from a small stream which was about 3-4 metres wide. We caught any runoff from this area by collecting all the surface runoff at the base of the experimental area. We also deployed lysimeters, these big suction tubes, into the soil to sample soil water. We used a vacuum to pull the water from the soil into the tubes, and we took samples. We also installed a groundwater bore at the base of the experimental area near where we collected the stream water samples. The photos show the locations where we monitored the runoff, soil water, groundwater, and stream water. You can see that the forest floor was a mixture of fir, grasses and a few ferns. It was about 50% vegetated, 50% bare. The picture also shows the lysimeter as we take a water sample out.

Again we were lucky with the rain, and drank lots of coffee. A total of 75 mls of rain fell over a few days, equivalent to a 1 in 5 year rainfall event. Stream discharge increased and groundwater levels rose, because of the rain falling into the catchment and soaking into the soil water to enter the groundwater. We collected 95 samples during our coffee drinking experiment, but we only analysed 56 because the analysis of 1080 is very expensive. We deliberately chose those 56 samples to have the highest probability of containing 1080. These samples were all collected in the first 8 - 12 hours. Our thinking was that if we found 1080 in these samples, then we would return and process the other samples to see how long the contamination lasted for.

We found little, if any, overland flow, despite the hill slope being quite steep. More than 99% of the rainfall infiltrated into the soil water, which we were quite surprised at. We found no 1080 in the groundwater, or in the overland flow and stream samples, despite using that huge amount of 1080. The only 1080 we did find was in 7 soil water samples, of which 4 were right at our limit of detection of 0.1 part per billion.

The highest concentration we detected was 1.4 part per billion, and this was found in a shallow soil water sample 10 hours after the rainfall started. To put this concentration into context, the Ministry of Health safe limit for drinking water is 2 parts of 1080 per billion, so we could have drunk that soil water and have been fine. After 4 days, the concentrations in the soil water had decreased even more, down to 0.3 ppb and 0.1 ppb in the shallow and deep lysimeters respectively. This simply reflected the fact that it had now stopped raining, and that water was slowly seeping through the soil, and becoming more diluted as it worked its way downhill.

To summarise these results, only minute amounts of 1080 were detected in the soil water, none in the groundwater, overland flow or stream water. This was despite the huge amount that we applied to a small area at the head of our experimental area. This result again demonstrates the huge role of dilution during rain. However 1080 was detected in soil water following leaching from baits, but only at very, low concentrations.

From these results, we concluded that surface water and shallow groundwater can become contaminated, but under a realistic scenario it is negligible.

To summarise:

- 1080 rapidly leaches from bait and is diluted to extremely low concentrations
- Leached 1080 has no demonstrable effect on fish and aquatic invertebrates
- Koura can consume 1080 and metabolise it without harm
- Aerial applications will result in only minute quantities of 1080 leaching into surface water
- Any 1080 entering soil and groundwater becomes extremely diluted – often below detection

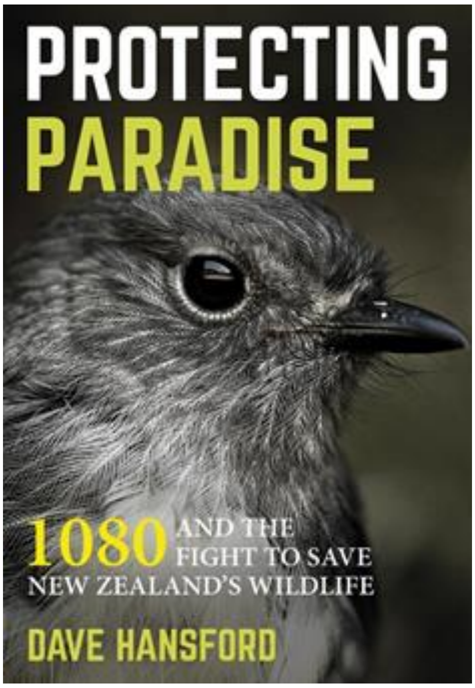
The relevance for lake restoration efforts is quite simple, in my mind anyway. Land based applications to remove pest species are unlikely to have any adverse effects on lake ecology or water quality and finally it is highly unlikely there would be any adverse effects at all on kōura.

1080 AND THE FIGHT TO SAVE NEW ZEALAND'S WILDLIFE

Dave Hansford
Investigative Journalist and Photographer
dave.hansford@me.com

Dave Hansford is an award-winning writer and photographer based in Nelson, specialising in science and environment issues. He spent 14 years as a press photographer before turning to freelance writing in 2002. He has worked as a science reporter for National Geographic News, and environment writer and columnist on The Listener.

TRANSCRIPT



Thank you for inviting me to come and speak today. I would also like to acknowledge a debt of gratitude to Alastair Suren, not only for that perfect primer to my talk but also for the fact that I cut and pasted nearly all of that into my book.

I grinned when I saw the title of the symposium was 'Troublemakers'. I am here because I wrote 'Protecting Paradise' and in it I looked at the science around 1080. I explored some of the popular myths and fallacies around 1080, those intractable fallacies that do not go away. I was so intrigued that much to my editor's concern I decided to find out why they are so intractable. Believe me that is a rabbit hole and I am going to take you as far down it as I can in 20 minutes.

- *Many poisons imbibed in parts per trillion by pregnant mothers are known to have disastrous effects on the off-spring. 1080 is one of these poisons.*
- *'From Dr Scanlon's report to the ERMA review in 2010 we learn of clusters of miscarriages, stillbirths and congenital malformations to the children of pregnant women following aerial 1080 drops. I remember the Featherstone (sic) outbreak. There was no warning.'*

This was a copy of a letter I received from a newspaper editor on the Coromandel recently. There has been a rash of these. It continues:-

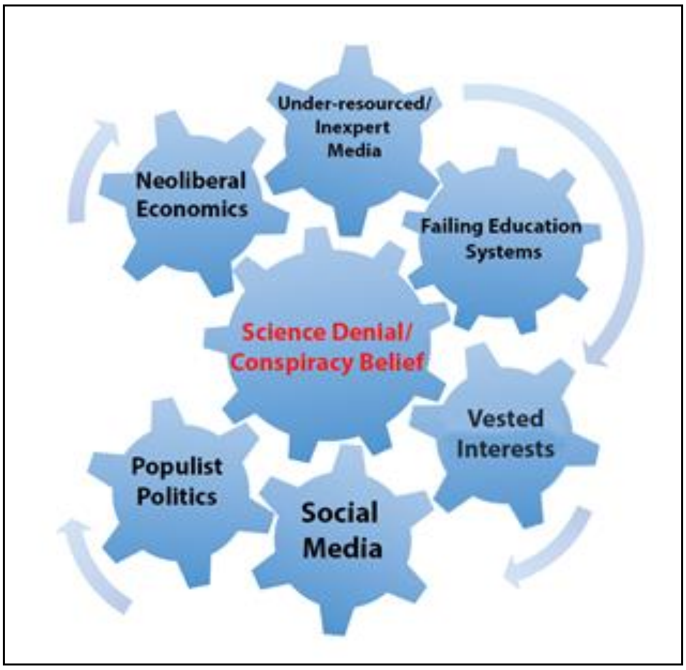
- *'If you live in Manaia for example, there is no way to prevent the streams being poisoned. All you can do is take your own precautions for yourself and for your growing children.'*

- *'To avoid dust stay many kilometers away from the area on the days baits are dropping. To avoid drinking poisoned water bring water in from outside the area for at least a year after the drop.'*

A newspaper editor sent this missive to me and said, 'Look I am trying to figure out whether I should publish this. Can you provide some comment on it?' So I duly did and I will return to that in a moment. I would like to point out, this was just written last week but it could have been written in1980. It could have been written in 1990.

This stuff will not go away, even when Alastair has so clearly demonstrated that so much of it is unfounded. I do not know about you but I am keen to know why it will not go away. I have been thinking more about the phenomenon which people increasingly refer to as the rising tide of science denial and ante intellectualism where somebody's beliefs and opinions are recorded the same value as evidence based science. Even worse they are portrayed that way in media and most certainly on Facebook.

I will take you through some of the socio-political and economic drivers that I have concluded are helping to pour petrol on this fire of science denial and conspiracy belief. There is growing evidence that the two phenomena are very strongly linked and I will hopefully provide you with some evidence for that as we go through.



There are those two drivers that I came up with and I would be very interested to hear from others if you have some more. My favourite topic is neoliberal economics. The contention is that our present systems of governance and the way that we now harness and use wealth have contributed to the growing inequity in society and that is self-evident. You see so many figures. The growing privatisation of what was formerly the province of the state; all those core government services - health, welfare, education and infrastructure - are disappearing. The regions are feeling the brunt of this dogma most painfully. It does not help when media start running stories like this.

Westpac closures reflect bigger trend affecting small town New Zealand

JOHN ANTHONY
Last updated 07:49, August 24 2016

JOHN BISSET/FAIRFAX NZ

If the Westpac branch in Fairlie closes, the town will be left without a bank.

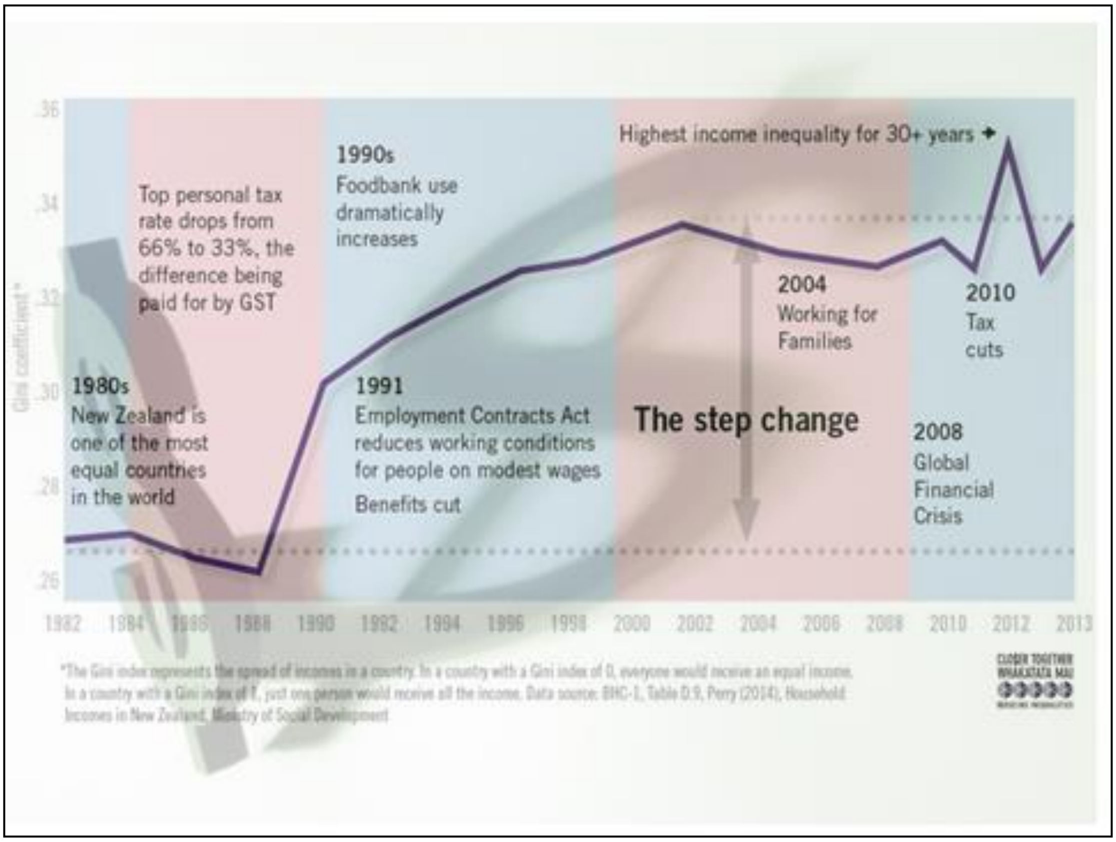
I want to give you my observation. When I looked at the hotspots of resistance or anti-1080 sentiment around the country there was a very clear demarcation between the attitudes of urban dwellers and those of rural dwellers. That is indisputable. So when we look at the real hotbeds of 1080 activism , the West Coast, Golden Bay and Coromandel – those happen to be the provinces that have been worst affected by what we refer to as 'Rogernomics,' the increasing privatisation of formerly state-run assets, neoliberal economics.

Newshub.
8 March 2017

HOME NEW ZEALAND WORLD POLITICS SPORT

Are NZ's small towns doomed?

28/02/2017 | By Scott Palmer

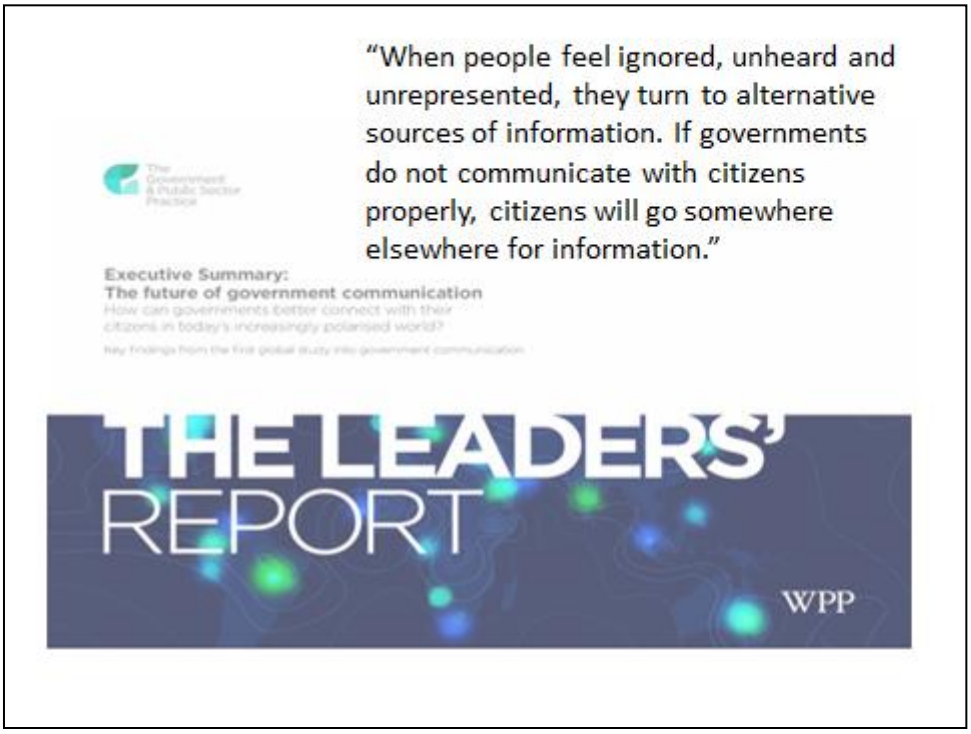


This is that step change I was talking about, the inequality. Ask yourself, 'How could this not have a social impact? How could it not leave people feeling like the system has let them down? How is it not working for them?' Would it be unreasonable to assume that it engenders distrust in the State, in the Government and of course in all its manifestations, all its agents, people, you and me? They seem to think I am part of the conspiracy, in the media.

This is where a lot of the growing sentiment comes from. If you have a quiet night, hold your nose and go onto Facebook and look at some of the anti-1080 Facebook pages and this is a recurring theme throughout. More than half the time 1080 takes a back seat and everybody is complaining about the 'damn Government'. Like I say, we really should not be surprised by this.

"Fucken DOC make me so angry I could scream. I seriously hate DOC & the government so much it hurts."

1080 Eyewitness, Facebook, 9 September 2015



This was a great study. If you are interested I urge you to look up the Leaders' Report from 2013, it was a very wide reaching study and spoke to public servants all over the OECD and makes for fascinating reading.

I talked earlier on about the purported link between conspiracy belief and science denial. Out there in the science community the jury is still out but a number of very important studies have come back with a conclusive link. I will leave that one over to you and you can make up your own minds.

Going back to people, in the absence of information, if you like, people feel like they can understand or trust. They create their own explanation for the things they see surrounding them. I am old enough to have read and relished Alvin Toffler's book, 'The Future Shock'. In it he contends that the rate and extent of change in the future will be so great that it will inevitably leave large sectors of society behind. I suggest to you these are just contentions, I am not a scientist, I am just a journo, but we may well be seeing that happening. People are now coming up with their own explanations for things that they either cannot understand, will not understand or simply do not trust.

This is a very popular theme. In a great deal of cases there is the notion that a lifestyle is under attack, that birthrights are being stolen. That is a broad and pervasive sentiment and, as I say, of course particularly strong in the rural sector. This happened last week in a very small town but residents again expressed the same old concerns about their water supply, they were going to be poisoned and there would be effects on the unborn. You can tick them off on your fingers nowadays.

I put this slide in by way of throwing a wicked question out to you. Every time we provide an alternative water supply during 1080 drops, we reinforce the belief. I do not understand the sensitivities that local authorities face when they have to deal with these things, but it is quite a vexed issue.


Council to supply temporary water supply

FRANCES FERGUSON
Last updated 13:25, August 24 2017

FRANCES FERGUSON / STUFF

Ohura resident Denis Smith is disappointed the Ruapehu District Council isn't doing enough to protect the water supply.

An alternative water supply is being arranged for residents of the small Central North Island town of Ohura after concerns over a 1080 poison drop in the town water supply catchment area.

If you want to know just how far this stuff can go I have put this in for a bit of fun. Most of you have got it already but the plot is quite a pervasive theme on anti-1080 Facebook pages. There is a belief out there that the Government owns the technology to trigger earthquakes at will. What happened to Kaikoura was the Government trying to clear it out to make way for Statoil so that they could get their hands on the oil and gas.

‘A lot of streams flow from that area (Kaikoura). It is almost as though the (1080) drop was orchestrated so survivors of the pre-planned quake or those on off grid blocks could be poisoned from meat or water.

Clean out the population to make a free for all for big oil or mining companies. The scam worked well for Christchurch. The dynamic duo of Key and Brownlee have their nose in the trough again.’

1080 Eyewitness, Facebook, 16 November 2016

Getting back to 1080, and it is quite a long bow, I could not find a 1080 drop around Kaikoura anyway, which let the theory down, but the Government is using 1080 to mop up the survivors from the earthquakes.

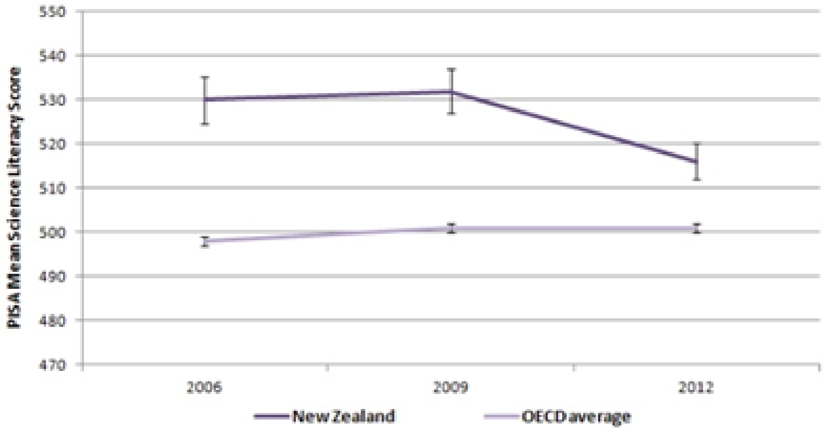
You cannot help but laugh at this but I am here to suggest that maybe we should stop laughing. The big contention is that we urgently need a programme of psychosocial research to help us understand what the hell is going on out there in certain sectors of New Zealand society, because it is very important.

Nicki Douglas talked about collective impact and the five principles, what we need to start prosecuting broad scale public policy and respond to all major environmental challenges that face us. Lord knows there are enough of them. They have to be informed by sound evidence based science. How do we do that if a growing proportion of the populace refuses to accept that science? It behoves us to start understanding this and that is my whole point. These things are always framed as a question. I do not need to tell you that there is absolutely no basis to any of these things.

> *'This Government is forcing us to urbanise and be reliant on what their trade and supply offer. That's a conspiracy theory!!! But it is the only logical reason that I can come up with for what they are recklessly doing!'*
>
> 1080 Eyewitness, Facebook, 16 February 2017

This leads me on to the second driver. We talked about the impact of fundamental capitalism on society and how it has left people disaffected. I want to briefly talk about our levels of scientific education. Historically we have not done too badly, hovering around the OECD average. Sir Peter Gluckman and many others have drawn the Government's attention to this inexorable slide, particularly at primary school levels. Maori and Pacifica students are struggling with Western concepts that come often couched in terms for which their own languages have no equivalent. So children are significantly disadvantaged right from the start. I wrote a story about this in 2012 and spoke to primary school teachers, many of whom had the same thing to say. They lack confidence teaching science these days and do not feel well supported. Health and Safety means they cannot do the old experiments in the lab with the Bunsen burners. It is very hard to win good practical moments with science any more.

Figure 1: New Zealand mean performance compared to OECD average (2006-2012)



May, S., Cowles, S. & Lamy, M. (2013). *PISA 2012: New Zealand Summary Report. Wellington: Ministry of Education*

> *'... In my view, school science education in New Zealand is not in terrible shape … but unfortunately we have a long tail of underachievement and we need to be thinking now about the challenges that are emerging.'*
>
> Chief Science Advisor Sir Peter Gluckman, 2011

The media is another cog in that wheel of science denial and conspiracy belief and a subject near and dear to my heart:

> *'... much of the media still tend to prefer controversies. We have seen how such a situation leads to the promotion of false debate when there is in fact, largely scientific consensus.'*
>
> The Office of the Prime Minister's Science Advisory Committee, *Scientists, the Media and Society: Where Are We Now?* 26 July 2013

This is not new. We know that the media have a love affair with conflict and 1080 in particular. When I started talking about 1080 - feel free to insert 'vaccination programmes', 'fluoridation', 'contrails', 'climate change', 'folic acid' - all of these things are gifts for media. We have a responsibility to report science based issues much better than we do.

I deliberately say 'We'. This is my favourite example. These two characters, Clyde and Steve Graf, are both committed anti-1080 activists. This story went to print in the Christchurch Press saying that Steve claimed that DOC had killed 12,000 native birds in one single 1080 drop.

I interviewed him and said, 'What was the basis for this?'
He said, 'Oh well, we found 9 birds there in the snow, and then we extrapolated.'

about to unveil their latest 1080 film, the matter is fiddly, but clear.

"We find that the people that actually support 1080 have a link, have a financial link to it," says Clyde Graf. "It's a big bureaucracy, so it's based on money more than anything. We are taking the cameras in so people can actually see the drop zone where they won't go into . . . because nobody goes into these drop zones and actually looks around. That's all."

"We just go for a wander" says Steve Graf. "We just go looking around to see what we can find, because this stuff is meant to be so great."

■ The Graf Boys' new 1080 documentary, *The Killing Fields – Revelations at Dawn*, will have its inaugural screening on Friday, February 6, in Hokitika in front of an invited audience. Their first 1080 film, called *A Shadow of Doubt*, was released two years ago.

In the dead zone: Campaigners Clyde, left, and Steve Graf have visited 1080 sites across the country for their new film.

That was a question that the Press journalist did not ask, and failed to point out that it was an unbelievably hard winter storm and birds tend to die in storms. By the way, 5 of those are blackbirds, so they do not count. The 4 natives were sent away and none of them was found with so much as a trace of 1080 in them but the damage was done. The story was out and people read it and they thought, 'My God, 12,000 birds!' It is easy to see how bad reporting only helps to feed science denial. **Beware fake news.**

Populist politicians are another cog in the wheel, although this one may have fallen off already. Not very long ago the prospect of banning 1080 was a promise that New Zealand First made. They now deny that and I keep sending them screen shots of their own press releases to remind them that they did.

A New Zealand First politician Richard Prosser toured with Clyde Graf and Kathy White and a number of others around those very regions that we talked about with some appalling anti-science. I sat in on one in Takaka. Fortunately only 13 people showed up but he said some truly egregious things about 1080 and ecology in general. Nothing is challenged so I include this political aspect because it is another coercive force in helping to legitimise bad junk science as an opportunistic motive force.

It gets quite militant at times and this is why it matters and another reason why we should stop laughing and take things seriously because anything that can happen already has.

"A vote for NZ First seems to be our best bet to get rid of 1080 Poison.
They have a track record for exposing Government and Corporate Corruption."
1080 Eyewitness, Facebook, 11 February 2017

What are the ramifications of science denial and conspiracy belief for blue sky projects? The immediate example that springs to mind is Predator Free 2050. I come from Nelson where we witnessed the most appalling spectacle of a small group of committed anti-1080 activists being able to capture a community group in Nelson by legally challenging the Brook Waimarama Fence Sanctuary proposed aerial drop of poison. They have done an excellent job of doing real harm to that community project. The bill for the Sanctuary is now close to $100,000 and it has gone to the High Court, having already been to the Appeal Court. They lodged an injunction, which was finally thrown out yesterday, but there is still an appeal and they talk of going to the Supreme Court.

There is a very real cost in practical terms to science denial, and particularly organised science denial. In my view, if we are going to achieve Predator Free 2050, we need a couple of game changes. One of them is almost certainly gene editing, a massive opportunity. It also carries some risks, but we must be able to make decisions on those 5 platforms and one of them must be evidence based science. We need to know what we are up against.

This is another cost and we see more of this now. I outlined a chronology of measles outbreaks in Auckland in my book. They were all in very recent history and none should have happened.

Measles outbreak spreads across Europe as parents shun vaccinations, World Health Organisation warns

'Misinformation about vaccines continues to proliferate on the internet. This is dangerous'

Katie Forster Health Correspondent | @katieforster | Wednesday 29 March 2017 11:26 BST | 24 comments

‘We are at the most dangerous moment in the development of humanity ... Right now we only have one planet, and we need to work together to protect it.

‘To do that, we need to break down, not build up, barriers within and between nations. If we are to stand a chance of doing that, the world’s leaders need to acknowledge that they have failed and are failing the many.

‘With resources increasingly concentrated in the hands of a few, we are going to have to learn to share far more than at present.’

Stephen Hawking, The Guardian, December 2016

I will leave you with Steven Hawking. At this point somebody usually puts a hand up and says, ‘What do we do about it?’ That is where I struggle because this science denial has been putting down hard roots for more than 60 years. We need an epic socio-political game changer to start turning it around.

If we start attending to those cogs around that central wheel we need a system of governance that re-empowers people, makes people feel like they count, and their decisions and choices will have an outcome. They need a grand vision. We made the mistake with climate change of getting bogged down on articles of science and facts. Facts on their own do not win arguments. Narratives do. Trump proved that. He had no facts going into that electoral campaign and look where he is now. We have got to learn from that.

When we talk about Predator Free 2050 we must not start off by saying, ‘Listen, gene editing will be perfectly safe.’ We talk about flocks of kaka. We talk about the fact that tieke are already nesting in people’s backyards now in Te Aro in Wellington. People must feel they want to subscribe because every study that has been done only reinforces the suspicion that if you try to counteract somebody’s belief with facts, all they do is double down. You attack them, because their beliefs are their identity and you are also attacking their tribe and affiliation, which, it turns out, is way more important than evidence or facts or reality. We need to get a better handle on these social dynamics and understand what motivates people, what frightens people, why they choose to invest all of this in belief rather than critical thought. We need to find a way to turn it around and I suggest to you we could start making society a little bit fairer.

Recently Maggie Barry gave a speech and said, ‘In terms of the anti-1080 naysayers, we are just going to have to leave them behind.’ I would suggest to you that a lot of those people are naysayers because they have already been left behind.

Thank you.

CASE STUDY – HUNUA 1080 PROJECT

Mace Ward and Rachel Kelleher
Auckland Council
mace.ward@aucklandcouncil.govt.nz

Mace Ward is General Manager Parks, Sports and Recreation, Auckland Council. The Parks Sport and Recreation department of Auckland Council is responsible for 4000 parks (45,000 hectares), 42 pools and leisure centres, sport and recreation management, and the administration of co-governed land, including the Tupuna Maunga. The department seeks to inspire Aucklanders to be more active, connect to nature, provide outstanding park destinations, conserve natural and cultural heritage and increase Auckland's Maori identity.

TRANSCRIPT

Kia ora mai tatou
Thank you very much for the welcome. You will notice that there is more than one of us. I am very pleased to have one of the real people who led the case study that we will talk about. Rachel Kelleher is the Manager of our Regional Parks in Auckland, all 27 regional parks across 40,000 hectares with 6 million visitors. The Hunua Ranges (Kohukohunui) regional parkland is what this case study focuses on.

