Proceedings

ROTORUA LAKES SYMPOSIUM 2019

FLOAT YOUR BOAT

Certify

Prevent Invasive Pests

Restore Lake Quality

2 Day Symposium
Thursday 7 November and Friday 8 November 2019
Millennium Hotel, Rotorua

Hosted by

Lakes WATER QUALITY Society

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.

Questions and open discussion 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, Sue la Roche and John Gifford 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 – John Gifford, Warren Webber, Stewart Edward, Colin Jackson, Stuart Corson

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Key Note Speakers

Dr Lars Anderson
Dept of Agriculture USA (Retired)

Lars has over 40 years experience focused on solving aquatic weed problems in the US, Brazil, Australia, Europe, and Mexico
in lakes, ponds, reservoirs, irrigation systems, estuaries, lakes and the highly complex riparian systems such as the Sacramento San Joaquin Delta and the San Francisco Bay lands.

Lars expertise and consultancies have helped result in successful fully integrated, eradication programs for hydrilla and the marine alga Caulerpa taxifolia, and most recently Elodea canadensis (and hybrids) in Alaskan lakes.

Guy Salmon
Ecologic Foundation

Guy Salmon leads Ecologic, a "think–tank" working at the interface of the environment and the economy.

Guy's work focuses on research, policy advice, and consultancy where this can improve environmental outcomes. He has had a nine–year involvement in the consensus–building Land and Water Forum, and two years ago, advised the Rotorua District Council in its successful application to the Freshwater Improvement Fund for Lake Tarawera.

Prof Troy Baisden
Professor & BOPRC Chair in Lake and Fresh Water Science, University of Waikato

Professor Troy Baisden holds the Bay of Plenty Regional Council Chair in Lake and Freshwater Science.

He specialises in understanding the flow of nutrients, water and carbon through terrestrial ecosystems and resulting impacts in freshwater. He holds a PhD from the Department of Environmental Science, Policy and Management at the University of California, Berkeley.

Troy studies land–to–water nutrient management and issues such as climate change at catchment scales, with a focus on implementing the Bay of Plenty's vision of a mountains–to–the–sea research programme driven by community and iwi aspirations.

Nicole Cartwright
Executive Director for Tahoe Resource Conservation District (USA)

Nicole serves as the Executive Director for
the Tahoe Resource Conservation District since 2017. Previously she was the Aquatic Invasive Species Program Manager for over 10 years developing and implementing programs including aquatic invasive
species control, watercraft inspections and public education.

Nicole received a Bachelor's of Science in Biology from California State University, Chico and had her first exposure to invasive species while working with yellow jacket eradication in Hawaii National Parks with the U.S. Geological Survey. Living in South Lake Tahoe, Nicole enjoys playing in her "backyard"
– biking, backpacking, snowboarding, kayaking and spending time with her friends, family and dogs.

John Walsh
Director Readiness & Response Ministry of Primary Industries

John is responsible for Biosecurity New Zealand's preparedness for and delivery of biosecurity responses. His team also manage or support a number of long – term pest management programmes. His team also provides response support services to the wider Ministry for Primary Industries organisation including in food safety and adverse events.

John joined MPI in 2014 as director Communications and Engagement. In that role he had significant exposure to the biosecurity system – in particular biosecurity responses. He helped lead the development of
the strategy and implementation plan for the Biosecurity Team.

Paul Champion
Principal Scientist, NIWA

Paul has specialist expertise in biosecurity, plant ecology and conservation of endangered plant species, especially in freshwater and wetland habitats. Focus research areas include assessment of weed potential of introduced plants, management of alien aquatic weeds (including surveillance, control techniques and strategies), assessment of environmental impacts of both freshwater pest invasions and weed control strategies and restoration of habitats impacted by invasive weeds. Paul has organised consortia of management agencies in order to introduce
new control tools into New Zealand and ensured their usage complies with Environmental Protection Authority standards.

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Previous Symposia Proceedings www.lakeswaterquality.co.nz

FOREWORD – ROTORUA LAKES SYMPOSIUM 2019

FLOAT YOUR BOAT – CERTIFY

Don Atkinson
Chair, Lakes Water Quality Society Inc.

The Society held its 11th Symposium at the Millennium Hotel, Rotorua on the 7th and 8th November 2019. Our earlier symposia have principally focused on the nitrification of our Rotorua Te Arawa Lakes, the consequential degradation of them and solutions for improvement. While this base theme has continued, in later years we have turned our attention to pests, 'Trouble Makers' as we called them. The arrival of catfish in two of our lakes caused our Society to pause and assess the protection offered by existing and proposed biosecurity for the lakes. The voluntary nature of the present and proposed rules leads us to conclude that they are woefully inadequate, had failed to engage all boat owners, and the status quo was unacceptable. This was evidenced by the introduction of catfish and the extremely high levels of invasive weeds found in all but one of our lakes (where public are excluded). This was the focus of the first day of our 2019 Symposium.

The second day explored progress in the restoration of native aquatic flora, nutrient flows within the Tarawera Greater Catchment and the gradual deterioration in the Trophic Level Index. Finally, we explored what has prevented the expected improvement in Lake Rotoehu and what additional work is proposed.

By bringing out Dr Lars Anderson from the United States we gained an international perspective on what was being done around biosecurity and how seriously it was being addressed. Nicole Cartwright, Conservation District USA, focused on Lake Tahoe and their achievements over the last decade in preventing any new invasive species introduction, by the requiring of a 'clean token' to be presented by launching boat owners. A strong consensus on a certification proposal for the Rotorua Te Arawa Lakes emerged.

The science around nutrient flows into Lake Tarawera is consolidating and Guy Salmon put the case for an eradication plan of wallabies. Phosphorus levels in the lake are slowly rising and wallaby pest eradication has been the focus of two prior symposiums. We were encouraged by Minister Parker suggesting an application be made to the Regional Development Fund.

The ongoing difficulties of Lake Rotoehu were canvassed and the Bay of Plenty Regional Council advised they were looking to procure a consent to allow alum dosing directly into the lake. They are hopeful this will allow time for the land use changes made to take effect.

My thanks go to all the presenters for their efforts and excellent presentations, the quality of that is found within these proceedings; secondly to the chairs of the different sessions. Our ability to allow all attendance at modest cost is due in part to the generous sponsorship provided by the Bay of Plenty Regional Council, Bay Trust, Rotorua Energy Charitable Trust, Rotorua Lakes Council, LINZ and Boffa Miskell Partnership, NIWA and Waikato University. My thanks to them for their contribution.

Finally, to my sub-committee who have tirelessly worked to bring this symposium together, namely: John Gifford, Warren Webber, Colin Jackson, Stuart Corson and Stewart Edward. A special note of thanks is due to Ann Green who has edited and collated these Proceedings.

LWQS is a charitable voluntary organisation which over the last two decades has achieved an enormous amount. Much of the restoration work to date has been stimulated, persuaded and encouraged by LWQS and I am hopeful that the current themes will be adopted for the betterment of the Rotorua Te Arawa Lakes and New Zealand.

INTRODUCTION - Don Atkinson, LakesWater Quality Society Chair

Thank you Dr Kennedy for your Karakia. I would like to acknowledge Chairman Doug Leeder and the Regional Councillors and Mayor Steve Chadwick. We have a change in the programme tomorrow as the Minister for the Environment, David Parker, will be replacing the Minister of Conservation, Eugenie Sage.

I would also like to acknowledge our life members: Ian McLean, Ann and John Green, Warren Webber, Elizabeth and Nick Miller. Thank you for your continuing support. I would also like to acknowledge our key sponsors, Bay of Plenty Regional Council, Rotorua Energy Charitable Trust, Bay Trust and the Rotorua Lakes Council. We get very strong support from NIWA and they have a stand in the foyer for posters so please take an opportunity to explore their work. We very much appreciate the support from Lands Information NZ Biosecurity Partnership, Waikato University, Te Arawa Lakes Trust, Pig & Whistle and the Rotorua Lakes Community Board. Thank you all for making this possible.

A special welcome to Professor Troy Baisden, who will be speaking later, and also Professor David Hamilton, well known to you all.

We come together to have good science presented, to hear and debate solutions around biosecurity and lake restoration, thank you all for your contributions and enabling this Symposium.

Overview

Before we look to what we hope to achieve out of our 11th symposium I would like to acknowledge the progress that has been made in the restoration of our lakes.

- Lake Rotorua enjoys water quality at targeted levels, albeit on steroids, the substance of Rule Change 10 has been confirmed in an Environment Court interim decision, much has already been achieved in the catchment but many hard yards are still to be done.
- The Lake Rotoiti Ohau Channel Wall is well proven, and the lake is nearly fully sewered.
- Substantial land use change has been achieved around Lakes Rotoma and Rotoehu, sewerage is being undertaken or provisions have been made.
- Lake Okareka has seen significant land use change and sewerage.
- At Lake Tarawera sewerage is planned to commence next year. In the Greater Tarawera Catchment farmers have been proactive in nutrient reductions.
- On the lake weeds front, Endothall has been consented and is being actively trialled. Aquatic Weed Plans have been prepared for all lakes and are in the final stages of adoption, they will allow the restoration of our native flora.

These are only some of the actions completed and LWQS acknowledges and thanks all stake holders who have put their shoulders and wallets to the wheel.

Looking forward on the first day we want to explore the biosecurity issues. As a district, with the support of Government, we have spent or committed a quarter billion $s to restoration and everything that has been achieved is at risk. We have renovated the house but left the back door open to invasive pests. We wish to explore how this risk can be reduced to an acceptable level and not break the bank. Our biosecurity has been inadequate, not only around our lakes, but throughout New Zealand. We have seen the

consequence of catfish and invasive weeds in our lakes, but other more dramatic failures have been seen with bovine mycoplasma, kauri dieback and Psa in gold kiwifruit.

In the second day we look to Lake Tarawera and the restoration plan. In focusing the science and our minds we hope to get a better understanding of what stake holders need to do to ensure Tarawera's decline is halted to ensure it remains pristine. While we cannot unwind all of the detractors, we can grab every nutrient reduction achievable and together they are our best opportunity to keep this lake iconic.

Last we turn to our problem child, Lake Rotoehu, and see what the doctor is prescribing.
I trust you will find this symposium informative and stimulating.

Session 1: REGULATORY AGENCY PERSPECTIVES

SESSION CHAIR – Don Atkinson, LWQS Chair

REGIONAL COUNCIL'S VIEW ON FRESHWATER AND THE LAKES

Doug Leeder
Chair, Bay of Plenty Regional Council
douglas.leeder@boprc.govt.nz

Vision

The lakes of the Rotorua district and their catchments are preserved and protected for the use and enjoyment of present and future generations, while recognising and providing for the traditional relationship of Te Arawa with their ancestral lakes.

TRANSCRIPT

Kia ora koutou katoa. Many here have known the journey we have been on but I will give you a brief outline of where we have come from and some of the challenges going forward.

In August 2000 the Rotorua Lakes Strategy Working Group adopted the original Strategy for the Lakes of the Rotorua district. It followed steps in the early 1990's by the Rotorua District Council to stop the direct discharge of sewage into Lake Rotorua. It was an important step towards a more coordinated approach between Te Arawa, Rotorua Lakes Council and the Bay of Plenty Regional Council in achieving community aspirations for the lakes.

That co-management approach was cemented through the Te Arawa Lakes Settlement Act in 2006. As part of that settlement the Crown committed $72m to restoring the four Te Arawa priority lakes: Rotorua, Rotoiti, Okareka and Rotoehu. The Crown funding commitment at that time was matched by the Bay of Plenty Regional Council at $42.35m and Rotorua Lakes Council $32.4m. The Rotorua Te Arawa Lakes Programme was established to coordinate and deliver restoration outcomes for not only those four deed funded lakes, but also on all 12 key lakes of the Te Arawa people.

Trophic Level Index (TLI) targets were set for those lakes in consultation with communities, and action plans have since been put in place and acted on to achieve those targets. It is important to note that way back in the nineties the community, including Te Arawa, were asked what attributes they would most like to see in the lakes going

forward. They wanted to see the water quality as it was in the 1960's. That is not a scientific expectation, but the expectation of the community; an expectation that the Regional Council, in partnership with the science community, had to endeavour to meet. Hence the TLIs and the many other interventions that we have put in place.

In 2012 the Bay of Plenty Regional Council, Federated Farmers and the Lake Rotorua Primary Collective, signed a Memorandum of Understanding called the Oturoa Agreement to significantly reduce nitrate levels in Lake Rotorua over the period of the next 20 years. The Rotorua Te Arawa Lakes Strategy was updated in 2012 in consultation again with the community. This vision was reaffirmed and remains the guiding direction for co-management via our Rotorua Te Arawa Lakes Programme work today.

While the focus of the strategy is on how the partners work together to deliver on this shared vision, it belongs to everyone who has an interest in the lakes now and in the future. That includes Iwi, the lakes' communities and lake users, as well as our future generations.

A key principle of the Lakes Programme work has been to make well informed decisions based on Te Arawa values, essentially Mātauranga Māori values, and the best available science. The programme operates in an environment of evolving science and technology, so action plan interventions are subject to change and reconsidered on an annual basis. An example of this is a science workshop held earlier this year to try and figure out why our improving trends had changed for Lake Rotoehu.

An independent review of our science work for Lake Rotorua completed last year found it to be one of the most extensively researched lakes in New Zealand, if not the world. That review also found that the nitrogen reduction targets we have set and the sources identified to achieve those are very robust.

Video shown - https://youtu.be/gAVezPYENWY (1 min 45s)

'As children we were taught to be kaitiaki, guardians of our lakes. The lakes have watched our people grow, and the land change over generations and hundreds of years. We belong to our Roto, it is our Whakapapa, our taonga. My generation has seen so much change already. Over the last 80 years, urban and agriculture growth has led to a decline in water quality across the region. Excess nutrients from land uses seep deep into the water table and over many years end up in our beloved lakes. Phosphorus and nitrogen are nutrients which aid the growth of blue green algae, pest weeds and cause the water quality to decline. We are working to restore and protect the water quality of our lakes by helping remove these nutrients. Through science, land use changes and action plans for each of lakes we are making progress.

- *We have removed over 30 tonnes of nitrogen from entering Lake Rotorua*
- *Planted more than 40,000 native plants around different Te Arawa lakes*
- *Caught and removed 35,000 catfish out of Lake Rotoiti*
- *We are working with 7 different care groups promoting bio-diversity around different lakes in the region*
- *Stock is now excluded from 90% of streams in the Rotorua catchment*

But there is still more work to do. It is our duty as kaitiaki to start the mahi that will lead this change.'

This diagram gives an assessment of the lakes showing the TLI targets and 2017/18 results for each lake.

- Green = improving
- Orange = stable
- Red = declining
- Grey = to be investigated

Achievements, such as removing 30 tonnes of nitrogen, are easy to say but not easy to achieve. The 35,000 catfish caught in the last 2 years after discovery were originally in Rotoiti and we have now discovered them in Rotorua, so there is more work to be done.

It may not be easy to read but the important thing to remember is that water bodies such as these are biologically dynamic. You cannot take one year in isolation and say that is the TLI or whether it is improving. Scientists identify the trend that occurs over time. A big influence in change is the weather which drives the dynamics; such as rainfall, temperature, wind effect.

We are making progress. Lake Rotorua was good in that particular year and shows over time an improving trend, but mostly driven by the application of phosphorus which I will talk about later.

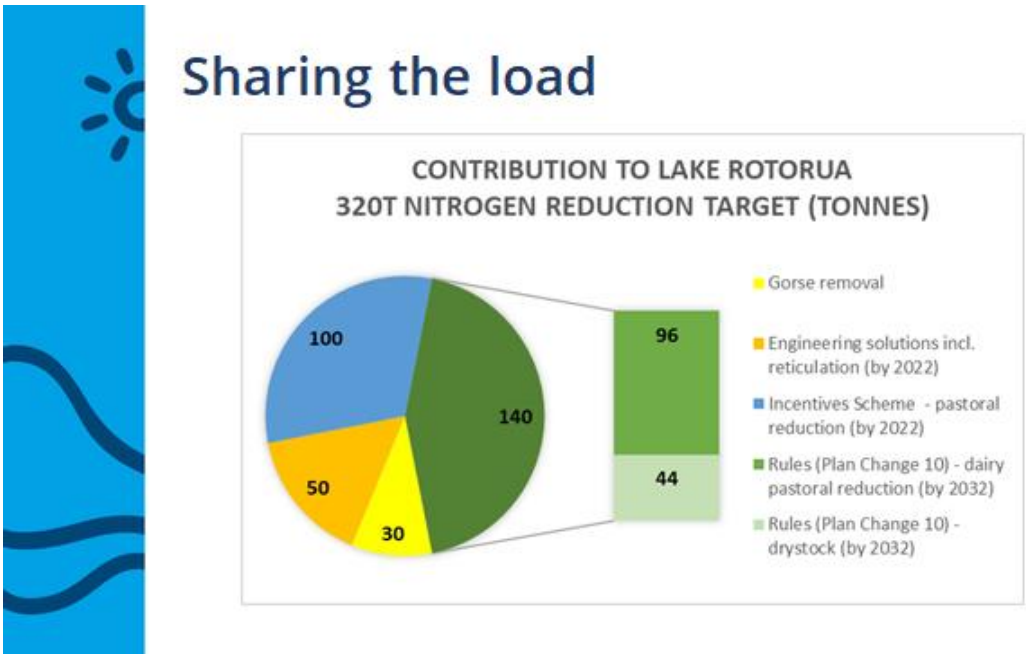
Through the lakes' action plans we have explored every option we could think of and many more suggestions from Iwi, industry groups and the wider community to achieve the water quality improvements that are needed to reach our TLI targets. We have offered large sums of money for ideas and voluntary land use change especially in relation to Lake Rotorua, and we have achieved some great wins and innovations. As that video showed this is a real community input.

With the Regional Council funding help, Rotorua Lakes Council and local residents have stepped up to replace failing septic tanks with sewerage reticulation schemes, landowners have fenced and planted their waterways and invested in wetland restoration, gorse

removal and land use change. We are about 12 – 18 months into the programme of Rotoma Rotoiti reticulation going to a discharge system above Emery's Store at Rotoiti.

Together we have completed a huge amount of work and invested more than $90m, as part of the original deed funding of $250m. But that is still not enough to halt the decline of water quality and meet the TLI targets on an ongoing basis for all our lakes. As we all know, restoring water quality is a long game and it will take many more years ahead before we can expect to see the full benefits of the work we have already done. We also know for certain that there is still more work to do, not just in the Rotorua Lakes but in other catchments throughout the region. Climate change is going to add to the scale and complexity of the challenges we have ahead for all our lakes.

How do we share the load?



This slide shows the contribution of nitrogen reduction to Lake Rotorua. The Lake Rotorua Integrated Management Framework developed by the Lakes' Programme partners to reduce nitrogen levels in Rotorua is based on the best available science and information from tangata whenua, industry and stakeholder groups. It is a great illustration of the role that everyone has to play in achieving water quality targets set by the community, showing where the gains have been made and the respective community and industry inputs. The framework was based on the concept of achieving all that we could through Council functions and incentivised voluntary action before resorting to rules-based methods for achieving the levels of change that are needed to restore lake water quality. Plan Change 10 is a rules-based methodology.

This diagram shows the targets set for reducing the total amount of nitrogen that enters the lake from the current steady state load of 755 tonnes down to 435 tonnes, a target calculated as a more sustainable level for lake health. We are now getting some real traction on delivering those targets:-

- All areas of large gorse have now been controlled (about 215ha), with the help of a $2.5m funding programme

- 30 tonnes of nitrogen has been purchased through the incentive scheme so far – a total of $40m has been allocated using this method to buy 100 tonnes of nitrogen discharge from landowners by 2022
- Through the $1.9m Low Nitrogen Land Use Fund we have fostered new ways of thinking about land use by exploring and trialling new options such as feijoa farms, sheep milking, hemp and eco-tourism enterprises
- Nutrient Management Planning work is underway for all rural properties >5 ha in the catchment and 33 consents have now been issued under the proposed Plan Change 10 rules - $2.2m is allocated to providing a land use advice and support service to help landowners comply with the new rules

With the Plan Change 10 appeal process just about complete it is hoped that the pastoral industry will have more confidence that the direction of travel has now been set and will participate in order to buy or sell some nitrogen. But having said that, nitrogen is not the only focus in this lake. Phosphorus is a key component and managing biosecurity issues such as last year's catfish discovery in that lake too.

There have been other innovative interim measures that the science people put together such as alum dosing at $700,000 a year to lock up phosphorus. The Ohau diversion wall cost just over $8.5 million and has improved the TLI for both Rotoiti and Rotorua. But they come with ongoing consenting requirements and maintenance costs and should not be seen as a vehicle to lull communities into a sense of complacency.

There are still issues here. Just because Lake Rotorua is not green and murky as in the early nineties and 2000's it does not mean that the problem is fixed on a sustainable basis. The problem is just not visible anymore. Alum dosing is okay for now and we have recently applied to renew our consent to continue for a further 20 years if it needs to be. Iwi have raised some issues in the appropriateness of that, but have agreed currently. We risk creating a new problem with lake buffering if we do not make faster progress on some of the more sustainable long term solutions.

Despite all our efforts and money, we have not got everything right. We are investing another $600k in the strengthening of the Ohau diversion wall that was originally consented for 12 years and to last 50. It has now been re-consented for another 35 but after 15 years it started to corrode, much earlier than we had expected. We will have to repeat underwater inspections every three years to maintain structural integrity and monitor what happens below the waterline of that lake.

We have achieved a lot but the pathway to date has been incredibly time consuming. It has been expensive and regulatory changes in particular have been extremely hard on communities, land owners and our staff. The planning processes are slow even with the world leading science, high level of community engagement and co-operative intent across partner and stakeholder representatives.

We are still in the Environment Court after $2m of investment and 6 years of work so far to cement the rules component that is necessary to secure long term lake health. There is a lot more work to be done and we all need to continue to rise to the challenge. We need everyone to move out of their individual and political trenches and work better together to deliver the fundamental outcomes that we all want and need, which is healthier waterways and lakes.

Sitting above all this is a key fundamental, the Te Mana o te Wai framework, the korowai that will sit over all these reforms. One of the impediments that every Regional Council faces in getting plan changes through is the time line. We have talked to the Ministry and asked for an improved streamlined planning process. That work is currently before the Parliament in reforms to the RMA. It will mean that there will be probably less consultation with communities to the degree that we have. But if we are to make progress on improving water quality in a timely matter, we cannot have some of these plan changes taking up to 10 years to put in place.

'Depending on central government's final decisions, the freshwater reform proposals that MfE has just consulted on should go some way to helping speed up planning processes. The proposals will bring cultural values to the forefront and set a common-sense hierarchy, based on Mātauranga Māori to the management of freshwater. The hierarchy guides priority considerations in water management decision-making:

1. First to the health and wellbeing of water
2. Second to essential human needs (e.g. drinking water)
3. Third to other water uses

Many of government's proposals will also take some of the decision-making about details such as the most appropriate farm practices, water quality measures and minimum standards, out of community and council's hands through new environmental standards, attributes we will be required to monitor and bottom lines we will have to take action to meet.

Action for Healthy Waterways

Central government proposals

- Te Mana o te Wai framework
- Streamlined planning processes
- New national standards and regulations
- New attributes and water quality bottom lines
- New direction for managing:
    - drinking water
    - storm water
    - wastewater

Overall the new proposals are well aligned with where we are already headed for the Rotorua Lakes' catchments and the wider region, but they will add extra work and investment of time and money for councils, tangata whenua and landowners.

The DIN/DRP bottom lines in the new NPS proposals do not apply to lakes and the current lake TN/TP bottom lines in the NPSFM are generally less stringent than our current lake TLI water quality targets.

The new government proposals around nutrient limits for rivers would apply across the region, and we have opposed them as they are not uniformly appropriate. In Lake Rotorua catchment, where we have set TN limits for the lake, we would need to do a bit more work to estimate whether the new proposals would be more stringent for any particular river catchment – we assumed they would not be for recent cost estimates.

Plan Change 10 currently only deals with N (& P to a lesser extent) for the Lake Rotorua catchment, and we have known since 2014 that we would need to do more for Lake Rotorua and the other lakes and waterways in the district to deliver on broader NPSFM requirements. We have already got information gathering for our next round of NPSFM work well underway but may need to broaden the scope of that depending what comes out when the national package is finalised – due mid-2020.

The national proposals also suggest that we may need to expand our existing monitoring programmes to cover other indicators such as indigenous fish, plants and possibly aquatic pests.

This aligns well with the direction that the vision and strategy for the Rotorua Lakes, Te Arawa Lakes Trust and LakesWater Quality Society have been heading in, and generally sits well with the broad scope the three partners (Te Arawa Lakes Trust, Rotorua Lakes Council and Bay of Plenty Regional Council) already have through the Rotorua Te Arawa Lakes Programme.

We are already holding the line on land use intensification through our Rule 11 provisions in the Rotorua, Rotoiti, Ōkāreka, Ōkaro and Rotoehu catchments. The new national proposals would give our other lakes a similar level of protection from intensification as an interim measure until nutrient limits are established. For Lake Rotorua we already have a nutrient allocation regime in place through Plan Change 10 which we expect will be the primary tool for managing intensification, but we have sought to confirm and clarify that through our submission.

This district is well ahead of the game in relation to the proposal to make farm management plans compulsory. Many of the landowners in the lakes' catchments already have farm plans or nutrient management plans in place, so we have a great base to work from, existing plans may need to be adjusted or built on to meet the new standard. Our advice and support team will continue to work closely with landowners in the lakes' catchments as we work through any necessary changes once the national package is finalised mid-2020.

Our submission asked for better recognition of existing farm plans and actions land owners have already taken, like stock exclusion, and a reasonable transition time.'[1]

Breaking Down Barriers

This picture shows communities working together outside a regulatory environment in Lake Rerewhakaaitu and a great example of a community led project. Landowners been have working together to take positive action for their waterways for the last 20 years and the Regional Council has been proud to be able to support their efforts through funding assistance and technical expertise.

[1] This section added from PowerPoint notes, but not used in presentation because of time constraints.

A key to the success has been to allow the farmers to explore the science and find the solutions for themselves in a non-threatening environment. The project started out in the 2000s with a series of Sustainable Farming Fund Projects that explored on-farm nitrogen and phosphorus mitigations. The learnings from those trials were then put into place and nutrient management plans were developed for each farm. Progress was independently audited and collectively they achieved total nutrient reductions of 18% for N and 28% for P - all through voluntary efforts.

They achieved that through a range of tools including detainment bunds, new wetlands, riparian fencing, shed wash water ponds, calibrated irrigators, science projects and farm environment plans. They planted 17,200 plants along the lower reaches of the Awaroa stream and were selected as a 2015 finalist in the Ministry of the Environment Green Ribbon Awards recognising outstanding environmental stewardship.

By 2015, with funding help from Bay of Plenty Regional Council, they developed an action plan for the whole Rerewhakaaitu catchment that the landowners were fully engaged with. They formed an Incorporated Society to deliver on that plan and have since expanded their approach to also support landowners throughout the Okaro, Rotomahana & Tarawera catchments. Their efforts have been a key contributor to TLI improvements achieved for both Lake Ōkaro and Lake Rerewhakaaitu. It has been done willingly outside a regulatory environment, and they are a great reminder and example of what a group of local people can achieve, together with agency help, when we are all on the same page.

But those farmers are now saying that, in the wider area in which Rerewhakaaitu has to operate, it is time to ask the regulatory authorities to put rules in place. Because new land owners coming in to that community do not all subscribe to what the current community are doing and how can you actually compel them? Maybe by peer pressure, but ultimately it can only be done by some regulatory form. This has been a great initiative by local people who understand their district really well.

There will be new national standards and regulations, new attributes in water quality bottom lines and new direction for managing drinking water, storm water and waste water, what we refer to as the three waters.

As I said many of the Government's proposals will take some of the decision making about details, such as most appropriate farm practices, water quality measures, minimum standards out of the community's hands through the new environmental standards and they will be regulated either through regulation or what we refer to as an NES – National Environmental Standard.

But it will not do what you and your neighbours and communities and local business and land owners can do because you people are best placed to achieve the outcomes. You can identify the problem, collectively you identify the solution with science back up and you people can implement it. In my view people best able to solve local problems are the local people who understand the challenges.

Thank you.

Nā to rourou, nā toku rourou, ka ora ai te iwi

With your contribution and my contribution the people will thrive

INTERNATIONAL EXPERIENCE WITH LAKE RESTORATION

Lars Anderson
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Dr Anderson retired in 2013 after a 37 career with the US Department of Agriculture where he conducted basic and applied research on the biology and management of invasive aquatic weeds. He has over 40 years' experience focused on solving aquatic weed problems in the US, Brazil, Australia, Europe, and Mexico in lakes, ponds, reservoirs, irrigation systems, estuaries such as Lake Tahoe and the highly complex riparian systems such as the Sacramento-San Joaquin Delta and the San Francisco Bay lands. His expertise and consultancies have helped result in successful fully integrated, eradication programmes for hydrilla and the marine alga Caulerpa taxifolia, and most recently Elodea canadensis (and hybrids) in Alaskan lakes. He has participated on numerous US and international technical advisory groups to address aquatic invasive species problems. He is a past president (and founder and Honorary Member) of the Western Aquatic Plant Management Society and a past president and Honorary Member of the Aquatic Plant Management Society. He is currently developing an integrated aquatic weed management plan for the Tahoe Keys in South Lake Tahoe.

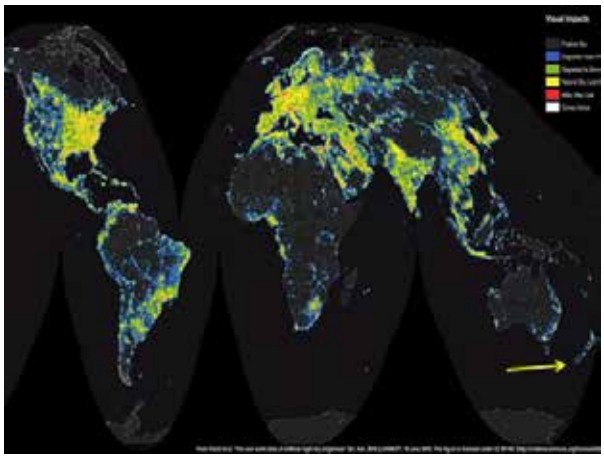
TRANSCRIPT

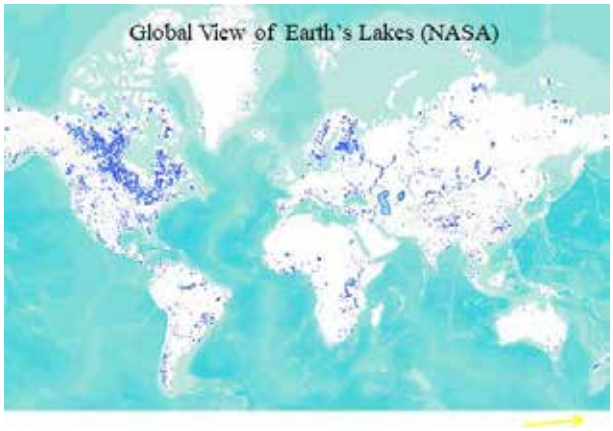
Good morning, this is my second trip to New Zealand and I have been more impressed this time around. I had a great tour on the lakes yesterday with the committee of the LakesWater Quality Society and thank you very much for the invitation to come out again to this wonderful land. I will say at the outset that I hope to encourage you to not let up your efforts on the lakes for restoration for sustaining the incredible resources that you have. In my slides I want to show you some international examples and also show that you are in far better shape than many places which means **don't to let up at all at this point**.

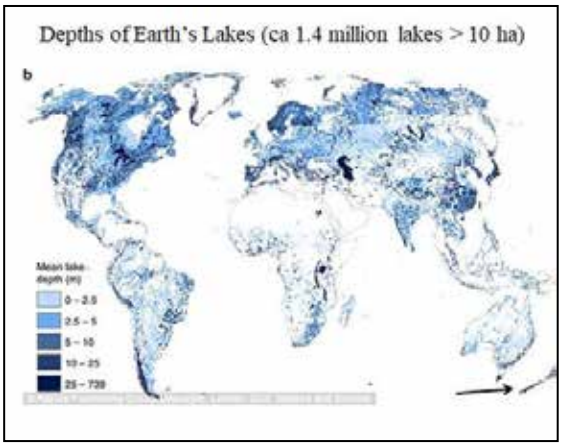
This is an aerial view of Lake Tahoe and it has a wicked problem with incursion of invasive aquatic plants and invertebrates. It represents the complexity of controlling aquatic invasive species in a resource with very high public use.

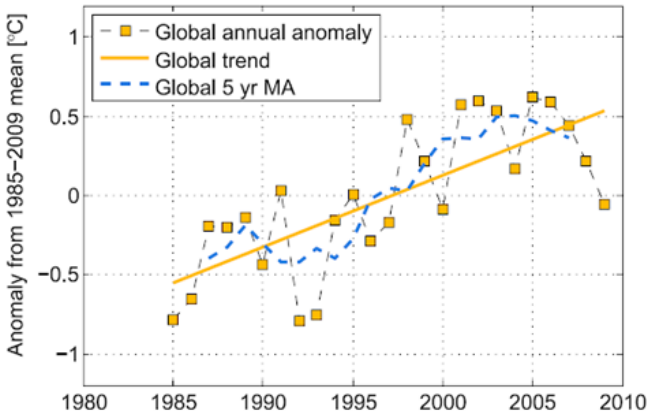
We will talk about restoration and whether one really can turn back the clock, then a conceptual model and discuss what driver knobs can be turned and examples, and lastly successful approaches to invasive plant management and conclusions at the end.

This slide is a June 2016 NASA enhanced dark sky image of the world and the slide below left is the global lakes' distribution. If you compare the two it clearly shows that we humans go where there is water and then we tend to mess it up. The slide below right is an example of the depths of those lakes worldwide, the darker the image the deeper the lake. It shows that in New Zealand there are some nice deep lakes. It also points out that we like to centre our populations around deep lakes and anywhere there is water and we tend to do activities that affect the water quality and their natural habitats.



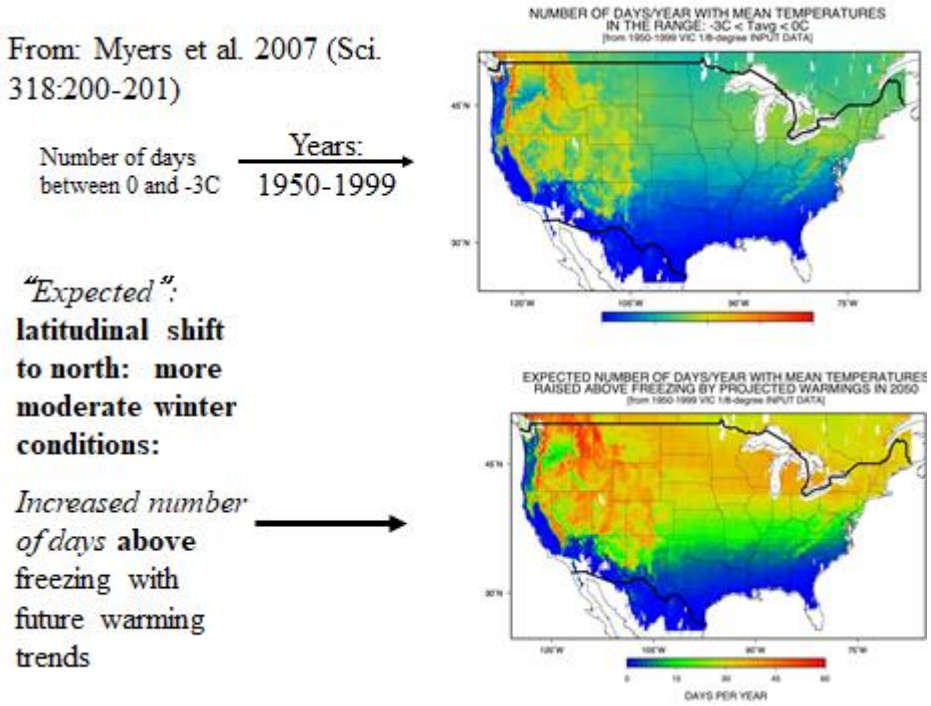






We are very concerned about global change, in spite of what you might hear about some folks in the US. It is happening. This slide shows the trend that is going to have a tremendous impact on most lakes whether they are deep or shallow. We see increases in temperature in Lake Tahoe that are astounding, it is a very deep lake, 1600 feet at its maximum depth, so this is another consideration for restoration activities and planning ahead for climate change.

The image below was published a few years ago showing predicted US temperature changes. The blue areas show the cool frost zones, the upper figure is the current period; the lower one is 25 years from now. In other words, there will be a lot more mild winters throughout the temperature zones particularly. That is a big change in the next 25 to 50 years and not a lot we can do about it, possibly slow it down, but it will happen.



What is Lake Restoration?

The common themes seen internationally in restoration projects are:

- *Return to pristine conditions* which must be defined. It is often unrealistic in many cases unless actions are started at an early stage such as some I have seen here in New Zealand.
- *Return to protect beneficial uses*
- *Improve habitats for native species*. Mostly in the western world projects it is fish habitats and secondarily plants. I am glad to see the focus here on native plants because they are an important part of our ecosystem.
- *Improve/Sustain recreational uses*
- *Restore/Sustain water quality*, a common theme
- *Improve/Sustain ecosystem services*

They all have to do with our ability to use the water for aquaculture, agriculture, potable water, hydro power, fisheries production, flood control and so on. With these themes and objectives in mind, what conditions affect management and restoration?

Metrics that Drive Restoration Strategies

- *Water shed area to lake volume ratio*. This is one of the reasons that Lake Tahoe is so pristine because it has a very small water shed for the size of the volume of the lake.

- *Turnover rates*, seasonal or multiyear? We talked yesterday about how some of the lakes here turnover. Most typical temperate lakes turn over twice annually; fall and spring. Lake Tahoe turns over about 1 to 3 years because it is so deep.

- *Nutrient inputs and cycling*. Nutrient inputs are a worldwide issue; most restoration programmes include reduction in nutrient inputs one way or the other. Yours is the most aggressive programme that I have seen. Cycling of nutrients is often complex and can be difficult to alter due to biotic and physicochemical interactions.

- *Turbidity and light field - w*hat happens to the light regime within the lakes' systems.

- *Pollution inputs* - what happens above the water column.

- *Hypolimnion DO/*Redox/oxidation status of sediments

- *Sedimentation rates* - a huge issue with restoration when dealing with shallow lakes because of run off. I suspect this will be aggravated by climate change, changing rain fall patterns creating more sedimentation and run off with the increased rain fall intensity and frequency.

- *Roiling fish* – such as carp. The introduction of fish can cause huge turbidity problems. For example, Australia is trying to remove carp to reduce turbidity in the Murray-Darling river/irrigation systems and it is a long-term process.

- *Primary productivity* (phytoplankton, macrophytes)

- *Ratio of Littoral zone to total benthic area*

- *Seasonal water level fluctuation*. In some of our western lakes and lakes in Europe changing water levels and managing the aquatic vegetation can improve water quality if done correctly.

- *Fisheries habitat/food web dynamics* are all part of restoration and most sophisticated projects consider these interactions to optimise restoration efforts.

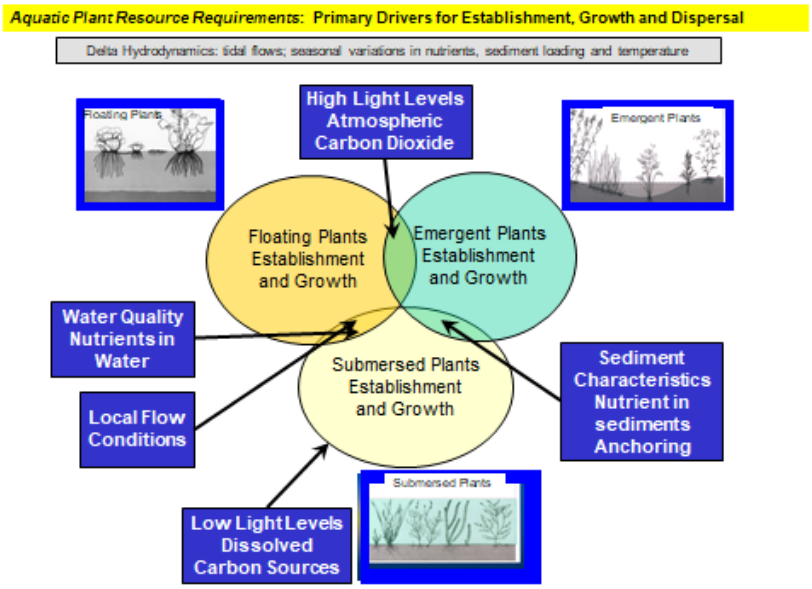
- *Wind fetch* cannot really be changed, but as in some Dutch lakes, turbidity in shallow lakes from high wind development creates difficulty in establishing macrophytes.