I want to start by acknowledging Dave Hansford who is a hard act to follow. Mayor Goff's vision for Auckland is to be a world class city and the contribution of parks and open spaces and the intrinsic natural and cultural values of parks and open spaces are integral to that vision. It is not all about infrastructure. It is about people and how they feel about their environment and community, a different sort of prose than Dave talked about. Rudyard Kipling said when he came to Auckland in 1891, 'Last loneliest, loveliest, exquisite and apart.' He was talking about Auckland but he could have been talking about anywhere in New Zealand. He described Auckland as 'a very beautiful city, perhaps the most beautiful I have ever seen'.

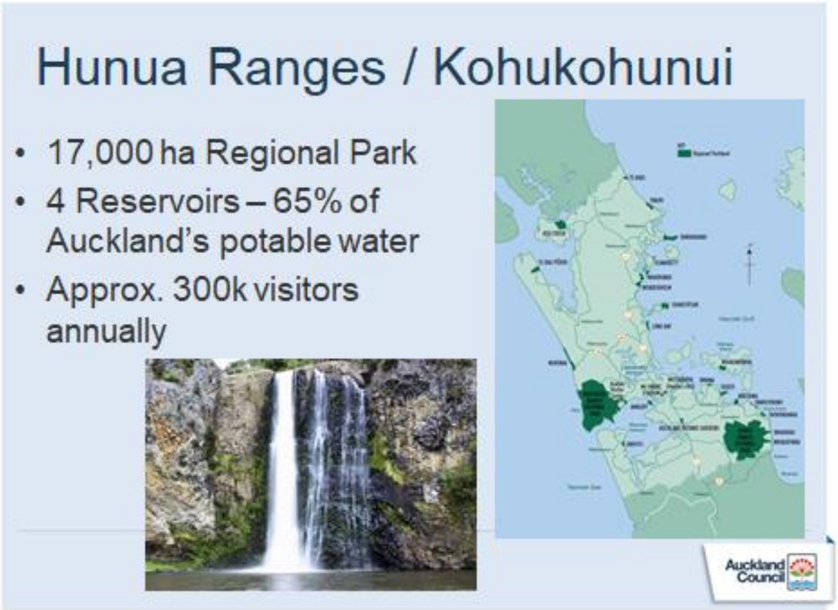
We had a problem. We had some troublemakers, rats and possum numbers in the Hunua Ranges parkland, an area that is significant ecologically and provides 65% of Auckland's water supply. It is our largest contiguous area of indigenous forest in Auckland with a significant connection to Tikapa Moana, the Hauraki Gulf. How were we going to deal with that? We had a long term programme in place but needed a game changer.

We will talk today about the history, how we took the problem to our elected members, our partners, Iwi and our community. We needed to share our vision and what we were going to do with our community. It was not necessarily about the science. We knew the science. We knew the problem and we knew how to deal with it. There were some options in how to deal with it but we needed to work with the community and to think about the narrative of what was talked about this morning, mokopuna. What was our legacy going to be? Were we happy to see the Hunua Ranges decline to a point where it was an unhealthy environment feeding and nurturing Auckland? Lastly we will talk about measuring success, celebrating those successes together with the community and continue talking to them.

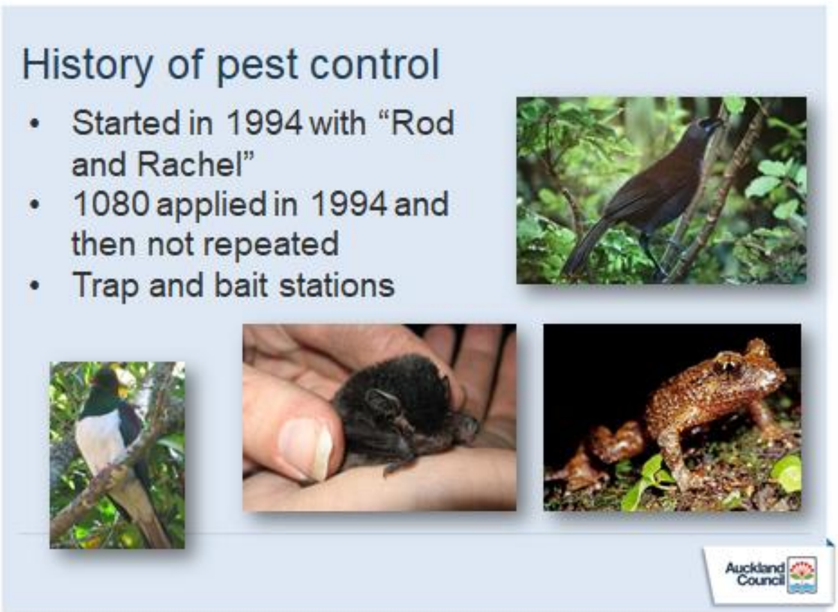
Without further ado I will hand over to Rachel and we will share some of this presentation.

Rachel Kelleher

Picking up on a comment of Dave Hansford, one thing that we did right from the outset when planning this operation was not to talk about it as a pest control operation. We talked about it being a programme to create a 'healthy Hunua', very much focussing our discussions around the outcomes and what we were trying to achieve as opposed to focussing on the methods and the way we were going to get there.



Very briefly, the Hunua Ranges is the dark green dot down there at the very bottom part of the Auckland region on the east coast, a 17,000 hectare regional park. What made this particular operation quite bold from a political perspective was that it contained four reservoirs that supply 65% of Auckland's drinking water. So a decision to use aerial 1080 in a catchment like this is one that has some controversy and requires a really good conversation. There are approximately 300,000 visitors annually undertaking a whole range of activities, mountain biking, walking and tramping. I found out through the operational planning that we have a small bore musket group and a whole range of other things as well as hunting.



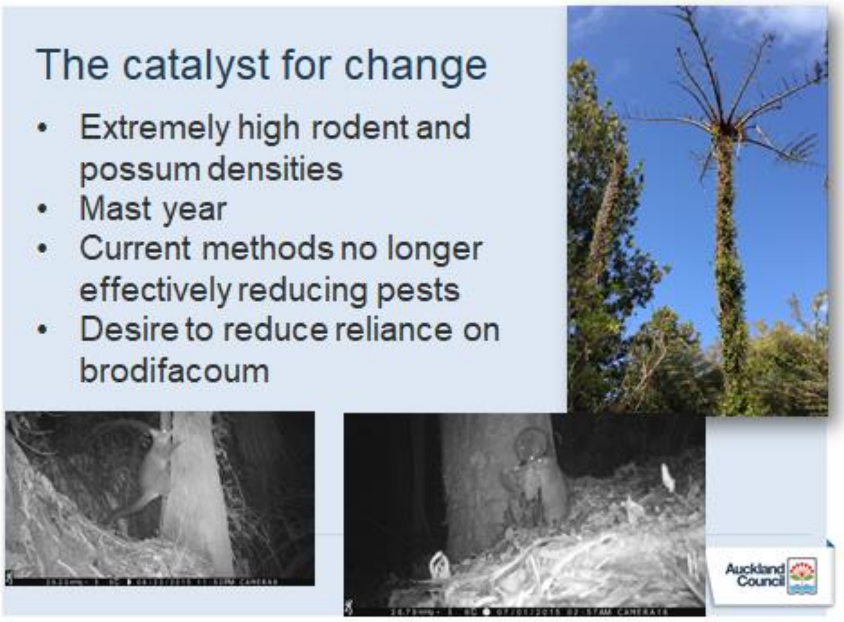
The Hunua Ranges are a fantastic forest ecosystem, in fact a whole range of different ecosystems – coastal, forest, wetlands right up to cloud forest in some of the higher altitudinal areas. There is also our only naturally remaining population of kokako in the mainland Auckland region. The pest control work started with a programme back in 1994. It began with Rod and Rachel, not me, a different Rachel. There were some ornithological surveys carried out in 1994 looking at the kokako and they found a significant decrease in the numbers of birds present.

That prompted a census; a survey exercise to determine that there were five breeding pairs still persisting in the range. They thought that was not great but better than nothing. They instituted a ring of steel around those breeding pairs, setting up a trap infrastructure and waited with bated breath to see how pest control using 1080 would help the breeding of those pairs. It did not go too well as they did not successfully breed. That prompted looking at why and they found that of the low numbers there were four male/male pairs and only Rod and Rachel were a female and male pair.

That began a real journey of recovery. A lot of pest control has gone into bringing that population back from the brink to now. It is looking like it is going to achieve, even exceed its projected targets for population recovery. We have had to do a bit of work bringing in new genetics and but that is one of our success stories.

Pest control is largely trap and bait stations. There is an intensively managed area of about 1,700 hectares where we focus on protecting kokako. Outside of that 1,700 hectares, across the broader park, we have an annual programme of pest control focussed on hotspots but never covering the whole range. It has been a moving pattern of pest control using ground based methods.

The catalyst for change was our extremely high rodent and possum densities. We do a lot of monitoring in the Hunua Ranges to inform our management, particularly around the kokako. We had a mast year which people may be aware of as a result of DOC's Battle for the Birds Programme that got a lot of media attention. It was prompted from mast year events that happen in the South Island but similar things happened in the North Island as well.



The current methods were no longer effectively reducing pests in our intensively managed area. We were struggling using methods that had been quite successful up to then to get our pest densities down. This was not surprising because when using anything for a long time there is resilience or resistance from the pests being targeted with those methods. We were also interested in looking at reducing the reliance on brodifacoum which is a commonly used pest control toxin. It is readily available, publicly accessible, but known to have impacts in terms of aggregation through the food chain.

Mace Ward

Process for Change: My job was to provide the leadership to talk to our elected members, iwi and our partners about this real need for change. We did some stakeholder surveys, canvassing our community to find what their interest was. We were able to tell the science story with comprehensive monitoring and technical review from others. We undertook a planning assessment of what we needed to do and ran a workshop with technical experts to share the knowledge with our community and partners including Iwi. Finally it went to the Regional Strategy and Policy committee in October 2014 for them to make a decision on the change of methodology, in a room that was quite hostile which was quite uncomfortable at times, but well worth seeing through. It was about telling the narrative of what we wanted to achieve - a healthy Hunua with kokako, reintroducing kiwi after 50 years, which we did achieve this year.

Why we chose 1080? Because 1080 effectively kills the target species we were after on this occasion – possums, rates and stoats. It was applied with minimal disturbance and impact to the natural environment. Unlike other parts of Auckland, the Hunua Ranges are kauri dieback free. For us to do that with a trapping network, which was an important discussion with Iwi in particular, we would have had to cut hundreds of kilometres of tracks, over 600,000 traps, to effectively do the same work. The adverse effects on species of non-target wildlife are known to be outweighed by the benefits of controlling the pests. We had to keep our eye on the prize and the risk to human health and community was minor and managed through strict national guidelines and requirements particularly in the context of the operational area being a water supply catchment. The design of our programme took that into account as well. It was cost effective at the landscape scale of over 20,000 hectares for the same price as partial control. Not only were we able to treat our land, we were able to include 4,000 hectares of other land around the parkland and that was quite important.

Key Partners:

- *Water Care Services*. Their objective is to provide clean, healthy water supply to Aucklanders. The water that comes from the Hunua Ranges does not have a lot of treatment, unlike the water from the Waikato River, and it is gravity fed into Auckland.
- *Department of Conservation*. We treated their adjoining land and private land
- *Waikato Regional Council*. Two thirds of the park, around 8,000 hectares, is in the jurisdiction of Waikato
- *Manawhenua.* Kohukohunui is a significant site. There was significant discussion with seven Iwi and tell the story about what we wanted to achieve. The environment was key and they weighed up the choice of rats or kokako and returning the kiwi to the Hunua Ranges and they chose the latter of returning those treasures and using 1080.

Manawhenua Engagement. In Auckland, like some other regions around the country, we have 19 Iwi and 7 have Manawhenua or Kaitiaki status in the Hunua Ranges. Engagement was really important and had to be open and honest and we needed to listen. At times we left Iwi alone in the room to make their own decisions. Hui, workshops, site visits with elected members, building trust and confidence and the support given was for kokako in favour of rats.

Mana Whenua Engagement

Iwi	Organisation
Ngāti Paoa Iwi Trust	Ngāti Paoa Iwi Trust
Ngāi Tai Ki Tāmaki	Ngāi Tai Ki Tāmaki Tribal Trust
Ngāti Tamaoho	Ngāti Tamaoho Trust
Ngāti Whanaunga	Ngāti Whanaunga Incorporated Environment Unit
Ngāti Maru Rūnanga	Ngāti Maru Rūnanga Incorporated
Ngāti Te Ata Waiohua	Te Ara Rangatu o Te Iwi o Ngāti Te Ata Waiohua
Tainui – Waikato	Waikato Tainui Te Kauhanganui

On the morning that we had the first drop, a number of Iwi were up there at dawn with us and they said, 'Last time we were here we were probably chasing each other around with taiaha.' But I have nothing to prove that that was the case.

We developed a cultural awa monitoring plan and since then we have been doing a lot of work to develop a Te Mahere Hononga Māori – Māori Relations Plan, to strengthen the relationship in the Hunua Ranges.

This was guided by two objectives:

a) To sustain the mauri (life force) of taonga within regional parks in ways which enable the significant place of tangata whenua to be acknowledged and their role as kaitiaki recognised.

b) To contribute to the hauora (long-term wellbeing) of tangata whenua, by providing for relationships and activities which enable the intergenerational transfer of tangata whenua knowledge and practices.

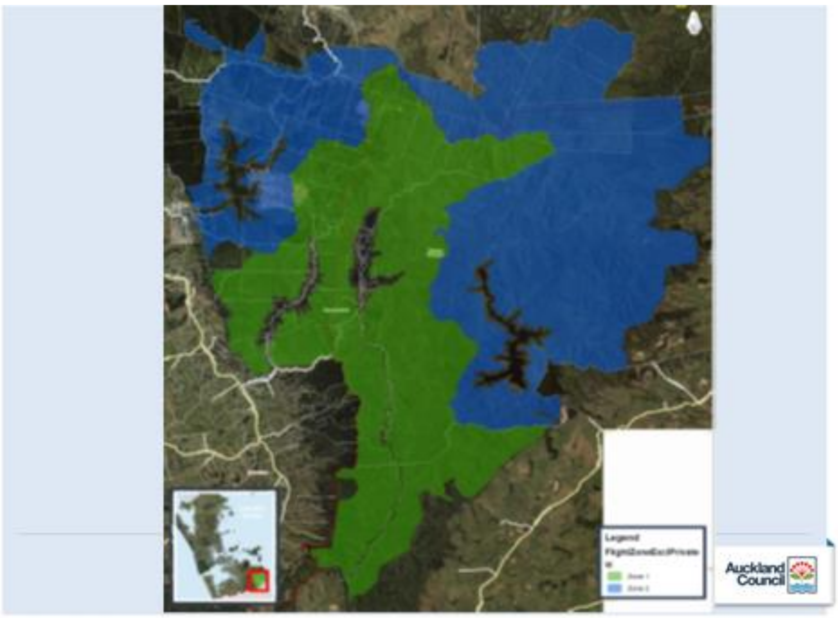
We also have an operational plan for track clearing and water sampling. We took the opportunity to develop a Kaitiaki cadet programme, involving people from Manawhenua and part of the success of the project.

Rachel Kelleher

The Operational Programme. We did a huge amount of work to get the message out. We had a website that received over 5000 dedicated views, press ads, fact sheets, paid advertorials, interpretive signs, and warning signs. At one stage I counted how many pieces of dedicated communication we had, and it was over 23 with landowners adjoining the operation specifically that mention the risk to dogs. We did a lot of work with our adjoining communities and the wider Auckland public.

The operational area was 21,500 hectares and included Council park land, DOC and private land. We ended up developing an operational programme that, in a large part, managed perception of risk rather than actual risk. Listening to Dave Hansford and Alastair Suren's comments, there is a question as to the extent to which we should manage perceptions. However, given that this was the first aerial operation we had undertaken in 20 years, we felt that it was prudent to do a robust operation that would give us good information to present back to the community for future conversations.

There were two treatment blocks and that enabled us to isolate the water supply in one treated block while we work in the area that was being treated. It allowed that water supply isolation. We used pre-feed of 1.5 kilos per hectare; the toxic sowing rate is 2.5 kilos. We had a range of measures to manage risk including exclusion zones, setbacks around the reservoirs, a water monitoring programme, track clearance of forestry roads and amenity areas and infrastructure checks like rooftops, water disconnection and reconnection. Regional parks have a lot of infrastructure.

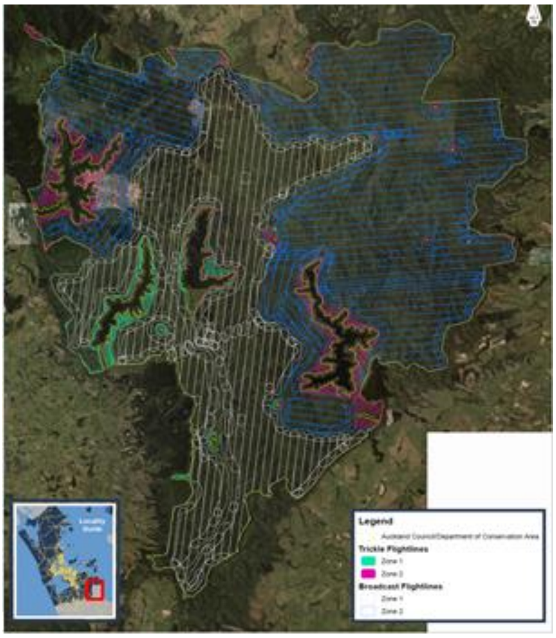


This map gives you an idea of what the operational area looked like. There were two operational blocks from a practitioner perspective, probably not ideal for flying a helicopter around that kind of shape but it was to enable the isolation of the reservoirs pairing up the smaller and the larger reservoirs with each other so that we did not have two small out and two large together.

The photo shows what one of those reservoirs looks like in part of that catchment. The operation was undertaken in two parts and these shots came from the actual operation to give you an idea of what is involved.

This was the Blessing of our first bait application and the photo on the top right was taken from a viewing platform that we have overlooking one of the reservoirs that I showed you.

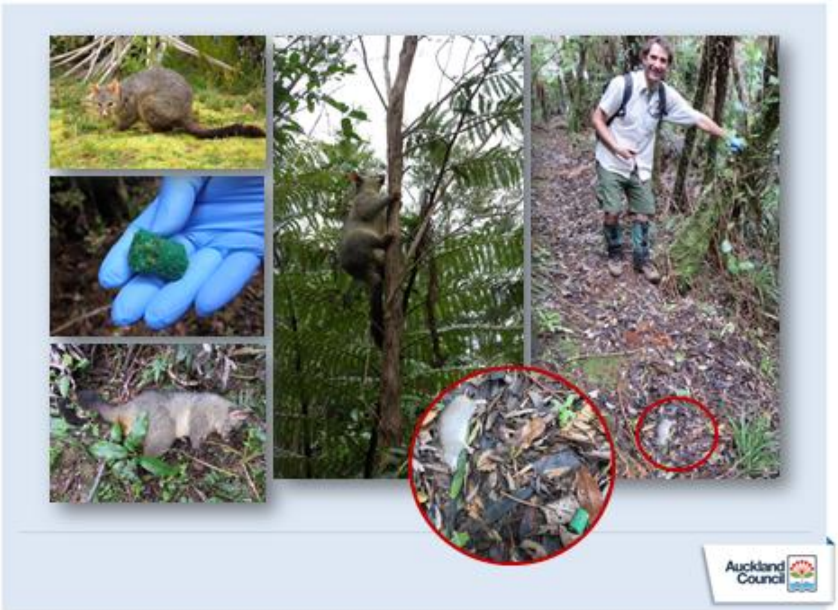
In our flying sites we had a couple of different helicopters working with two different buckets. One was a trickle bucket which trickles bait out in a very precise way and used to apply bait around the margins of the reservoirs and the perimeter of the operational area. The green buckets was used as a broadcast way of infilling that operational zone.



This is a print out of the operation showing how accurately the information is captured about where bait has gone. The broadcast bands are much wider in white and blue and the trickle lines are in purple and green around the reservoirs and the perimeter of the operational area.

We captured that information in live time down at the operational loading site. As a helicopter came in we would download the track log information. We knew at that point in time exactly where they had been, whether there were any issues with where the helicopter had applied bait and also good information about how to base our track clearance programme and when staff could start to move into the site to collect water samples.

One of the biggest challenges we had was the track clearance programme. From a public health perspective the largest concern our Medical Officer of Health had was about exposure of young children to bait on track. We had an extensive track clearance programme with multiple staff going out. On one day we had up to 70 staff out on site clearing tracks. We also had assistance from our neighbouring Waikato Council, which we were very pleased to have, volunteers and members of the Manawhenua came and helped as well.



These are examples of what we saw out on the day. There were also a lot of animals out the next day showing signs of lethargy having consumed the bait. The fact that we saw so many possums out the next day was testimony that there were a lot of possums out there. I have done a lot of these operations and you do not usually see heaps of animals out the next day but we did in this instance. Searching for bait the next day was like looking for a needle in the haystack, but once you get your eye in they are quite obvious, particularly in open track environments.

Water monitoring. We had four reservoirs of about 500 hectares in size. We also developed a programme of monitoring across 14 streams and rivers of variable size, some quite small to those much wider. A criticism of water sampling programmes is that often samples are collected around a 24 hour timeframe. Those who have concerns about these types of operations say that is not soon enough to detect 1080 if it is present. I am not sure what the benefit would be. If you get to 24 hours not detecting 1080 then you are not detecting it! So we did collect samples right from 4 hours after the operation through to 4 weeks. We did have one heavy rainfall event after our first operation and that constituted a whole new testing regime.

Over 300 samples were collected. It was the largest sampling programme that has ever been carried out for any single 1080 operation and not a single detection of 1080 from any of those 300 samples.

Post control pest monitoring results

Result Target	Treatment Block	Result	Monitoring line details
Less than 5% Residual Trap Catch (possums) for treatment area	Block One	0.25% ((-0.04% - 0.54%) +/- 0.29%)	40 monitoring lines 400 traps 1200 trap nights
Less than 5% Residual Trap Catch (possums) for treatment area	Block Two	1.00% ((0.45% - 1.55%) +/- 0.55%)	50 monitoring lines 500 traps 1500 trap nights
Less than 5% Tracking Tunnel Index (rats) in Kokako Management Areas (KMA and Piggots)	Traversed both blocks	0%	10 monitoring lines 100 tracking tunnels
Significant reduction in Tracking Tunnel Index (rats) across wider treatment area (pre-operational result 91.6%)	Both Blocks	1.03%	29 monitoring lines 290 tracking tunnels

These are our results. We did extremely well achieving well below our targets for all the pests we focused on. Possums and rats were both below 5%.

We did an extensive programme of breakdown monitoring, monitoring both carcass and bait breakdown in real time to inform the reopening of the park for dogs in particular. We were able to say with confidence that there was no risk posed to dogs at the time that we declared the site free of any issue. When we lifted the caution period it was based on practical information rather than theoretical information. This gives you an idea of what that looks like.

We had a range of different outcome monitoring - kokako nesting success, general forest bird monitoring, vegetation photo points, Hochstetter’s frog and the long-tailed bats. The six pairs of kokako are monitored annually. In 2014, before the operation, no eggs hatched and adult birds were predated. In the 2015 and most recent 2016 breeding season we have had 13 chicks of each of the six monitored pairs which is the best output that we have had.

The challenges - Park closures, vandalism, protests by a small dedicated group of about six people, one confirmed dog death that happened despite those 20 plus pieces of communication, offers of emetics and also free muzzles that staff were available to help fit, which were declined in that instance. We also had graffiti around the place but all in all a fairly minor impact.

A few facts and figures

- *8: the number of signs/barriers ignored by one tramper* the day after bait application. We closed the park and had a whole range of different ways of closing it. This person decided it was a good time to go for a tramp because it would be nice and quiet and he felt like a bit of solitude and knew he would not meet anyone on the day. He had gone past eight different barriers to get where we found him.

- *5: the number of dogs caught by staff inside the operational area* unaccompanied by owners, Lucky for those dogs, staff were able to catch them and they were safely moved outside the operation. But in all instances the owners knew the operation was happening, thought their dogs were secure but they were not.

- *>1100km: covered by track clearance teams across a number of days*.

- *0: the number of rats and mice detected following* *three* *successive monitoring periods* of our kokako management area after the operation. We got over six months of no detection of rats, mice and possums in that area.

- *1: the first nest and fledged chick outside the intensively managed areas*

- *5390: dedicated website views*

Thank you.

THE NUTRIENT IMPACTS OF FORESTRY

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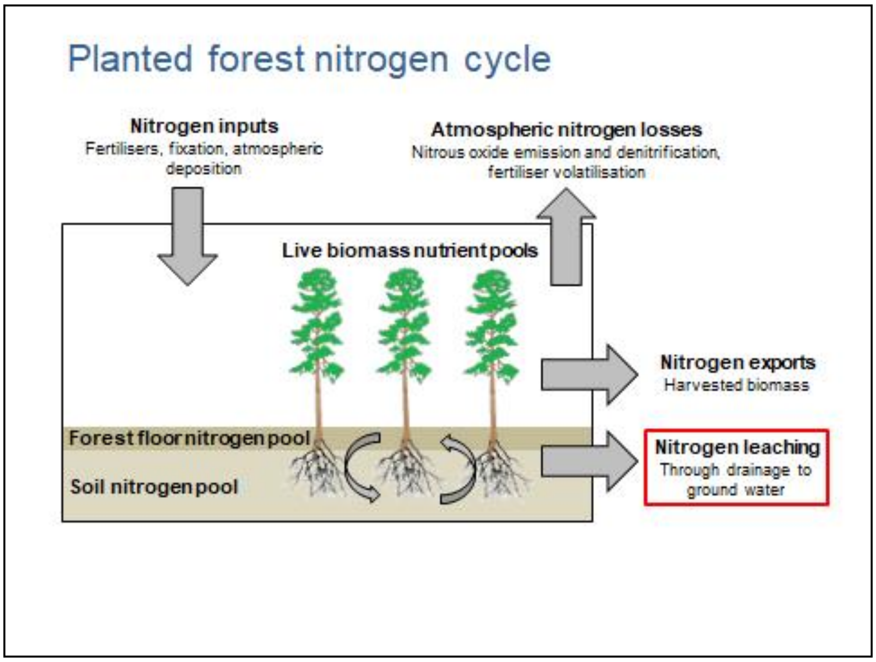
Peter Beets has worked as a research scientist at the New Zealand Forest Research Institute since 1974. He has research interests in:

- *Measurement and modelling of carbon stocks and changes in planted and natural forest*
- *Modelling stand productivity, water-use, and nutrient cycling in Pinus radiata*

TRANSCRIPT

Good afternoon ladies and gentlemen. Kia ora
I have had a long history in forestry and it started early as I was raised in a little place called Kaitawa at Waikaremoana. I roamed in the bush when I was a little kid and I have not lost the enthusiasm for trees and forest.

I have been working on New Zealand's Land Use and Carbon Analysis System (LUCAS) for the Ministry for the Environment to quantify carbon stocks and changes for planted and natural forests. I originally started at Scion when it was called the Forest Research Institute working on tree nutrition. It is relevant for me to discuss this topic now because after we put the carbon models together I was able to come back to tree nutrition. I was amazed to find the papers we published years ago were still in journals and not incorporated into models that we could use for tree nutrition. I suggested to the managers that it was time for me to put away administrative things and managing projects and focus on reading all those publications, not just from Scion, but other agencies too and put them into models. We are making progress.



A model is just a representation but to understand what happens in a planted forest you have to remember that they are very dynamic. The title was ‘Forestry Impacts’, which means a management component. We know that trees are planted, they grow, they accumulate biomass and nutrients that cycle around and you can see that in the flow diagram. There are nitrogen inputs coming from the atmosphere and nitrogen taken up from the soil, which accumulate in live biomass and dead matter in the forest as it grows. Some nitrogen can be exported in harvested logs but how much of that nitrogen in the forest ecosystem can leach?

There have been reviews of factors that influence forest nutrient cycling and leaching losses and what the forestry impacts are. Davis (2014), and Baillie and Neary (2015) showed that land use history is one of the important things to consider when looking at forestry’s impact. It may be different from what you might expect but the fertility of the site is key. When trees are limited in terms of nutrition they take up nitrogen very efficiently. You do not expect nitrogen to leach out of a forest plantation that is short of nitrogen.

LU history - unimproved shrubland with C/N = 24:
N & P loss to ground water are minimal

Knight and Will (1977), Warsnop and Will (1980) - lysimeter drainage water quality, Kaingaroa Forest, Pumice soil)

Parameter (loss kg/ha/year)	Age 1-3 years after harvesting	Age 6-12 years	Age 14 years (2nd year after fertiliser applied)
NO_3 – N	4.8	0.0	0.006
NH_4 - N	0.0	0.0	0.005
PO_4 - P	0.096	0.007	0.0

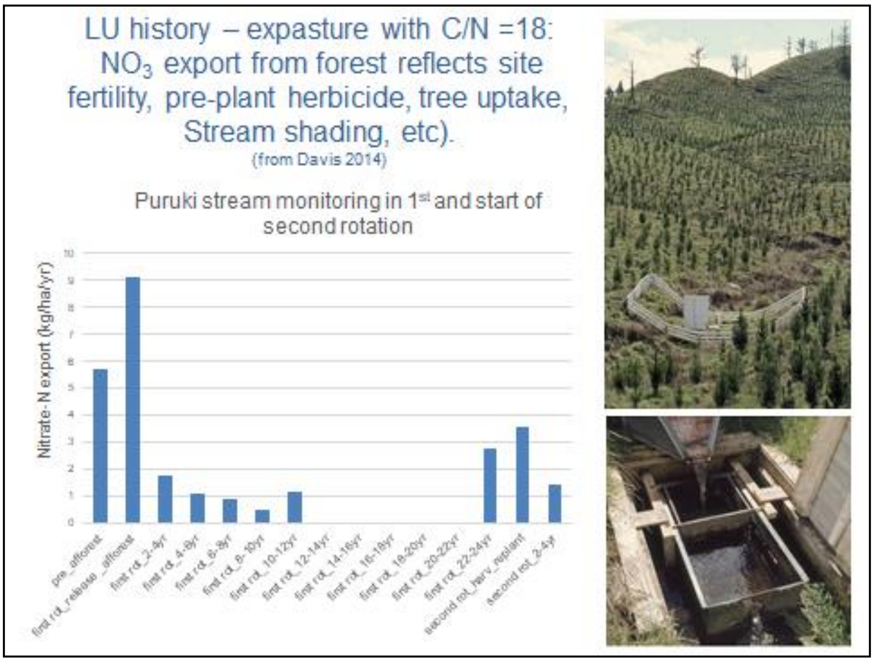
Rainfall averaged 1500mm
Drainage occurred Sept/Oct each year, and commonly in June-Oct

200kg/ha of ^{15}N enriched urea applied Feb. 1975 (13 year trees)
- Monitored for 3 years: virtually no N leached to groundwater
- NH_4 – soil elevated in week 1 (maximum in week 4)
- NO_3 – surface soil elevated in week 2 (persisted for 3 years)
- Week 2: 90% of N recovered in forest floor/soil to 30cm
- Week 4: 60% of N in floor/soil, and 50% after 3 years
- Timing and method of application minimized losses
- Trees accumulated 100kg fertiliser N/ha - demand > supply

The Kaingaroa Forest is an example of a forest not overly rich with nitrogen. It has had a history of shrubland (not a farming history) so nitrogen availability is quite low. A lysimeter study that collected water draining from the soil under the forest showed that zero nitrogen leached from this forest once the tree canopy had fully developed. The tree demand for nitrogen is too high at that stage to allow nitrogen to escape. This lysimeter study also showed that even after nitrogen fertiliser was applied to the soil to improve tree growth, hardly any nitrogen leached from the soil. For nitrogen to leach there has to be water draining from the soil. The fertiliser was deliberately applied in summer (February), when trees use lots of water, and soil moisture storage capacity was sufficient at that time to prevent drainage from occurring. So even though there was nitrogen as nitrate in the soil surface, it did not leach. Nitrogen moved deeper down in the soil profile but we also know how deep roots are. The rapidly growing trees had sufficient time to take up this nitrogen.

When tree growth is interrupted following a harvesting operation suddenly there is a completely different ecosystem. New trees are planted but their nutrient requirements are initially very low and nitrogen levels in the soil water increase. All sorts of weeds grow back rapidly, using some of this nitrogen, and there is spraying to control weeds. Tree evapotranspiration is low because there are hardly any leaves on the young pine trees in the first few years. Evapotranspiration is the amount of water the pine forest is using. Drainage therefore increases following harvesting and more water moves down through the soil beyond the reach of tree roots. The newly planted trees do not take up all of the available nitrogen so some nitrogen leaches at that stage.

A very fertile site is quite a different story. Does the supply of nutrients exceed the requirements of trees? If it does that excess nitrogen is not used and will leach under the type of soils that we have.



Here we see a little data series of stream nitrate exports when a fertilised pasture catchment is converted to pine forest. These are called land use history catchments. The Puruki experimental catchment was set up as part of the international hydrological decade. There were several catchments in this 1960s study, and this site has been monitored almost continuously since that time. Where the young pine trees are growing used to be pasture. There is an adjacent catchment left as pasture. There is also a native forest catchment there so it is a very interesting study.

There were lots of agencies that worked here including NIWA and scientists at the Water Quality Centre. A lot of data was collected. Interestingly in those days researchers seemed to be partitioned in what they were allowed to do. The Water Quality guys worked on streams and measured the quality of the water. We were forestry people and our focus was on measuring the forest. It is curious now because, as we have heard over the last few days, what goes on in the land determines what is going to happen in the water. One wonders why the separation. The good thing about this study was that it was an interdisciplinary interagency programme and allowed us to talk to each other and find out what was happening. As the data was collected there was plenty of discussion going on.

The graph shows that stream water nitrate levels vary markedly over time. The series begins pre-afforestation when the catchment was still in pasture, continues after tree planting, and ends after harvesting and replanting of the catchment. The area was sprayed prior to planting the trees, to release them from competition, and there is an obvious pulse of nitrate in stream water at that time. You all remember what happened at Hubbard Brook[1] don't you? If you keep on spraying, a lot of the nutrients will leach out. Then the trees grow quickly and there is a rapid reduction in the nitrate in stream water. Unfortunately there was a gap in the record. Water Quality monitoring commenced again just before the trees were harvested, when it was apparent that nitrate nitrogen in stream water had slowly increased as the trees became mature. This time series indicates that forestry has different effects at different times in the rotation. It is not just 'here is a forest effect and there is a pasture effect'. In a managed forest, tree requirements for nitrogen change over a rotation. Nitrate nitrogen that is not being taken up leaches from the soil and drains into the stream.

When the harvesting operation occurred, this tree age-related pattern repeats itself. Interesting pattern isn't it? To understand it, in the next few slides we will look at the nitrogen cycle in a managed forest more closely, but before doing this, one more piece of research is helpful to consider.

LU history – ex-pasture with C/N =18:
Soil water versus stream export (1984 with 11yr old pine) of N, P, and ratios for pasture versus pine
(from Cooper and Thomsen 1988)

Land use	Parameter	Soil loss (in springs) kg/ha	Stream loss (catchment baseflow) (kg/ha)	Stream loss (catchment total flow) (kg/ha)
Purutaka pasture	$NO_3 - N$	8.1	0.29	1.19
	DKN	0.15	0.72	2.62
	Total N		1.15	11.95
	DRP	0.13	0.037	0.37
	Total P		0.122	1.67
	TN/TP	63.5	9.4	7.2
Puruki pine forest	$NO_3 - N$	1.23	0.4	0.55
	DKN	0.43	0.19	0.52
	Total N		0.63	1.31
	DRP	0.07	0.017	0.036
	Total P		0.038	0.095
	TN/TP	23.7	16.6	13.8

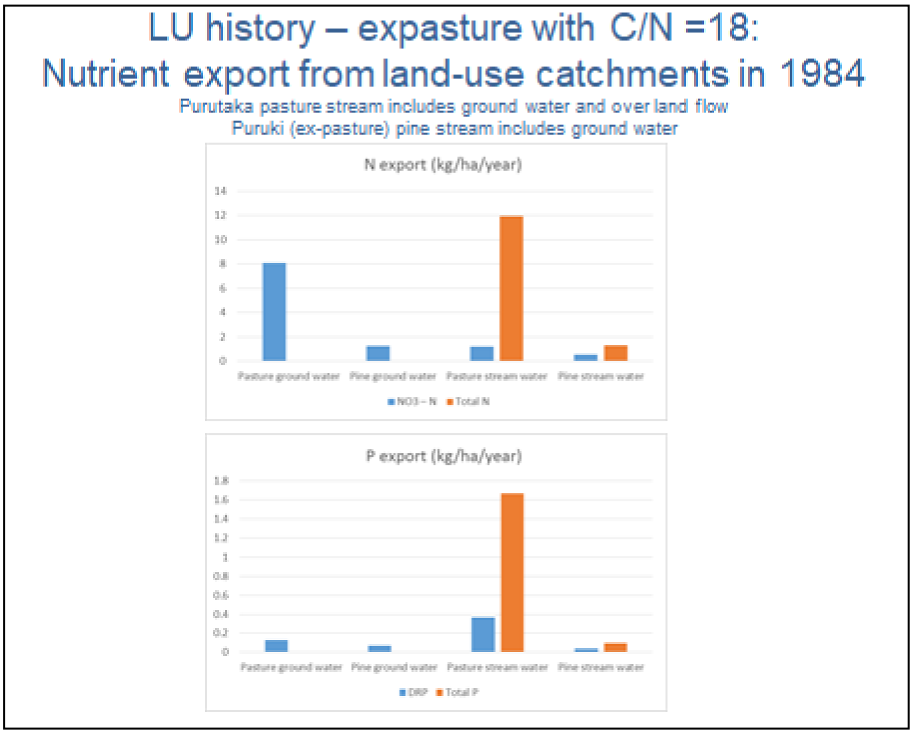
[1] https://hubbardbrook.org/ At the 8,000-acre Hubbard Brook Experimental Forest in New Hampshire, long-term studies of air, water, soils, plants, and animals have produced major discoveries about human and natural disturbances to the forested landscape of the northeastern United States. In a collaborative research project spanning nearly six decades, scientists have discovered the existence and origins of acid rain; unlocked the mysteries of lead, salt, and nitrogen pollution in streams and lakes; and charted the rise and fall of bird populations because of climate change and other threats. Research findings at Hubbard Brook provide the raw material for education and policy-outreach programs that deliver authentic data to students, policymakers, and members of the public who care deeply about our natural world. Hubbard Brook is much more than an ecological field station in New Hampshire—it represents a new paradigm of 'ecosystem thinking' that has changed the way we understand how nature works.

The previous slide is the work that Bryce Cooper and colleagues did showing soil (ground) water versus stream water export of nitrogen and phosphorus at Puruki. The trees were 11 years old at the time they did this study which showed that ground water draining from a pine forest catchment (that used to be pasture) contained much less nitrate than ground water draining from an adjacent pasture catchment. Why is that? The modelling work that comes next shows that 11 year old pine require a large amount of nitrogen, most of which comes from the soil. In the stream is a different story. In fact ground water and stream water monitoring tell different stories. What is it they are telling? As water trickles down the stream channel changes can occur in the form of nitrogen.

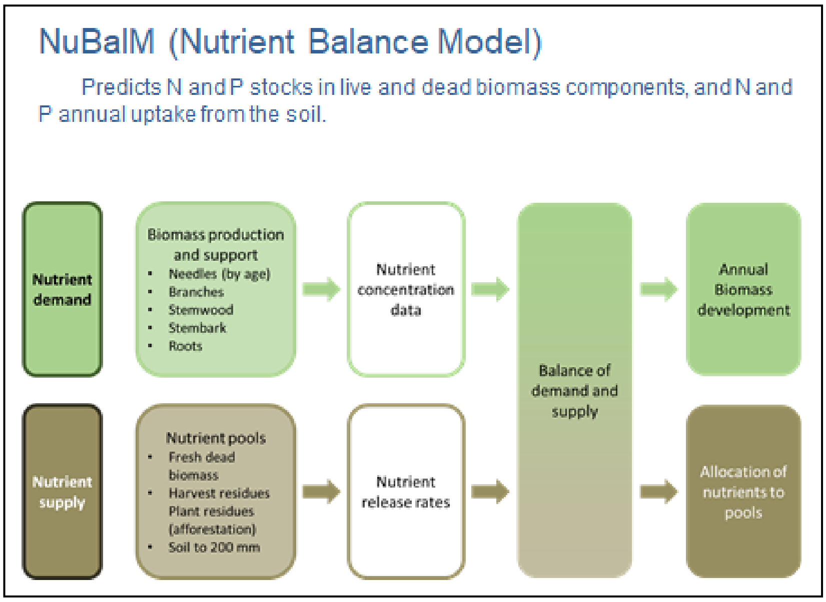
The relatively high levels of nitrate in ground water draining this pasture catchment were markedly reduced after entering the stream. That is the in-stream processing where vegetation growing in the stream channel takes up nitrate and stores it as organic matter before it even reaches the weir where measurements of nutrient exports are made. Organic forms of nitrogen from the vegetation growing in the stream channel are still exported, but this occurs mostly during storm events, which explains why the total nitrogen export from the pasture stream is high.

It is a similar story for dissolved phosphorus in ground water. However, total phosphorus export increases markedly from the pasture catchment when overland flow transports additional P, presumably from animal waste, during intense or prolonged storm events, which was not evident in the pine catchment.

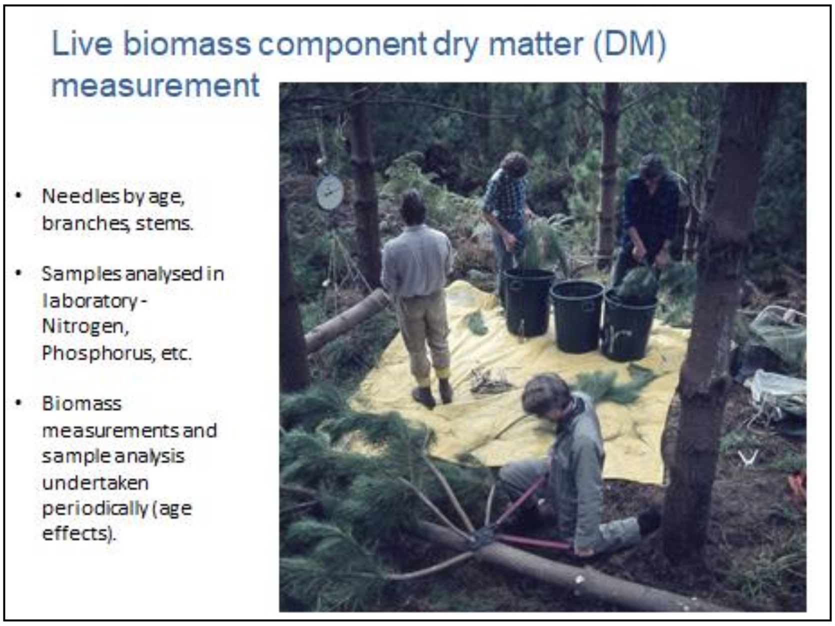
Unlike the pasture catchment, forest cover largely shades out vegetation that would otherwise grow in the stream channel, and in-stream processing of the nitrate in ground water that enters the stream does not occur. Therefore the export of both nitrate and total nitrogen from the pine catchment is low, as is the export of total phosphorus.



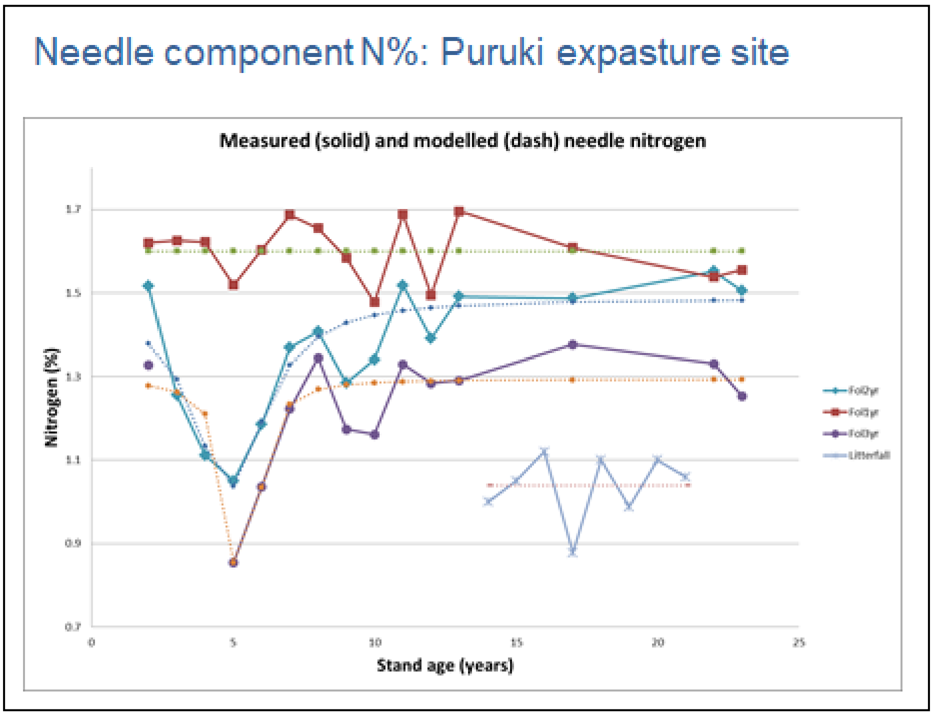
This slide shows a nutrient balance model (NuBalM) which has been developed for radiata pine to help explain and predict what goes on as a forest grows. We have biomass, the representation of different parts of a tree and nutrient concentrations which are needed to estimate N and P uptake from the soil. There is also dead material accumulating and decaying on the forest floor, which cycles nutrients including N and P back to the trees.



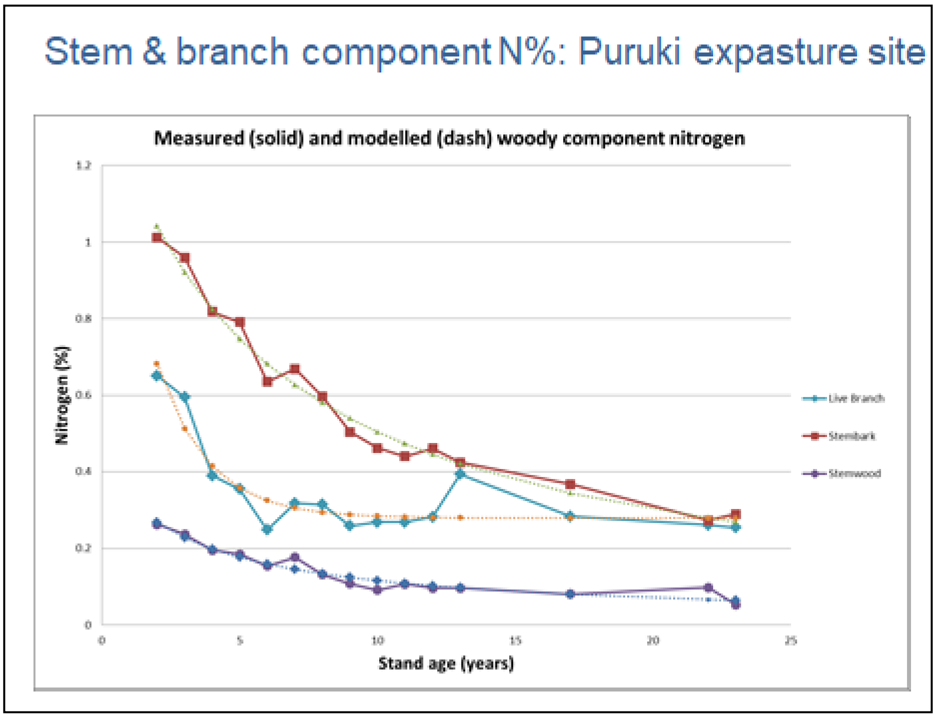
To get that kind of data you have to pull trees apart, age the needles, look at the different components such as the branches, stems and root, to work out how much requirement there is for nitrogen as a forest grows. Samples are divided into different components and analysed to look at their nutrient concentrations.



The new and old needle growth was measured and there is a big drop in concentrations between the two ages of needles when the trees are 5 years old but not later on. That is interesting. The litter fall comes when trees let older needles fall.



We also looked at how much the stem wood, stem bark and branches take up by tracking the concentrations in these components. Going back to the same forest year after year and re-measuring another sample of trees gave us data for modelling nutrient uptake.



The next slide shows the forest floor litter layer formed from the needle fall measurements in un-thinned and thinned pine stands. The most interesting information is the average value of 0.5, which states that the rate at which needles in the forest floor turned over nitrogen is half the rate at which the carbon turned over. In other words, the litter is rotting away but the nitrogen is retained for twice as long. That has implications on the graphs that follow.

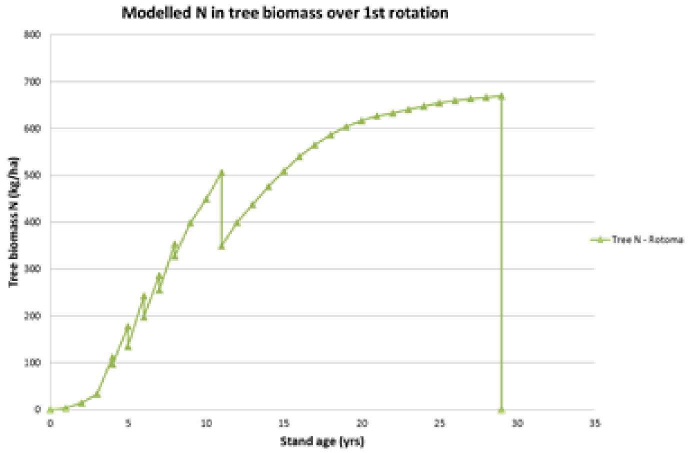
Litter N%: Puruki expasture site

Puruki Subcatchment	Forest floor (LFH) pool at age 22 years (excl. dead branch)			Average annual needle fall from age 14 – 21 years			Turnover rate		
	DM (t/ha)	N (kg/ha)	N (%)	DM (t/ha/yr)	N (kg/ha/yr)	N (%)	DM	N	Ratio N:DM
Plant 2200 sph, unthinned	35.9	762	2.12	6.33	70.8	1.12	0.18	0.093	0.53
Planted 2200, thin to 676 sph	23.5	509	2.17	5.15	53.4	1.04	0.22	0.105	0.48
Average									0.50

- Needlefall measured continuously (1987-1994).
- Forest floor measured in 1995 (to determine turnover rate).
- Nitrogen turnover rate expressed relative to dry matter turnover rate.

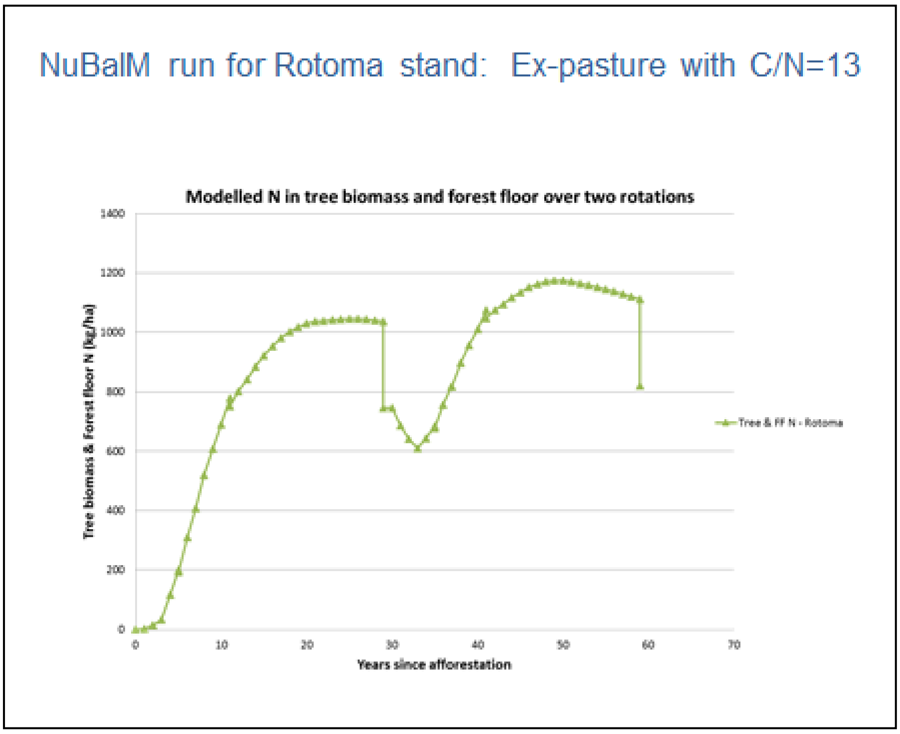
This shows the result of modelling nitrogen in live tree biomass in a first rotation stand at Rotoma. The tree biomass takes up over 600 kilos per hectare by the time the trees are about 30 years old. Pruning and thinning operations at Rotoma cause the periodic drops in nitrogen (saw tooth effect), which are followed by recovery of N in the tree biomass

NuBalM run for Rotoma stand: Ex-pasture with C/N=13



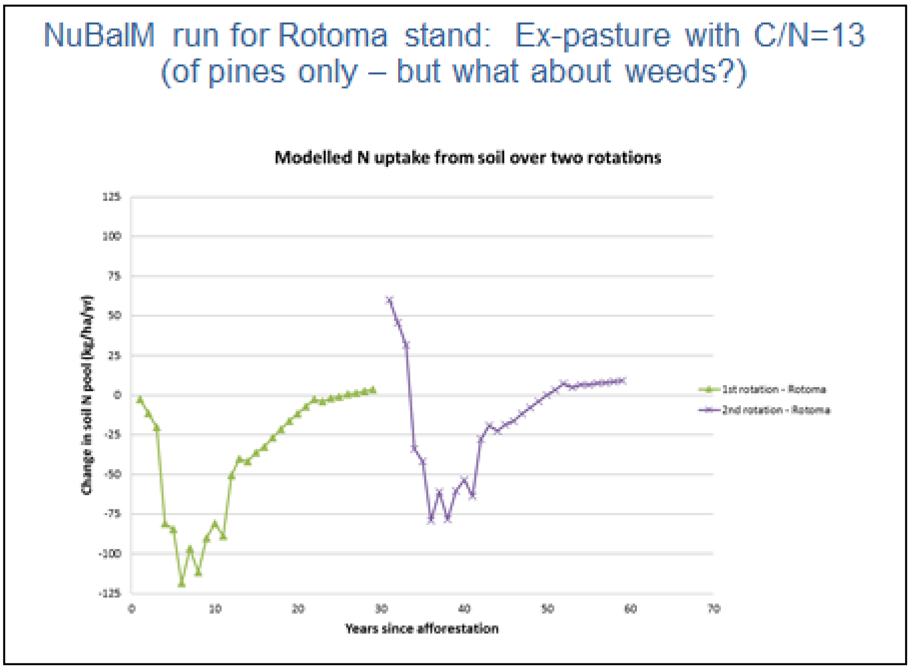
This shows the total nitrogen (live biomass plus forest floor) in a first rotation stand (climbing to just over 1000kg/ha) followed by the second rotation (about 1100kg/ha). At harvest there is a decrease in nitrogen (nitrogen in harvested logs is removed off-site and harvest residues decay) and then nitrogen climbs back up again as the second rotation trees grow. With the subsequent regrowth of trees nitrogen accumulates to over 1,000 kilos per hectare after 50 years. All that nitrogen comes from the soil, except a little bit from atmospheric inputs.

You would have seen harvest residues at a harvested site - they provide the nitrogen for the second rotation. The sudden drop at about year 30 results from removing the nitrogen as logs. The first rotation tree crop does most of the work of pulling nitrogen directly out of the soil and the second rotation relies a lot on recycling of nitrogen in harvest residues. This information has interesting implications in the longer term if the intention is to continue to draw down excess levels of soil nitrogen to reduce nutrient leaching.



This slide gives an idea of turning the nitrogen accumulation graph (the previous slide) into the annual nitrogen demand from the soil. The slide does not show the stock of nitrogen in the soil, but the change in stock (negative values mean the soil nitrogen stock decreases by the amount shown). So, how much is the forest needing out of this soil each year? At around about age 5 or 6 (1st rotation) the soil must supply about 100kg per hectare per year. That is a lot of nitrogen. You will then notice that, from age 10 – 20 years the annual nitrogen requirement from the soil gradually decreases (slowly becomes less negative). That is because nitrogen is increasingly being cycled through the litter fall and cycling through the forest floor.