- *Lee affects, protected areas*

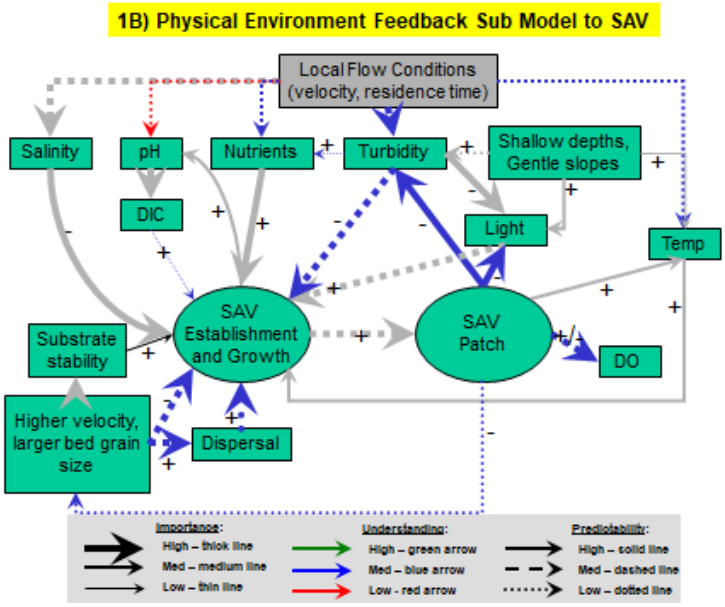
- *Aquatic invasive species* – impacts to native species, food webs and physicochemical environment affect restoration actions and cause major problems.

- *Stakeholder goals and cons*ensus. This is a common issue internationally with restoration. Unless there is consensus amongst stakeholders there is no progress. There is clearly lots of consensus here regarding the Rotorua lakes but it is a continuing process. There is a lack of consensus at Lake Tahoe about how to manage invasive species impacts. There is some consensus about goals but how to achieve those is contentious.

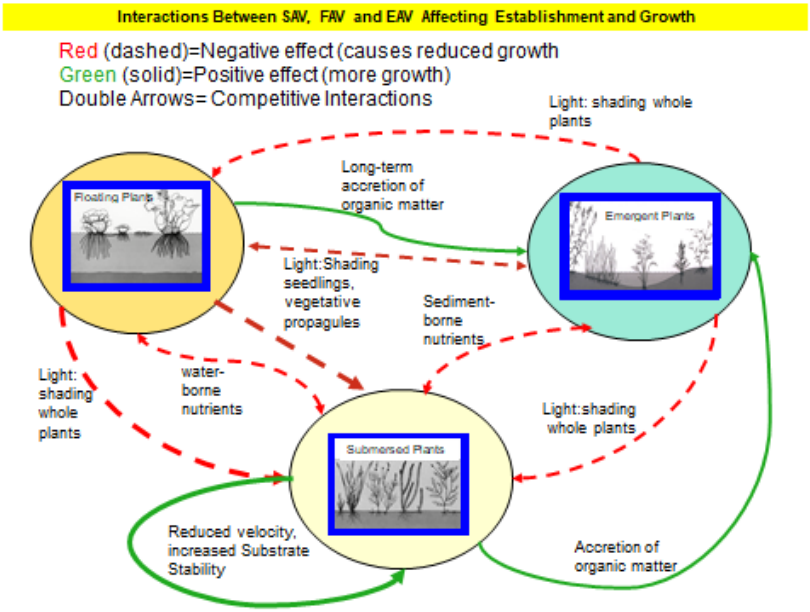
This slide illustrates how these interactions of aquatic plants affect water quality and sedimentation, they are complex interactions. I always say it is more difficult than rocket science. Rocket science is physics, its maths, but these are dynamic biological processes within a complex system that we try to tweak and change in some way.



The slide below is a somewhat complex conceptual model to illustrate plant/physical interactions to help determine how to tweak the 'driver' knobs in the Sacramento San Joaquin Delta. All these interactions go on underwater and unseen. They also occur seasonally in different lakes at different times. To change little knobs in this model in different directions, you have to have a lot of basic information about how these



interactions occur. I am not suggesting that we have all the answers, rather that information on these interactions needs to be developed. The interactions between aquatic plants of various types, (submerged, emerging and floating) and fisheries populations are all complex interactions and shown below. That is why I say it is more difficult than launching something out of a launching pad, which is just physics.



Reality Check – What is the track record?

Most attempts fail because –

- *Too little and far too late*
- *Not the right tools, methods or strategies*
- *Transient planning*, and the right consensus for successful restoration
- *Loss of funding*
- *Unrealistic goals* – It is critical in post restoration projections to have a goal that is achievable. Without this people get confused and frustrated, especially funding agencies, if the goal is unachievable. It is important to have a consensus on what the goal is and critical paths to get there.

- *Death of Expertise* - A lack of respect and confidence in science is growing in the Western world, perhaps globally. Anyone can be an 'expert': just go on the internet for half an hour and learn everything needed to know about a subject or a 'solution to a problem. The only problem is that when the lay public uses that approach and has an answer in their head, talking to scientists at a meeting becomes problematic. Scientists who have worked on the subject for 10 to 15 or more years have a foundational knowledge, lacking in 'Internet expertise'. It is frustrating for everybody. This is a long-term trend that we have to be careful about. (See 'The Death of Expertise' by Tom Nichols for in-depth discussion.)

- *Translation ecology* is a term that describes the integration of all appropriate methods with effective consensus building through informed stakeholder inputs.

The slide below shows a few examples. There is a lot written about restoration of the Florida 'Chain of Lakes' and the Sacramento San Joaquin Delta. Lake Victoria in Africa is also a nightmare. However restoration has been attempted in a lot of lakes worldwide and some have worked better than others.

A Few Examples

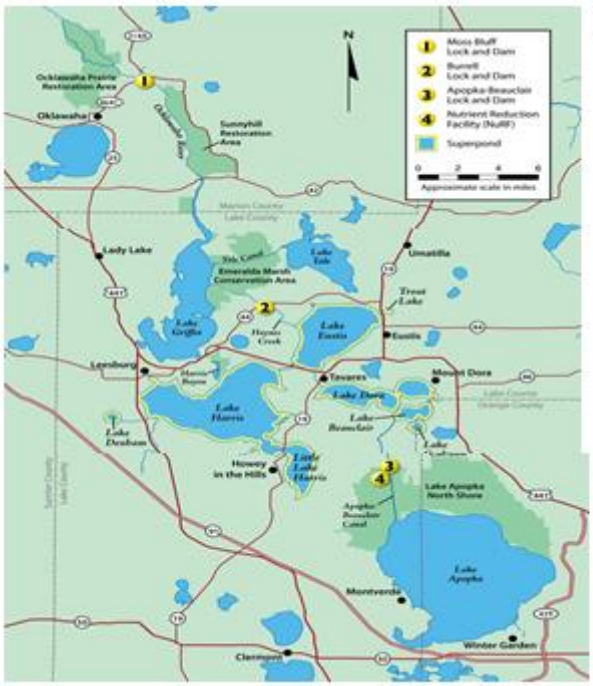
- Florida "**Chain of Lakes**" SAV (Hydrilla): herbicides; sediment Everglades Restoration
- **Sacramento- San Joaquin Delta**: SAV/FAV/EAV: herbicide; reconfigure bathymetry/shoreline
- **Lake Victoria** (Africa) (WH): harvest, biol., herb.)
- Lake Tahoe (SAV: harvest; various barriers; UV light)
- Polish Lakes (primarily available P: reduction> aeration)
- Dutch Lakes (shallow/wind/ Turbid: reduce carp &Establish macrophytes)
- Chinese urban Lakes: Turbid, Algae: Establish macrophytes
- Lake Conroe (TX): SAV/Hydrilla/*Nymphoides cristata* : Biol. Control- Grass carp; re- vegetation; herbicides; mechanical
- Brazil Reservoirs (SAV/Hydrilla*/ E.densa*): mechanical; herbicide; (biological control)
- Australia- Turbidity, taste/odor, HAB, macrophytes: biol. Control, herbicides, fish management

The Chain of Lakes in Florida is somewhat reminiscent of the Rotorua Lakes, although the scale is much smaller than this. The Chain of Lakes restoration has been going on for a long time, primarily to remove *hydrilla verticillata*, the most important invasive weed there. Below shows that there were a lot of separate projects with spending $US14.87 millions in 2018 alone. What has been most successful is reducing *hydrilla* populations. The rest has been only partially successful; this is a very complex system.

Harris Chain of Lakes Restoration Strategies:

- Technical Advisory Group (TAG)
- Improve methods - NOTE: 1988 - 2016: $US 303 million!
- FY 2018: allocated $US 14.87 million
- Return to 'nothing less that pristine' conditions (?)

- *Projects:*
  Dredging L. Apopka for vegetation
  NO lake-wide aeration
  Maintain high water levels
  Establish SAV in some lakes
  Increased AIS management
  Fish attraction structures
  Septic Tank studies
  Solar energy sources
  Legislative: Sustaining funding



Harris Chain of Lakes Restoration Council
(Florida-USA)

Objectives:

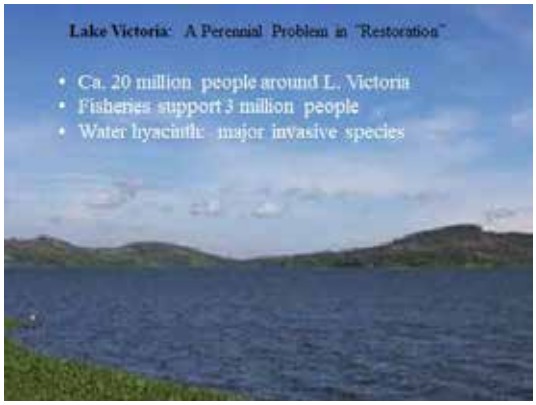
- Shoreline restoration
- sport fish population recovery
- Sediment Control
- Exotic Species Management
- Navigation
- Water Quality
- Fish//Wildlife

A better example, but a little more frightening, is the Florida Everglades which is an $US8 billion plan. It is a very impressive area but there are complex interactions. We have over 200 different invasive species; submerged as well as emerged, including water hyacinth, in that area. The restoration has been going for 30 plus years and a continuing battle. It will probably never be restored to the pristine conditions.

Examples of Costs for Aquatic Plant Management Projects: Florida Everglades/Restoration: 30+ years, $8 Billion Plan!

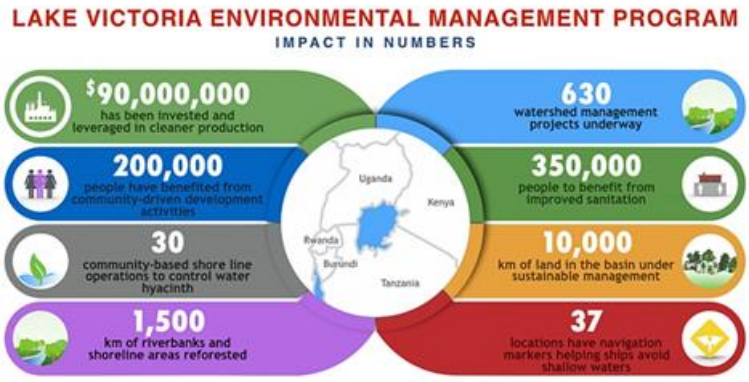
- ✓ *> 200 invasive, exotic plants (terrestrial, wetland, aquatic)*
- ✓ *1.8 million acre restoration project (total 8 million acre ecosystem) Cooperative Invasive Species Management Areas (CIPMS)*
- ✓ *Shinus terrebenthifolius: conservatively ca. 125,000 acres; Melaleuca & Casaurina>10,000 acres*
- ✓ *Panicum repens: impedes establishment of "Stormwater Treatment Areas"*
- ✓ *Other aquatic weeds (e.g. Hydrilla)*

Lake Victoria in Africa is one of the largest in the body of lakes surrounded by several countries. You can imagine that collaboration and consensus building here is a real challenge. There are a lot of arms and coves where water hyacinth, which is the main problem, has been controlled; and then there is all the rest of the lake. The picture shows a hint of water hyacinth on the left-hand side. There are 20 million people around the lake, fisheries that support 3 million people, so if there are no fisheries it affects a very large population.



The Lake Victoria Restoration General Objectives and Strategies

- Improve collaborative management (multinational)
- Reduce the environmental stress
- Remove point source pollution through control/prevention of input of nutrients
- Watershed management
- Fisheries resources

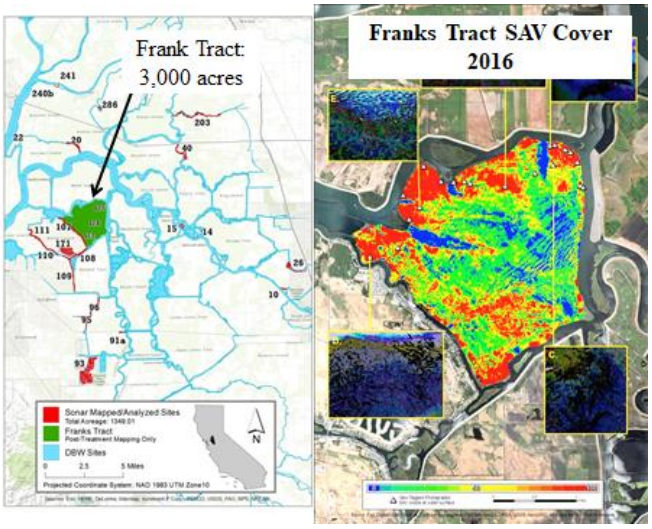


The slide above indicates the impact in numbers of the management programme. It shows the complexity of the system. In comparison your lakes are on the verge of making real progress to keep their health sustained and improved. But this picture shows how frustrating it is in 2018 at Lake Victoria.

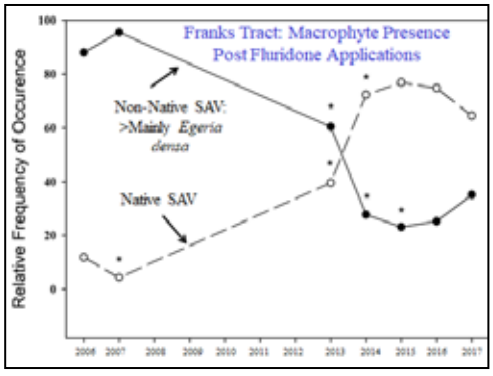
Shifting on to the California example of Franks Tract in the Sacramento San Joaquin Delta, which has an area of about 3,000 acres, the main infested area in the lake has *Egeria densa* and *Potamogeton crispus* (curlyleaf pond weed) and some native plants as well. The restoration plan assumed that it was possible to sustain equal goals, public use and ecosystem viability and health. Personally I do not agree with that, I think we should slant it more towards the environment. But this was the political compromise about 20 years ago when state agencies originally developed a restoration programme.

The goal was to restore fisheries, some of which are non-native fisheries such as striped bass (a strange thing). The goal was also to protect the 10 or so environmentally endangered species in that system and continue with recreational resources and commercial vessel navigation. The specific water use includes agricultural, domestic (potable water) and commercial activity within the delta.

On the right-hand side of the slide below is a 'heat map' showing where the vegetation is in Franks Tract and the importance of this within the State of California. The California Department of Parks and Recreation is responsible for maintaining and controlling the aquatic weeds in the Delta systems.



In 2016 there was an encouraging result from long-term use of the herbicide, fluridone, to manage invasive weeds (primarily *E. densa*) in the system. This is a tidal system with a flush of water coming back and forth every 6 hours. Imagine the challenge of achieving a contact time and proper concentration of a herbicide with that scale of water movement.



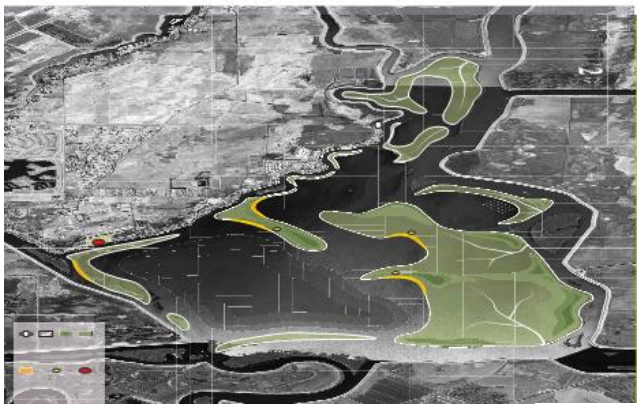
The graph indicates a shift in submerged aquatic plants in the system. In 2006, mostly non-native plants, *Egeria densa and Potamogoton crispus,* dominated the area. But the management programme of the past several years caused a shift in the dominance toward native species. This has been sustained with treatments every other year with fluridone, not the entire 3,000 acres but perhaps around 25 to 40% on an alternating year basis. These tidal fluctuations required frequent fluridone applications and use of 'controlled release' formulations. (See Caudill, et al. 2019)

There is further funding to restore Franks Tract over the next 10 years and we are currently reviewing alternative configurations to improve native fish habitats. This shows what it looks like right now, the typography over the basin region, it is not a very deep system, maybe 12 to 15 feet, and at high tides a little bit deeper.

We are considering 3 alternatives.

Restoring Franks Tract: No Action (as is)

Franks Tract: Proposed Alt. 1

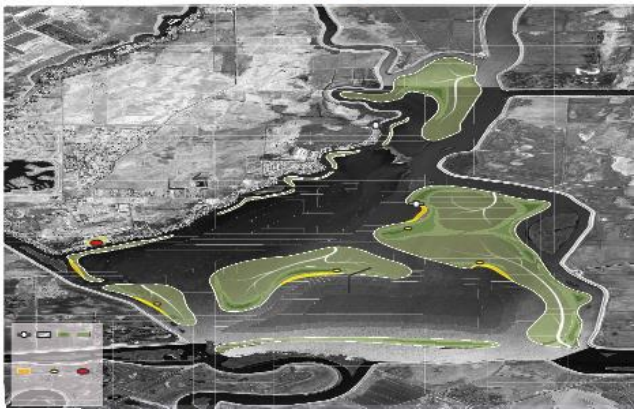


The first one proposes to add marsh land areas with some tidal marshes in the middle of Franks Tract, reducing the total open water but deepening some of that open water. The little yellow dotted areas are proposed public beaches.

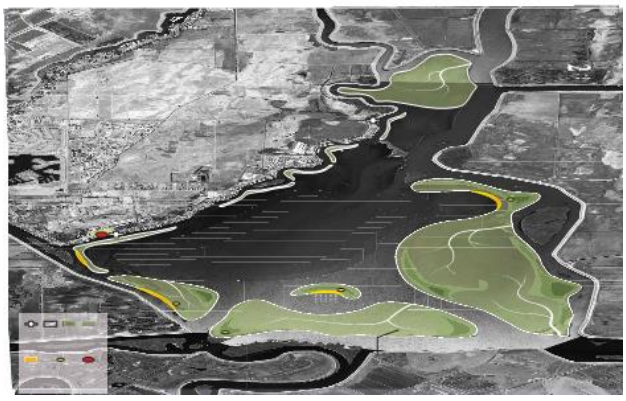
At first glance there is not a lot of difference between the next two alternatives

However there are differences in the shorelines and how much deep water there is. In the reviewing process of the alternatives we will look at the likelihood of reducing impacts from *Egeria densa*, *P. crispus*, and some of the other invasive plants that we have there. There is another very invasive South American plant that has been spreading in the Delta called *ludwigia spp*, ('water primrose' species), which you do not want here in New Zealand.

Franks Tract: Proposed Alt. 2



Franks Tract: Proposed Alt. 3



The alternative restoration configurations range from 'no action' with no increase in shoreline, to the other alternatives with fairly significant increases in shoreline. However, though increased shoreline results in more public access it also creates more shallow water habitat that favours submerged plants. Clearly, there will need to be a balance in these needs and arrive at a compromise of these goals.

Returning to 'translational ecology', this is actually what a lot of us have been doing for the last 10 to 15 years; bringing together not only the stakeholders, but the science to attain the goals for an ecosystem. The translational ecology approach then is a process that combines collaboration, engagement, commitment and communication in the process of decision-framing. The key to success is identifying actionable science. It is great to have theory and laboratory studies, but if it does not translate into the field and operational use it does not do a whole lot of good. So actionable science really means methods and strategies developed from, and founded in, basic research translated and adapted to something that has practical application and produces results in the field.

NIWA is doing exactly that here. The basic and applied research shows what can be done. Finally translating the research into useful effective, coordinated effort among researches and operational managers. One of the advantages of the California approach to pest management is in the role of the Extension Service through which extension specialists take the basic research, such as at UCDavis, for example, to the grower or field manager. The extension scientists are the intermediary to translate research into practical applications in the field. We used to have more of these in the aquatic environments, but now their numbers have been reduced quite a bit. In the Western States of the US we find that extension mode is now being shifted into a professional (private) mode which can work. But the problem in the aquatic environment is that it is very difficult to get research in the field quickly in part due to the sensitivity of any actions taken in aquatic sites.