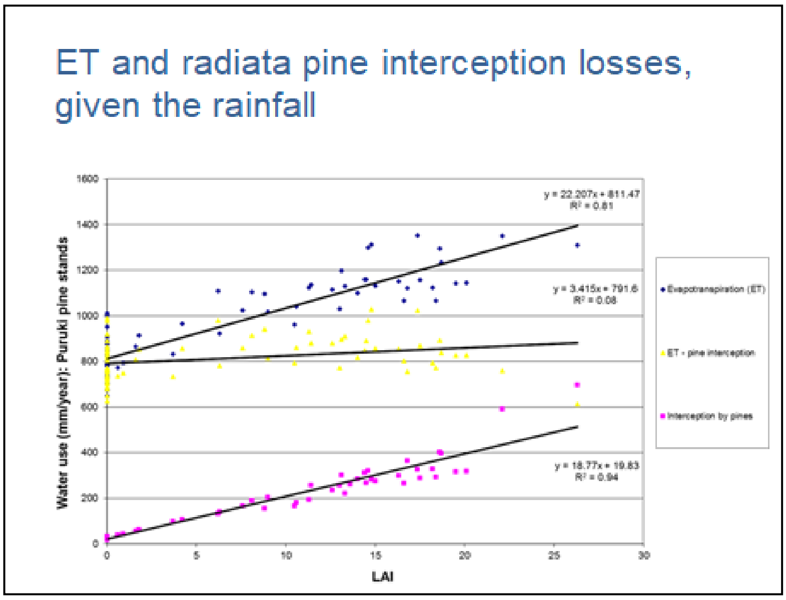
The annual demands on the soil eventually decline right away as the trees get older and rely increasingly on nutrient cycling. This nitrogen uptake pattern repeats itself in the 2nd rotation. However the demands on the soil are not as great now because the decaying harvest residues left on site provide nitrogen. In fact, the positive values at the start of the second rotation indicate that the amount of nitrogen released from decaying residues exceeds the annual requirements of the newly planted trees. Some of this nitrogen will be taken up by weeds and the rest will leach if soil water drainage is occurring.



To test the model, we used the NuBalM Water Balance Module at Lake Rotoma to see what is expected to happen. Rotoma had pine plantations recently harvested right near the lake. Working with the Bay of Plenty Regional Council, using lysimeters, we wanted to know how much nitrate nitrogen was in the surface soil water both prior to and after harvesting. The intention is to look at nitrogen leaching to the lake.

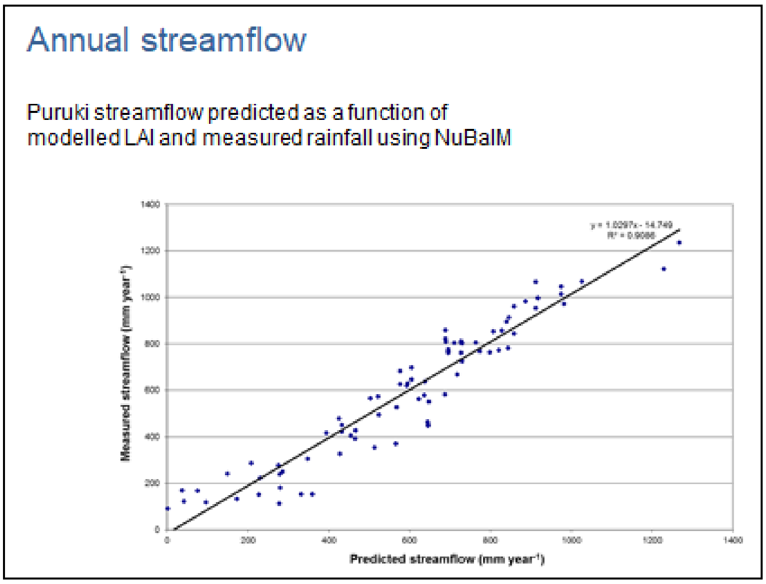
To get nitrogen leaching there has to be nitrate in the surface as a measurement. We have got a measurement of 1.29 milligrams of nitrogen per litre from these lysimeters at 1 metre depth. Then you need to have water draining through the soil to take the nitrate out. There is plenty of water fluxing through the soil at Rotoma (drainage is 985mm/year) when there is that much rainfall. Nitrogen leaching, based on calculating the concentrations at that one metre depth, is 12.7 kg/ha/year. We have ground water bores installed at Rotoma to compare with loss estimates based on lysimeters. Lysimeters 1 metre from the soil surface do not allow for tree uptake below 1 metre depth.

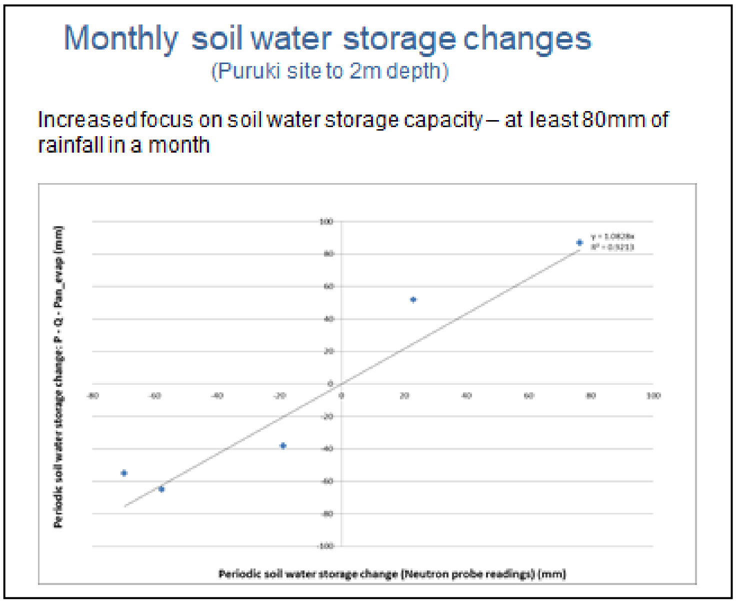
This shows a road cutting to look at how far down tree roots go. There are masses of fine roots well below 1 metre depth. When measuring the concentration of nitrogen in the surface, it does not mean it is necessarily going to leach to the lake. There is plenty of opportunity for the deep rooted species to grab hold of nitrogen before the soil water moves below the root system.



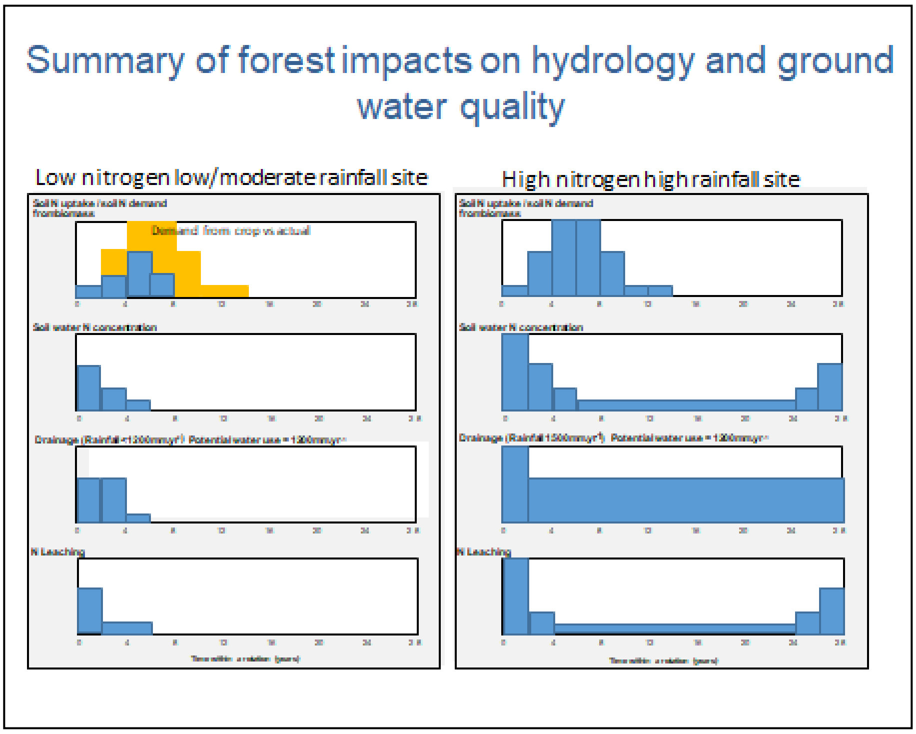
We can work out the drainage rates from a forest because we can calculate how much water is used by the forest from its leaf area (LAI). These three slides are based on the international hydrological decade study at Puruki. In this slide there are many layers of pine needles stacked on top of each other (that's the LAI = 20 when the tree canopy is closed) intercepting about 350 - 400 mm of rain. Intercepted rain evaporates before it reaches the ground. Evapo-transpiration (ET, is overall water use including interception loss) by forest is therefore higher than pasture because forest has higher interception losses. When there is 1600 mm of rainfall and the leaf area index of the pine forest is 20, evapo-transpiration is 1200 mm. Take that off rainfall and there is drainage (or streamflow) of 400 mm.

The slide below compares measured streamflow with the predicted drainage from the model. With 1600 mm of rainfall, drainage from the pasture will be about 800 mm, which is double that from a closed canopy pine forest. So that is why water use of forests is higher than farmland, which some people complain about. But it means that soils under forests are not as wet as those under pastures and can therefore accommodate more and larger storms.





The above slide shows that soil water storage can vary by about ±160 mm from one month to the next at Puruki. Depending on how wet it is, the soil content can absorb rainfall events of 80 mm or more without any drainage occurring. Those sorts of things have to be brought into the modelling to be able to predict nitrogen leaching.



The above diagram shows the main principles around nitrogen leaching that I want to summarise with respect to tree demand, soil nitrogen supply, and drainage.

Left panel: At a low nitrogen site, trees still demand a lot, they want to grow fast, they are pine trees growing but there is not enough nitrogen in the soil for them to take up. The nitrogen uptake is less than what they demand and cannot get. Can nitrogen leach then?

No. Of course early on there is hardly any leaf area and tree demands are still very small, so nitrogen supply from the soil exceeds the demand. That is when there is some leaching loss at low nitrogen sites - in very young stands after harvesting. Water comes in as rainfall, nitrogen is in the soil water and water comes through because there is not much leaf area on a young pine tree. That leads to nitrogen leaching.

Right panel: On a farm site planted with trees in an area with excess rainfall, leaching is quite different, the tree demand for nitrogen now being fully satisfied by that rich soil providing the nitrogen. There will always be some nitrogen left over in the soil water. This will drain away and some nitrogen leaching losses occur every year. The pattern of nitrogen leaching loss mirrors what we saw in the stream data on page 3 where a peak loss of nitrate (when the trees were small) is followed by a rapid decrease in leaching loses as the tree demands go up. There is a little climb later towards the end of the rotation, which the model predicts will happen because more demand is met through nitrogen cycling.

Sediment is probably the most difficult issue for forestry to deal with. Harvesting is the only time in the life of a stand where there will be more water coming off per hectare in drainage water than when there is pasture. For the rest of the time the trees will use more water than pasture. More water run-off means there is a greater potential for sediment loss.

This shows endeavours at Rotoma to trap sediment, considered to be needed in case the dry gully begins to flow. If we start planting more forests in lake catchments we need to consider sediment mitigation options. This issue has not been fully explored yet in terms of smaller wood lots with respect to the new National Environmental Standards. It will need to be looked at very closely, particularly around harvesting. Rotoma is one of those dreaded dry catchments that hopefully does not become a raging torrent in downpours. I do not think it is a sensible to plant up farm stream gullies that will later be harvested. Where would you put in a forest? Trees do not need fertiliser on ex-pasture sites.

This summarises some of the benefits of having forest on farms to reduce leaching losses to ground water:-

Soil fertility

- Trees do not need to be fertilised
- N and P leaching losses diminish relative to pasture land use
- Forest demands on soil nutrient reserves are large in first rotation but small in the second rotation (with stem only harvesting)
- Research shows that soil nutrient depletion occurs using more intensive organic matter removal practice or intensive biomass harvesting (eg. for energy) – is this desirable?

- The challenge is to close the cycle - fertiliser inputs to farm could be reduced by cycling nutrients trapped by trees back to pasture
- How? Tree species for silvo-pastoral systems (fodder). Litter raking (bedding)

  Sediment issues
- Run-off increases when harvesting. Sediment transport control options need to be considered

In the old days they used to litter rake for bedding which was used under stock in their yards. Litter raking reduced forest productivity, until that practice was banned in some countries. It is an example to show that nutrients can be drawn down by removing and raking all the forest floor away, and accentuating the drawn down in areas where there is too much nutrient, which might be in zones where nutrients are trapped.

I talked about pine because we have lots of data but there are other tree species and silver pastoral systems that could be considered. Apples and all sorts of woody vegetation used to be grown with pastures. It was not all pure pasture but mixed up and the variety of species provided key nutrients. We bring in palm kernel for key nutrients. I do not know why. Why not grow other species to do that?

The NuBalM model development research described in this presentation is funded by New Zealand Forest Owners through the levy. Every grower of a stand pays the levy when the trees are harvested. Research now is focussed on linking this modelling system to different types of soils around the country but it is mostly focussed around here at this stage.

FARMER PERSPECTIVE

Chris Sutton
Farmer, Rerewhakaaitu
crisanda@xtra.co.nz

Chris Sutton is no stranger to Rotorua's political and environmental scene. He has been involved in Project Rerewhakaaitu for over 10 years. He was also a member of the Land Use Futures Board, past Provincial President of Rotorua/Taupo Federated Farmers and National Vice Chairman of the Federated Farmers Dairy Section. Chris and Rosemary Sutton have farmed 105 hectares in Rerewhakaaitu for 23 years. Up until three years ago they were milking 260 cows, today they fatten heifers and steers. Chris and Rosemary are thoroughly enjoying the change in stock class within the new farm system.

TRANSCRIPT

When we did the biography and it was only 100 words, I gave it to my wife and said, 'Well there we are, 30 to 40 years gone'.

We are beef farmers now. We went to the Rerewhakaaitu area as dairy farmers and four years ago, on 23 September 2013, we sold the dairy cows and moved into a beef unit. We have been a beef unit ever since on 100 hectares. When we first got married, Rosemary was a nurse from Te Whaiti and we both decided to own a lifestyle block either at Kaharoa or Rerewhakaaitu and ended up buying at Rerewhakaaitu in a roundabout fashion.

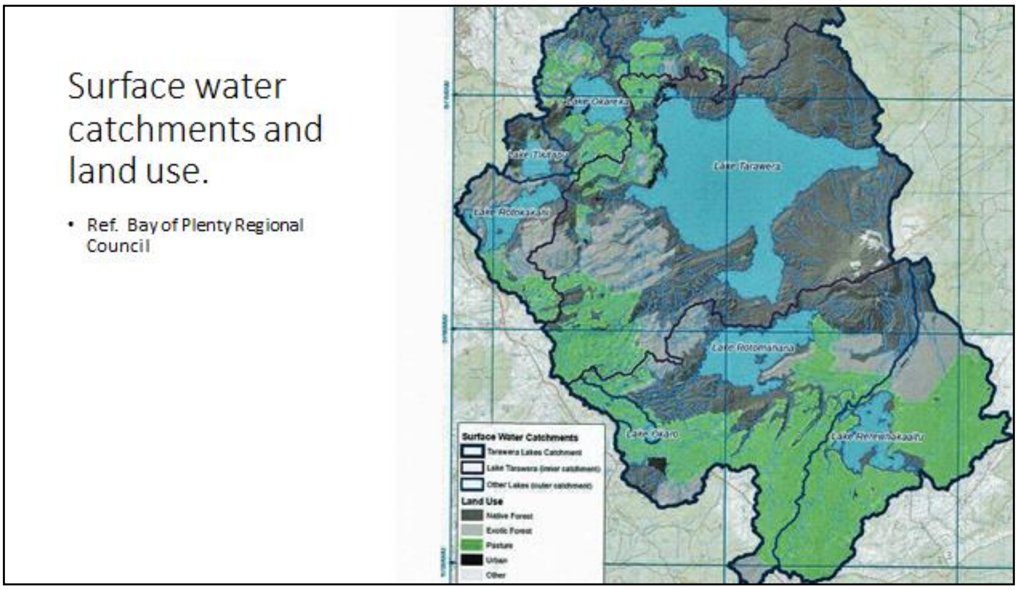
Thanks very much to those who have said good things about Project Rerewhakaaitu. I get embarrassed about it. I sit down and go, 'Well, what have we done, what did we do?' I find it a little hard to handle that compliment, sorry about that, but thanks very much anyway. It is good to know that (due to time constraints) there is no discussion afterwards.

So we get to Paul White. I am the only well in Rerewhakaaitu scoring 8 and we all know why. It has nothing to do with the farm. As you move towards Rotomahana and Tarawera, the wells get a little lower and in the end they are about 4 - 4.5 pmm. The work that we have done shows that if we measured some of the wells up in the forest, unbeknown to the forest owners, then went down through the catchment, we do have an input. There is a footprint and that is expected but it does not show an increase as you go towards Tarawera, where the water is supposed to go. So just remember that.

We need to acknowledge the staff and personnel of the following, without whom this would not be possible:-

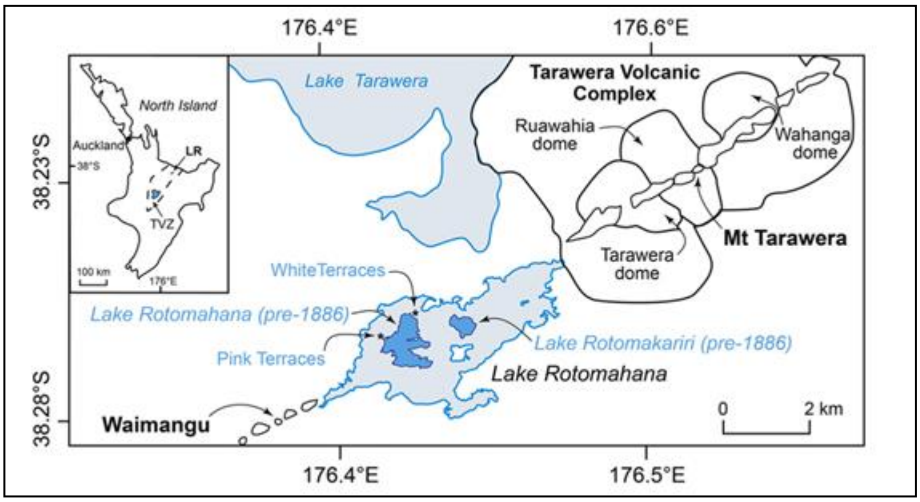
- AgResearch
- Fruition
- Dairy New Zealand
- Beef+Lamb New Zealand
- Bay of Plenty Regional Council
- Rotorua Te Arawa Lakes Strategy Group
- Blackman Spargo
- Fonterra
- Sustainable Farming Fund
- The farmers

Without them nothing would happen and I would not be standing here if it was not for AgResearch and Fruition. I went to a symposium in 2002 and met Mike O'Connor of AgResearch and Bob Parker from Fruition. After I got up and asked a couple of questions they came out to Rerewhakaaitu and from there the project grew. There is a 7-page summary of the project up until 2015 available outside for those interested. The entire group has helped us out over the many years. Fonterra is now involved and the Sustainable Farming Fund and farmers.



This shows the surface water catchments and land use of the area and I farm over on the bottom left in the Rerewhakaaitu catchment. Rerewhakaaitu 1A2B is a lot of land. They have just had it handed back after a 99-year lease, 'lease' being a polite word. Onuku is another big player. Both blocks have got 3 or 4 dairy farms and a large sheep and beef unit. The same with Onuku and Lake Okaro. The dairy farms stop just past Lake Okaro on the Okaro/Waimangu Road. They are predominantly dairy but not intensively dairying. (pointing to Rotomahana & Rerewhakaaitu lakes catchments). Several own quite a few farms. I only own one and not that rich.

From here on around it is sheep and beef and we have been asked to pick up Crater Lake Farm. They are not great players as far as high stocking rates go. There are some privately owned forest areas. There are also a couple of little private forests.



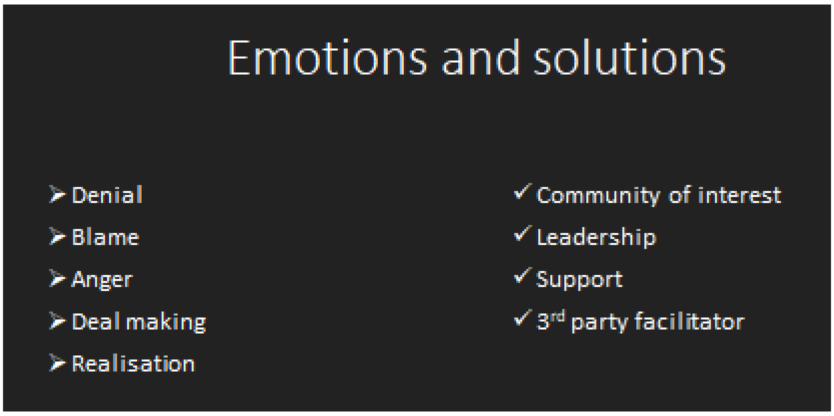
The above slide is another map showing the White Terraces and the two small lakes (Lake Rotomahana and Lake Rotomakariri) prior to 1886 and the Pink Terraces. There are steaming cliffs and it is quite active. We had Professor Hamilton out recently. He told us a year ago that between 60% to 70% of the phosphorus entering this lake is coming from geothermal. GNS rate this lake to be as volcanically active as White Island at idle. It is humming along and goes up and down. Andy Bruere tells me it breaks out into Tarawera every now and then and so do the hunters.

The average take home pay to the guides prior to the 1886 eruption was £10,000. The museum says it was £8,000 but a YouTube presentation in the Council Chambers by Te Arawa had it at £10,000 and I believe them.

If I understand correctly, the hotel was owned by local Iwi and Crays was the manager. Bainbridge Road is over our way and Mr Bainbridge was the gentleman killed in the hotel. The rocks that you see at the Buried Village came from Tarawera but did not land originally at the village but north of Lake Rerewhakaaitu. One of the members on our committee took 16 truckloads of rocks to the Buried Village. Do not believe everything you see in town especially if it is Rotovegas. It is a tourist town.

When you put something together in the community by social reengineering and say, ‘Hey, you have got to stop doing what you are doing, you get denial. With the work and positions I have been given, one of which is on the Upper Waikato Catchment Committee, I have got to know staff there who have put together a similar project to what we have here in Rerewhakaaitu on the Whirinaki arm. It will be good to see that happen. We went out to Waiotahi the other day to sit with some farmers.

Back in 2002 we did not have the support that we have now. We turn up to meetings and people from DairyNZ, Fonterra and the Regional Council are all there to help. The hand has been extended and you have to take it up, and you do. But there is another hand and it has not got a carrot. We went through denial and blame. We blamed the forestry or we blamed the farmer next-door, the new guy, the big guy and all the rest of them. We went through all those things. There is the anger and sometimes you get them all back to front. You try and make a deal and then the realisation comes.



These are all the emotions you get with any sort of trauma that happens in a family. But the thing is, while you are trying to save the environment, the general population does not understand that Rosemary and I and the kids have put everything into the farm for the last 30 - 40 years and you want us to change.

Sure, we changed three or four years ago and are most probably the better for it, but that is what these farmers go through. When you go to the community as a staff member of one of the agencies that is what you are dealing with. The easiest way is to find the community of interest. We have that in Rerewhakaaitu. There was always interest in the mountain and the lake. We cleaned up the pines around the lake. Woodsman came from Woodsmen School and cleaned up the mountain. We all did it together as a community.

Leadership is a big thing. We started out with three of us - Mike, Bob and myself. We grew to a group of 5 or 6, then to 10 and now we have 15. We needed support and had AgResearch, the science support, and support from the Regional Council. It is good to have a third-party, a facilitator, which was like a filter. It stops the shit going both ways. At the beginning it was necessary but good staff on the Regional Council made a difference.

This is what we believe in and we wanted to work with the Bay of Plenty Regional Council, so any submissions we have will always head with that. There is no way we are going to fight them. In 2002 I was Provincial President in Federated Farmers, and one thing I learned is that change happens, and change is going to come at you. It is what you make of that change, how you can get something out of that change, or it will run you over.

We believe if we are part of the problem we need to be part of the solution. We also believe that if farmers are fully involved in the process, they will take ownership of the solution. That is the big one. If you take us through and include us in how you arrived at that solution, you set the scientists in front of us, do the experiments; get the farmers to put the phosphorus socks in the streams, get the farmers to understand how it all works, then they will take ownership of it all. They will understand. It is their community and they want to stay there.

There were huge challenges put before us. Bill Bayfield, Chief Executive of the Bay of Plenty Regional Council before Mary Anne MacLeod, asked us to take control of our destiny. As a Deeded Lake, Lake Okaro had gone through an action plan process, which was advertised and everything else. But no one in that catchment submitted to that process and yet there were 13 submissions from outside submitters, everybody else telling those people in that catchment what to do. Bill Bayfield said get into making submissions and be involved.

Warwick Murray asked us to take ownership of the project too. This was just after we had changed from dairying to beef, about 2014 and 2015. He wanted us to contribute to the action on the ground, which we were doing anyway. We wondered what Warwick was on about but, hey, that is okay.

Warwick was Chris Ingle's predecessor as was Paul Dell, so we have been through 3 of these guys. Warwick, I knew quite well because I spent 3 years with him on the Land Use Futures Board in Rotorua, which was good. We understood where he was coming from. We took ownership of the project by making it into an incorporated society and that moved us into understanding 'we were it'.

Mike Barton of Taupo Beef said to ensure that all farmers understood the science so that they could understand the solution. That is a big thing.

Doug Leeder, Chair of the Bay of Plenty Regional Council, said hunt as a pack. Doug goes through a lot with us about where we are heading, where we need to understand the rules and everything else that comes at us.

Trevor Hamilton, a farmer, said we have to be in the black to deal to the green. That was obvious.

Project Rerewhakaaitu, 2002 – 2015 had 4 phases. An important thing to look at is the 16.4% reduction in nitrogen and 15.4% reduction in phosphorus from the farmers in the catchment between 2009 and 2013. That is for the Council really, but it was good for the farmers to know. We get ranked and we have a third-party audit. Another big thing was that all plans had short, medium and long-term action lists. The farmers got a plan and understood what nitrogen and phosphorus is about. They worked to their plans, got involved and took ownership.

At the moment on our committee we have 15 members, both men and women, 2 from the Bay of Plenty Regional Council, 1 from Dairy NZ, 1 from Beef+Lamb NZ and Simon Park from Land Connect, who is implementing the land environment plans. It is quite a big meeting and easy to operate. It is my job to make sure they are up to date. It is very positive, they discuss and decide, constantly looking for solutions. There is an unwritten policy of no secrets and we will get on to that later on. That has to be there. There is a strong relationship theme all the way through.

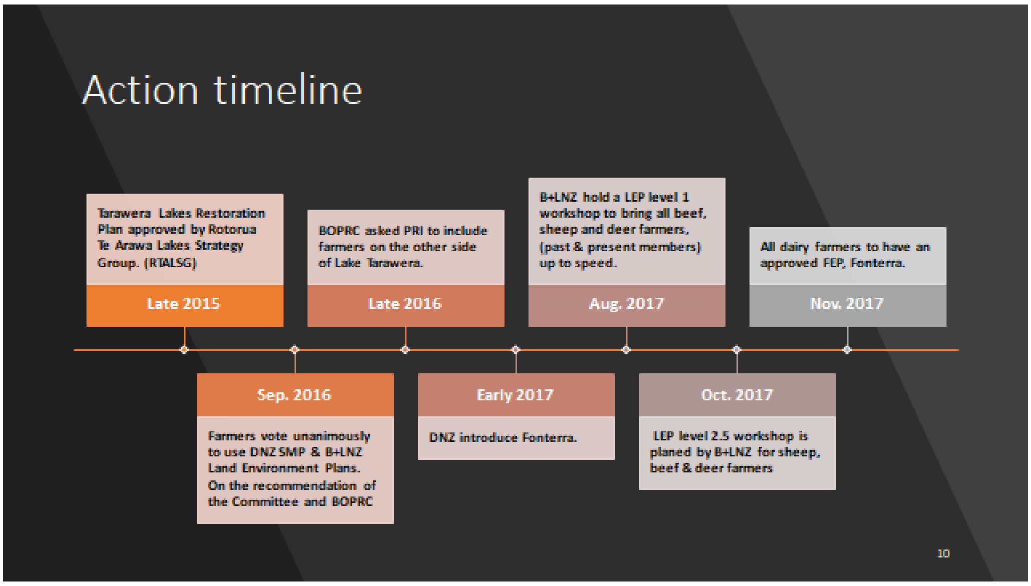
We have accountability being an incorporated society. You do not want to be on the Action and Unfinished Business List. I am usually on that and others are too, but Professor Hamilton got off that the other night with a presentation to the community.

Transparency and ownership is a given. We have 75% paid up members and everybody gets a newsletter. This tells us how many people are really in the game. At present 86% of farmers have farm environment plans either with AgResearch or Beef+Lamb NZ. We do meet the action plans at the moment, but we are going beyond that.

There are now new farm environment plans. We have 50 farmers in the catchments, 28 are dairy farmers, 22 are sheep, beef and deer farmers. Fonterra will do the action plans on all the dairy farms at their cost to the standards of the Regional Council. That was a big windfall and good for everybody. We look for nitrogen, phosphorus, E.coli, silt and bio-diversity. Phosphorus is the target problem, and as David Hamilton has told us time and time again, if P is the target, forestry is not the answer.

This plan recognises past improvements which came from the previous plans funded by farmers. We have not got handouts. I is our own money back there.

The data from Overseer is called amalgamated data which models the catchment and comes from the nutrient budget, part of the farm environment plan in Action 6. Once these plans are in place we will start discussing Action 5.



We have an action timeline. We tried earlier to get where we are now, but we slipped up. PC10 dragged us back down in there, but it allowed DairyNZ to bring Fonterra in. We were ready to do the DairyNZ 'sustainable milk platform' plan. When DairyNZ found out that Fonterra was trialling a farm environment plan, we managed to get them to fit their trial in this area. If it is successful here, there is a good chance that it may roll out even further. That is their news to break, not ours, so that is a win.

Summary of actions

All actions included in the document including expected reductions and estimated costs are summarised in Table 5.

Table 5 Summary of all actions

Actions to reduce nutrients				
Action	**Nitrogen reduction kg/year**	**Phosphorus reduction kg/year**	**Cost**	**Cost per kgN and kgP**
Action 1 – Reticulate houses in the Lake Tarawera urban community and upgrade conventional septic tanks outside the future reticulation zone.	2,829	283	$12,400,000 (+GST)	$43,816 /kgP $4,383 /kgN
Action 3 – Control nitrogen fixing pest plants in the Lake Tarawera Catchment.	230	n/a	$161,000	$700 /kgN

Actions with no reductions		
Action	**Outcome**	**Cost**
Action 2 – All agricultural properties within the Lake Tarawera Inner Catchment to have environmental management plans.	Voluntary reductions in phosphorus from agricultural land in the inner catchment.	$60,000 (Includes cost of consultant only. Does not include cost of any nutrient reduction actions)
Action 4 – All agricultural properties within the Lake Tarawera Outer Catchment to have environmental management plans by 1 December 2020.	Voluntary reductions in phosphorus from agricultural land in the outer catchment.	$120,000 (Includes cost of consultant only. Does not include cost of any nutrient reduction actions)
Action 5 – Develop a rule to limit land-use changes that increase nutrients in the Tarawera System.	Cap on total nutrients in the catchment will safeguard the lake from increased nutrient loading.	Costs met by other Council work streams or projects.
Action 6 – Build a model of the Lake Tarawera groundwater system.	Better understanding of the land-uses that contribute to water quality in Lake Tarawera.	Costs met by other Council work streams or projects.
Action 7 – Carry out a Cultural Health Assessment of the Lake Tarawera Catchment.	Better understanding of the interrelationship between lake water quality and tangata whenua values.	$60,000 (Includes cost of consultant only. Does not include cost of any nutrient reduction actions)
Action 8 – Investigate geothermal inputs into Lake Tarawera.	Better understanding of the geothermal inputs into Lake Tarawera.	Costs met by other Council work streams or projects.
Action 9 – Summarise science around minor nutrient sources.	Consolidated science around minor sources of nutrients in Lake Tarawera.	$10,000
Action 10 – Keep community informed (in Plain English) of science updates and reports when available.	Well informed and engaged community.	No cost

11

We had a Summary of Actions and a Land Use Capability Workshop as well to understand land use classification. If you are into that, it is really good, and it was where we saw two regional councils work together on the day.

Chris Ingle talked about the action plan. Action 1 of reticulating houses is in place. While I have sat on the Tarawera Sewerage Steering Committee, that figure has gone to about $18M.

Action 2 is in place with funding sought.

Action 3 has been done. Andy, tell me if I am wrong, as I understand the nitrogen fixing plants have been taken out.

Actions 2 and 4, which are plans on the inner and outer catchments, are in place and in process. There will be savings because Fonterra and Beef+Lamb will be picking up a fair bit of the bill plus everything else.

Action 5 - we have talked to Rebecca Burton. The outcome in Action 5 is a cap on total nutrients. I want to know that the cap is on my head, not on my shoulder nor on my waist, otherwise we will have a different discussion. A cap is a cap otherwise do not call it a cap. Then there is protection, if there is any change in land use that could come in and erode our work. We need to protect the work that we have done over the last 15 years. We do not want someone to upset the model. It threatens the science, it threatens the lake, it threatens everything. So, Action 5 will take place pretty soon.

Action 6 will work because it gets the data out of Actions 2 and 4 and will be under way as well.

Action 7 - I understand from Andy that a cultural assessment will take place.

Action 8 is a biggie and where Paul White will see out his days on geothermal investigations on that job.

Action 9 summarises the science and the minor nutrient sources at a cost of $10,000.

Action 10 is keeping the community informed and at no cost. Some people say they know the cost of everything and the value of nothing. But if you get that wrong this all falls over and is so important. It is the only thing that is tripping us up at the moment but it will take place.

What does the future bring? Agriculture will continue to be processed by regional councils throughout New Zealand and give effect to the National Policy Statement on Freshwater Management. That is going to happen, no matter what, right throughout the country. Regional councils will process district councils to meet the said Policy Statement. That will happen, and they will go through denial, anger and frustration.

Regional councils will have to work with forestry owners to address the issue of logging and Class 6 land and other sensitive areas. I could take you for a drive to show land that does not look good. If I cannot crop Class 6 land, why would I be allowed to log it? It is one thing to plant trees; it is another thing to take them away. Forestry should work with agriculture, not oppose it, and land use should be complimentary, not competitive. New Zealand Inc. should consider land use capability, understand its capability classification and add a science component to fully utilise New Zealand's natural resources. Not all land is suitable for farming.

If we could throw everything up in the air and let it settle back down in its right place it would be good. To get them to move from one land use to another involves money. We are driven by nothing else. As I said, you have got to be in the black to get in the green.

Surveillance drones will be as common as electric cars. Chris Ingle tells his staff there had better not be a surveillance drone operating anywhere near here. If I had got wind of it the next thing it would be on the front page of the paper that we shot one down. But to be honest and fair, it is our money that is spent to survey what we are doing. Aeroplanes and helicopters are great, but drones are wonderful. You could come into the Rerewhakaaitu catchment, set up a programme on your laptop, sit back and let one go and it would check out all the ponds and everything else needed from the air. That would be wonderful.

Wind turbines are suitable at Kaharoa which is not the only place, but this is the way we are heading. Dams are yesterday's dinosaurs. That will be a discussion in the future as to how effective the hydro dams are, we will see more wind turbines around, in my opinion. I am allowed my own opinion even though I sit on all those boards and committees.

More science is needed around mitigation and less around litigation; because that is the way it happens at the moment. People look for blame and then it ends up in a fight and there is a lawyer involved. I would like to see more science because I constantly get calls from farmers looking for knowledge and scientists. Do not underestimate the influence scientists and farmers can have belly to belly in the field. We have had Professor Hamilton out several times and he was out there again the other night with 25 in the room. One farmer with 10 farms, not all in our catchment and some in the South Island, came up to me after the meeting and said that that meeting was the best presentation he had had. It is the ability to sit down with scientists, such as David, one to one with the farmer and a laptop and talk things through in a non-threatening way. At the end of the day if they can change something on their land, and it does not cost a lot of money and gets the desired result, isn't that what we want? Go the other way with a hidden agenda, it just does not work.

Farmers have a huge bullshit detector. They can detect it straight away. I sat there the other night and I can tell by the body language. If they lean forward on their knees and put their heads down, it goes over the top and they do not want to listen. If they sit back, they are taking it in, and that is how it should be.

Hey, thanks very much.

Session 7 : RESPONSIBILITIES, VALUES AND FUNDING

SESSION CHAIR - Bill Cleghorn, Bay Trust

CLEAN LAKES – WHAT VALUE? WHAT COST?

Hannah Mueller
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Hannah is an ecologist working at Kessels Ecology in Hamilton. Earlier this year, she finished her PhD at the University of Waikato, which focused on an assessment of ecosystem services of lakes. Her research analysed catchment and lake values, the impact of land use on water quality of the lake, and the context of lake restoration of the Rotorua Te Arawa Lakes. Her talk today focuses on the values associated with the ecosystem of Lake Rotorua and its catchment, the costs of restoration, and some ideas around getting the best value out of future management of the lakes.

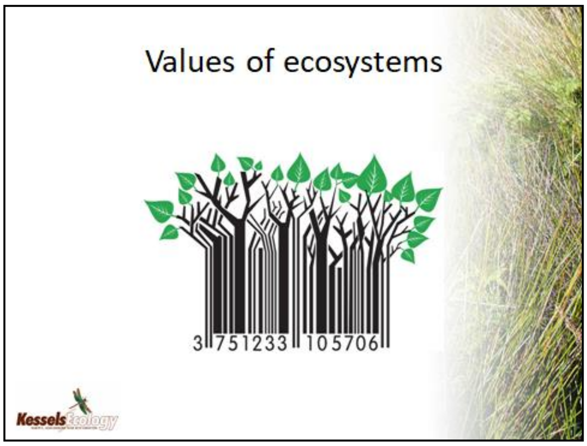
TRANSCRIPT

Kia ora everyone and thank you so much for making it back to the last session of this wonderful symposium. Thank you so much to the LakesWater Quality Society for inviting me here to speak today. I am excited by the opportunity to share with you some of the findings of my PhD research that I finished earlier this year.

Before I dive into costs and values of Lake Rotorua and its catchment, take a moment to look at this beautiful lake and think about what values you personally associate with a lake. It is actually not Rotorua but Lake Rotoma.

In this very diverse audience there will be many different values that come to mind. A lake ecosystem is hard to value because there are a lot of complexities and things that I have not been able to address. This was a pilot study to explore the values that we can associate with ecosystems rather than being a comprehensive study.

I will talk about the lake itself and the ecosystem services as values that it provides, as well as looking at the potential costs associated with degradation of that ecosystem. Then I will look at catchment land use values and ecosystem services as values that are associated with the catchment. Lastly I will look at the opportunity costs that might be associated with looking at different land use change scenarios.



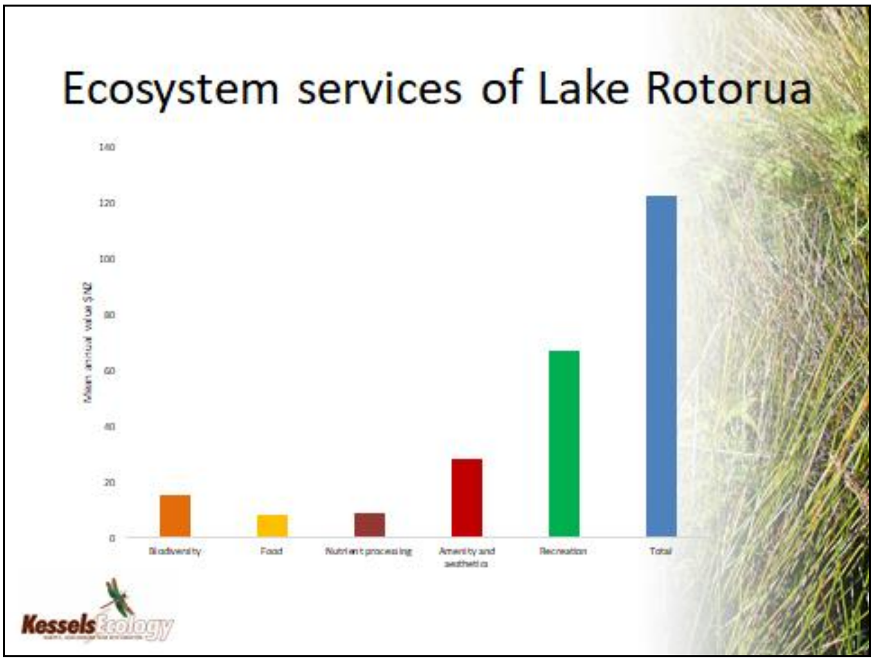
When we talk about values of ecosystems, people associate something like putting a barcode or dollar on nature but that is only half the story. My study looked at what alternative options we have in looking at the value of an ecosystem such as a lake, what means can we describe the values and how can we put that into a context of weighing up the cost of restoration? What might we gain from the restoration and the complex interaction between the lake and its catchment?

It is not purely about putting a dollar figure on an ecosystem, rather looking at values beyond traditional land pricing. How else can we derive value? There are a lot of values that I have not been able to address in the small scope of my study and a lot more that can and should be done in this sphere.

The main concept I used for my study was ecosystems services which are a tool developed to describe those services that are provided by a certain type of ecosystem that benefit humans, whether they be flood regulation or climate regulation or food provision. There are many kinds of services that humans benefit from. You will notice that by definition this concept is very human focussed and a human centric concept. It is all about what benefit we derive from this ecosystem?

My study also looked at different types of land use especially in the catchment of Lake Rotorua and I would like to point out that often when we look at land use we have a very one-sided perspective on how we value land use types. So often we only look at the productivity of the land and what money we might be able to get out of, say, productive uses of the land. But there are all kinds of other land use or land cover types as well that come with their own different values, whether that is plantation forest, indigenous forest or wetlands or other areas. These types of land uses are also very valuable to consider when looking at the catchment and its interaction with the lake.

My case study was Lake Rotorua, one of the Rotorua Te Arawa Lakes. We are very familiar with it and in fact right next to it now. I studied both the ecosystem services of the lake and the catchment as well.



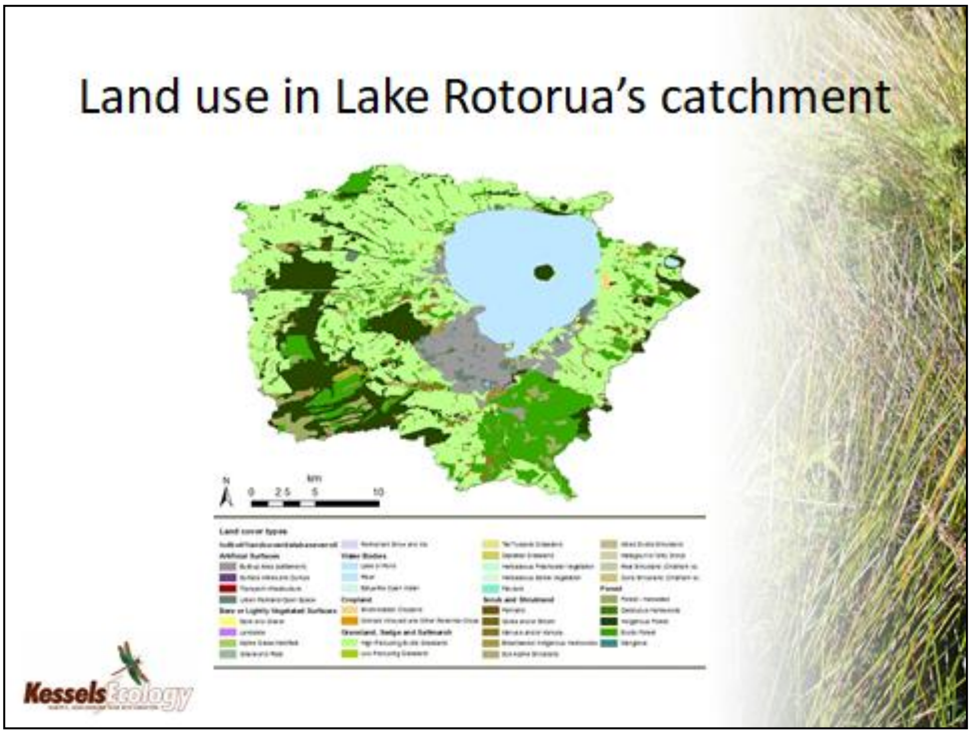
I identified 5 different ecosystem services. This is the bare minimum in terms of value and there are a lot that I have not accounted for but it does not hamper my outcome of concluding that this lake ecosystem has a very large value and even larger than I estimated.

The 5 ecosystem services were:

- biodiversity or habitat values
- food provision
- nutrient processing capacity of the lake as a value
- amenity and aesthetic values
- recreational values

As an iconic lake, it is not surprising that the recreational values were the highest value, any type of recreational usage such as fishing, boating and visitors to the lake are very important for this ecosystem. The total value was an average of about $122 million contributed by the ecosystem services of the lake every year. That is a fairly substantial contribution considering that we have not even looked at the wider management decisions at this stage.

As a second step I looked at the values we stand to lose if we allowed the ecosystem to degrade further from the state that it is now. I looked at a scenario predicted by a water quality model, indicated by the Trophic Level Index as a representation of the state of the ecosystem. I looked at the degradation of the current status of the TLI to 4.8 which is a slight degradation within the eutrophic range. Looking at the associated degradation of ecosystem services provided the annual cost was approximately $30 million that we stand to lose if we allow further degradation to happen.



As a third step I looked at the land use in Lake Rotorua's catchment. About half of the catchment is agricultural land, particularly dairy and dry stock farming. We also have a relatively large area of urban cover, the city of Rotorua itself and some indigenous and plantation forest cover as well.

Looking at the types of land use and how we can value them, there are different options. I have chosen 2 for my study. Firstly I looked at the very basic traditional profitability of the land, how much money is derived per hectare for each of those productive land uses? Then I looked at the ecosystem services provided by different types of land cover and how they can be valued using that concept.

Current management decisions tend to focus on traditional land use values only, land profitability. But consideration of ecosystem services showed substantial amounts of value associated with different land use types. I believe it is important to try and account for those as well and inform management decisions that way.

The current catchment ecosystem services were about $176 million per year which comes to about $3,300 per hectare per year of the entire catchment. Examples of other recreational values of forests in this Rotorua region include:

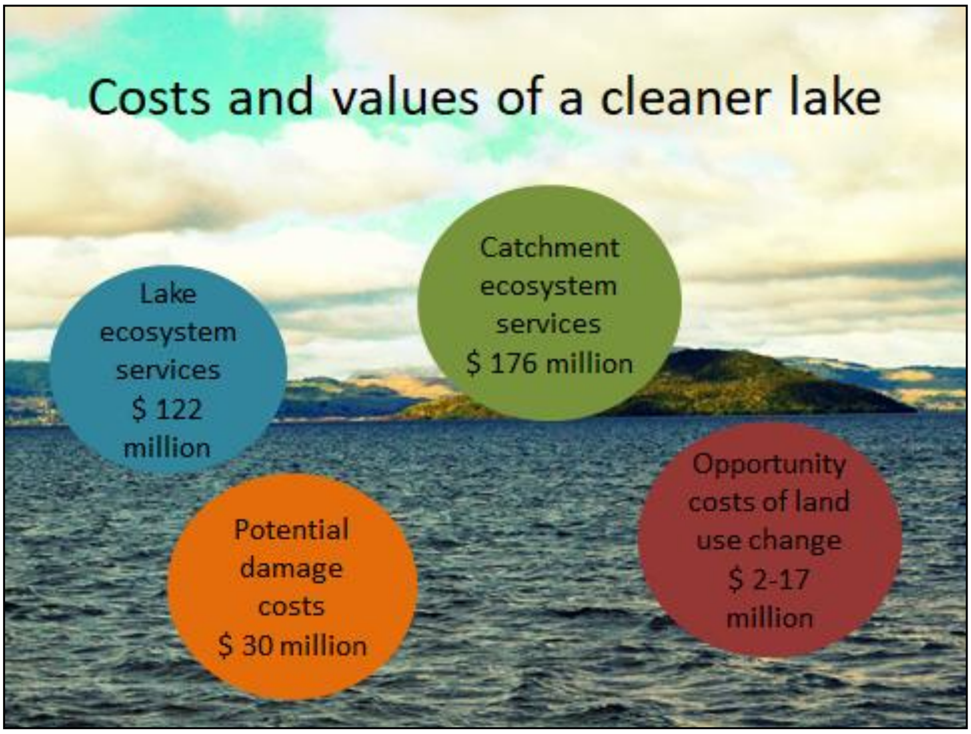
- Hunting usage: $15/ha/year (Yao et al. 2017)
- Conservation forest: $200/ha/year (Yao et al. 2016)
- Mountain biking: $50/visit (Dhakal et al. 2012)

These are not figures I have taken into consideration in my studies but examples of other studies to put it into context.

Lastly, we want to know the costs associated with different scenarios of land use change. For example, moving away from dairying to a different type of land use, what are the costs associated with the loss of profit? The loss in profit from agricultural land use converting to other uses such as forests, depending on the scenario, was about $5 to $17 million per year and mitigation costs. These are the opportunity costs of lost opportunities and productivity of the land.

There were quite a few scenarios on different combinations of land use and mitigation on land which I do not have time to give here. **But if you are interested in the details it is neatly packaged and written up in my PhD thesis that is publicly available on the Waikato University website.**

An interesting finding that came from my studies was that this value is slightly lower when looking at ecosystem services value as well due to the fact that certain amounts of value are gained in the ecosystem services through a change in land use. We reduce the cost of loss and profit slightly by $2 to $13 million per year roughly. Putting that into context, the mitigation costs within the lake at this stage might have gone up a little now especially through alum dosing which is about $1 million a year spent on maintaining the current water quality level on the lake.



This slide summarises the different costs and values of a cleaner lake. First of all the lake ecosystem services of the lake itself were about $122 million and the potential damage costs of further degradation of the lake would be around $30 million a year. In comparison the catchment ecosystem services provide about $176 million a year and we could face the costs of between $2 and $17 million in opportunity costs playing through scenarios of land use change away from the more intensive land uses towards potential alternative options.

I am not going to do the maths because I do not think it is an equation done from a scientific point of view, but it definitely shows that it is worth spending money to incentivise land use changes. In order to protect the lake, the Council is already proposing the intention to save money at the other end with a lake that is in a healthier state.

The Hon Dr Nick Smith said there must be pain on all sides including Council, land owners and ratepayers. He might have a point but I have to slightly disagree. That is a very negative way of phrasing it and not necessarily the way to go. It is not how to motivate people to bring about change. While I am not naive enough to believe there will be a win, win scenario in all kinds of different situations within the catchment, there are a lot of diverse options for profitable land use while also improving environmental outcomes.

Looking into the future, it is possible to come up with solutions where landowners can diversify and make a profit with a more limited impact on the environment, be it through a change in farming or a change in land use or a combination. We need positive motivation rather than further costs. In some cases, new land use types might be more profitable than further intensification. I am not expecting everyone to start mountain bike parks on their farms but it could be a good idea for some farmers, or a combination.

New regulation sets out funding for land use change and we need to future proof land use and find concrete options that work for all. How can we incentivise positive change toward different types of land use that can create profit in the end for the land owner and the wider region rather than punish a few farmers who struggle with the way their farm might impact the environment?

To conclude, it is definitely time to rethink how we look at the different ecosystems and how we look at land use and value it or look at alternative more holistic points of view. So many people have already come up with innovative ideas and new ways of dealing with the challenges that we face in water quality and the protection of these Rotorua Lakes. I am very optimistic. Listening to all the talks at this symposium, great things are going to happen in managing water quality and Rotorua is definitely ahead of the curve in New Zealand. We need a lot of positive motivation, good thoughts and great innovators working together. We need to plan in the long term. If you plan in the long term the opportunities are there to take up.

I would like to acknowledge the following:-

University of Waikato
LERNZ
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National Institute for Water & Atmospheric Research
Fish & Game NZ
Funding: Ministry for Business, Innovation & Employment

Kia ora, thank you.

LAKE TARAWERA – THE COSTS OF P MITIGATION AND PEST CONTROL

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Greg Corbett
Greg is the Biosecurity Manager with the Bay of Plenty Regional Council. Originally from Auckland, he escaped as soon as he left school in 1983 to work for the old Hawkes Bay Pest Board chasing rabbits and possums. Over the following years pest and biosecurity work has taken him to the Wairarapa, Central Otago, Gisborne, Ruatoria and finally to the Bay of Plenty. Since arriving in the Bay Greg has held various positions from Pest Animal Officer, to Bovine TB Vector Manager to Land Resources Manager and now Biosecurity Manager. In his current role Greg has the pleasure of leading a broadly skilled and passionate team who are dealing with some fairly big challenges, such as lakeweed, catfish and wallabies. In his spare time he enjoys mountain-biking, fishing, hunting pheasants with a German pointer dog and tries to do at least one tramping/climbing/hunting trip to the southern alps each year.

John Paterson
John Paterson is a Sustainable Farming Advisor with BOPRC. Independently of Council, he also works as Project Manager for the 'Phosphorus Mitigation Project'. In his spare time he farms deer at Kaharoa, 20km north of Lake Rotorua.

TRANSCRIPT

Greg Corbett

Kia ora tatou
With a background in pest management, my only experience in phosphorus is mixing it with apple paste to poison rabbits a few years ago. Bringing John along to tag team with me brings a level of credibility to this presentation.

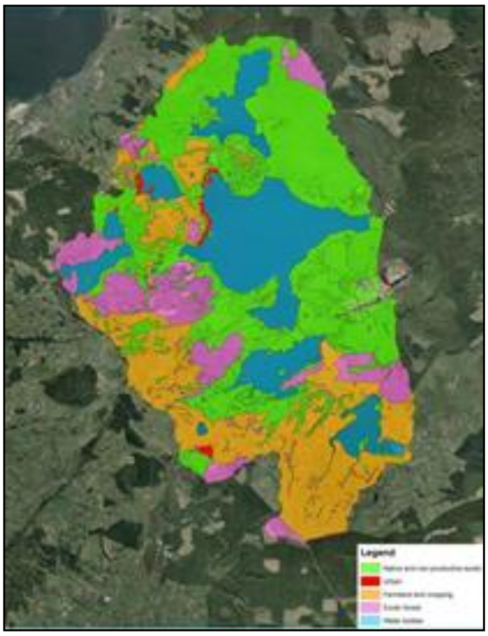
Firstly, we have been asked to talk about the costs of mitigating P in the Tarawera catchments. It is reasonably well understood that farming activities can lead to phosphorus loss if they are not managed properly. Recent studies have also shown the possible links between pests and phosphorus loss in forested catchments.

John and I will give this presentation in two parts. I will talk about pests and then John will move to farming. Neither of us will predict how much phosphorus could be managed nor comment on the cost-effectiveness of any actions. We simply attempt to provide ballpark figures for work that could reduce phosphorus losses to the lakes to some degree.

The basis for our talk is the Tarawera Lakes Restoration Plan, which Chris Ingle talked about this morning. He alluded to the fact that there is a target of reducing phosphorus by 1,200 kilos which is about 10% of the total 11.4 tonnes of phosphorus entering Lake Tarawera each year. The plan also wants to address all known sources of phosphorus and promote better management of agricultural land.

We have made some assumptions and included human-introduced animals as anthropogenic sources in this definition:

- Target P from anthropogenic sources
- Heavy rain leads to P in the lake
- On-going intensive pest control will restore forests and reduce P losses
- Community, stakeholders and funders will support long term work programmes
- The mitigations will not unduly compromise farm productivity
- Costs are indicative only and based on currently available methodologies



Tarawera Catchment Land Use: The green area shows native forest and scrub, the orange areas are farm land, the purple areas are exotic forests and the small patches of red are urban or industrial land:

Urban	196 ha	<1%
Farmland	9,033 ha	31%
Exotic forests	4,634 ha	16%
Native/Scrub	15,521 ha	53%
	29,384 ha	

Over 70% of these catchments are forested with less than a third being used for farming or urban uses.

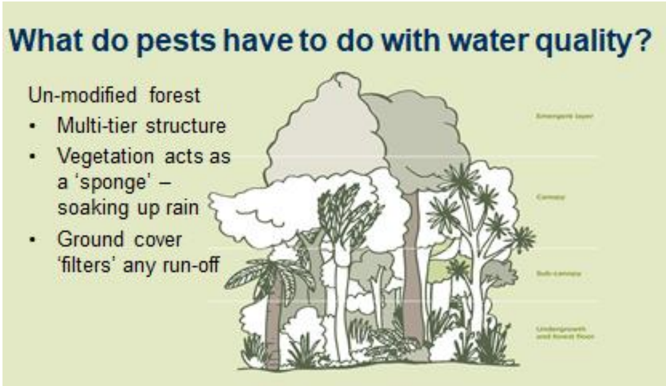
Pest management: There is substantial pest habitat around the Tarawera Lakes:-

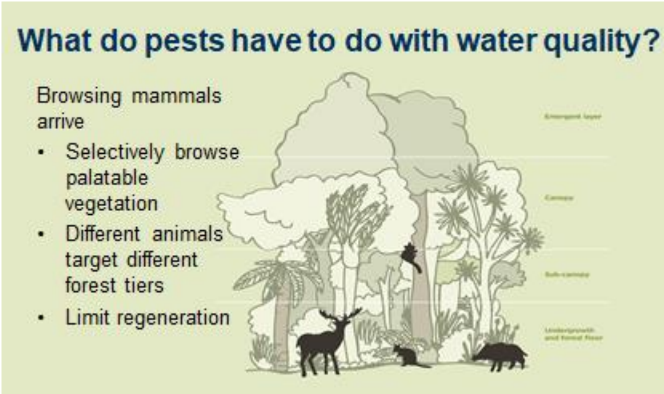
Exotic forests	4,634 ha
Native/scrub	15,521 ha
	20,155 ha

It is just over 20,000 hectares. We do not know whether we need to control pests in the whole area but it doesn't make good sense to only do parts. This will probably lead to increased costs and reduced effectiveness as we would end up with constant pest reinvasion.