Restoration Conclusions and Recommendations

In summary restoration:

- Makes Rocket Science look easy!
- Requires understanding of causations – not speculations
- Connect causes with monitoring metrics
- Consider projected scales of impacts with risks of doing nothing
- Set feasible goals with stakeholder consensus
- Sustain long term resource stream
- May require fees for benefits('users pay')

The science of restoration requires a good understanding of causation, not just speculation, and this is a continuing problem when there are doubts about who believes the experts, who believes the science and how well-established is that science? Connecting the causations out there with the metrics is a key point, because if the right variables and 'drivers' are not known and measured you will not know if the actions taken are correct. This is also the benefit of the tie between the research laboratory, the basic level, and what we call the extension research translation component in the field work. If the monitoring of the field does not have the right metrics to determine whether or not your research has been applied correctly, or has flaws, it is hard to figure out what is happening and difficult to improve methods and strategies.

Scale of impact is really important as in the example of Lake Victoria where the scale is monumental. It is not just shorelines; there are many impacts around that ecosystem. Sacramento San Joaquin Delta in California has impacts up and down the state. For example the Delta is the source of potable water for 20 million southern Californians, so you can bet that they are interested in what happens upstream in that system.

You need to set feasible goals that are practical, with buy in from stakeholders and that support sustainable long term research. One of the common threads I see in international attempts at restoration is short time frames on projects, typically because of funding. Funding is often from international banks who might provide support from 3 to 5 years to restore a project site. We all know most of these systems require 10 to 15 years, if not longer, to completely turn around, so it is not always realistic.

Finally consider the concept of 'Fees for benefits'. When we drive down a road in many countries we pay for those roads primarily through our gasoline tax. There may also be other use taxes, toll fees and so on. In California and most states in the US when buying a boat it must be registered in order to go on the water, not just the trailer, but both boat and trailer. Those fees for boat registration were historically contributed toward general water and boating safety and public facilities. Now, with some increases in fees, they are used to deal with aquatic invasive species including aquatic plant management. If there is no funding stream that is consistent and connects with, and based on the users' benefits, it is hard to sustain any kind of restoration programme in my belief. Whether it is short or long term, the income stream must not be based on politics, it should be based on the 'user benefit' which to me is the most sustainable approach. An additional outcome of this approach is that it provides a useful mode of direct communication with boaters, which can be used for outreach and education purposes.

Thank you for your attention. I am happy to answer any questions if there is time.

QUESTIONS

John la Roche, LWQS: I'm very interested in the 'do-nothing' option that you talked about. Often it is very difficult to estimate how 'do nothing' is going to eventuate but could you please tell us more about how you estimate the disadvantages of allowing weeds and other things to flourish and the other problems associated with doing nothing.

Lars Anderson: Yes, very good question. What happens if you don't do anything and you let whatever condition continue? The best example of how we look at invasive plants in general is what we see elsewhere. There are all kinds of ways to rate how invasive a plant might be, a new plant coming in for example. If you start looking at what happens elsewhere you see a track record of what a plant, an invasive fish or even an invertebrate has done, and if it has been establish for some time.

Certainly in the Western States of the US we looked at invasive aquatic plants that had been around for a long time, and we saw a progression in infestation and decreased water quality. You would have to assume that some kind of natural event may reverse that pattern if you expect to see a reversal in those metrics that we measure, whether its water quality, fisheries habitat or ability to use the water. Even looking at harmful algae blooms for example, unless there is some way to reverse what is causing that, it gets back to causality. There is no reason to assume that it is not going to get any worse.

So to answer your question, look at the trend in the monitoring of these sites. Ask the question - 'Is there anything in the future that suggests there may be a change in the drivers of that change that could help pre-invasion conditions to come back to where you want it?' The other part of the question is, if you do not do that and it goes wrong, what is the outcome? Do you care? That is where stakeholders become involved. At some point

there is a push back and they may say we can no longer use this site so we have to do something about it.

John Green, LWQS: I am interested in the whole concept of fake news and all the politics you have in your country and the issue with the internet and how does that interfere with science. We got the programmes going so well here because we trusted the science, we embraced it and walked with the scientists. A long journey as you know. It appears to me that the internet encapsulates most science that has been recorded. People go to the internet science when they have a problem. This seems a great opportunity for the scientists to embrace the smart people out there looking for a better solution that the scientists cannot solve. The ballpoint pen was a classic one. Somebody looked at it differently and all of a sudden we completely changed the world. How can scientists use their current knowledge, which is sitting on the internet, and their future knowledge and embrace interested people. See if we can get an even greater sum of the parts.

Lars Anderson: There is lots of good information on the internet. Maybe the best example I can give you is at Lake Tahoe and you will hear more about this from Nicole. Lake Tahoe has a complex array of stakeholders and many at the lake do just that, go to the internet and they say can we solve this problem? Why haven't you tried x, y and z? Of course we have tried that if we look way back. That is okay as long as the dialogue is a respectful dialogue back and forth between the lay person and the scientist who supposedly is an expert, it works really well.

But I can tell you from personal experience, there have been occasions where that internet information has been somehow translated by a person who completely turned it around to something that it is not. It is not so much that the information out there is bad, but how it is interpreted and applied to a different situation. One of the realities, after over 40 years of working in aquatic environments, is that almost no two lakes are alike. Even ponds that are built supposedly the same, are not. So when people go to the internet and see the silver bullet, and it worked, why isn't it going to work here? We have seen the value at Lake Tahoe with good input from the public, and I will be talking about some of that this afternoon and methodologies for aquatic plant management.

Stuart Corson, LWQS: Just the other day I had a request from Wikipedia, which most of you all know is a remarkable resource of scientific or factual information across the whole world knowledge base. They reminded me that only 2% of users of Wikipedia made any contribution to the continuation of that resource. So quite possibly we should think as much about the value of good factual information as we do about our concern for fresh water and ensure we resource the communication streams that will bring this knowledge to us.

Lars Anderson: Yes, I agree, I think we have a responsibility to communicate to the public a lot more effectively than we have been.

NEW ZEALAND FRESHWATER BIOSECURITY PROCESSES AND REGULATORY TOOLS

John Walsh
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John is responsible for Biosecurity New Zealand's preparedness for and delivery of biosecurity responses. His team also manage or support a number of long-term pest management programmes. They also provide response support services to the wider Ministry for Primary Industries organisations including in food safety and adverse events. John joined MPI in 2014 as Director, Communications and Engagement. In that role he had significant exposure to the biosecurity system – in particular biosecurity responses. He helped lead the development of the strategy and implementation plan for the Biosecurity Team.

TRANSCRIPT

Morena katou. I am really pleased to be here talking about biosecurity and the biosecurity system but firstly I would like to congratulate the Te Arawa Lakes Trust which this week was the Supreme Winner in the New Zealand Biosecurity Awards for its catfish killers' programme. This is a wonderful example of people working to resolve biosecurity problems in their community.

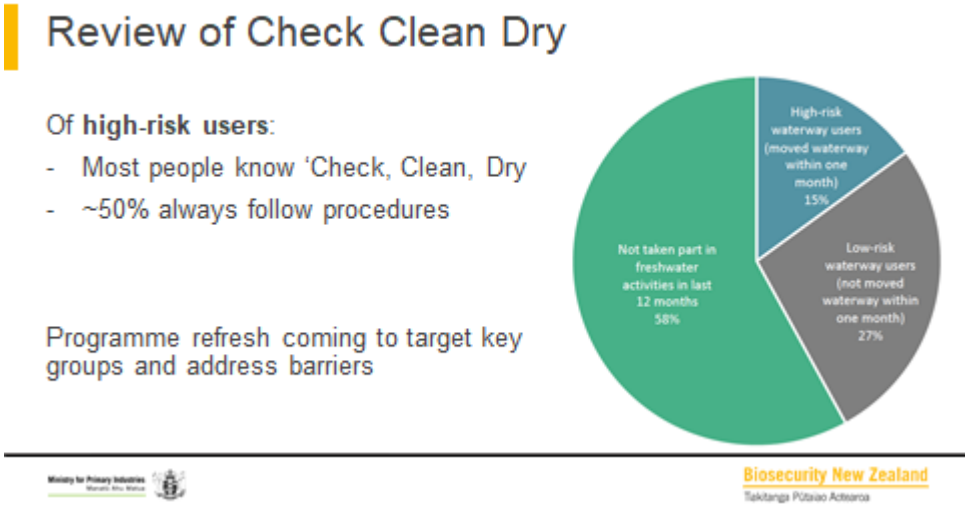
I work in Government on biosecurity. One of our goals in biosecurity is to change people's behaviours, for example, what they do when they cross the border. For instance, what is their thinking on pest management, and when importing materials into New Zealand how do they avoid the spread unwanted organisms around the country?

In government we have four key levers to help us achieve those outcomes. They are **taxation, regulation, communication and collaboration**. In our agency we do not pull the taxation lever so I will talk about the other levers we have.
The fresh water biosecurity partnership programme is *Check, Clean, Dry,* a programme

that has been operating since the Didymo outbreak in 2004. It was a core response to the South Island Didymo outbreak. The *Check, Clean, Dry* initiative got off the ground in 2005 and in 2011 it was enlarged to encompass the management of a wide range of fresh water pests. It is a nationally coordinated partnership programme. It uses a range of interventions including regulation through things like providing 'unwanted organisms status' to certain pests. This means that we have regulatory tools available to manage those pests.

Collaboration, research, awareness and behaviour change are at the heart of that programme. The key outcomes are to manage the spread and impacts of freshwater pests and reduce those impacts throughout New Zealand. It is vital to build knowledge of high value sights and domestic pathways for the spread of freshwater pests. Also it is important to understand the pests themselves and most importantly to adopt and promote behaviours around the way that we manage or avoid the spread of pests.

Key partners in the programme, other than MPI Biosecurity of New Zealand, include Department of Conservation, Regional Councils, NGO's and hydro power companies. Fundamentally the programme is built on relationships between partner agencies and has been developed and running for well over a decade.



The *Check, Clean, Dry* campaign, which is at the heart of the programme, is about to undergo an important refresh. The core message is the same but the way in which we target those core messages may change. Some interesting research we did earlier this year helped us to design the evolution of that programme going forward. I would like to share some of the outcomes of that research with you. It contains some helpful data and will be on our website in the not too distant future.

We found that compared to the general population –

- High risk users of fresh water resources are more likely to be younger (under the age of 45) and more likely to be male
- High risk users are people that are likely to move between waterways, therefore risk spreading a fresh water pest at least once a month
- Just under half of high-risk users are confident that they always follow *Check, Clean, Dry* procedures

- Therefore more than half are only somewhat or not at all confident the follow *Check, Clean, Dry* procedures

You probably know when doing surveys yourselves one tends to over inflate behaviour! The survey showed that there is some good behaviour but there is certainly room for improvement.

- About one third of fishers and white baiters have high levels of compliance with *Check, Clean, Dry* practices
- People involved in eeling and catching koura have lower levels of compliance
- Kayakers and canoers are reasonably compliant
- People using motor boats are the most compliant, but the levels are not as high as they should be
- Most high-risk users move between waterways one to four times a year, but some much more - 10 times a year plus
- Most high-risk movements take place within the same region
- High-risk users were most likely to recall that they need to clean or wash their equipment to stop the spread of disease
- Checking and drying was much less frequently mentioned

Having been involved in fresh water fishing for too many decades now, I have always known the *Check, Clean, Dry* message. I have been stopped once on a river by a DOC officer and another time a Fish and Game officer wanted to educate me about *Check, Clean, Dry*. But I had forgotten that drying means drying for 48 hours.

- Some high risk users are not familiar with actions to reduce the spread of fresh water pests or with the phrase '*Check, Clean, Dry'*. This tells us we have more grounds to gain, more benefits to reap.
- High risk users suggest that signage near rivers and lakes is the best way to learn more about preventing the spread of fresh water pests
- Many of those high-risk users are under the age of 45 and say that social media is also a good platform

All this research data will be used to refresh the *Check, Clean, Dry* programme probably kick in later this year and move forward into next year.

Another lever is regulatory tools, namely the Biosecurity Act, which is 26 years old and we have just initiated a major overall of it. This has been driven by a number of things. A lot of the challenges that we face in biosecurity and freshwater management were not challenges that we envisaged 26 years ago when the legislation was put together. It is now creaking at the edges.

We did not imagine either the volume growth of people or trade moving across our borders, nor its complexity. We certainly did not envisage climate change or the establishment of the pests and diseases that we currently have. These things are driving the need for this Biosecurity Act overall.

The Minister has asked us to undertake comprehensive engagement in a collaborative design process. Right now we are out talking to Iwi, Hapu, Councils, primary industries and other stakeholders about what is bothering them about the Act and what they want to

see in a new piece of legislation. The aim is to have a consultation document out to the public and stakeholders in about March next year.

We have 6 work streams going on around the Act overhaul looking at the fundamental purpose and principles of the Act and how the Act helps to manage and fund biosecurity responses. This is a significant challenge. Last year Government and the dairy and beef industries committed to spend $800 million on the mycoplasma bovis response.

One of the challenges in my job is that we have very limited pre-funding for biosecurity responses. So, when we initiate a large, new response we frequently have to take urgent actions and we may be doing that with no budget in place and we need to find that retrospectively. We have to find a better way to manage through that.

Compensation is another matter that will be looked at. If we run a biosecurity response and require you in your personal life or in your business to do something which causes you economic harm, we are obliged to compensate you for that economic harm. That is because we want to encourage people to report unwanted pests and diseases. If people have concern that if they report an unwanted pest or disease we might lock down their business and it will cost them, they might not want to report that unwanted pest or disease – unless they are compensated.

On the other hand, biosecurity is not the only type of 'event' outside of people's control, where people suffer economic loss as a result of something they did not do on purpose, but in these other areas (like earthquakes for example) they do not receive compensation from the Government. These are interesting policy conundrums and one of the things that we are looking hard at.

We are also reviewing pest management. The pest management work stream is looking at the current regulatory tools available to us for pest management and whether they are fit for purpose. This includes exploring options to develop new regulatory tools, new approaches to incentives and compliance, and simplifying some of the current regulatory tools we have. I know your interest is in revenue streams and the way to improve local government's ability around biosecurity to impose infringements and fines. The Act review at least gives us a chance to have the conversation and who knows what might come out at the end.

The last thing I wanted to talk about was a new programme called *Ko Tātou*, *This Is Us*, which is a Biosecurity 2025 programme aiming to get all New Zealanders participating in biosecurity. We originally started this programme from an interesting piece of research which showed us that most New Zealanders understood what biosecurity was and thought it was important. But it also showed us that only 2% of New Zealanders thought that biosecurity was personally relevant to their daily lives and to their businesses. We developed an advertising campaign which we ran at the end of last year and is about to go to air again, designed to create that personal relevance.

(Advertisement played)

Following that, can I just say congratulations to you all because you are all looking after and protecting Aotearoa. Thank you from Biosecurity New Zealand.

QUESTIONS

Jonathon West, University Student: I am with Victoria University but an independent scholar. My question is around the new regulatory tools you hinted might be out there and wondered if you could explore any of those you think might be relevant to the challenges facing the lakes here.

John Walsh: Not currently because it is a co-design process and it is not the appropriate time. We are open to ideas and are in the design process.

Jonathon West: No, typically Government caution.

THE ECONOMIC IMPORTANCE OF THE ROTORUA LAKES

Hon Todd McClay
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Hon Todd McClay has represented Rotorua as the Member of Parliament since 2008. He held the portfolios of Minister of Trade, State Owned Enterprises and Revenue when the Key National Government was in power. He has also been the Associate Minister of Health, Tourism, Trade and Foreign Affairs. He is still responsible for that area in opposition.

TRANSCRIPT

Good morning and thank you for the invitation to speak. I have been fortunate enough to be involved with LakesWater Quality Society and the various Symposia for almost a decade now.

Firstly Don I would like to recognise your hard work and those of your committee. I take pride in what has happened in the Rotorua Lakes and so does Steve Chadwick. No other area in the country has done it quite like we have; local people working together from a very positive point of view to find solutions for the restoration and management of the lakes. Without doubt the LakesWater Quality Society has been at the front of that.

Can I recognise Ian McLean for whom I have a huge respect, particularly for the work we did a few years ago bringing together different groups in the community that found it much easier to fight each other than sit around a table to find solutions. It was Ian who phoned me one day and diplomatically said we needed to get on and do something, and we did. I will talk more about this later.

I am here briefly as I have to return to Wellington. In Parliament today we have the final vote on the zero-carbon bill and it is very important that we get this right. I will not indicate how we, as the largest party in Parliament and being the opposition, are going to vote but we take our role seriously and responsibly.

In all areas to do with the environment, whether it be climate change, fresh water or the Rotorua Lakes, we as a party want to progress and make the right decisions. But we need to be mindful that even our scientists sometimes have uncertainty about what we know and what we should know. Therefore we need to balance out the significant cost in making decisions to communities, to businesses and to the environment. We may make a decision too quickly that does not work out or perhaps not move quickly enough.

LakesWater Quality Society was originally formed over 50 years ago to deal with a problem that really only happens in clean water – lake weed. Back then Lake Rotoiti had too much lake weed and it was affecting peoples' enjoyment of their lake. It was good for the fish which grew large, but if the boat gets stuck it is hard to catch them. LWQS was very successful in dealing with that problem but over the next decades the water quality of the lake deteriorated and so too did the amount of lake weed.

The Society was able to morph itself into the next challenge, a much larger one dealing with water quality. But once again the issue that first brought LWQS together - lake weed and the effects on the enjoyment of lakes - has come back.

That tells me two things. No 1 - things are cyclical and No 2 - if you fix one problem another one can come up. Maybe if we take a little bit of time, step back and allow ecosystems breathing space, they do things that we cannot model as well as we would like, and maybe Mother Nature can sort herself out if people get out of the way.

I have been asked to talk about the economic importance of the Rotorua Lakes. I almost changed it to the economic importance of 'clean' Rotorua Lakes. But I chose not to because what we talk about are healthy lakes, not necessarily clean. When we went through the process over many months of bringing the LakesWater Quality Society together with the Rotorua Farmers' Collective I worked out fairly quickly that both sides were saying the same thing but with very different language and understanding of what each other were saying. A bit like a marriage sometimes but in this case there was no wife involved so we did not know who was right. I almost took their passports off them and locked the door.

They kept talking, and talking, and talking, working through the issues, until they realised that: both sides were nice people, they wanted to find a solution, that the LakesWater Quality Society did not want to get rid of farming but rather find reasonable practices that would help the lakes, and that the farmers also wanted healthy clean lakes. They both talked about a sustainable farming model in our catchment that would allow sustainable lakes for everyone to enjoy. Once we reached that point the steps forward were easier to consider and understand, although very difficult then to work through on how to implement.

The reason I say healthy lakes rather than clean is one of the challenges we have in the view of the wider New Zealand public and those overseas of what is happening in our lakes. Media headlines are wonderful for a politician, not being talked about is much worse than being talked about. However that is certainly not the case when it comes to the reputation of the Rotorua Lakes. A quick scan to see the headlines of over a decade ago show: 'Rotorua Lakes Dying', 'The Poisonous Lake', 'Dirty Lakes Hurt Businesses', 'Dirty Water to Skip Rotoiti', 'Lake Rotorua Health Warning', 'Sewage Water Waste', 'Algal Bloom Discovered in Lake Rotorua'. Just picking one or two headlines, I would not be keen to let my kids swim there.

If we dig deeper and look at what was written at the time in those articles we have even more reason to be concerned. In the *Daily Post* and the *Herald* in January 2006 a local water sports operator on the Rotorua Lakes said he was concerned about the affect health warnings were having on their business. The Ikinui Charters take people trout fishing on several of the district's lakes. When the health of the lakes decline the representative of the company said they noticed a fall in business, lower numbers of enquiries and bookings, and that hurts. He said we tell them, 'You can still eat the fish just don't put your hand in the water.'

A kayaking company owner admitted he did not tell his clients of the potential dangers to skin in contact with affected water in some of the Rotorua lakes unless they asked directly. He said, 'I wouldn't say to them don't jump in the water, but if people do see the health signs or they already know then I explain. I get questioned quite often about it; people make comments.'

For those two tourism operators whose businesses are here solely because of the lakes, there is a direct economic impact upon the reputation of what happens in those lakes.

In 2006 the New Zealand Herald said the task of saving the dying lakes which have been polluted by nutrients from human activity would require a herculean effort over decades, not years. Water quality in the lakes has been declining since the 1970s from human activity such as farming and sewage. Polluting nutrients leach into waterways creating toxic algal blooms that are now a perennial hazard in many lakes. Over the last couple of decades many people chose to leave Rotorua. It would be hard to attribute what is happening with our lakes directly to population and to business. But we do not need scientists or economists to tell us what such gloomy headlines and stories are doing for our reputation. Yet people living here are still fishing and swimming. The reality of what is actually happening is quite different from that perception.

This brings us to why our lakes are so very important. I found on the United States Environment Protection Authority website a study looking at the effects on the economy of nutrient pollution in waterways. It said the tourism industry loses close to a billion dollars each year through the loss in fishing and boating activities as a result of water bodies that have been affected by nutrient pollution and algal blooms. It also stated that in real estate the value of homes near polluted waterways can reduce by 25%.

Why do we all want to live near the water or have a view of the water? It is very hard to describe but there is no doubt that having clean waterways is good for a local economy. One only needs to look at the thousands of dollars of difference in value to properties and the businesses that grow around people who choose to live by water bodies.

As a child we visited an uncle and aunty in Te Kauwhata and I recently enjoyed visiting them again on the way back from Auckland. There were large signs about property development around the lake (Lake Waikare) which is nothing compared to the smallest lake in the Rotorua area. , However there are thousands of houses being constructed because there is a lake. Why? It is just a waterway and now there are restaurants being built and industrial parks created and lots of people moving in. Who knows about the about the water quality but people want to live there and economic growth and development comes with that.

Compare the value of properties in Waiouru to Lake Tarawera; they do have a beautiful mountain, close to the skiing, and an easy drive to Lake Taupo. But Rotorua has something over other parts of New Zealand if we value the importance of those lakes.

We know that visitor numbers go down if our reputation is not good. That is not only about lake water quality but its reputation across the board. As the premium visitor destination in New Zealand we get many more New Zealanders visit than international travellers. But those international visitors continue to flock here based upon the reputation of the great things they hear about New Zealand. We have everything in Rotorua, from the lakes, to mountains, to forests, to the mountain biking, to the generous people and to Maori culture.

But think about the importance of our economy and the uncertainty that comes from not knowing what will happen because of changes that are needed to clean up an unhealthy lake. It can have devastating impacts upon our local economy and directly on peoples' lives. What happens when there is uncertainty in a business affected by rules that may change in the future; you do not invest. You wait because you are not willing to take the risk. I like people who want to take quantified risks in business because that is what makes an economy grow and create jobs. However a quantified risk is decided on a

playing field that will not change unless well signalled. But when it comes to the change signalled that would be needed to restore and manage the Rotorua lakes there was no certainty for anybody in the business community, or start up to do with the lakes and tourism, the agriculture sector, engineering or people that supply our rural area.

For more than 10 years we have gone through a very uncertain period about how tough the rules would be from the Regional Council, now to an ongoing court case, and the farming community do not know what to do. Many want to make change but the banks would not lend to them because they did not know whether or not they would be viable at the end of that process. In turn that meant that businesses supplying the rural sector, engineering or transport, were all very uncertain about what would happen over the decade.

When we pulled those two groups together, the Farmers' Collective and LakesWater Quality Society, we negotiated and signed up two agreements. The Waiora Agreement was an agreement to join collectively to discuss with the Regional Council and then the Oturoa Agreement which was an agreement between the stakeholders and the Regional Council, to set in place a process to reach the position where everybody could agree. The moment that the agreement was signed with the Regional Council banks started to consider lending more freely and rural property sales increased after virtually nothing at all. Now not one single rule had been changed other than a signal that we would work this out and there was a future for farming sustainably and sustainable healthy lakes and that gave some certainty.

What we need from an economic point of view as quickly as possible are people sitting around a table. Really the only people over the last two decades who have enjoyed clean water ways are the lawyers through their big fat fees when everyone sues each other and goes to the Environment Court. It is time to set aside the lawyers and commit to working together to find solutions that are good for the entire catchment, not one small part of it, because everybody faces costs here. **The time to commit is now.**

Those two groups that came together, LakesWater Quality Society and the Farmers' Collective, can be very proud of how they stuck with the process over more than a year and reached agreement. In that first meeting they wanted to tear each other apart and run to their respective corners and scream. But that was a recognition that it was not working for anybody. When we were able to reach an agreement with the Regional Council, they too can be very proud. We have shown we can do this better than anywhere else in the country. For the sake of the wider Rotorua economy, for the people who have invested their life, their savings, and taken all of the risks to have a business here, to buy a house here, to farm here, we owe it to them to find solutions and work collaboratively to move forward.

Finally, in opposition I am a spokesperson for economic development, for trade, for tourism, for workplace relations and for health and safety. I view all of those through an economic lens. The Rotorua community owes it to the New Zealand population to continue to be a leader in the way we move forward to make our lakes healthier. Without Rotorua the tourism offering is nowhere near as good as it should be. The millions of New Zealanders who have come here and will continue to come here with their children will have to choose somewhere else. By golly Te Kauwhata was beautiful but it has nothing on Rotorua.

Kia ora, thanks for your work and I appreciate the opportunity.

Session 2: IMPACT OF AQUATIC WEEDS AND PEST FISH

SESSION CHAIR - Steve Chadwick, Mayor of Rotorua Lakes Council

IMPACT OF AQUATIC WEEDS

Paul Champion, Mary de Winton and Daniel Clements
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Paul has specialist expertise in biosecurity, plant ecology and conservation of endangered plant species, especially in freshwater and wetland habitats. His focus research areas include assessment of weed potential of introduced plants, management of alien aquatic weeds (including surveillance, control techniques and strategies), assessment of environmental impacts of both freshwater pest invasions and weed control strategies and restoration of habitats impacted by invasive weeds. In addition to his research areas, Paul has effectively communicated his and others' research in the development of policy and management directions and provided strategic guidance to central and regional government agencies and other resource managers. Paul is passionate about training and regularly runs workshops for various management agencies and scientists alike; on plant identification and management , also producing a series of three books on weed identification with the NZ Plant Protection Society.

TRANSCRIPT

Kia ora tatou. Thank you very much for that lovely introduction and thanks to the LakesWater Quality Society for all their support and keeping the war against invasive species at the fore. This talk is on behalf of Mary de Winton and Dan Clements and the rest of the Aquatic Plant Group and sets the scene about:

- The species (submerged weeds)
- Spread and invasion history
- Ecological impacts
- Impacts on human use

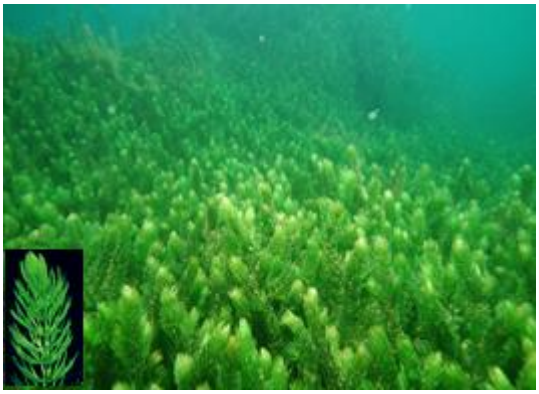
Aquatic Weed Risk Assessment Model (AWRAM)

In 2000 I developed this model with John Clayton. It looks at the characters of the submerged weeds species, how invasive they are, what habitats they can invade, how competitive they are with similar plants within their life form, how they move around, their reproductive output, whether deliberate or accidentally spread by humans.

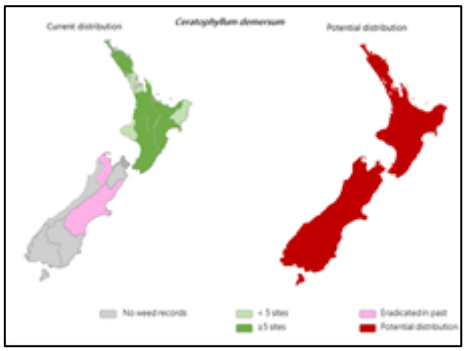
The model also assesses the impacts; economic, environmental and recreational, and looks at the potential distribution, where it is now and where it could be. It is important to understand the management issues, what methods are available and how effective. Theoretically the perfect weed scores 100. The highest ranked New Zealand weed is *Phragmites australis* , AWRAM score 75 and is also a NIPR species . *Hydrilla* at 74 is another NIPR species and both are managed for eradication.

Pest Plants in the Rotorua Lakes

Hornwort is the worst weed (with the highest impact) in the Rotorua Te Arawa Lakes, widely spread in Lake Rotoehu. This plant is found everywhere but Antarctica, and not as a native species in New Zealand and Tasmania.



- It has no roots
- It invades waters with a wide range of nutrient conditions
- It can grow to >10 m depth
- The beds are 4 m or more tall

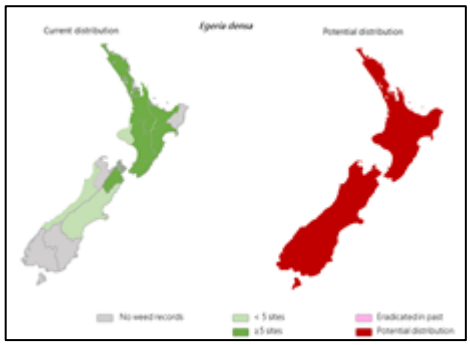


Hornwort was first recorded as a naturalised plant in 1961 in Napier and within 2 years it was naturalised in the Waikato River. It only reproduces by stem fragment in New Zealand and is therefore reliant on human assisted spread. The current distribution no longer includes the South Island due to the two successful eradication programmes there.

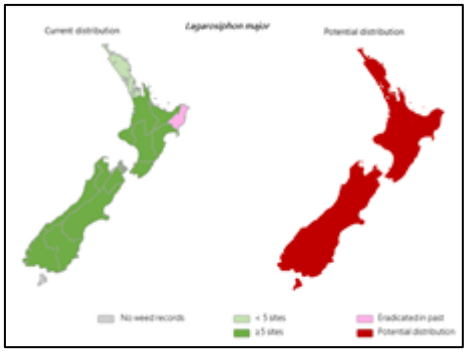
Hornwort has an Aquatic Weed Risk Assessment score of 67 and potentially could be a problem throughout New Zealand. It has 'unwanted organism status' under the Biosecurity Act, is not allowed to be sold or distributed through the aquarium / ornamental pond plant trade and has been banned since 1982. The second eradication programme of Hornwort was the result of it being declared a National Interest Pest Response (NIPR) species (Ministry for Primary Industries (MPI) led eradication responses) in the South Island.

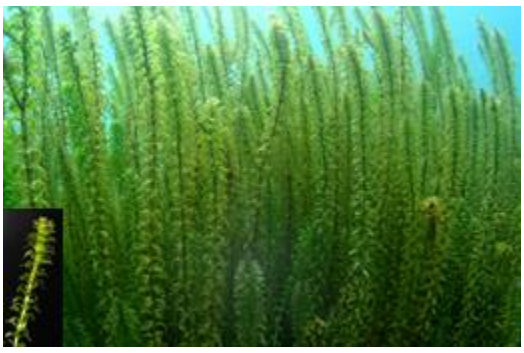
Egeria, an oxygen weed, is second to hornwort, less dominant in low nutrient conditions; therefore, it will probably not thrive as well with the reduced nutrient targets for the lakes. But it can have a boom/bust growth. When introduced in Lake Tarawera around the same time as Hornwort, initially it formed quite dense canopies, but now is far reduced compared to its first colonisation. This boom/bust phenomenon is quite common ecologically. An invasive species arriving in a new habitat can experience exponential growth and then settle back.

Originally discovered in the Waikato River in 1945, Egeria can grow to depths of up to 8 - 10 metres; the beds can be 2.5 - 3 metres tall and is really dense like Hornwort beds. Like all these species, it was spread by humans with stem fragments. It has an AWRAM score of 64, a major submerged weed and unwanted, not available in our aquarium shops.

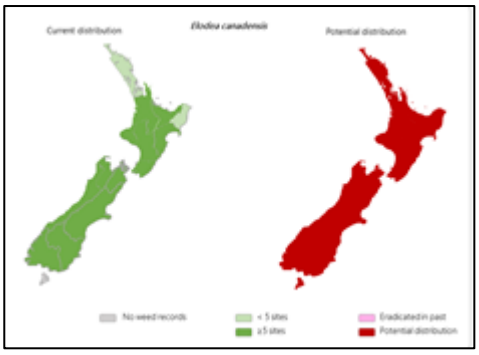


Lagarosiphon, seen here growing in Lake Rotoma, first recorded in 1950 in Lower Hutt, was introduced to the Rotorua lakes earlier than Hornwort and Egeria. Under certain conditions those species can replace it. It can grow up to 6 metres depth, not as deep as the other two but equally as tall and dense. It is found throughout the North and South Islands, but one site in Gisborne District has been eradicated. It has an AWRAM score of 60.





Elodea canadensis, Canadian pond weed, is a pioneer species which can co-exist with native species and is usually replaced by the other more invasive species. It can grow equally as deep as Egeria and as tall, but is not as competitive. It is regarded as a moderate rather than major submerged weed. It was first recorded in the 1870's in Christchurch. With little thought, it was deliberately spread throughout the country with



liberation of trout because it was an oxygen weed. It is uncommon in Northland and the Gisborne District. Sale and distribution prohibition would not have a major impact on further spread and it is still sold in aquarium shops.

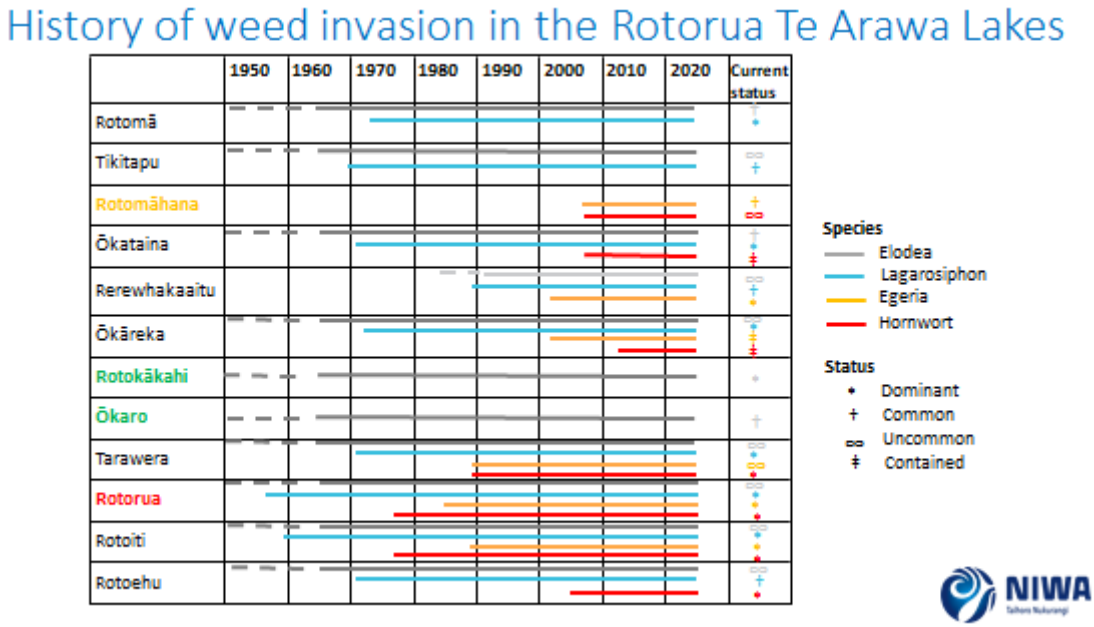
Pathways of introduction and spread

Humans are recognised as the primary vector of the spread of invasive aquatic plants between countries and introduced as aquarium pond plants which are a massive trade overseas. The commercially grown plant in this slide is water hyacinth, sold in Europe at 5 Euros a pot. Despite the ban on keeping such species, there are still aquarium keepers and international introductions happening in New Zealand.

Once these plants were over the border, liberation from aquariums and ponds enabled their access into water bodies either by dumping or flood events washing out plants into natural water bodies. After that most of the dispersal has been accidental transfer related to equipment, boats, boat trailers and fishing equipment used in water. Natural dispersal by birds or wind is not implicated for these four species.

Pulling up your anchor is a great way of putting one of these weed species into the anchor well, which is nice and moist and gives long term survival for the weed.

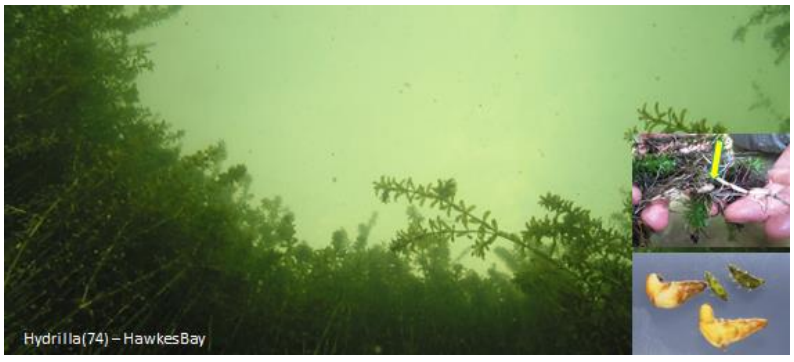
The spread of invasive vegetative weeds across the Rotorua Te Arawa Lakes has a strong correlation with boat traffic, lake accessibility and attractiveness for recreation. Ian Johnstone and colleagues (Johnstone et al. 1985) showed that viable shoots can be transported about 100 kilometres on contaminated boats. More recent work by Mary de Winton and a student Tanya Compton (de Winton et al. 2009 and Compton et al. 2012) showed that the likelihood of weeds turning up is related to a population centre, attractiveness of a water body and the number of roads and access points to the lake. Johnstone et al. (1985) noted early weed introductions were noted to be mainly at boat ramps.



This graph shows the history of weed introductions into the lakes. Elodea for most of the lakes has been there since the 1950's. Lake Rotorua was the first receiver of all these weeds species because of its popularity. One of the least accessible lakes, Rotomahana, got only the two worst weeds in the mid 2000's and still has no Lagarosiphon or Elodea. Lakes Rotokākahi and Okaro only have Elodea.

New submerged weeds on the horizon

Hydrilla (74), the second worst potential aquatic weed in the country is (or was) in four lakes in Hawkes Bay. It is competitive with the other species but it also has 'propagules' (tubers seen in the photo) which can sit in the sediment for over 10 years and remain viable. A lot of effort is involved in the intensive programme that MPI are funding and leading. The good news is that Hydrilla has not been seen in those lakes in the last 4 years.



Eelgrass (51) (*Vallisneria australis*) was in the Rotorua Centennial Gardens and also in a pond near Te Puke. It has naturalised in water bodies in most regions around the Bay of Plenty. It does not score as highly as it propagates through planting in a water body rather than being spread from stem fragments.

Humped bladderwort (54) (*Utricularia gibba)* is different to all the other weeds in that it is spread by water fowl. It was first noticed in Northland, north of Kaitaia, in 1999 and since then has been seen moving through Northland, Auckland, the top of the Waikato, in coastal Tauranga last year and also in Taranaki. If these plants are imagined as trees, this is 'Old Man's Beard' or Japanese honeysuckle', smothering over the top of other vegetation.

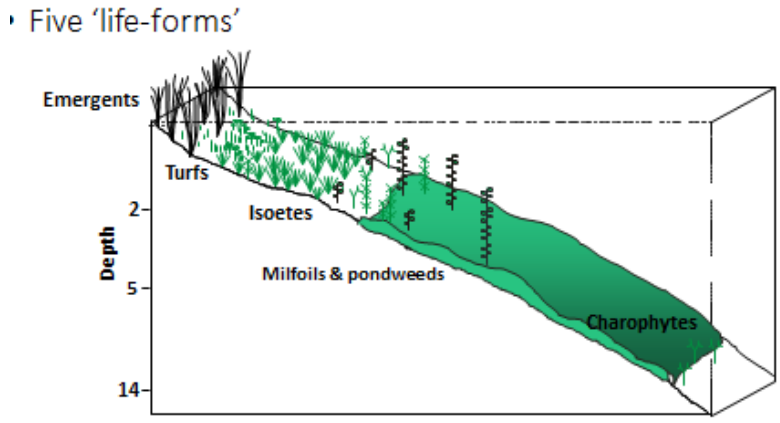
Cabomba or Fanwort (53) is the latest weed species to naturalise which until 2016 was a common aquarium plant. It is a weed of national significance (WoNS) in Australia and now there is one naturalised site in West Auckland.

In this symposium we are clearly dealing with weed issues already in the Rotorua Te Arawa Lakes, but these previous slides illustrate that there are potentially more problems in the future.