Concerns were raised at a previous symposium about increasing P levels in the largely forested catchment of Ōkataina and were wallabies responsible? The University of Waikato investigated the drivers for changes in water quality over time. (Theo Kpodonu, PhD, 2016) Theo determined that erosion was a primary driver for lake productivity and also concluded that invasive mammals, together with climate change are likely to increase sediment and nutrients entering the lake. Given this, there is a case for invasive mammals being considered for management in forested catchments.

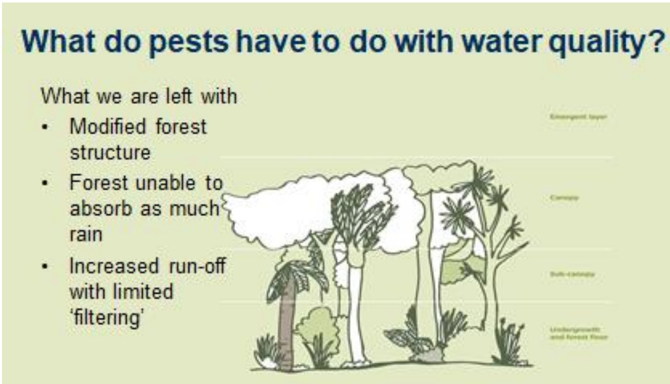
So what do pests have to do with water quality? Firstly, if we look at a normal lowland forest, it is structured with a complex system of plants and shrubs in 4 general tiers. During rain events it acts like a sponge. Once water filters through all the leaf layers to reach the forest floor it begins to pool and flow but we have mosses and ferns and other ground covers there to filter that overland water flow.





Enter a few animals. Most of the browsing mammals in New Zealand selectively browse our forests taking out certain components of the forest and, as this slide demonstrates they target different tiers of the forest. Different pests will have different impacts on the forest.

What we are left with is a thinner forest. The forest structure is compromised and no longer absorbs as much moisture during rain events and allows water to pool and flow over the ground more quickly. There is less ground cover to filter those overland flows and more ability for that water to carry soil particles with it.



What does it look like in the bush?
This is the wallaby exclosure at Dogger Bank in Okataina. Inside the fence on the right-hand side are seedlings, saplings and ground cover recovering. Outside the fence it is a very different story. Those seedlings and ground covers are conspicuous only by their absence.

What pests are we talking about? There will not be many who would defend these two critters. Possum impacts are well-documented; however the impacts of wallabies on native forests are less well-understood. We were lucky that the Forest Service set up a series of exclosures at Dogger Bank in 1984 and these provided us with some useful insights. When Wallace re-measured these plots in 1995 he concluded that wallabies were inhibiting kanuka forest regeneration.

Now for something a little more controversial. These may look like a couple of photos of deer to most people but the hunters out there will recognise red deer on the left, which are the most common deer in New Zealand and hunted for venison. The other one is a Sambar deer which are highly prized trophy animals of limited distribution through New Zealand but found around Rotomahana. The reason we should not ignore deer came from the exclosure plots as well. When the plots were re-measured in 2001 by Mathew Benes and 2007 by Stephen Hall, they both concluded that deer had a greater impact on the forest understory recruitment than wallabies.

The last animal I include in the photo is no less controversial. These pigs are bulldozers on four legs and we cannot ignore them. They do graze vegetation. Their habit of rooting up ground to hunt for invertebrates exposes soil, leaving it vulnerable to erosion.

As Cam Speedy said at the last symposium, 'There are many methods and approaches to control pests but there are no silver bullets.' Each method that is available has its advantages and disadvantages. How an operation of the scale we are talking about could be carried out can only be determined through genuine engagement and consultation with land owners, Iwi, adjoining communities and stakeholders.

Basic principles we need to consider:

- Must be effective, i.e. will achieve outcome
- Must be affordable for the long-term
- Must be socially acceptable and supported by the community and Iwi

I have not used the word 'cost' effective here as a criteria because there could be some methods that are cost effective but not affordable in the long term so I separated those two. This is about a long term programme of works which must be supported by the whole community.

To do this costing I made a few assumptions. We have not had the conversations with the community about what might be acceptable and how the control would be carried out. But since I don't know what will be acceptable to the community I have based it on a range of control options that meet the effectiveness and affordable criteria and have based my costing scenario on the first two - largely what is effective and what is affordable.

My scenario – the basis of costing

Method	% of habitat	Cost range	Frequency
Aerial 1080	75%	$25 - $30 per ha	3 years
Ground (includes community groups)	25%	$12 - $200 per ha	2 years
Ground hunting	75%	$5 - $10 per ha	3 years of knock down then every 2 year
Operational monitoring	100%	$10K - $20K	Annual
Outcome monitoring	75%	$810K - $349K	10 years
Planning, management	100%	5% - 10% of annual cost	Annual

BAY OF PLENTY REGIONAL COUNCIL TOI MOANA

You will note that my costing is based on some form of aerial 1080 and includes some ground work and community work as well. We have several groups working in these catchments doing good work. I propose that we have very intensive ground hunting for pigs and deer and also that there is a significant monitoring component to this work. We need to understand the status of our pest populations from year to year to ensure control operations achieving the right results and are implemented when needed. We must also understand what the response from the forest is to those control operations.

Costs

	Year 1 ($,000)	Annual ($,000)	20 years ($,000)
Planning, management	$110	$110	$2,206
Aerial	$401	$140	$2,804
Ground (includes community groups)	$471	$235	$4,709
Ground hunting	$113	$62	$1,238
Monitoring	$306	$59	$1,175
Total	**$1,401**	**$606**	**$12,132**

BAY OF PLENTY REGIONAL COUNCIL TOI MOANA

Based on that assumption, and assuming that we have approval to implement the whole area in the first year, we would need about $1.4M up front in the first year and then every year after that a cost of about $600,000 a year. It is important to note that if we did end up with a programme that involved less aerial control the costs would climb substantially. For example, if we could only control half the area with aerial 1080, the remaining being done on the ground, then the costs would climb out to 20 years by an additional $4 million to $6 million. It is important to note this work will not be a one-off operation. It would need to be implemented over at least 15 – 20 years before we know whether we are making any difference and assuming we were then carry on indefinitely.

I would like to conclude by repeating a few thoughts from speakers from the last LakesWater Quality Society Symposium (2015). Willy Shaw recognised the significant ecological threats that these animals pose but did wonder whether the erosion generated by them was significant when compared to storm-induced landslides and lakeshore erosions from fluctuating lake levels, and we are seeing a lot of that this year.

Rob Allen also talked on the status and drivers of change to New Zealand's forests and concluded by posing a few questions:

- Are undesirable changes to our forests reversible?
- Is it economically, socially and biologically feasible to reverse them?
- Do we have a robust evidence-base for our actions?

Who knows? These are still good questions when thinking about implementing a programme of work of the scale that would be needed and the costs involved.

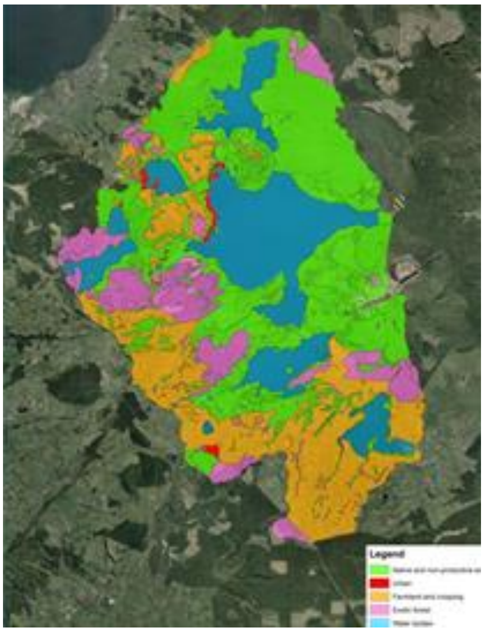
Thank you. I would like to hand over to John now.

John Paterson

My name is John and I am a P addict. My last fix was on Monday night between 8.00 and 9.00 pm. What am I talking about? Phosphorus. I had another as I sat down to dinner at 8.00 last night. Rain. Heavy rain. High intensity rain. That is going to be a repeating theme in my presentation.

I do have to take issue with Chris Sutton. I liaised with Chris for quite a few years and as a Council employee he has always had that line, 'No surprises, John', but his last slide showed that he had bought a wind farm or was going to convert a farm up in Kaharoa to a wind farm and that is a real surprise.

On-Farm Mitigations: Farmland area is shown in orange and is a total of 9,033 hectares, about 31% of the catchment. My presentation is about the cost efficiencies of some farm applied mitigations, not the total cost accountability of P mitigations on farms which is a subject worthy of a whole symposium on its own. P loss from the catchment is highly intermittent and only flows off the land during storm events.

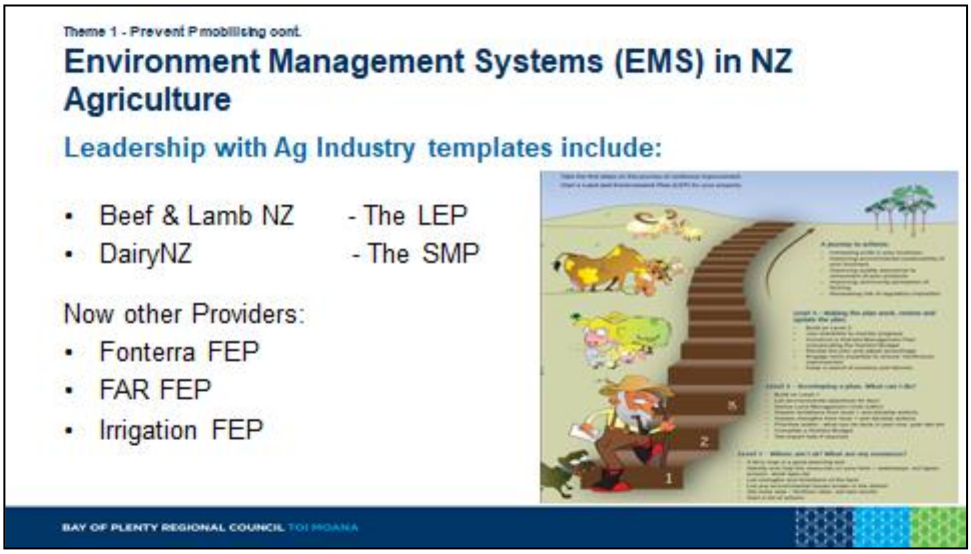


We have some obvious opportunities to deal with P loss that we do not have with nitrogen loss. There are three themes:

- Prevent P mobilising in the first place, achieved largely through good management practices
- Intercept P in transit, like holding down the bolting horse and not as good as the first option
- Treating P loss at its destination with flocculants.

Preventing P mobilising: Phosphorus focussed research is continuing to deliver a growing list of good management practice options but these have to be owned by land managers - farmers, farm owners and farm managers. They have to be perceived as an asset and farmers be convinced they will work and be normalised into land management practices.

The very first step is for farmers to have a farmer-owned Environment Management System (EMS). We have seen really good initiatives on environment management systems in the Tarawera catchments. At the field day at Lake Ōkaro on Wednesday Megan Birchal told us about the environment management system that farmers had engaged in some years ago which was an early version of the Beef & Lamb LEP. Chris Sutton talked about the environment management systems being implemented in the Tarawera Lakes' catchment and that is also the industry LEP and originally the DairyNZ Sustainable Milk Plan.



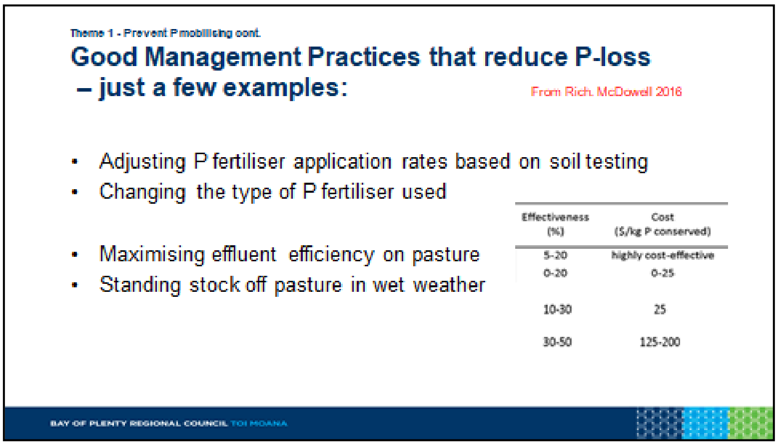
This slide goes back into the history of the development of environment management systems in New Zealand. We need to have confidence in these vehicles. The first environment management system in New Zealand was introduced in 2004, the first published environment management system was in the Deer Farmers' Land Care Manual. I am very familiar with that because I wrote it. In 2007 Beef+Lamb developed their LEP, an interesting exercise, and they went to great pains to be inclusive of every farmer, and to give no farmer any reason to say, 'No I don't want to be involved'.

I put the cartoon sketch in when involved in that working party to try and illustrate the easy first step but unfortunately the cartoonists could not get the angry look off the farmer's face. This is the first time that cartoon has ever been publicised. Some years later

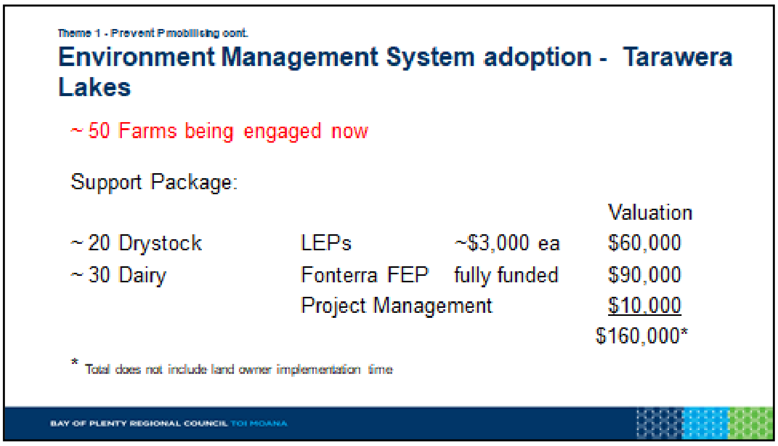
DairyNZ developed a prototype of an environment management system called the Farm Environment Action Plan which was trialled here in the Rotorua catchment on two farms.

I need to explain what an EMS is and the ISO14001, the international standard for environment management systems. It is a very well thought-through plan - Do, Check, Act, Cycle and Continuous Improvement. Nicki Douglas talked about Collective Impact as the goal in the centre. The goal of continuous improvement is what the Council is very keen to promote with farmers and farming groups. It does not matter where they start but engaging in a programme of continuous improvement is fantastic.

This presentation is about costs. Chris Ingle covered this more thoroughly in his presentation, but very roughly, 50 farms are engaged now and the support package is:



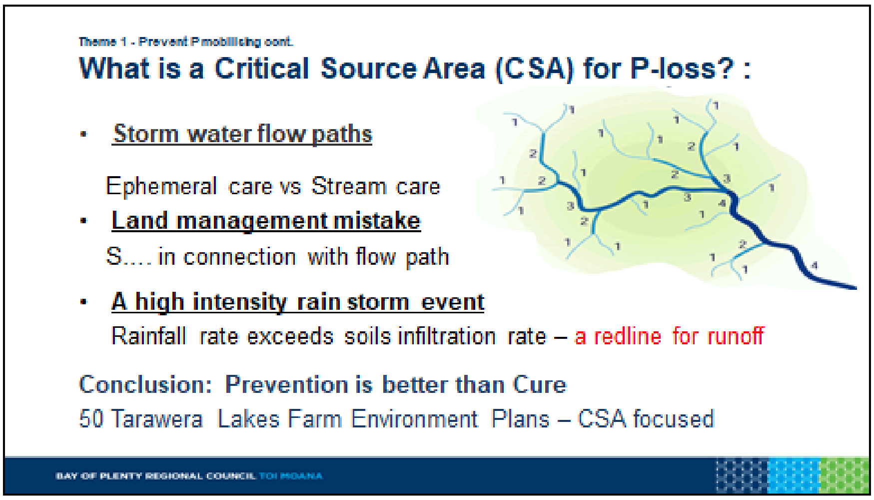
I used the heading 'Valuation' because the industry has really stepped up which is great. We are aiming to have all farms on board by early 2018. Just remember that the pioneers of the Tarawera project are not the Council but some dedicated leading farmers with BOPRC right beside them.



Good Management Practice (GMP) refers to an evolving suite of tools or practices that can be put in place at a land user, sector and industry level to help achieve community agreed outcomes – such as water quality. Some good management practices actually cost very little and some of these slides show material repeated from Richard McDowell's work. Simple things such as adjusting the P loss application rate to be mindful of the optimal agronomic level for pasture growth can cost very little and be highly cost effective with minimising the loss of phosphorus.

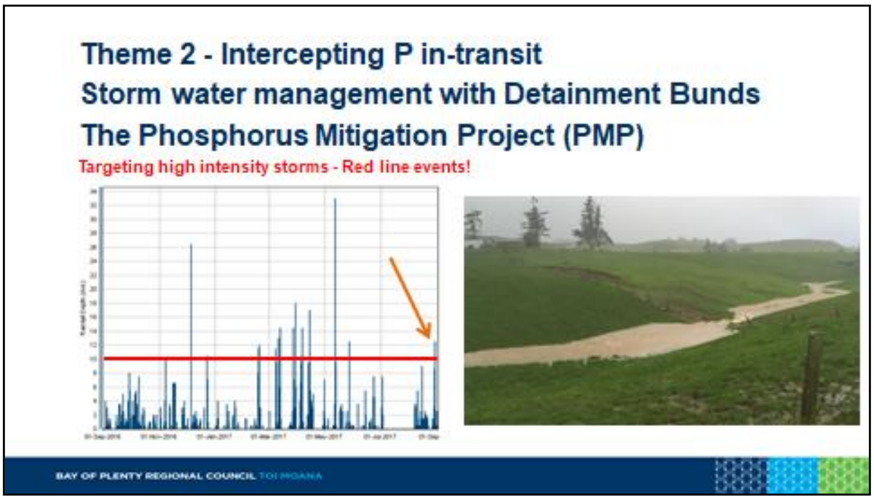
The second low cost possibility with good effect is changing to a less soluble fertiliser. On the bottom line things cost quite a lot more and standing stock off pasture can be quite an expensive process.

Dealing with critical source areas can achieve high cost efficiency. Rich McDowell did a study of 14 farms around New Zealand and noticed that for only a cost of 2% of earnings before interest and tax, 40% reductions could be achieved which shows that things do not necessarily need to cost a lot of money.



What is a critical source area? Just to take the anatomy a step further, it is a combination of not making mistakes in stream flow paths and ephemeral flow paths. Storms generate water flow where water does not flow usually. Those are the first order streams or ephemeral parts of the landscape on everybody's farm. If a farmer makes a mistake in one of those flow paths he gets caned by high intensity storm events which shift it. The red line is those high intensity storms and I referred to my last fix being Monday night when we had a high intensity storm. That is when phosphorus really leaves the landscape.

This is what a critical source area looks like. There is a major storm flow channel through the middle. The farmer has made a mistake in cultivating and putting a fodder crop there. There will be a number of storm flows through the winter. Normally there are about six a year but this last year has doubled to about 12. Exposing such areas to P-loss risk, disturbed soil, concentrated animal excrement is a critical source area and obviously a change in land management practice there would have avoided that. Other critical source areas include poor timing / placement of fertiliser, inappropriate cultivation of slopes and when such mistakes are in places where storm water run-off can wash over them.



The red line is for phosphorus loss which is generally about 10mm per hour but the important thing is looking at the opportunity to intercept it. It only happens for those tiny points in time normally, only a few hours per year. We have moved from doing the preventative stuff to looking at what we could do to intercept this horse which is about to bolt. That photo was taken on Monday in a paddock near my place. The rain on the roof was only 2.5mm in our catchment rain gauges, so it was not a run-off event. Not a P loss event.

To further hijack this event, I want to talk about the Phosphorus Mitigation Project which is a wonderful project that I work on independently of Council. This is a ‘watch this space’ slide. Brian Levene, a PhD student, is working here for three years to prove how much phosphorus we can catch in these storms if we build low level earth detainment bunds like that shown in the centre photo.

Lastly the acknowledgements. Greg wishes to acknowledge Dale Williams, Dave Paine, Shay Dean (BOPRC), Phil Commins (contractor), Cam Speedy – papers and reports and OSPRI .

I have taken a lot of material from:

- Rich McDowell 2010 – 2016 various papers / presentations
- Genevieve Carruthers (2005), an Environment Management Systems Australian expert who came here to speak to Rerewhakaaitu farmers some years ago.
- Dylan Clarke (2013) who did the first thesis on detainment bunds for mitigating phosphorus and sediment loss
- Phosphorus Mitigation Project (2017 – 2019) MPI Sustainable Farming Fund and 7 co-funders including all 3 New Zealand Pastoral sectors

Thank you very much.

THE COST OF AQUATIC WEED CONTROL IN THE ROTORUA TE ARAWA LAKES

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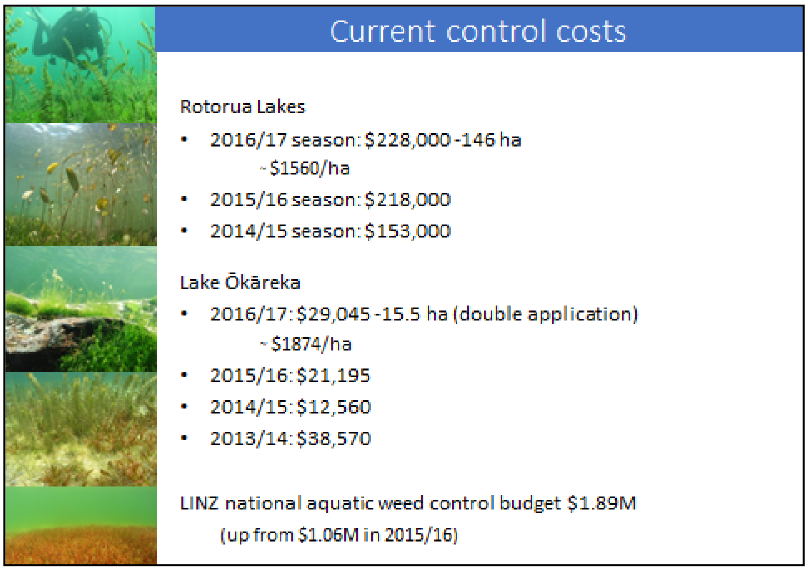
TRANSCRIPT

Firstly, we would like to acknowledge Don Atkinson and the LakesWater Quality Society for the topic. We will present information on the costs of aquatic weed control in the Rotorua, Te Arawa Lakes and thank all of the people who have willingly given us their estimated costs. Hopefully, this provides guidance on what current activities cost and what future scenarios might be feasible.

We will cover current control, organisations and responsibilities, lake focussed management plans, comparative control costs and then considering the future and gaps in the picture of aquatic weed control. This talk draws on all of the talks from the last two sessions yesterday and the talks we have heard this morning.

Currently the control of pests within the Rotorua Te Arawa Lakes is co-ordinated by the Aquatic Pest Co-ordination Group, with members being Bay of Plenty Regional Council, Te Arawa Lakes Trust, Rotorua Lakes Council, Land Information New Zealand, Boffa Miskell, Fish & Game, Department of Conservation and NIWA.

There is a range of activities already happening in the lakes. The Biosecurity Awareness Programme that Hamish was talking about, which is run by Bay of Plenty Regional Council; MPI put some funding into this. There is the Bay of Plenty, Weed Cordon Programme and the Lakes Surveillance Programme involving 8 at-risk lakes, to ensure that new weeds do not get into these water bodies. Then there are the incursion responses in lakes Ōkataina and Lake Ōkareka. There is also the lake weed spray programme co-ordinated by Boffa Miskell, funded by LINZ and also with input from the Regional Council. Other lakeweed work by BOPRC involves harvesting in Lake Rotoehu which is nutrient management rather than a control of the pest plant per se.



These are the costs: $228,000 was spent on the biosecurity and amenity weed management of the Rotorua lakes. The area treated with diquat was 146 hectares at about $1,500 a hectare for the control costs. Lake Ōkareka has had an eradication programme for hornwort and reduction of other introduced weed species. There was an initial big investment in 2013 when hornwort was first detected and inputs increased in the following year with a double diquat application showing real benefits. Diquat was used on 15.5 hectares and the treatment costs in 2016/17 were $29,000 or nearly $1,900 per hectare.

The Rotorua Lakes' costs (that LINZ run) compare with the national budget of $1.89M for aquatic weed management. That budget includes a lot of South Island systems as well as lakes like Karapiro in the Waikato hydro-system.

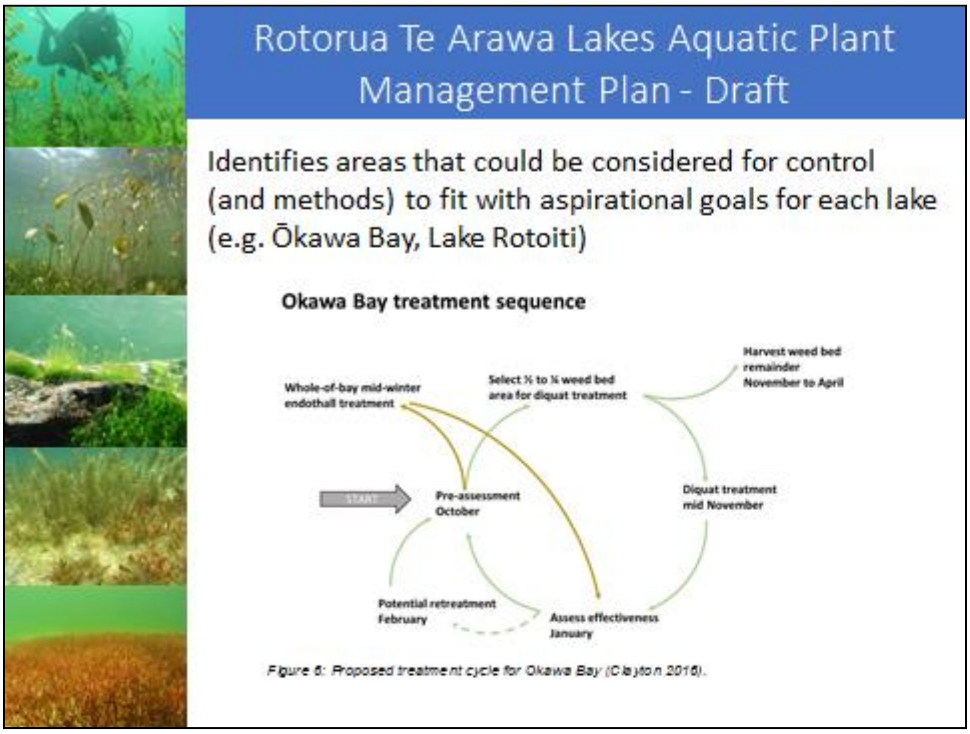
Weed management - The Rotorua, Te Arawa Lakes are 12 separate, very different water bodies, all with different values, human use and each with a unique spectrum of not only the weed types but the issues and impacts that they cause. It is quite different from the water quality issues. Each lake requires a tailored weed management plan. Invasive plants grow where people access the water bodies. It is not about monitoring in the middle of the lake, but rather the littoral zone or lake edge. A lot of nutrients enter via the margin of the water body. It is not just about nuisance weed issues; there is a role for the aquatic plants in nutrient uptake as well as other impacts.

Reactive management addresses the immediate issues and provides tangible benefits at targeted sites. To effectively manage the whole suite of lakes in a long-term goal, we need to account for actions in one lake having an impact on adjacent lakes. The current surveillance plans are integrated into the management plans.

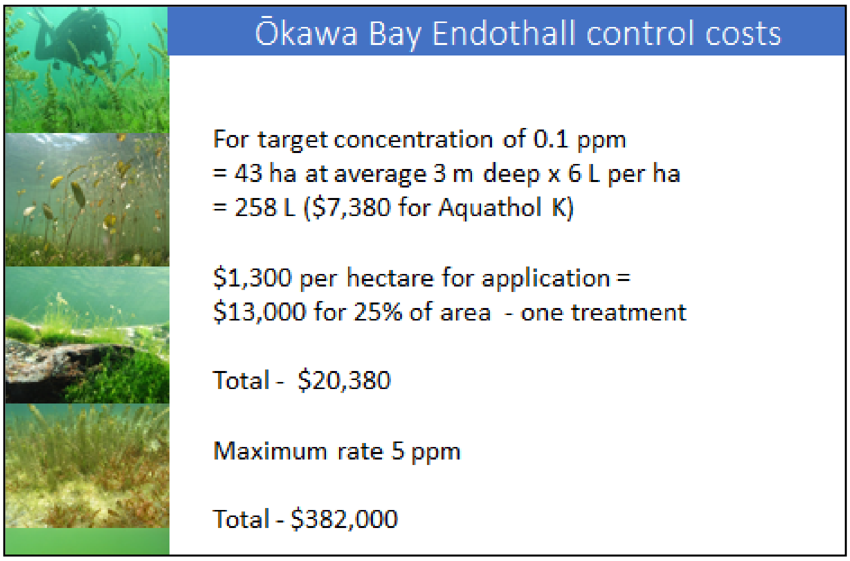
In developing management plans for each lake it is important to define the problems in each lake, identify the weeds, the risks and the impact potential. It is vital that the community and the agencies align and develop a shared vision. Weeds need to be prioritised for each lake, and the plan must clarify roles, and identify the best tools.

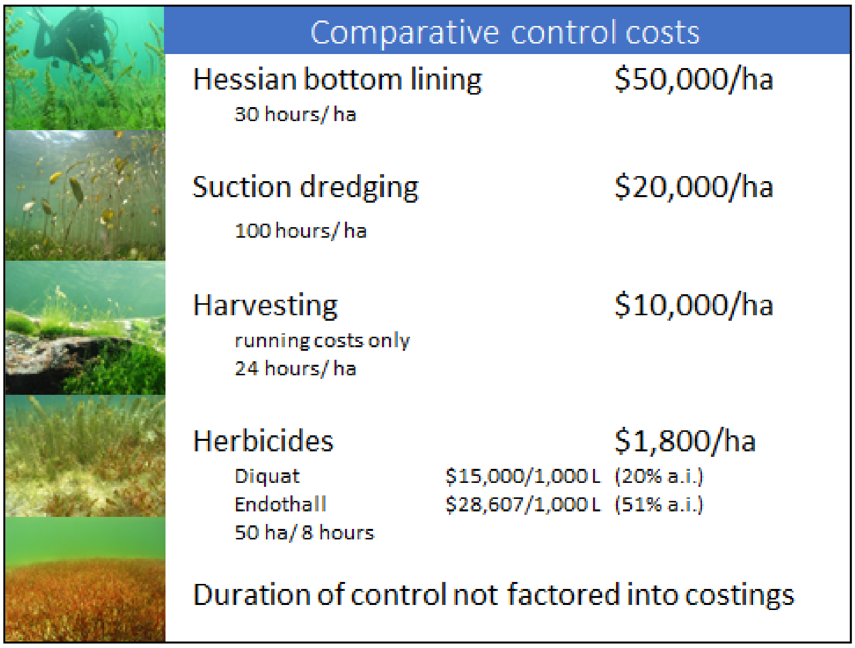
The Lake Weed Management Plans have been developed by BOPRC jointly with LINZ and prepared by Boffa Miskell with NIWA technical input. The draft document is currently out there for stakeholder input with medium term goals, guide objectives and outcomes, as signposts pointing the way to the desired destination. These plans are the initial part of the process.

The draft plans identify areas and methods (next page) that could be considered for control strategies to fit aspirational goals for each lake. Within Okawa Bay (Lake Rotoiti) a treatment sequence is presented as a series of flow diagrams. It has to be based on feedback mechanisms; pre-assessment firstly then scenarios to test options, such as using endothall or diquat in split applications, or even a harvester. All the different techniques that could be used for management of each situation like this are being considered.



Below is Okawa Bay; it is about 43 hectares in area. We have done a cost option for the management of Okawa Bay weed. Rohan talked about the spectacular result we got for the eradication of weeds at 0.1 part per million active ingredient of endothall. Three metres is the average depth to which these plants grow, so applying 6 litres per hectare, you would need 258 litres. That is $7,380 for the aquatic herbicide Aquathol K, plus application costs of $1,300 per hectare. For one treatment that is $20,380. However, for maximum effect, you could use the maximum label rate but this $20,000 ramps up to $382,000. That is a big difference, and it really needs more than just a dollar figure for how much it costs to control weed.





Looking at the various control options, the most expensive is the hessian bottom lining at $5.00 per square metre or $50,000 per hectare and taking about 30 hours to cover 1 hectare of lake bottom. Suction dredging using a diver and venturi pump costs about $20,000 per hectare and 3 times as much time as the hessian.

For harvesting I have used a costing derived from Lake Karapiro and thanks to Andy Bruere and Hamish Lass for a costing of the harvester work in Rotoehu. The running costs are $10,000 a hectare, not including the purchase of the machine or the disposal costs of the weed. It takes about 24 hours to 3 days to harvest a hectare.

An average cost for herbicide is $1,800 to $2,000 a hectare. Boffa Miskell has obtained diquat for $15,000 per 1,000 litres and endothall at $28,500 for 1,000 litres. However, the important thing is the active ingredient and herbicidal rate. Diquat is only 20% of the formulation applied. Endothall is just over 50% active in Aquathol K. They are quite a similar cost for the active ingredient and dose rates.

What is not factored into these costings is the duration of control. In the case of harvesting, it is really mowing the lawn and is going to need frequent repeats. With endothall, potentially there is long term control. Rohan showed the advantages of double applications of diquat where initially the plant is knocked down followed by re-growth. A second treatment is much more effective, so there is a range of techniques that can be used to improve outcomes.

The management in the Rotorua Te Arawa Lakes was underpinned by a funded research programme run by John Clayton back in the days of MAF through to the early 2000's. The funding optimised the use of the control tool diquat. In the present we do not have such funding, but there remains a need to ensure that any proposed management actions are independently peer reviewed and scientifically justified. There must be a consistency of approach, best use of resources, protection of public safety, compliance with relevant legislation and statutory monitoring.

Returning to the Okawa Bay example, there are a wide range of costings, There was nearly $300,000 difference between the maximum and minimum rates using endothall. Compliance agencies could reduce compliance costs, there could more targeted effective control methods and the possibility of lake-wide eradication, which is going to markedly reduce costs.

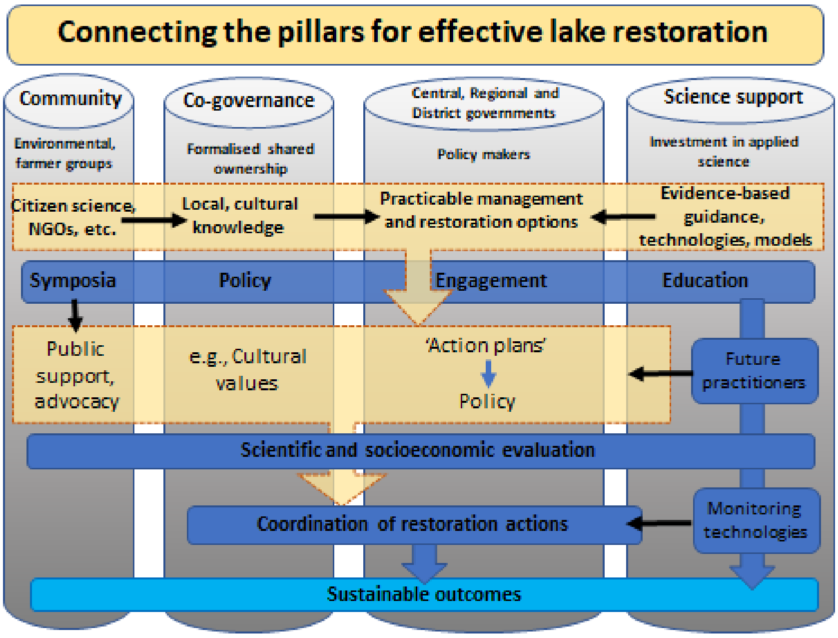
Monitoring is another important part of a control programme. As soon as something different is done, many observers attribute lake changes to that new action. A good example of effective monitoring is the Hawke's Bay hydrilla eradication programme which the Ministry for Primary Industry funded. They also funded major monitoring of the biota in the lake and water quality. When there was a long hot summer, which led to stratification and problems, we saw the result but could show that the grass carp had been in the lake for 3 years, with no problems in the intervening years and there were no beds of hydrilla involved in the algal bloom. This allows us to conclude that whatever was causing the issue, it was not necessarily from the weed control programme.

Research will support the implementation of operational plans that come out of this proposed way forward with weed management plans and the best tools, trialling new techniques as they are developed and monitored to assess effectiveness, selectivity, cost efficiency, all feeding back information into the action plan.

What is missing? There are different rationales for controlling weed in these lakes. Biosecurity seems to be the major focus and quite rightly so, but also the impacts of the plants growing and how they interact with water quality in shallow marginal areas is not well understood. Deborah Hofstra talked about restoration and the benefits of doing that work.

There is some confusion about central government agencies? Sections of the Regional Council are also different for each of these goals. Not all legislation is aligned with the goals and can impede progress. For example, the Hazardous Substances New Organisms Act is overseen by the Environmental Protection Authority and there are delays which Rohan talked about such as the label issues with the herbicides, and there are similar issues with rotenone and other formulations that cannot be used in New Zealand at the moment.

We need a pathway for the evaluation of new tools and experimental use permits. When we develop new products, the largest size tanks are 1,600 litres in our testing facility. These new products need to be tried in small areas in the field prior to widespread use, but we do not have a practical mechanism to do that. Remember with incursions, time is the enemy because they keep on increasing in an exponential way.



Thank you very much David Hamilton for giving us this slide. It reflects what a well-resourced and science-backed programme can provide. These are the water quality management action plans that are happening within these lakes and here in New Zealand we are world leaders and are seeing the benefits of improving water quality. It would be great to have a similar approach to the weed management where everyone is on board and potentially we could have a Rotorua Te Arawa Lakes Biosecurity Research Programme and look at massive gains.

Another example, Peter Beets talked about the work in forestry where they have a research model where all of the plantation forestry groups are contributing to the research programme. They are involved in governance, goal setting, funding and measurement of outcomes. A similar approach could be used with all organisations involved with aquatic weed and pest management. However, in this case not everybody will have the same goals and you are never going to please everyone.

The Aquatic Pests Co-ordination Group is a good start as far as getting everyone together. Currently it is very much focussed on the implementation of these strategies. Maybe if there was a bit more strategic input and policy, potentially there is also a link to the Ministry for Primary Industry led Freshwater Biosecurity partnership, which includes other government departments.

We would really like to thank the LakesWater Quality Society for putting on another splendid symposium and all of the Aquatic Plants Team, thank you for all your input. Big thanks to Marcus Girvan and Kieran Miller from Boffa Miskell for providing a lot of the figures, Dave Mole from LINZ, Hamish Lass, Andy Bruere and Greg Corbett for their input from Bay of Plenty Regional Council and also Geoff Angell (AquaAg), Pieter van der Westhuizen (Etec). Prof David Hamilton and Stu McNaughton (Aquateq) and finally NIWA SSIF F/W Biosecurity Programme funding.

Thank you very much.

NEXT FOUNDATION: PERSPECTIVE ON FUNDING

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Jan is currently the Environmental Director for the NEXT Foundation, residing in Te Tau Ihu, Nelson. Prior to joining NEXT in 2015, Jan spent 7 years with the Department of Conservation leading teams at district, regional and national level building partnerships and developing large scale collaborative impact projects focused on people, biodiversity and water. Jan was DOC's Conservator for East Coast Bay of Plenty around 5 years ago and was previously on the technical advisory group for Rotorua Lakes back in 2007 whilst leading the implementation of the Lake Taupo Protection Project with Waikato Regional Council.

TRANSCRIPT

I want to congratulate the LakesWater Quality Society for putting this symposium together and the high quality of speakers that have been through. It has been absolutely fabulous for me and a lot of things I am going to say have already been said because what we are looking for in terms of investment, you guys are already doing.

Coming back here after being away for a few years, it is great to see how much the work has progressed and how much is being done on the ground. It is nice to see the impacts being achieved, so well done.

I want to give a background on the NEXT Foundation, how we came to exist, a bit of a repeat on what Nicki Douglas covered this morning on collective impact and how to get that at scale. I will then talk about how we are trying to implement that in some of our projects around the country. I will also look at our investment portfolio on healthy rivers, which we have not really started yet, but ideas on how we get to that place as well.

NEXT Foundation's vision is to create a legacy of environmental and educational excellence for the benefit of future generations of New Zealanders. Education and the environment have been chosen as the two categories for support and investment because we consider that they have the greatest potential to inspire and create lasting value for New Zealanders. We aim to empower young people today and the leaders of tomorrow. Education opens the door to personal development, economic opportunity and innovation for society as a whole. New Zealand has an excellent education system, but there are a wide range of initiatives that can drive higher achievement and outcomes, including innovative projects at the edges of traditional systems.

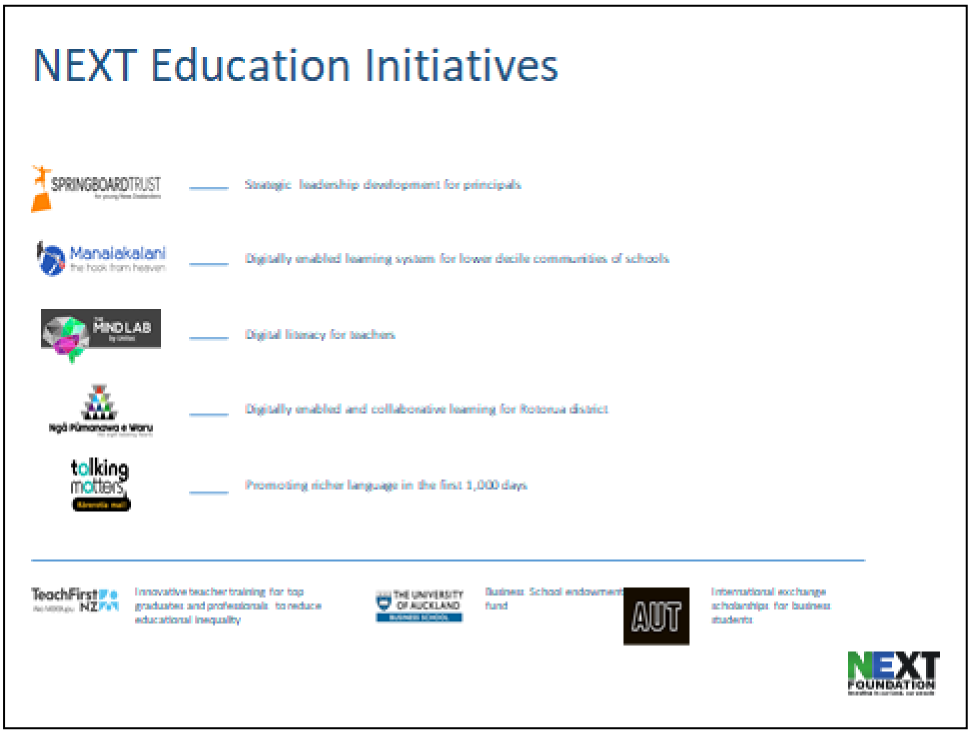
We will invest in projects that strive for educational excellence to provide all New Zealanders with the opportunity to fulfil their potential and develop into talented individuals with the skills and confidence to confront the challenges and embrace the opportunities of a globalised world economy.

New Zealand's natural environment is the foundation of not only our economy but also our sense of identity. Our vision is to ensure our natural environment remains healthy so that it will continue to provide us with the essential resources that underpin a thriving and prosperous New Zealand. Focussing principally on conservation, there are many threats to be managed or overcome such as habitat loss, introduced predators, urbanisation and water use.

The NEXT Foundation was endowed by a couple of very generous New Zealanders, Neil and Annette Ploughman, who are very smart and also very dedicated New Zealanders. It was launched in March 2014 and through their acumen and business they gifted $100 million over 10 years, a substantial amount of resource to New Zealand for the outcomes they envisaged. It is a different kind of approach, a spend down strategic approach with a timeframe to spend the money focusing on outcomes and ensuring that they are sustainable in the long term.

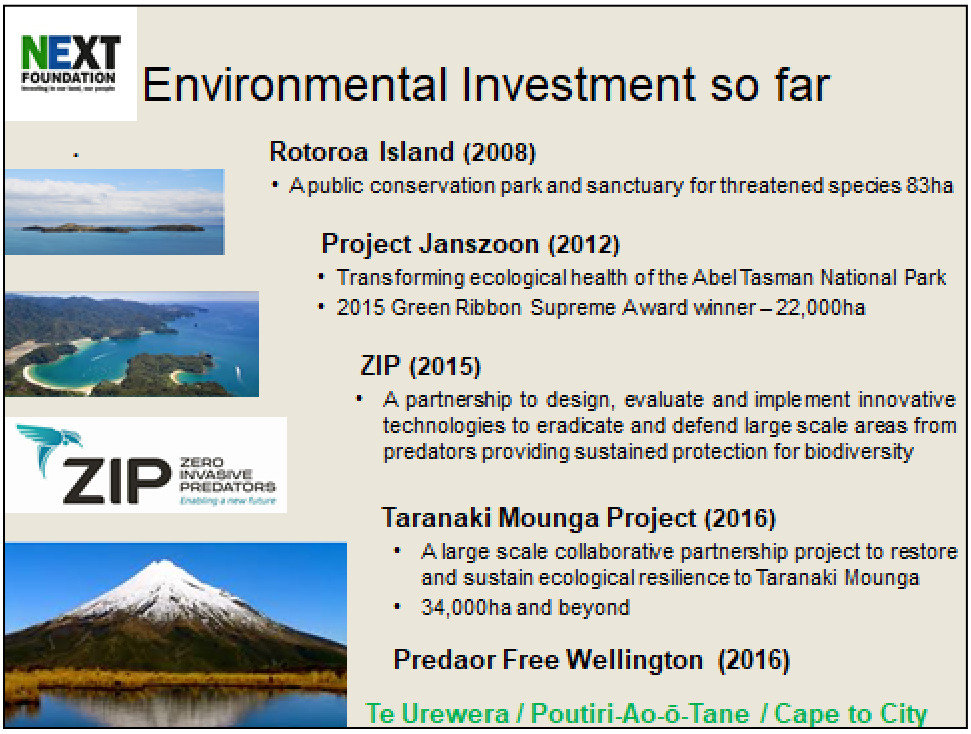
We look at large scale interventions of $3 to $15 million per project over 10 years hoping that whatever we invest in will be sustained in the long term. They need to be transformational and inspirational so others will take these exemplars and follow them, and business like and rigorous. A critical element which lots of people have already talked about today is leadership. It is collective leadership, not about individuals and throughout all of our programmes.

We not only support people with funding but we bring lots of networks from the businesses that we have worked with over the years and the work we have done between each of us in various organisations. It is also helping people to be successful in their own personal or organisational missions. It is not just about money. There is other stuff, social capital that we can bring to these projects.



Predator Free New Zealand - Martin Kessick talked about this earlier and brought to bear the co-benefits of Predator Free, particularly on erosion and its impacts here in the Rotorua Te Arawa Lakes.

Healthy rivers and environmental education - A whole business approach on education and here in Rotorua there is the able leadership of Leith Comber in the Ngā Pumana e Waru collective doing fantastic work, enabling leadership development and digital access with the schools and there are others around the country doing similar great work.



These are some of the environmental investments so far. My focus is the environmental side of the NEXT business. Prior to NEXT forming, the Ploughman's invested in 2008 to restore Rotorua Island, an area of 83 hectares, as a public conservation park and sanctuary for threatened species. It is now completely predator free and fully restored with an education centre as well.

The family and advisors then looked at Project Janszoon in 2012, a restoration of Abel Tasman National Park. Whilst developing that it became obvious there was not enough focus on research and development of tools to control predators so we then built a public-private partnership company called Zero Invasive Predators (2015) (ZIP) to design, evaluate and implement innovative technologies to eradicate and defend large scale areas from predators providing sustained protection for biodiversity.

In 2016 we moved on to the Taranaki Mounga Project, which I lead. This was a large scale collaborative partnership project to restore and sustain ecological resilience to the mountain, ranges and islands of Taranaki from pests and restore and revitalise wildlife; a large area of 34,000 hectares and beyond.

In partnership with Wellington City Council and the Greater Wellington Regional Council we are supporting Wellington's mission to become the first Predator Free capital city in the world.

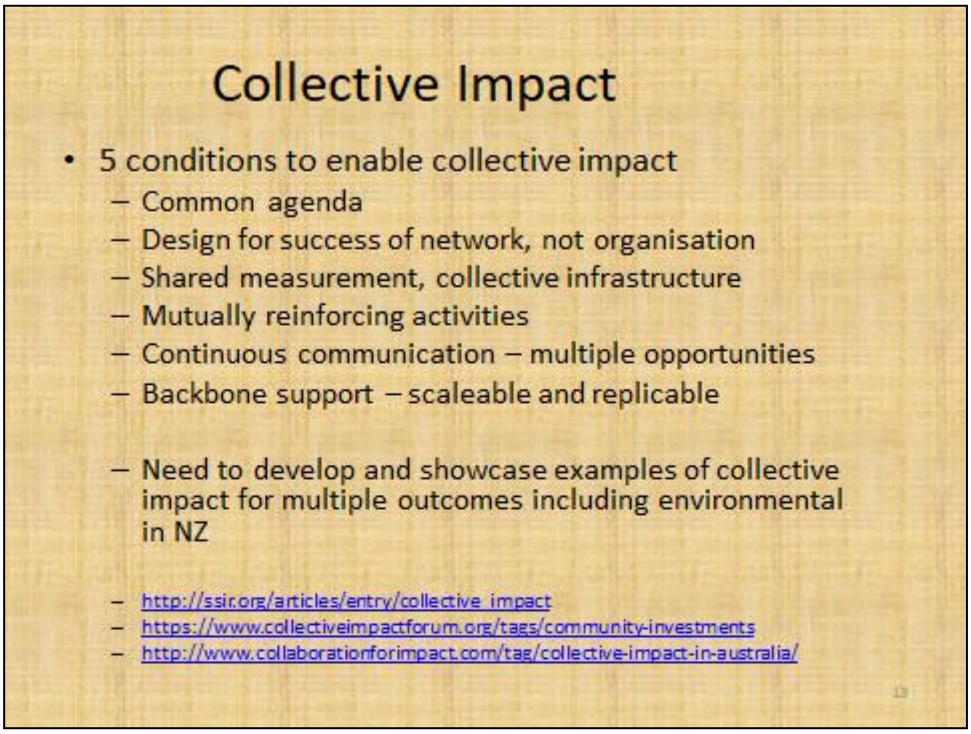
There are other projects and approaches as in Te Uruwera, Poutiri ao ō Tane and Cape 2 City in Hawkes Bay and others around the country that I have worked with in the past that we take learnings from, both in values, systems and the human dynamics of how we might build these sorts of projects at scale.

Other investments that we support are a project called Cacophony led by an entrepreneurial engineer called Grant Ryan using artificial intelligence and open-sourced learning to go much faster on video and acoustic detection and lures for predators to use in the field. We also support James Mansell in a Data Commons project because we believe that presenting data in a more clear and meaningful way will enable people to own their problems and better contribute to the solutions.

When looking for investment opportunities it is important to provide assurance. We are not risk averse, in fact we look for the high risk areas, but we provide assurance to other investors as well as ourselves that the programmes enhance or are sustainable in the long term. They must have effective and compatible partners, as you have in the Rotorua Te Arawa Lakes Project. There must be a clear and coherent purpose that everyone aims for and is socialised across the agenda which in itself should be adaptive and emergent. Of course leadership is key and we look for projects which can be scaled and replicated. If we can provide a learning to share across the country to change the entire system we have been successful.

The Tomorrow Accord was brokered with the Government in 2014, led by Nick Smith at the time, who was the Minister of Conservation. It says that if we invest up front in achieving transformation, doing the heavy lifting such as providing abundant species in a particular place or removing predators or cleaning up some waterways, then the Government will maintain those outcomes in the long run. This means we invest in the large spend up front and the maintenance costs will be picked up by Government. That provides investors, not only us but others whom we bring to the party, a whole lot more assurance and commitment to other projects because then you can take your spend further and enhance the potential for innovation and other shared input.

Slide 13 - Nicki Douglas covered collective impact really well this morning and I can see a lot of the elements in the conversations today. But we need to think about how to lift the scale up. We do biodiversity here, waterways there and social impact elsewhere. However we must take a far larger scale approach to achieve the outcomes to save our rivers and bring back biodiversity.

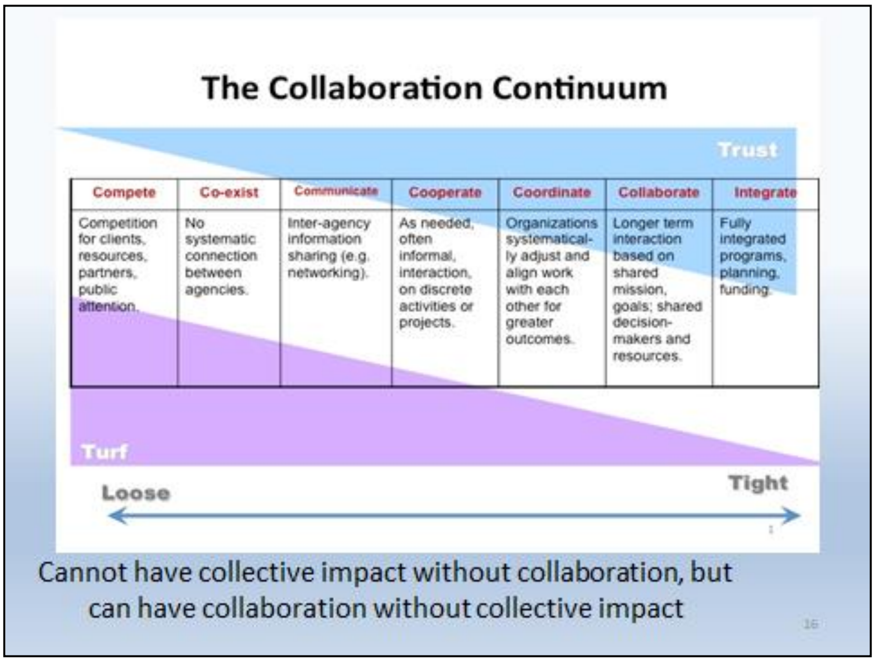


Collaboration is required to fix the wicked adaptive and intractable issues, complex and complicated systems:-

- Incomplete or contradictory knowledge
- Large economic burden
- Many different views and vested interests
- Difficult to frame
- Reactions (cause/effect) not clear
- Diverse stakeholders with unique experience
- No right or wrong path
- Needs objective measure of success

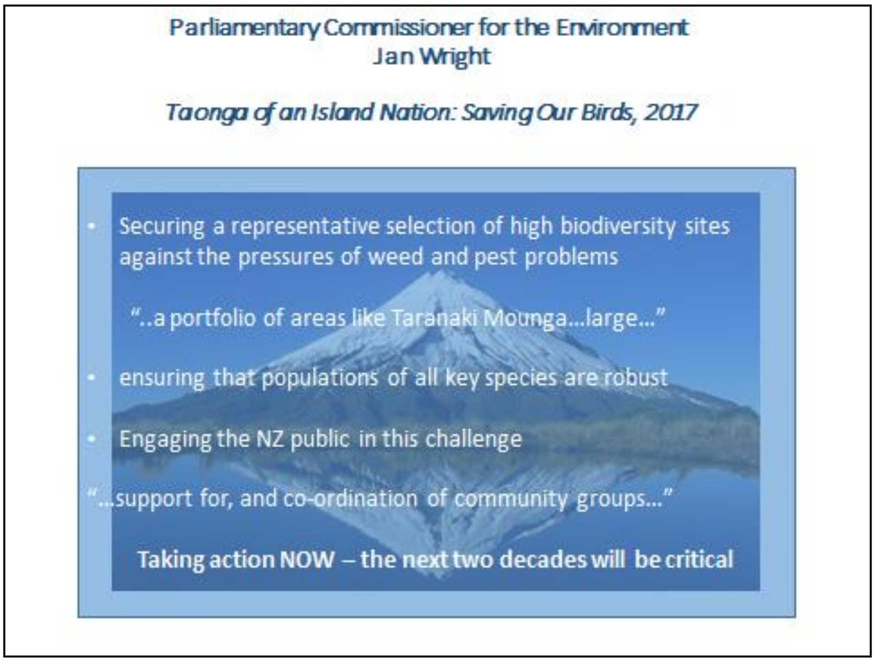
Nicki mentioned the Cynafin Framework but we do not talk enough about the external drivers from things like climate change. Prof David Hamilton talked yesterday about the increase in lake temperatures and how that is going to affect dissolved oxygen and therefore the ecosystems. How will that change the overall systems and those places being looked after? We are not doing enough. We need to think about how we operate fast changing systems and have good values and approaches to deal with these difficult intractable issues coming our way.