Ecological Impacts

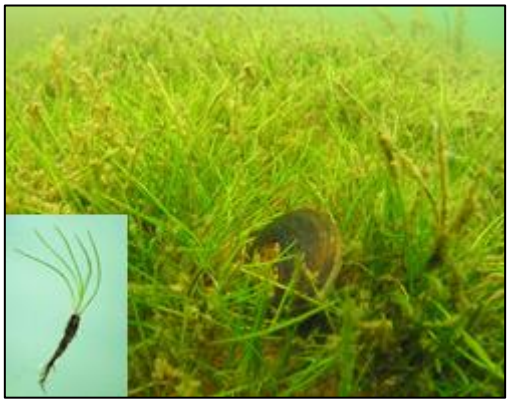
The worst ecological impact made by three of the four species in the lakes is that they displace diverse submerged native vegetation, threatening the biodiversity in the lake habitat. Native plants also provide habitat for animals utilised as food by fish and other biota with impacts on the water quality in those areas. The native species usually have positive impacts but weed species tend to decline, decrease or completely change the water clarity and quality. There is also a reduction in invertebrate habitat and fluctuations of oxygen concentration and pH within those weed beds.

Native lake plant biodiversity



Emergents (reeds and rushes)
Native vegetation in the sheltered lake margins consist of tall species like Kuta and Raupō. In more moderately exposed sites, turf plants and quillwort are found in shallower water with charophyte meadows as the deepest vegetation. The emergent species importantly intercept nutrients entering the lake. There are 6 species in the Rotorua Lakes district which require sheltered shorelines and soft sediments to grow in.

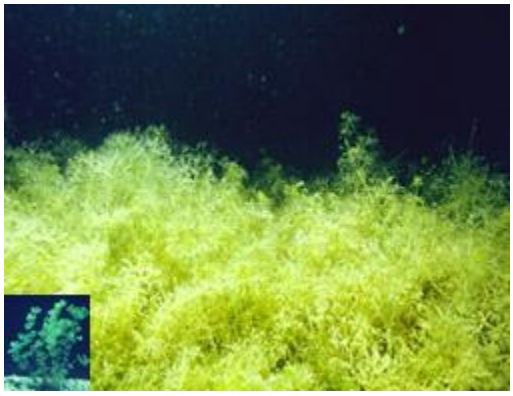
Turf plants (amphibious) have the greatest diversity and 11 of the species grow in more exposed areas; they tolerate wave action and grow in soft to sandy sediments in a tight low mat. They can have an important role in stabilising those very dynamic areas.



One of the species, **Isoetes (quillwort)**, grows down to 4 or 5 metres in exposed lake fronts, even in rocky exposed sediments and tolerates much more wave action. This community has decreased in the Rotorua lakes since the 1980's.

Milfoil and Pondweed beds, with their little pink flowers reaching the surface in spring and early summer, grow in tall, open beds rarely deeper than 5 metres, rather than the dense beds of the oxygen weeds and Hornwort.

Charophytes are the real stars in Rotorua lakes' native vegetation and are an internationally endangered community. In many of the Rotorua Te Arawa Lakes the 10 species can grow as deep as light will let them, thus forming a carpet over the surface called a charophyte meadow. Some can grow down to 40 plus metres depth in the South Island.



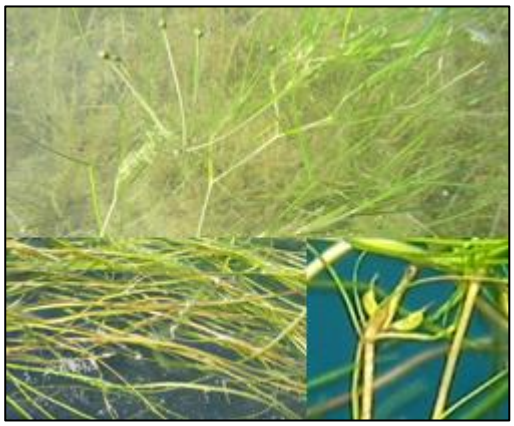
Chara fibrosa forming a beautiful meadow in Lake Rotoma. They rarely grow taller than a metre, carpeting the bottom sediments and grooming the water.

Threatened Species – Nationally Critical

On the left is *Nitella opaca* which used to be found in Lakes Ōkāreka, Tikitapu, Rotokākahi, Tarawera and Ōkataina but it has not been seen in the Rotorua lakes for more than 10 years. As far as we know it is now only in Lake Waikaremoana, Lake Taupo and one of the lakes in northern Hawkes Bay. It is nationally in critical danger of extinction within 3 generations.

Likewise, *Utricularia australis* (or as it was called *Utricularia mairii*), on the right, was found in Lake Rotomāhana, but not found after the Tarawera eruption. Weeds or water quality cannot be blamed for its loss in that lake!

Threatened Species – At risk

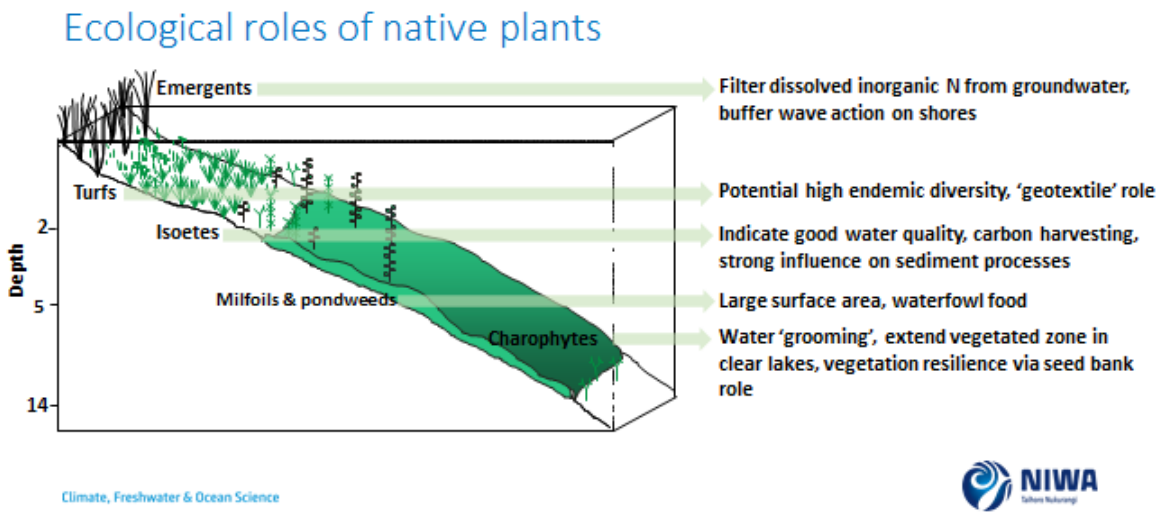


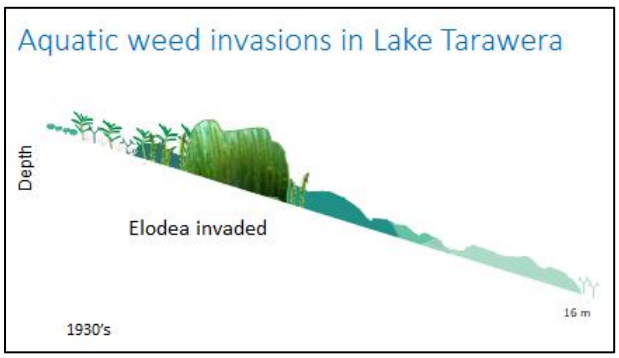
The national decline and loss of Quillwort, *Isoetes kirkii,* (above) has triggered its classification to be declining and 'at risk of extinction'. It is in the North Island but much reduced in many Rotorua lakes since 1980.

There are 3 naturally uncommon species *Ruppia megacarpa* (top), *Stuckenia pectinata* (left), *Zannichellia palustris* (right) found at Lake Rotomāhana, normally coastal and saline influenced but the chemistry of that lake's water allows them to grow there.

Ecological roles of native plants

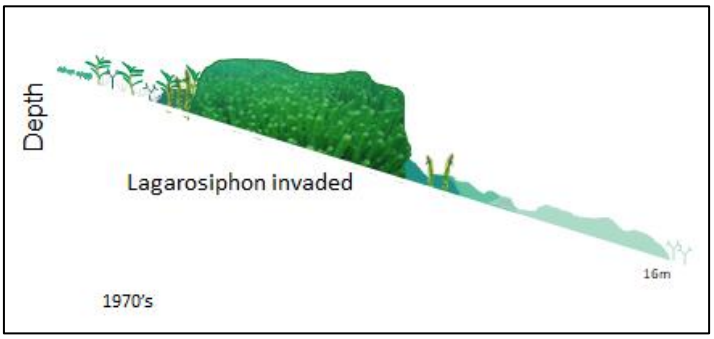
The next slide shows the different ecological roles that the native plants play; filtering nutrients from entering the lake, buffering wave action, stability factors, binding the sediments and food for water fowl and invertebrates.

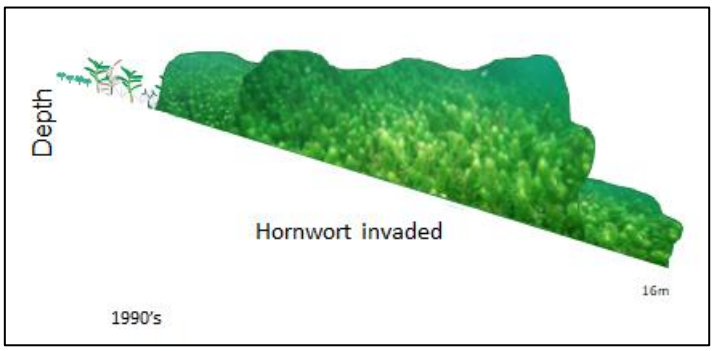




Rohan Wells (Wells et al. (1997) characterised the invasion sequence in Lake Tarawera. Elodea established itself in the 1930's and displaced the tall vascular species.

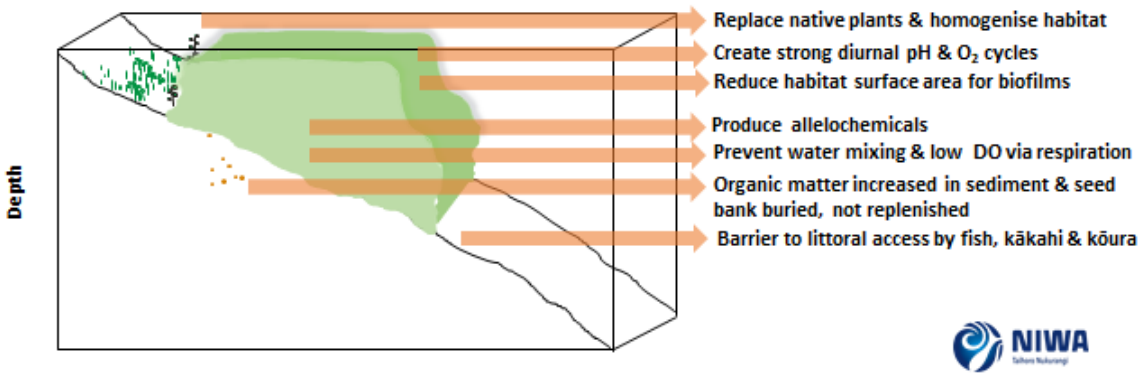
In the 1970's Lagarosiphon not only displaced native species but also the Elodea.



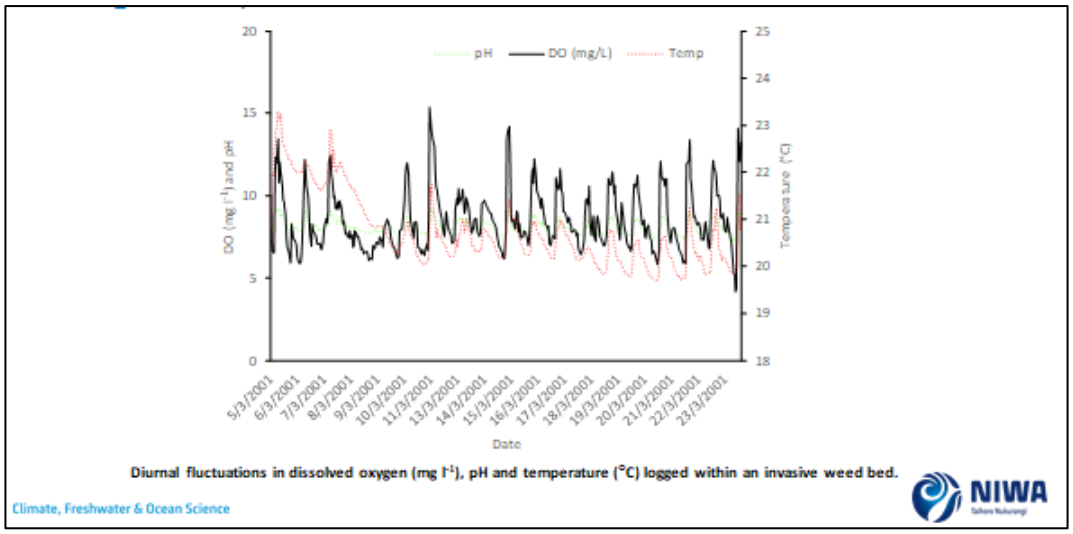


Then in the 1990's Hornwort arrived, displaced the lower edge of the Lagarosiphon and then slumped right through finally killing all the charophyte meadows.

Ecological impacts of invasive weeds



This shows the negative impacts that affect those native plants. They are nearer the surface so they grow taller. Photosynthesising plants produce oxygen, thus a high concentration of oxygen in the daytime. These high oxygen levels produce high or alkaline pH in surface waters. That combination and the loss of nitrogen through nutrient uptake can trigger the development of cyanobacterial blooms and additional negative impacts within the weed beds.



The graph shows dissolved oxygen in black and pH in green. Notice the change, dissolved oxygen concentration is more than 10 mg/litre during the day which is super saturated. During the night dissolved oxygen approaches 5 mg/litre where many aquatic animals cannot survive.

The bottom of the weed beds are dingy black areas, very flocculent organic sediment, an unsuitable habitat for species that should be there, like the Kākahi below.

The consequences of cyanobacterial blooms are well known

Impacts on human use

The impacts of tall, often surface-reaching, dense weed beds on human use are all about obstruction and aesthetics:

- Cultural impact - traditional tau kōura fishing methods for kōura are declining due to entanglement of the ropes in the dense, often surface-reaching weed beds
- Recreational problems, risk of entanglement when swimming in these beds, even drownings
- The weed host the molluscs that are an intermediate host for swimmer's itch

- Impact on recreational fishing
- Weed strandings on the shore, reduced quantity and quality of nearshore activities, devaluation of lake front properties

Impacts on human use elsewhere in New Zealand

Hydro-electric power
Irrigation
Drainage

Outside the Rotorua lakes area we rely on water flow to generate power, about 70% of our power needs come from hydroelectricity and this percentage was previously much higher. The diversion of water to areas for irrigation and away from areas for drainage is all impacted by these invasive weed species. All this means there are practical problems in using water affected by surface reaching weed beds.

An example of ‘duck itch’ or ‘swimmer’s itch’ after a swim in Lake Tarawera. The molluscs that are an intermediate host for this painful nuisance find the weed a very suitable habitat.

Direct measures of human usage of lakes and correlation with weed abundance records

Data availability:

- Publicly available Fish and Game NZ (FGNZ) angler usage surveys between 1994/95 and 2014/15 (four surveys).
  - Daily angler lake usage data under FGNZ jurisdiction as a measure of attractiveness.
- NIWAs aquatic plant database (AQPD: 1980s to present).
- Sample size of 238 lakes

https://fishandgame.org.nz/about/research/

Angler usage of New Zealand lake and river fisheries

Results from the 2014/15 National Angling Survey

Prepared for Fish & Game New Zealand

July 2016

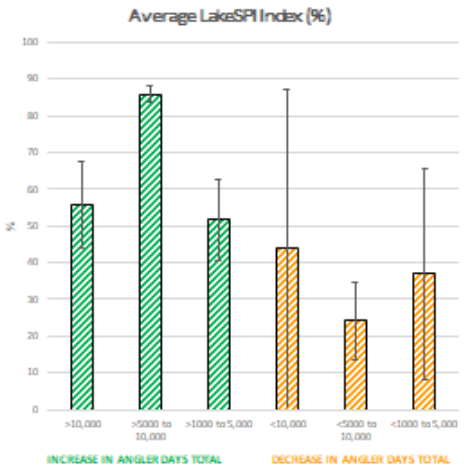
1. National Angler Survey 2014-15 Unwin (2016)
2. National Angler survey 2007-8 - Unwin (2009)
3. National Angler Survey 2001-2 - Unwin (2003)
4. National Angler Survey 1994-5 - Unwin (1998)

Climate, Freshwater & Ocean Science

NIWA

Publicly available data on the Fish and Game website show angler surveys between 1994/1995 and 2014/15, measuring daily angler use in water bodies throughout New Zealand. We have paired that with the distribution data of our worst weeds in the NIWA Aquatic Plant Data Base.

High Use Lakes (1000 to >10,000 changes in angler days between 1994/95 - 2014/15)



Between 1994/95 - 2014/15

When there is a high LakeSPI Index (better ecological condition), the trend is an increase in angler days

NIWA

This graph shows the ecological conditions measurements. The green bars on the left-hand side, show an increase in angler days when there is a higher LakeSPI index, over the period 1994 to 2015.

The presence of individual species, Hornwort, Lagarosiphon and Egeria, is correlated with decreasing angler use, apart from Lagarosiphon in a couple of South Island lakes where there is a Lagarosiphon incursion. In these cases, these are being actively managed by LINZ and Boffa Miskell, so even though the weeds are there, they are not impacting on those systems.

Only photos, I can't replicate the very foul smell! This demonstrates the aesthetics problem with stranded weed beds, really bad news for those living around these lakes.

Take home messages

- Not all aquatic weeds have the same level of impact
- Humans are the primary weed spreaders
- Popular and accessible lakes were/are invaded first
- There are new weeds out there
- The worst weeds have a massive impact on lake ecology

- Especially in the most biologically productive zone – the littoral
- Impacts on humans relate to obstruction and aesthetics
- Prevention of further spread is paramount

Acknowledgements

I would like to acknowledge –

- NIWA Aquatic Plant Group, past and present
- The Bay of Plenty Regional Council who funded the recent review of aquatic plant management for the lakes, mainly authored by Mary de Winton, and from which most of this talk is taken.
- The Biological Heritage National Science Challenge funded the pathway analysis work, thanks to Professor Phil Hulme (Lincoln University)
- NIWA SSIF through MBIE for the Freshwater Biosecurity Programme funded the other research referred to in this talk.

Thank you very much.

IMPACT OF CATFISH & OTHER FRESHWATER PEST FISH - WHAT LEARNINGS FOR THE CATFISH INCURSIONS IN LAKES ROTOITI AND ROTORUA?

Michel Dedual
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Michel was originally from Switzerland and arrived in New Zealand 30 years ago. After his postdoctoral at the University of Auckland he moved to Taupo where he has been working since then as a scientist in the management of the Taupo Fishery. During this time he has explored some aspects of the ecology of brown bullhead catfish that invaded Lake Taupo in the late 1970's early 1980's.

TRANSCRIPT

Good morning, I am here today to give feedback about the Taupo journey and experiences with the introduction of catfish. I will also say what is doable and what is probably not doable to control or eradicate them. The first consideration when managing the invasion of a non-native fish species, such as the brown bullhead catfish, is to decide what to do about it. Do we need to do anything? Do we need to control or contain it, or do we want to eradicate? The answers to these questions are very important because they will dictate everything in managing the new species.

What needs to be known about catfish in the Rotorua Te Arawa Lakes since their introduction? Firstly are they a problem? This is not an easy question and has an even harder solution which I will talk more about later on. If they are a problem then how abundant are they? Sometimes it is because of large numbers that they are a problem. What is their migration? Is it easy for them to travel from one spot to another which introduces confinement issues? Then there is the question of what is to be done and this is dictated by how much is known about the species.

The approach for the decision making process must first consider the implication of the 'real' impact of catfish on the Rotorua Te Arawa Lakes. The introduction of catfish is Rotorua, as it did in Taupo, has probably generated a feeling in the population that it is impossible that this fish can be good for the lakes. This immediately generates a mental model that catfish are bad, and therefore we need to do something about it, but what? It is essential to learn as much as possible about the ecology and biology of the catfish, because without knowledge it is impossible to make any decisions, unless of course you decide to do nothing.

What are the possible control and/or eradication methods have been trialled in New Zealand and worldwide? This question brings quite an amazing story. I was commissioned by Environment Bay of Plenty to put together a list of possible ecological impacts of brown bullhead catfish because firstly we needed to know what they do in Rotorua.

This table shows the ecological impact that has been suggested in the literature worldwide. For example, if the impact is negative sometimes that impact can also be positive whether it be in New Zealand, Lakes Rotoiti or Rotorua or overseas. The ecological impact deals mostly with nutrient excretions (churning the bottom), bioturbation and predation, and all are negative. But the reality is that in New Zealand we know very little about the real impact. The only scientifically demonstrated impact that we have come from the work we carried out in Taupo, and also becoming clearer in Rotoiti, is that catfish are having a substantial impact on koura.

1. Possible ecological impacts of brown bullheads

DESCRIPTION	EFFECT	DESCRIBED			
		OVERSEAS	NEW ZEALAND	ROTOITI	ROTORUA
Nutrient excretion	Negative		No	No	No
Bioturbation	Negative		No	No	No
Predation	Negative		Yes, kōura, goldfish (Taupo, Rotoiti)	Yes	No
Predated upon	Positive		Yes, Brown trout (Taupo)	No	No
Loss of native macrophytes	Negative		No	No	No
Loss of exotic macrophytes	Negative-Positive		No	No	No
Food-web modification	Negative		No	No	No
Interspecific aggression	Negative-Positive	Yes	Yes, goldfish (Taupo)	No	No

In Taupo we also have evidence that the interaction between catfish and goldfish has been affected, especially for goldfish because that population has been reduced by the presence of catfish, principally because of competition for habitat but also by predation. We have analysed the gut content of thousands of catfish and regularly found goldfish in them. That is a negative effect.

But we also found in Taupo that catfish have a positive impact on brown trout which was something that we did not expect. The brown trout are a serious predator, probably the only significant predators of catfish in Taupo but they eat them only when small. Catfish can lock their dorsal and pectoral fins almost like an open umbrella, which makes it very difficult for anything to eat them. But when young their fins are still soft and for the trout a good source of food. We know that brown trout will grow more quickly with access to large prey.

The next table shows further impacts that have been suggested in the literature. Biologically, if the catfish could be a vector of disease introduction, of course all of these effects would be negative. But unfortunately, absolutely nothing is known about that in this country. For example, something that has been mentioned quite often in Taupo was the effect of turbidity. Real estate agents were concerned that the churning of the lake edges by catfish would make the lake murky and then drop property values. Not that there was

much proof but it was mentioned. The erosion of stream banks does not seem really important for New Zealand.

Possible biological and physico-chemical impacts of brown bullheads

IMPACT TYPE	DESCRIPTION	EFFECT	DESCRIBED			
			OVERSEAS	NEW ZEALAND	ROTOITI	ROTORUA
Biological	Disease introduction	Negative	No	No	No	No
Physico-chemical	Alteration or degradation of habitat	Negative	No	No	No	No
	Erosion of stream banks	Negative	No	No	No	No
	Increased turbidity due to foraging behaviour	Negative	No	No	No	No
	Reduced water quality by disturbing sediment	Negative	No	No	No	No

This next table (below) indicates the economic impacts and here we see some negative and positive. Again, mostly negative but unfortunately virtually nothing is known about those potential economic impacts in New Zealand. Overseas new angling opportunities are mentioned quite a bit and a possible opportunity in New Zealand. However, the only real positive outcome comes from the processing of koi carp carried out in Waikato, where carps are digested and turned into a product 'carppuccino' that is used as fertiliser. This process turning something bad into something good makes a lot of sense.

IMPACT TYPE	DESCRIPTION	EFFECT	DESCRIBED			
			OVERSEAS	NZ	ROTOITI	ROTORUA
Economic	Hinder local commercial and sport fisheries through competition with target species.	Negative	No	No	No	No
	Hinder local economy (tourism)	Negative	No	No	No	No
	Eating quality	Positive	No	No	No	No
	Transformation (compost)	Positive	No	Yes, carp in Waikato	No	No
	New angling opportunities	Positive	No	No	No	No
	Employment through control/eradication	Positive	No	No	No	No
	Export market	Positive	No	No	No	No
Cultural/ social	Decline of fish species sought after by traditional activities.	Negative	No	Yes, kura	?	Yes
	Decline of aesthetics	Negative	No	No	No	No

The cultural and social impact shows the decline of the fish species (koura) sought after by traditional activities. We know in Taupo this is the case and the initial assessment of the impacts of catfish in Rotoiti also show that koura are badly affected by catfish. There is also mention of a decline of aesthetics, something that is conceivable but there is absolutely no data or no proof.

What is known about catfish?

- They are schooling fish
- They protect their nests and juveniles
- They are very abundant in weedy and shallow rocky habitats
- They are very active at night
- They move from deep to shallow water at night
- They have not been observed in Taupo deeper than 20 metres
- They have nasty sharp spines on their fins.

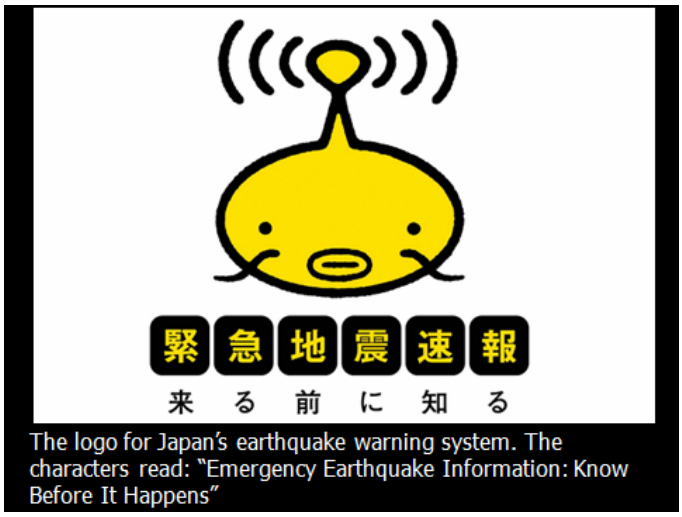
Because of those sharp spines handling the catfish is not easy. This picture shows one of the rays of the pectoral fin. It is like a harpoon and stays in like a hook. It can cause a nasty infection.

We also know that they do not have many predators as adults but the brown trout is the only predator on their juveniles. We do not know about their eggs. Other organisms that can predate on catfish are the seagull and the cormorants who had to develop a new strategy to deal with catfish. They catch them, pull them out of the water, hit them on the head until dead and then skin them like we would a blue cod. It is interesting to watch. The importance of those predators to control the population is probably not enough.

They are very opportunistic feeders; they are very tolerant of temperature and oxygen, which is complicated in management or eradication. They can virtually live without oxygen. Originally when we started in Taupo we wanted to kill them as humanely as possible. We put bins of catfish in the freezer thinking that we were dealing with them in a nice way. We left them for about 45 minutes and they were frozen solid when we removed them from the freezer but they all recovered soon after. Not so easy to get rid of.

They make substantial seasonal migration, something that could be useful depending on the strategy to control them. We also know that they displace other species. We have learned that they are very vocal and sensitive to seismic activity and electricity, which may be useful to control them. For example, using explosives or electric currents.

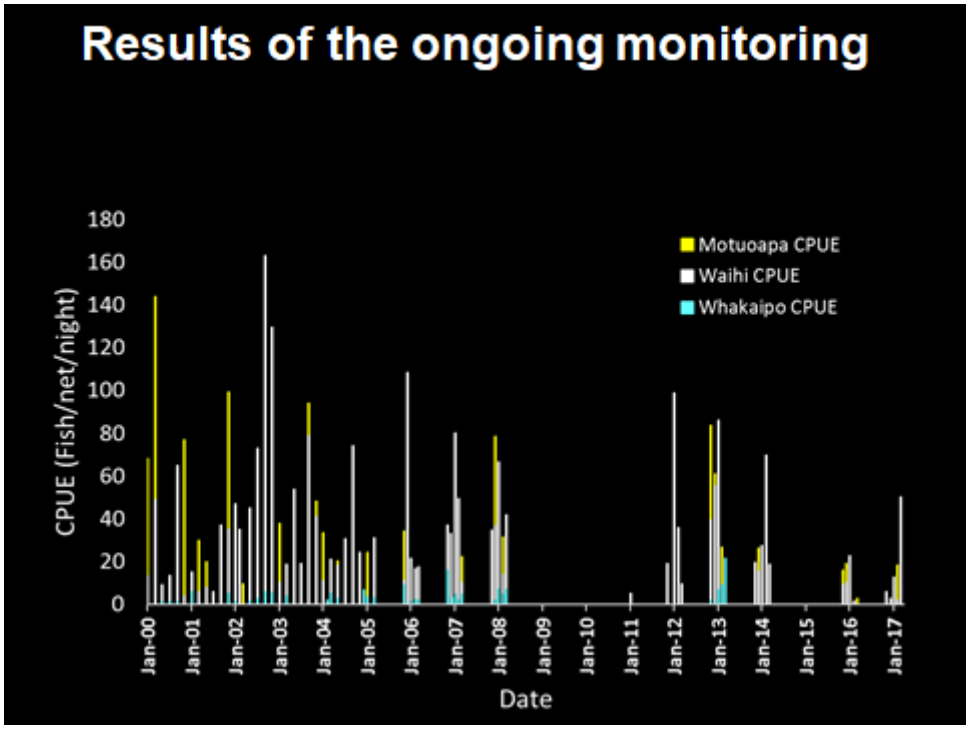
The Japanese believe that catfish are the best indicators of earthquakes and the Chinese have the same view keeping catfish in an aquarium to watch their behaviour. They believe that when the catfish start to behave oddly an earthquake is imminent. There was an article I read about China where, because of the behaviour of catfish in an aquarium, they managed to save tens of thousands of lives moving people out of the danger zone of the city using the ability of catfish to detect seismic activity.



The logo for Japan's earthquake warning system. The characters read: "Emergency Earthquake Information: Know Before It Happens"

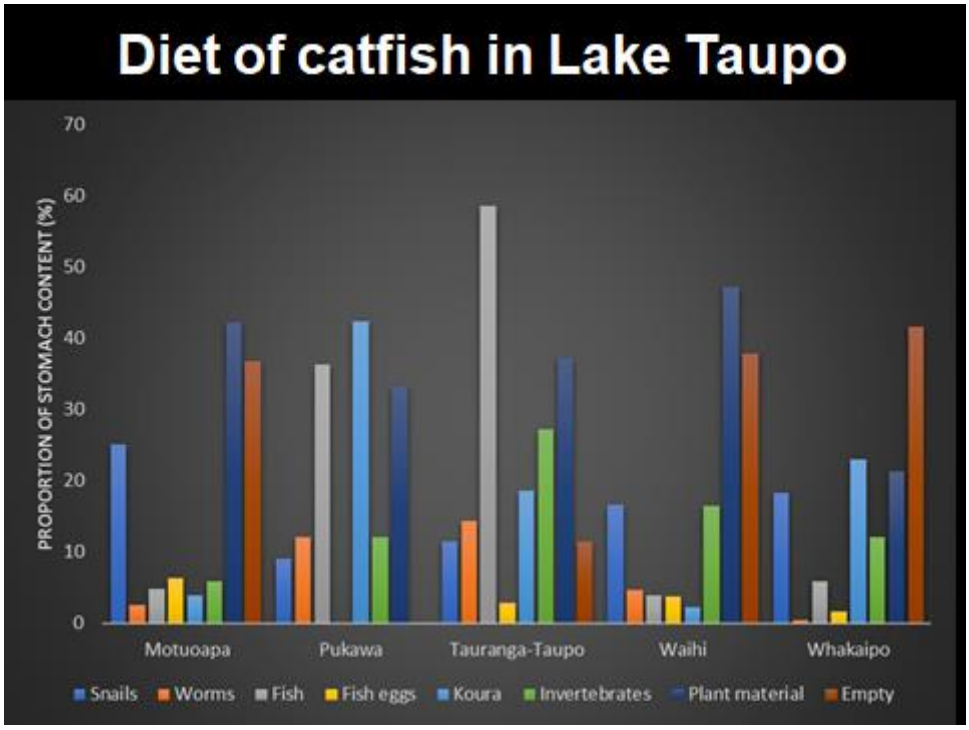
This is a picture of catfish in Taupo. Interestingly, there are few descriptions in the literature research on catfish of their behaviour in the water simply because in America the water is generally far more turbid and it is hard to see what they are doing. But in Taupo the water is so clear that they can be filmed. We could observe schools of catfish in mid-water that are easy to approach and very conspicuous. But we also observed another type of catfish that are far shyer and stay close to the bottom. They see the bubbles of the divers and are off. This behaviour has never been reported before because it could not be observed.

The graph (next page) shows results of the monitoring that we did in Taupo, all good background information. We were interested to see how the population is evolving through time, first measuring the abundance in 2000 until 2017. It is relieving to see that catfish appear to have reached their peak population in Taupo. We do not expect to see a further increase. They have invaded all their suitable habitats.



We covered three different areas. It is interesting to note that in Whakaipo Bay at the northern end of the lake, which is a long way away from the weedy protected bay of Motuoapa and the more shallow Waihi Bay at the southern end of the lake, the population (in blue) has remained virtually nil with few catfish in evidence. So, they have not spread all around the entire lake. It looks reasonably static at a certain level and not going any higher.

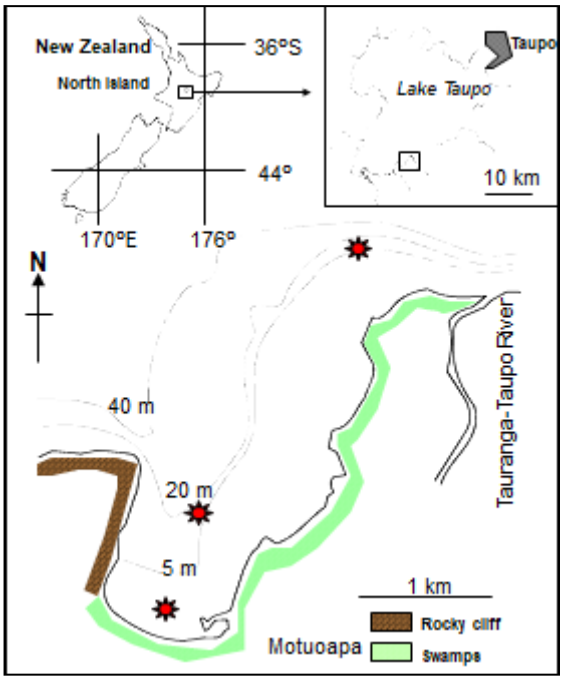
This graph is the diet of catfish in Lake Taupo. They are opportunist feeders so we look at



what they have mainly in their stomach when caught. Motuoapa Bay is the southern eastern end of the lake and Waihi Bay is at the south western end of the lake, Tauranga-Taupo is on the eastern side of the lake, and Whakaipo at the northern end. The graph shows that a lot are empty because the catfish may have been caught in fyke-nets soon after they started to become active and not yet taken any prey, so of course they will be empty. But for those who have something in their stomach snails, invertebrates and plant material are very important. It may be that they browse the algae to get as much of the snail as possible.

The problem is the koura which we know they eat. We looked at the size of the catfish that can catch koura, because koura are not an easy prey to deal with especially as adults. They fight back because they do not want to get taken by catfish, probably a completely different story for the larvae. This means that catfish need to be large to eat the adults. We calculated that if they are not longer than 270mm, they would not be able to deal with an adult koura. Taupo is different to the situation in Rotorua in a sense that the lake is very deep. We know that koura can live down to 100 metres of water. So, with such a refuge for koura they can survive, something that is available to Rotoiti but probably not Rotorua.

We also looked at the swimming behaviour of brown bullhead catfish in Lake Taupo by using acoustic tracking with transmitters equipped with a pressure sensor (Vemco VR16-1H) (62 mm long, 16 mm diameter, 6 months battery life) transmitting the depths that the catfish were swimming. We were able to calculate their swimming depths and their movements by adding a series of automatic receivers (Vemco VR 1). This was set up in Motuoapa Bay.[1]

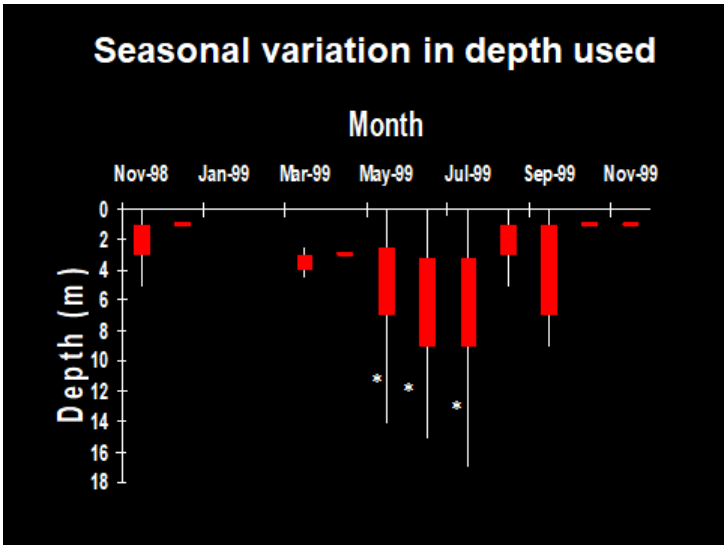


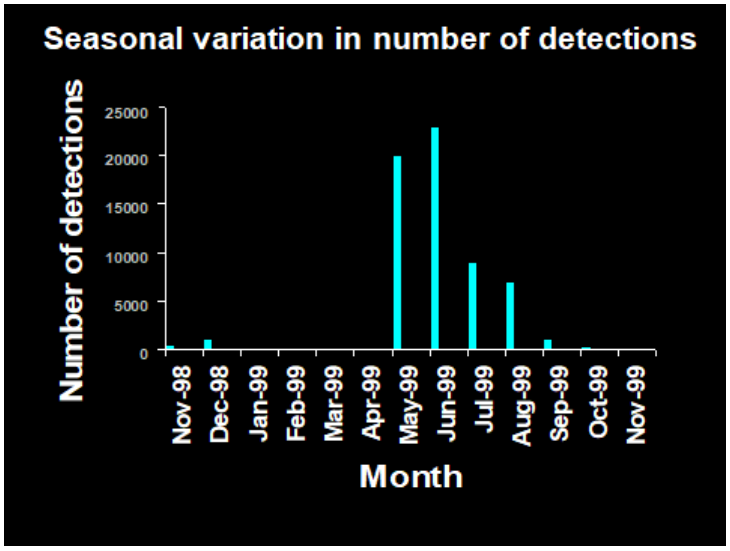
This map gives an idea of the scale, from the Tauranga-Taupo River mouth to Motuoapa Bay, about 5 or 6 kilometres.

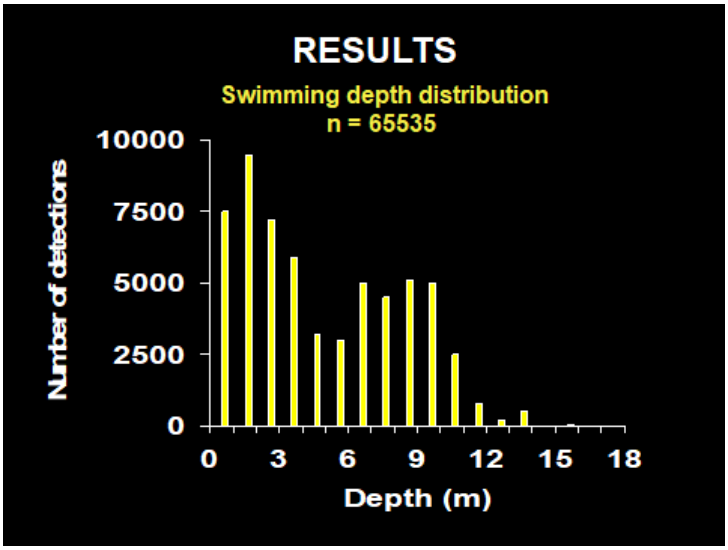
The next graph shows that catfish spend most of their time in very shallow water between 0 and 3 metres. During the day they will be slightly deeper, around 6 to 10 metres. I suspect they will do the same thing in Lake Rotoiti.