Collaboration, as most of you know, is working across power differentials for a common purpose. There are different groups with different authorities and resources but if we can bridge those and build trust by action we achieve that common purpose. There is far more capability to achieve an outcome if you can convene across the system and keep everyone on the same page through efficient and effective communications. The example from the Hunua Project in Auckland this morning was quite amazing. If we can integrate across systems at scale and think about outcomes not just for ecosystems, for water, human elements and terrestrial ecosystems, then there is a far greater chance of succeeding.



Collaborating is not doing things in silos, understanding where the common ground is and supporting each other in having a clear purpose to achieve that common goal. I am sure many of you would have seen this in the past.

Why do we need biodiversity? Because it is in decline. It is quite chilling to think of the number of species and birds being chewed every day by the predators out there in the environment – we think 70,000 a day. Some 3,000 iconic species, both flora and fauna, are endangered. There are 168 of our unique native bird species. But our investment will never solve that problem alone so we need to get much better and smarter. We have new risks coming from climate change which are going to cause chaos in the ecological systems and we have to learn to deal with it. Spending will go towards saving infrastructure rather than biodiversity. We must act quickly.



I was pleased to see Jan Wright's report come out recently. She provided us with a vision for the country to build abundant, resilient, and diverse populations of species. She was talking about birds, but it gave us assurance that our work was on the right track when she said that we need to be working at scale. Here in the large area of the Rotorua Te Arawa Lakes systems you are all looking at outcomes together, with multiple agencies working for a common purpose and engaging your public in that challenge.

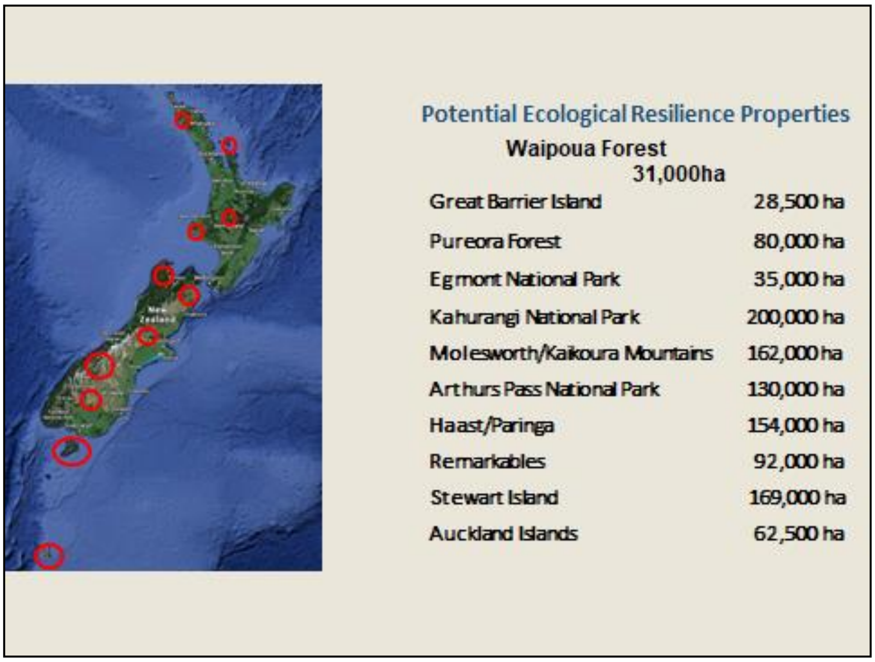
It is one of the things that we do not do very well, engage the public and communities. We do not tell the story well enough in my view but we could get better and work on it far more collectively. Community groups are where the action hits the ground and it empowers those guys to be even more effective but we have to be doing it now.

A bit more detail on some of our projects. Project Janszoon based in Abel Tasman National Park. There was an initial investment which was a contractor, being DOC in this case, and funder, being us. Two parties shifting what was merely around $60,000 a year biodiversity budget and is now up to about $1.2 million. There is a 20,000 hectare trapping network and regular 1080 campaigns. Half a dozen species have been translocated back into the park and coincidentally the tourist numbers have gone from 140,000 five years ago to over 300,000 last year. There are quite significant changes and it is also providing us with learning for other projects as well.

I want to talk about building collaborations, Zero Invasive Predators (ZIP) being one example. It is a private public company with charitable status, primarily a partnership between DOC and the NEXT Foundation but a separate company of its own. It is also funded by the Morgan Foundation (Gareth Morgan), Jasmine, which is his son Sam, various dairy companies, all funding at quite a high level, about $4 million a year in total. They provide technologies, methodologies, tools to eradicate predators and they are tracking really fast. We think we are getting close to a possum eradication tool.

ZIP's purpose is all about research and development of new tools and techniques to remove predators. That is all they do. They do not do social engagement, nor do they do the science or a lot of written papers that one would normally expect when doing research and development. They are getting to the tools and getting the tools out there as fast as they can.

I mentioned ZIP because I do not think we understand it well enough. Most pest programmes are largely around suppressing or controlling numbers. But ZIP is a different kind of science with different tools. We need better detection and to be ruthless, getting every last critter or it's wasting our money. That is the mind-set we must bring to the challenge of Predator Free 2050.



After Janszoon was underway we started to look across the country to invest. We asked DOC where we could go if we had the opportunity to do other large scale investments. We looked closely at all these large potential ecological resilience properties. In the end we chose Taranaki Mounga for a number of reasons. It is iconic, has a mix of dairying in the wider catchment, a strong possum self-help programme led by the Taranaki Regional Council and a large connected community. If we could be successful there and provide exemplars and templates then we could roll these models out elsewhere in the country. To be clear though, NEXT is on the backseat. We are helping to build it but in the end the community, Iwi and locals will be leading this project in years to come.

Initially we worked with DOC to build the portfolio and establish the programme. The Tomorrow Accord got off the ground in 2014 providing our backers with the assurance that their money would be well spent and the impacts achieved. We hosted Taranaki Iwi at Abel Tasman to show the work that was being done and how effective it is if applying those collective impact approaches. We signed an MOU with all parties and looked for other sponsors. It is now a $24 million project committed for the next 10 years to eradicate predators and bring back species to restore the mountain's vitality once again.

Once we had the plan built and convened the partners, we were able to ask other potential sponsors and founding partners if they would like to invest as well. We have Shell New Zealand and some may disagree but they have been very helpful, not just in their rigour but also their understanding of community processes and bringing some 'commons' approaches to our engagement.

Sam Morgan of Jasmine Social Investments is helping as well and the Taranaki Savings Bank Community Trust is very important. They bring a lot of insight into how that community works and help to fund the work programmes. Landcare Research is alongside providing research background to our project as we progress.

The Project Outcomes:

- The ecological resilience of Taranaki Mounga is restored
- Taranaki iwi Chairs and community, supported by local, regional and national government embrace and sustain the transformation
- The Taranaki Mounga Project inspires other communities and investors to address NZ's ecological challenges at landscape scale

We do not do IP; we like to share all our knowledge and learning as much as we can.

Nicki touched on values and purpose this morning and these are really important. Systems that are changing fast are potentially chaotic and it is essential to move fast or if evidence is missing and decisions must be made, it is important to have good values, based on integrity which come from the Iwi of Taranaki.

It has inspired the Regional Council to think about how they move towards a Predator Free Taranaki. They have a plan to roll out each year for predator control across the region off the back of their possum control programme. They will be trialling some possum eradication techniques in that region this year.

This programme has an objective to encapsulate health and wellbeing as part of the whole solution as well. Rangatahi are co-designing excursions and learning on the mountain to achieve health and wellbeing benefits from being involved in conservation and learning skills. There are some simple things going on. Someone with no shoes, who has lived in New Plymouth all their life and never been to the mountain is now part of designing a programme to help other youth get involved in this project. That is important for the long term sustainability of projects like this.

Indicative roll out

	HA	Cost (mil)
Year 1	17,000	$2
Year 2	30,000	$3.5
Year 3	14,000	$1.5
Year 4	27,000	$3.5
Year 5	27,000	$3.5
Year 6	25,000	$3
Year 7	17,000	$3.5
Year 8	30,000	$4
Year 9	18,000	$2
Year 10	20,000	$2.5
Total	235000	$25-30m

Taranaki Regional Council

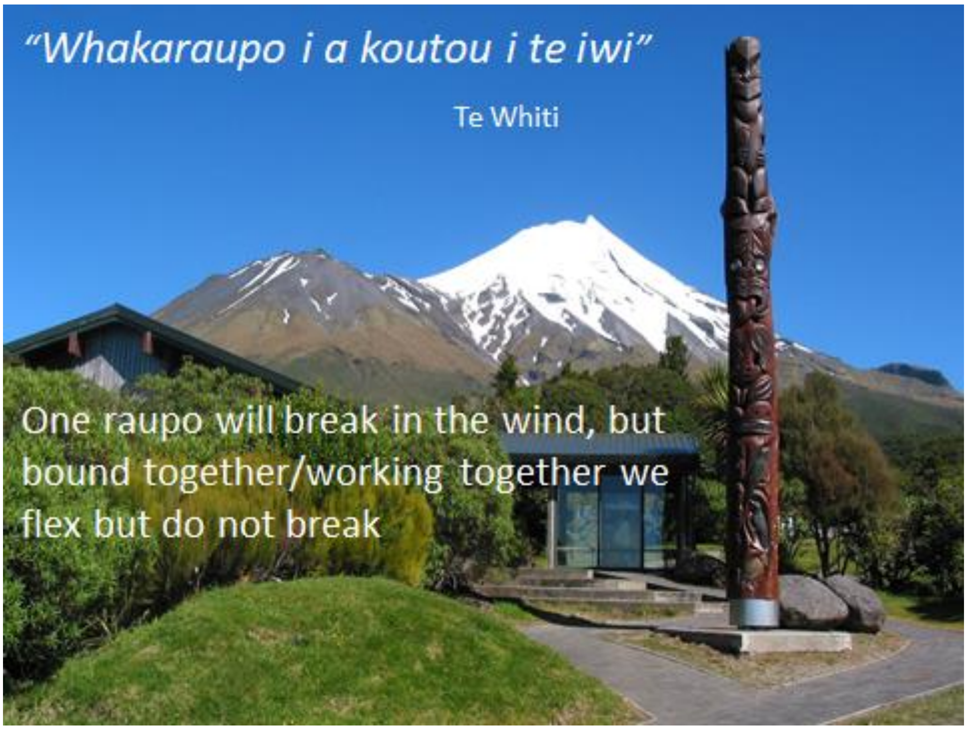
Working with people | caring for Taranaki

There have been a lot of challenges and there always will be. No one has gone to eradication at this level before so finding technical capabilities is difficult. We have to build as we go. It takes time to develop partnerships operating with common values, to build trust and to share the stories like this. It has taken three years for us to get started. Systems for maintaining and sharing data do not exist and we need to move that along and tell our story in more meaningful ways so people in communities understand the problem and the solutions. We will be investing in that more as we go forward. As scaling up occurs, maintaining agile and effective management and co-ordination systems have to change as more people get involved. It is important to have the right kind of efficient process for sharing learnings and involving others.

In conclusion:

- To make impact at scale we need to provide investment assurance because there are always other investors interested in our progress because they could help in other projects.
- The common vision, common metrics and values are important to share learnings as you cannot manage what you cannot measure.
- A common agenda so the various players across the organisations are working for the same goal.
- The backbone infrastructure is far more important than people realise, administration, printing newsletters, bank accounts, all needs to be done well.
- There are multiple opportunities to connect and build for the network, not just the organisation on its own.

There is a major opportunity and more access to meaningful data in layman's language. If we can empower communities to own their waterways, own the problems, we have a better chance to sustain the solutions. We are looking to work in that space as well.



Kia ora mai tatou

QUESTIONS

Andy Bruere, BOPRC: I have a question for Hannah Mueller around the valuation of Lake Rotorua. You say it is worth about $122 million annually. The cost for recovery is just under $100 million being spent on the lake. My first question is does that sound like good value and are we spending enough do you think?

The second question is what is the value of water quality restoration in other catchments where lakes are not receiving water at the bottom of the catchment; it is just a river catchment or a farming catchment?

Hannah Mueller: Thanks Andy. Is it worth spending money on restoring the lake? Yes it is definitely worth spending money. I think that I have shown that. There is economic benefit associated with improving an ecosystem, not only a cost associated with the degradation but also a gain in value associated with restoring an ecosystem. While we do not usually incorporate those kinds of values in our management decisions, neither do we look at it that way, and it is definitely worth exploring those values and incorporating them into our equation.

The second question was what are the values of other receiving water bodies that are not lakes and different kinds of catchments? Was that the question?

Andy Bruere: Yes, probably more along the lines – if you have a lake at the end as a receiving catchment, what happens if there is no lake? What is the value of restoration there and how do you account for that?

Hannah Mueller: If there is something else other than a lake … an estuary or ?

Andy Bruere: There is no lake, just a farming catchment and then it goes to an ocean.

Hannah Mueller: That is a really good question. It is not something that I have thought about before but in terms of ecosystem values, even though there may not be a lake at the end of a catchment, there are still other ecosystems worth protecting, whether it be forested land or something else that provides ecosystem services. I certainly have not looked at any other examples but it is definitely worth studying for other catchments as well.

Paul White, GNS: For my sins, I have done resource and economic valuation work with Basil Sharp at the University of Auckland so I have a comment to your question Andy and also a question for you Hannah.

Andy, the value of the Waikato River for industrial production alone is $2 billion capital value, so it can be done, and the numbers are big. I would recommend you look at the total economic valuation, Hannah, because firstly it gives bigger numbers and makes our work look much more impressive. You do that by capitalising your annual costs or benefits.

My question to you Hannah is how did you get the profit figures for farmers in your catchment study?

Hannah Mueller: Thanks for that. I have looked at total economic value before and am certainly familiar with the concept but this was just a very brief snapshot of what I have worked through in the last year.

The profit figures for farmers were based on a representative value taken from a couple of studies done throughout the Rotorua Region. They were an average value looking at productivity values of the dairy, dry stock and forestry land use so they are not really a land value as such. They are not the sale value but an averaged value of how much profit can be taken.

Paul White: Okay, did that include interest and tax?

Hannah Mueller: No, not in that figure.

Warren Webber, LWQS: A question for Jan. You were not here yesterday afternoon when we looked at figures on funding for weed control and my recollection is around $1.8 million per year is provided by LINZ for weed control in lakes throughout New Zealand, is that correct?

Jan Hania, NEXT Foundation: $1.9 million

Warren Webber: $1.9million. There you go, pretty small. We have some exciting technology coming through with endothall. As I see it, we will struggle to implement what we need with that sort of funding. Is this the sort of thing, as a national or even a regional programme that the NEXT Foundation might be interested in?

Jan Hania: Unless it is going to change the system across the country, probably not. I think we would look for things that are going to be sustained in the long term. I could not say straight off but that is in my thinking at the moment.

Paul Champion, NIWA: One of yesterday's talks was the restoration of native vegetation and if that could be achieved then that would be equivalent to the terrestrial examples that you were talking about.

CLOSING COMMENTS

Don Atkinson, Chair, LakesWater Quality Society

I would now like to invite Emeritus Professor Warwick Silvester and Dr Kit Rutherford to the podium to give a summation of what we have done over the last two days. Their comments come with a lot of experience because Warwick reminded me today that he did the same thing back in 2001. It is an enduring programme. They have both been very intimately involved with the Rotorua Te Arawa Lakes and the Rotorua catchment in particular. Kit has done the Rotan plan within it and both have been involved in the Technical Advisory Group.

Dr Kit Rutherford
There are two slides (at the end of this summary) before you rush screaming from the room. We are going to play a tag team. Because I put this table together, I will probably start off and Warwick has offered to come in with his philosophy from time to time.

Firstly I would like to look at the second and third line about monitoring. We have heard a lot about monitoring and what struck me is that we have the tried and true traditional monitoring techniques - TLI, LakesSPI and Fyke netting (SCUEP) and they have produced excellent information. Five lakes are improving and we have two that are deteriorating. The question cropped up - why Rotoiti? Science questions have come out of that monitoring. We also heard about innovative monitoring techniques such as eDNA, Tai koura and autonomous monitoring buoys and I summarise those by saying, ‘Wow’.

The eDNA, which sounds a little like testing sewage to find out which of the university dorms is smoking marijuana, clearly has potential and once developed, is going to be fantastic. The Tai koura is really exciting. It is Matauranga Maori at its best and the potential to engage stakeholders.

I go back to what the politicians tell us, and we have heard it all before, stakeholders want simple, practical, cost-effective solutions based on sound science. But we have Prof David Hamilton and others telling us that life is complex. Sometimes it is nitrogen, sometimes phosphorus or the weather causes things to change. We can resort to modelling but as a group of scientists we are still faced with complexity and uncertainty, and decision-making in the face of uncertainty is a huge challenge.

This leads into the need for trust, leadership and dialogue and so many times we see that complexity and uncertainty is an excuse for inaction. I am sure Warwick will have some wise philosophy about that topic.

Professor Warwick Sylvester
Going right out to left field now, I want to talk about what happened when I did this sixteen years ago at the first symposium. The contrast between this meeting and the first one is enormous. There were two things that struck me at that original symposium. It was a meeting about all the data and trying to get the regional and district councils to talk to each other. I could not believe just how much friction there was. This meeting is such a contrast because we have a large number of groups talking to each other over the past 15 years and coming up with an amazing body of data, all done within a community of cooperation. The results are enormous.

Not only that, this meeting has achieved far more. It addressed the problems of the lakes and then moved way outside to other environmental areas which impinge upon our attitude toward the lakes, particularly last night at the sustainability forum. It was very illuminating to bring Rod Oram here to talk and also brilliant to introduce a school boy. It opened up so many subjects that relate very much to the problems being resolved for the lakes. I will talk about that again in a minute.

Dr Kit Rutherford

Just finishing off this slide, it takes a community to save a lake. I would like to reiterate what people are saying, how the LakesWater Quality Society team have, through their symposia, brought together so many of the community over the years to discuss the issues of the Rotorua Te Arawa Lakes. It is a wonderful example of exactly that – a community saving lakes. I compare what has happened in the Ruataniwha where I have been closely involved. As of yesterday the proposal to produce a dam in the head waters and irrigate 30,000 hectares of the Plain has finally been shot in the head. The process was carried out so badly and in such a marked contrast with the way things have been worked through here. The Hawke's Bay Regional Council failed to take the community with them and that led to so much anger, bitterness and resentment. It is going to take a long time in the Hawke's Bay for people to get over that process.

But it is not all plain sailing:-

- Todd McClay said, 'Decisions are best made at a local level with national standards'. The cynic in me said, 'Yes, we had a national standard of wadeable rivers'.
- John Green, bless him, was able to stand up and say, 'We cannot let the politicians make the decisions' and alluded to the Nordic model. For those of you who are unfamiliar with it, that is where non-negotiable environmental goals are set.
- Rod Oram reminded us of Geoffrey Palmer's assessment of the Resource Management Act, which was his baby of course. He had always intended to have very strong national policy statements and somehow not very many of those have emerged. As a young scientist, I was involved in the RMA and we expected to put up lots of water quality standards to support the RMA. Somehow that process got hijacked.

Professor Warwick Sylvester

Again I will move sideways because we are here to honour famous men. I have been at this game for some time and there are a group of people I have identified that have made this all possible. Twenty years ago it was an impossible task and only a few people who cared. There is No.1 - Ian McLean. It has been said before and I am going to say it again, the work that Ian has done has been absolutely brilliant. He took on a task, which for many of us would have seemed impossible, to deal with this enormous problem and bring groups together that were fighting over territory. It was an amazing feat and I give you honour. Arise Sir Ian. Thank you.

That was followed by a number of people, and excuse me if I mention names. First of all John Green and Don Atkinson, who have taken over the mantle of organising the LakesWater Quality Society and the work goes on. It has been brilliant. I have worked with a few within the Regional Council too, particularly Paul Dell and Andy Bruere. I mention them because they managed the whole programme and also had a relationship with the farmers who respected them. They also talked to us, the scientists. I used to go to TAG meetings, a place of common minds with a common goal and they went very well. I want to honour those two as well - Andy, and Paul Dell who has gone up north to do good things.

Dr Kit Rutherford

These discussions very quickly turn to cost benefit and equity. Costing material things is easy because they are bought and sold. Hannah introduced us to non-market values and several have dabbled in that area and explored ecosystem services. It is a highly contentious area but clearly one that opens up the discussion to get away from, 'How much does it cost to build a fence?' to 'How much production will be foregone if I alter the way in which I farm?'

Now, Rod Oram and Rob both talked about changing behaviour. 'Stop giving away value' was the way Rod Oram put it. We want good growth and not bad growth. Nobody in this room or in the country would disagree with any of that but why doesn't it happen? Rob Fenwick made the point that it is leaders who stimulate innovation and leaders appear at random. I would put myself in the group of timid followers.
We are going into sheep milking but as timid followers we need information, incentives and guidance. So we need leaders and a shared vision.

I would like to say that leaders are not that rare on the ground. Sir Toby Curtis shows fantastic leadership with this statement, 'When you grow up beside a lake it becomes part of you'. Those sorts of leadership statements take us back to this big shared vision. Something I have taken out of this symposium, rather than getting bogged down in nitty-gritty and finding reasons not to do things, is that if we concentrate on shared visions and talk about them we will make progress.

Professor Warwick Sylvester

I wanted to talk about the anti-science movement because it has been one of my big bugbears and have had to put up with the anti-science movement for the past 50 years or more. When someone comes to talk to me about such things in their belief system I have developed a habit of saying, 'Don't tell me what you believe, tell me what you understand'. We had an amazing paper by Dave Hansford on this whole movement which was most enlightening, but also very dispiriting because it is out there and growing.

I take heart in using the LakesWater Quality Society as an example of taking science into the community, working with scientists and ensuring that science has a place. The model that this Society, scientists, the community and the two Councils work within is amazing and it needs to be written. I have talked to Ian twice about this during the meeting and wondering whether Ian and others might like to write this up as a case history of the way in which good science can work with the community to have good outcomes. I think this is an amazing sociological experiment that has worked.

Dr Kit Rutherford

Nick Smith said, 'We don't want to talk about the good and bad guys, we want to have some action, we polarise issues too much.' I thought, for goodness sake Nick, this is exactly what you do in parliament. Why don't you get some common ground between the parties?

Coming back to Jan Wright's recent paper, she pointed out the awfully sad picture that New Zealand gives on its approach to climate change. The graph for carbon is going up very quickly. In Britain the graph for carbon is going down because they have had a cross-party agreement in parliament and come up with legislation to fight climate change. Many other countries in Europe have also done this very well with cross-party agreements and have attacked the problem. Don't give me good guy, bad guy. Get on with it guys and at the end of the month we might start to think about that.

Finally, we had a talk about who owns the water. I agree that the Iwi situation is bad and our talk about water is going nowhere. Mary de Winton gave us the idea of the commons. Water is the commons and remembering the eighteenth century problem with the commons, there are a lot of parallels in how it was treated 200 years ago. We might take some lessons from that because the problem of the commons in Europe is similar to our situation here.

Professor Warwick Silvester
I would like to reiterate what an amazing conference this has been and an enormous step up since 2001. It has showed enormous progress, not least of which back then was the discussion to appoint a chair in lakes restoration and management. I want to salute David Hamilton and the work that he has done which has generated so much information on what we are doing here.

We have had papers from David Hamilton, Paul White and our other modelling friend here, Kit Rutherford. These are the three modellers that have inputted into the whole system and moved things forward enormously. Their protégé, Chris McBride, gave that brilliant paper this morning. He has taken over the mantel and David has moved on to greater things in Australia. Chris, I congratulate you and the LakesWater Quality Society on a fantastic conference which has raised so many other environmental issues out of the work that has been done.
Thank you.

Don Atkinson
Thank you Warwick and Kit. That is a fantastic summation.

I will wrap up from the Society's point of view and say we can leave this symposium knowing that we have a community to restore a lake. That has been demonstrated on all levels and it is a great achievement. All the stakeholders that are involved in this process have come together to achieve a common purpose.

I do want to leave a few challenges with the Bay of Plenty Regional Council, the Rotorua Lakes Council, with DOC and with Government. We have demonstrated clearly that there are opportunities to address the issues that we have raised at this symposium in our three different sections.

We cannot allow the catfish to get away on us. We must eradicate and nothing else would be acceptable. Think about them in the upper streams in the Rotorua Region taking out all the trout or down the Kaituna at the other end to the sea. That is the potential. Eradication is the only way we find acceptable.

Our second section of the symposium was lakeweed and clearly we have the tools available. Our Society is frustrated that the consent process is taking so long but I am sure that the relevant people will focus on ensuring that the tools are available. Plans are in process to allow endothall to be used across all our lakes. The funding in relation to the value of these lakes, as demonstrated by Hannah, is relatively minor to the total cost that we have expended to date. It is not petty cash but it is a minor portion of the total investment that has been made and we cannot afford to allow these lakes to deteriorate with invasive weeds such as hornwort and lagarosiphon.

Our final focus was the Tarawera Lakes complex and it is great to see the build happening at last. We started to focus on it just two years ago and work has been going on in the background but it is far more complex than we ever thought. The questions are hard but the solutions are not unattainable to restore those lakes to where they ought to be as prize possessions of this district and country. From our Society's point of view it has been fantastic to see the cooperation and willingness to move things along and I congratulate everybody.

To the presenters, can I say absolutely excellent. All the papers built on each other and established a total picture. Thank you very much.

Thank you very much to the chairs and to my committee. There is an enormous amount of work that goes into these symposiums. Thank you also to everybody else who has been involved in bringing about such a successful three days.

Finally, thank you all for attending. We will circulate you by email to understand your thoughts about the symposium which will be helpful for building our understanding.

Science knowledge	Gaps in the science	Uptake by stakeholders
Strong research BoPRC-UoW TAG & STAG, etc.	Complexity: sometimes N, sometimes P, affected by climate, varies between lakes etc. ➔ Need for modelling ➔ Complexity/uncertainty Decision making in the face of uncertainty Requires trust, leadership, dialogue	Stakeholders want simple, practical, cost-effective solutions, based on sound science Complexity/uncertainty an excuse for inaction
Monitoring – traditional TLI LakeSPI Fyke netting (CPUE)	5 improving, 3 stable, 2 deteriorating	Rotoiti: DO depletion. Tarawera: high P – why? Citizen science – depth sounders map weed beds Catfish/koi – commercial fishery?
Monitoring – innovative eDNA Tai koura autonomous monitoring buoys	Wow! Matauranga Enables sophisticated modelling	Engage stakeholders
Pest control Planning/Toolbox Successful eradication – small lakes Novel techniques – hessian matting Risks from 1080 – shown to be low Terrestrial pests – possums, wallabies	Responsibilities divided between agencies Ad hoc – differences between Councils 24 years to register Endothall!	Public 'buy in' – cleaning boats/gear Stakeholder concerns about 'poisons' Science denial
	But it's not all plain sailing…	Evidence-based science. Stakeholders – science interaction. It takes a community to save a lake Strong community engagement: Te Arawa Lakes Trust, Lakes Council, BoPRC, LWQS, working groups, TAG, STAG

Decision making Cyclical, build trust Listen/empower	Wadeable! Vigilance Shared vision - plan - act/monitor - communicate Evidence-based science (eg 1080)	McLay: Decisions best made at the local level with national standards Green: Can't let the politicians make the decisions. Nordic model – non-negotiable environmental goals Palmer: RMA intended to set national policy but.. Oram/Fenwick: Need both carrot & stick Douglas: people coming together Hansford: rising tide of science denial
Costs – reasonably easy Benefits & cost/benefit? Who benefits/who pays? Innovation	'Non market' values Smith: Treasury 'valuing' National Parks Mueller: explored Ecosystem Services at Rotorua US timid 'followers' need information, incentives, guidance Shared vision	Smith: Cap & trade a success (Taupo) but 'grand parenting' difficult. 'Natural capital'. Fenwick: to chair a group investigating natural capital in decision making Oram/Fenwick: change behaviour. Stop giving away 'value'. 'Good growth' not 'bad growth' Fenwick: Leaders stimulate innovation – random process finding leaders Curtis: When you grow up beside a lake, it becomes part of you.

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