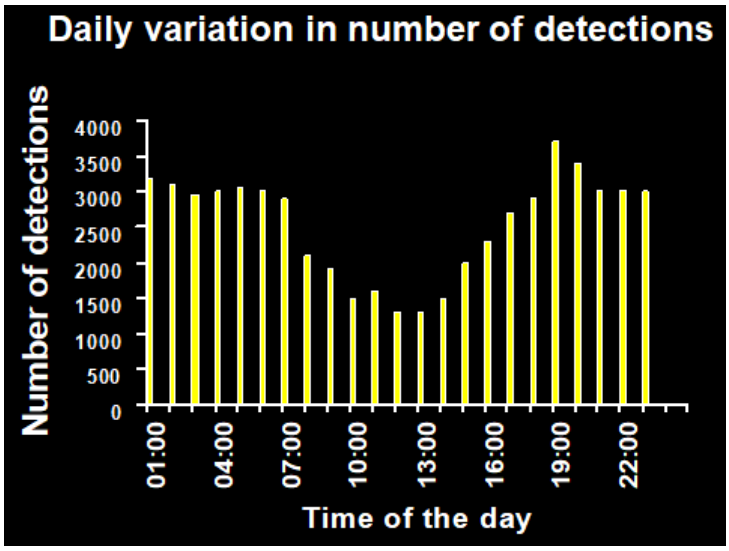
We also plotted the seasonal variation in the number of detections and noticed that at certain times of the year they were far more active. It was easier to detect them because they were swimming all around, particularly in winter. The results shows that in winter they also generally swam deeper than the rest of the year. All this is useful information that can help put together a plan of attack if needed.

[1] (Dedual, M., 2002. Vertical migration and movements of Brown bullhead (*Ameiurus nebulosus* Lesueur 1819) in Motuoapa, Southern Lake Taupo. *Hydrobiologia* 483(1-3):129-135


Seasonal variation in depth used
Month
Nov-98
Jan-99
Mar-99
May-99
Jul-99
Sep-99
Nov-99
Depth (m)
0
2
4
6
8
10
12
14
16
18

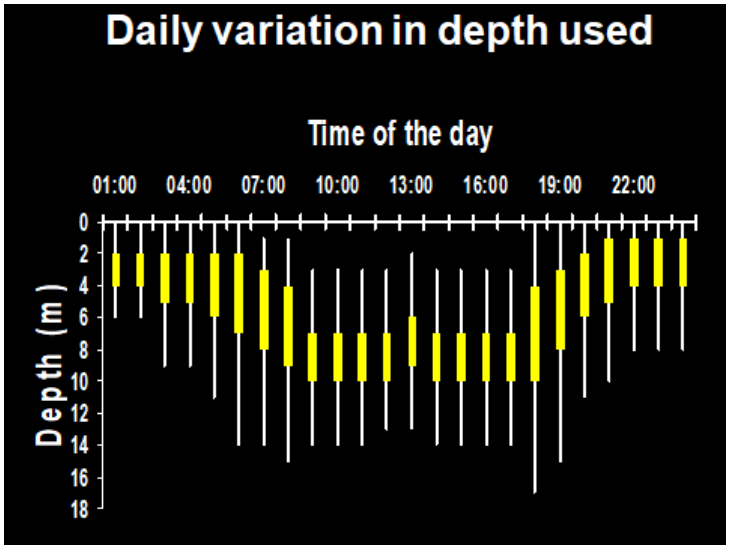

Seasonal variation in number of detections
Number of detections
25000
20000
15000
10000
5000
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Month


RESULTS
Swimming depth distribution
n = 65535
Number of detections
10000
7500
5000
2500
0
0
3
6
9
12
15
18
Depth (m)



This graph shows that as soon as daylight arrives the catfish start to dive, staying during the middle of the day at a deeper depth and they start to come closer to the surface just before dusk.

Below shows the depth in relation to the time of the day.



Once we understand this information and know the real impact of catfish in Taupo or in Rotoiti and their interactions with other fish species, what do we do next? How much can we do?

I have put together some methods of control but of course the matter of control will have different aspects to it. Some methods will be suitable for control , some for eradication , some have already proven effective , and others need more information . The cost will depend on the combination of methods selected and their ease of implementation . Another factor is whether it is selective for catfish to avoid collateral damage.

It is also important to understand how the public will react; are they going to be happy about the methods used in the lake to rid the pest species? Is it going to leave long-lasting marks on the environment? The question that many will ask is: would eradication be possible in Rotorua/Rotoiti?

Some of these methods are very simple and also very effective such as dewatering. In a small pond the entire flow can be controlled by draining the water out and then eradicating everything. The cost will depend on the set up. But the problem is that it is not selective.

3. Possible control methods of brown bullheads

METHOD	CONTROL	ERADICATION	PROVEN EFECTIVENESS	COST	EASY TO IMPLEMENT	SELECTIVE	PUBLIC ACCEPTANCE	PERSIST IN THE ENVIRONMENT	FEASIBLE IN ROTORUA
Dewatering	Yes	Yes	Yes	?	?	No	Yes	No	More info needed
Fyke nets	Yes	No	Yes	$$$	Yes	Yes *	Yes	No	Yes
Gill nets	Yes	No	Yes	$$$$	Yes	No	Yes	No	Yes
Traps	Yes	No	Yes	$$	Yes	Yes *	Yes	No	Yes
Beach seine	Yes	No	Yes	$$	Yes	Yes *	Yes	No	Yes
Trawl nets	Yes	No	Maybe	$$$	No	No	Yes	No	More info needed
Electrofishing	Maybe	No	No	$$	No	Yes	Yes	No	More info needed
Explosives	Yes	No	Yes	$$$	No	No	?	No	More info needed
Biocontrol	Yes	Maybe	No	$$$$	No	Maybe	No	Yes	No
Virus	Yes	Yes	Maybe	$$$	No	Maybe	No	?	No
Piscicides	Yes	Yes	Yes	$$$	No	No	?	No	No
Genetic methods	Yes	Yes	Not yet	$$$$	No	Yes	?	No	Not yet
Pheromones	Yes	Yes	Not yet	$$$	Yes	Yes	Yes	No	Not yet
Commercial fishing	Yes	No	Yes	$	Yes	Yes	?	No	Yes
Recreational fishing	Yes	No	No	$	Yes	Yes	Yes	No	Yes
Sound attraction	No	No	Not yet	$$	No	Yes	Yes	No	Maybe
Integrated approaches	Yes	Maybe	Not yet	?**	Maybe	Yes	? ***	No	Yes

Imagine a situation with a lake containing catfish but with other species that are threatened. Clearly that would not work. One major attractive aspect of dewatering is that the impacts will not persist. Unfortunately this method is not feasible for Lakes Rotorua and Rotoiti. Dewatering is a very popular control/eradication method in Australia.

Fyke-net as an effective control method, but to eradicate the population of catfish in lakes the size of Rotorua and Rotoiti it will not work for a number of reasons. Its effectiveness has been proven in Europe. I found a case in Belgium where they managed to eradicate catfish by using fyke-nets but it was in a small pond and completely different from Rotorua. Going down the list the costs creep up and it can be a really expensive exercise to control everything with fyke-nets and requires a high labour cost. Traps, trawl nets and others are all similar to, fyke netting. They work for control, but not for eradication, should eradication be the selected option.

Electro fishing as a control needs more information as it has not been tried. We know that catfish are very sensitive to electricity and it could be an effective way. Explosives as a control method have been done a few times in New Zealand. They tried to eradicate koi carp in Taranaki. We know that catfish are very sensitive to seismic activity, so maybe a first detonation that puts them all in another place where there is a net setting, maybe.

Down this list are more tricky solutions such as dealing with viruses. I am aware of 3 lakes in Europe where catfish have been absolutely eradicated, not because someone introduced the virus, but the population spontaneously caught that virus and was wiped out without any damage to other species. However, the use of viruses needs serious thought. Because we are in a rush, we face the same problem; there is a lot we do not know about most of these methods.

Future research and Conclusions

- Life history/biology of brown bullhead in Rotorua lakes
- Bullies biology
- Koura monitoring
- Curb the recruitment
- Control method that pays for itself

What is needed in Rotorua is a far better understanding of the catfish biology. There is a tracking experiment starting soon, similar to what we did in Taupo. The bullys biology is another area to research because there may be an important aspect that bully's potentially are predators of catfish eggs, but we do not know. The koura monitoring that is in progress will give more evidence of whether catfish are having an impact. The idea is to curb the recruitment of catfish by whatever method is chosen. If it could be a solution that pays for itself that would help. We know there is a limited amount of money and resources available, but with smart marketing you could find a market to buy catfish, a situation like deer control where the commercial hunters hunt and sell the deer. Such a control method would work on its own because it pays for itself and would suit most people.

Thank you.

PLANTS REFLECT THE ECOLOGICAL CONDITION OF THE ROTORUA TE ARAWA LAKES

Mary de Winton and Tracey Burton
NIWA
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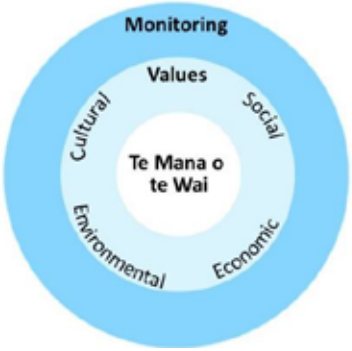
Mary is a freshwater ecologist based at NIWA in Hamilton and manager of the Aquatic Plant Group, a team of researchers working on vegetation aspects across varied aquatic systems. A focus of Mary's research is the management of aquatic weeds within the wider framework of freshwater biosecurity. Current research projects include monitoring of weed control operations to explore trade-offs between impacts and benefits along different timescales. Mary frequently provides operational advice to agencies including the LINZ Annual Control Works Programme for aquatic weeds. On the flip-side, Mary is also involved in research aimed at restoring native submerged species to degraded waterways.

TRANSCRIPT

Thank you Mayor Chadwick and Tena koutou katoa. It is my pleasure to give this presentation today on behalf of my colleague, Tracey Burton. Tracey is in the USA also presenting at a conference. I would like to acknowledge the Bay of Plenty Regional Council who funded the work from which the data that is presented today has been drawn.

National Policy Statement for Freshwater Management

- Te Mana o te Wai - the integrated and holistic well-being of the water



We have recently heard much in the news about the management of freshwaters; this is communicated in the National Policy Statement for Freshwater Management. At the heart of the statement is the concept of 'Te Mana o te Wai', defined by the Ministry for the Environment as the integrated and holistic wellbeing of the water.

This is exciting for a freshwater ecologist like myself because I can see that there is potential for more emphasis to be placed on the biological life-supporting processes of fresh water. But importantly, the Government clearly indicates that it is whanau, hapu, iwi,

regional councils and the community who decide what it is about the values that they recognise, which might be quite diverse. This signals to me that we need more monitoring approaches, diverse and holistic indicators to track our outcomes and progress relative to targets in terms of fresh water management.

My interest in particular is around the environmental side of monitoring. Both here and overseas we are increasingly using submerged plants in our waterways as bio-indicators. What I want to explore here is how plants growing underwater can reflect the wellbeing of the Rotorua Te Arawa Lakes.

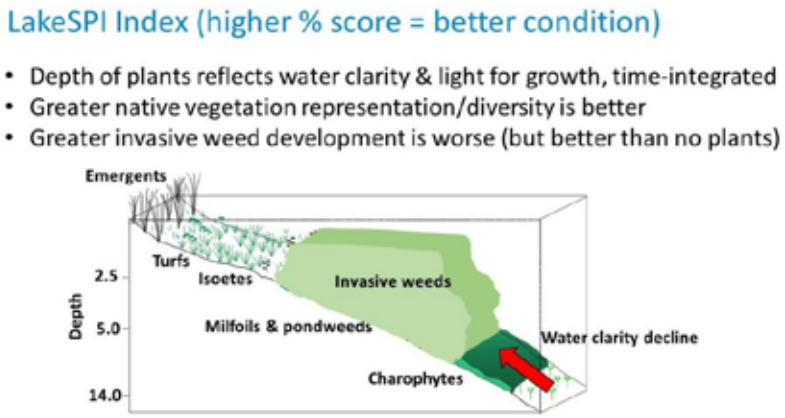
Firstly, plants have values in their own right. They are a source of biodiversity and they provide habitat diversity in the waters. They have intrinsic functional values, they provide structure in the littoral zone of lakes, and they provide habitat, refuges and food for biota. They have a biochemical influence in the littoral zone, particularly in shallow lakes. They integrate conditions in water in the way that they grow or are lost, and this is expressed over time. Plants are easy to monitor, but diving is required in some cases to observe them in detail.

I would also like to introduce a concept of bio-pollution seen in our submerged vegetation, which is considering weeds and pest fish as contaminants, just like other contaminants are considered in freshwaters and in bio-monitoring. We can see how submerged plant indicators might contribute to the integrated and holistic measures of lake wellbeing.

In the Rotorua Te Arawa Lakes monitoring has been done using a bio-monitoring method called LakeSPI (Lake Submerged Plant Index) with the submerged plants as indicators. The concepts behind LakeSPI involve the current state of the lakes and how they have changed over time. Funded by the Bay of Plenty Regional Council, these lakes have been monitored every 2 years since at least 2001, resulting in a good data set.

In this talk I would like to introduce the concepts behind LakeSPI, looking at the current state of the lakes and how they have changed over time. We have not got time to go through all 12 lakes but I picked out some examples to consider.

The LakeSPI Index is a measure providing a score, expressed as a percentage, where the higher the score the better the lake ecological condition. There are a few basic assumptions behind this index, the first one of which is that the depth of the plants reflects water clarity because the plants require light for growth and it is integrated over time by the growth of those plants. It also assumes that greater native vegetation representation and diversity is better for a lake.



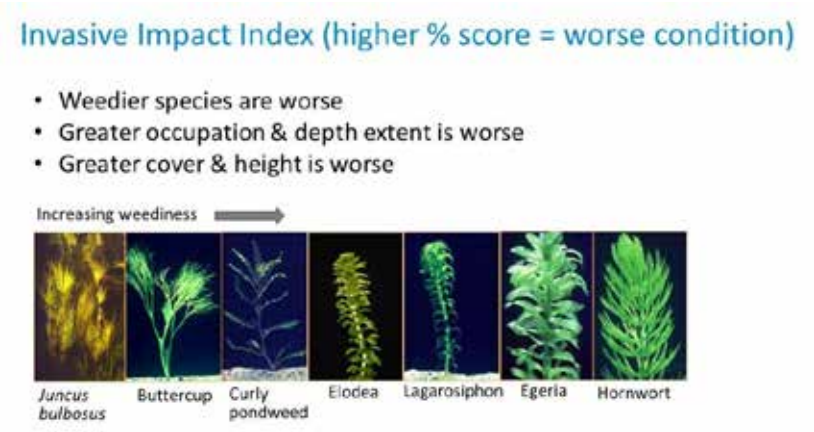
We were introduced to all the plant communities that are found in the Rotorua Te Arawa Lakes by Paul Champion this morning.

The LakeSPI method also assumes that greater invasive weed development is worse. Diversity can be reduced by the invasion of weeds, but it is recognised that even some weeds are better than having no vegetation in a lake. This is a risk for our fresh water lakes going forward. Where there is declining clarity of water, there is a retraction in the extent of vegetation in a littoral zone and the plants retreat from the deeper levels. In worse case scenarios the deeper vegetation is lost first and in even worse situations the entire vegetation from a littoral zone can start to disappear.

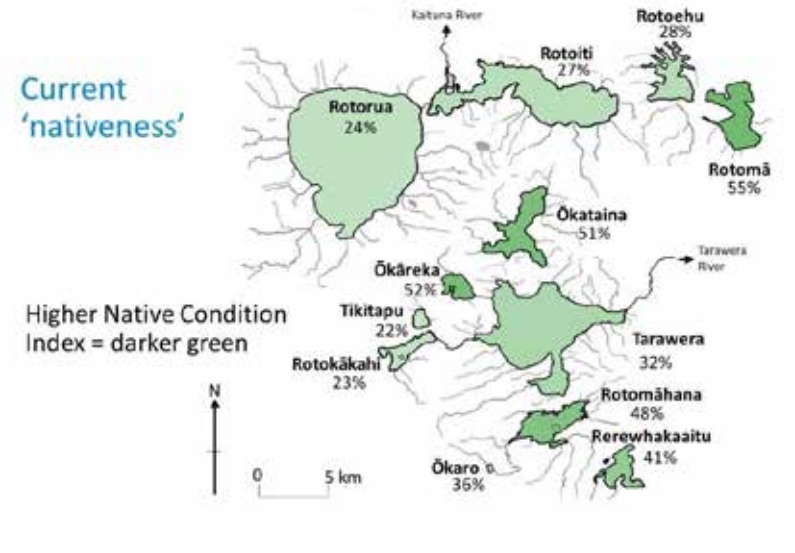
The LakeSPI Index is supported by two other indexes. The 'Native Condition Index', like the LakeSPI index, indicates a higher score for a better condition in the lakes expressed as a percentage of what lakes could or should be scoring. This recognises that greater diversity of native plants is better and so is a greater occupation of the littoral zone. It also recognises that deeper overall depth extent by native vegetation is more desirable.

This slide shows a line-up of the communities that are recognised in the Rotorua Te Arawa Lakes; the emergents, the turfs, *Isoetes* (or quillwort), milfoils, pondweeds and charophytes. Both diversity and occupation of the littoral zone by native species is better and we recognise that where charophytes form meadows a deeper overall depth extent is better.

The 'Invasive Impact Index' is another supporting index in opposition to LakeSPI and the 'Native Condition Index'. A higher score in this index means a worse lake condition. It also recognises that not all weed species are equal.

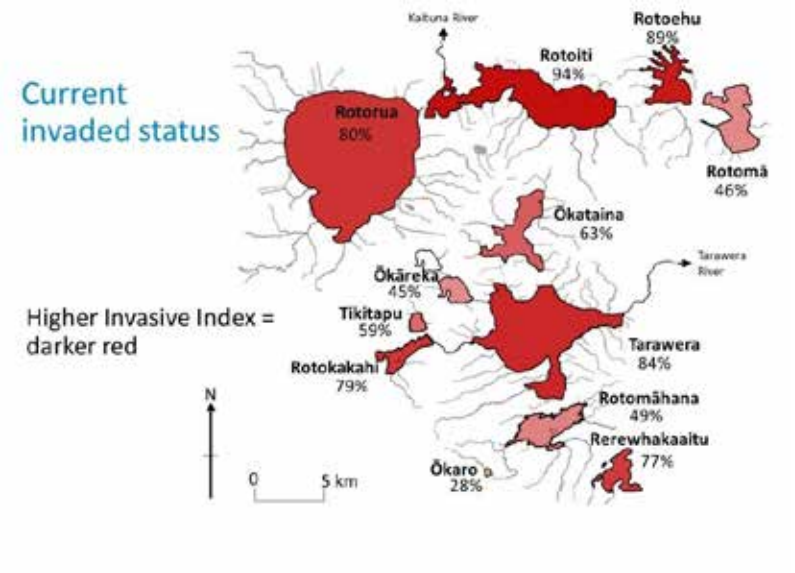


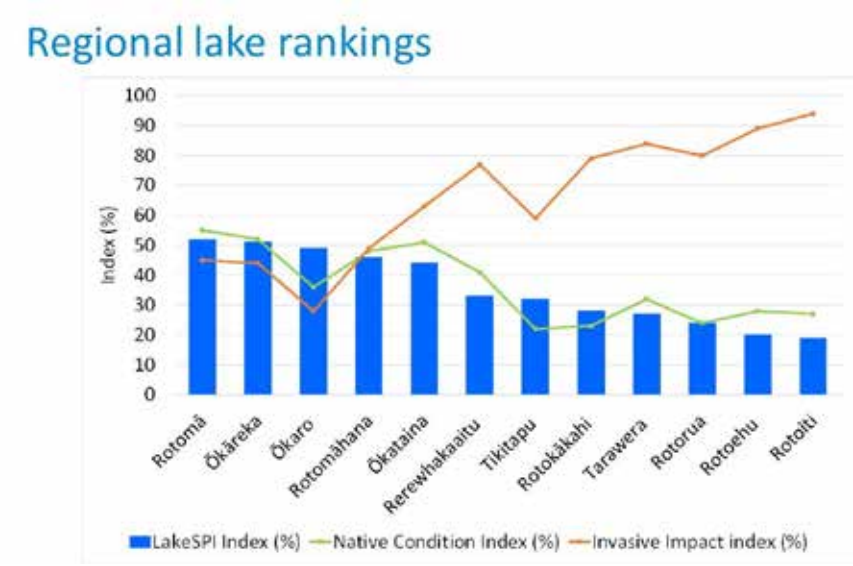
This previous slide shows a progression towards the right of 'more weedy' species. The more benign weeds, *Juncus bulbosus*, water buttercup, curly pondweed, are displayed on the left-hand side, then it moves through the moderate elodea to the really bad weeds, lagarosiphon, egeria and hornwort, those known to have big impacts in a littoral zone. The presence of these weedier species, with greater occupation, depth extent and greater cover/height of these weeds is recognised as the worst scenario.



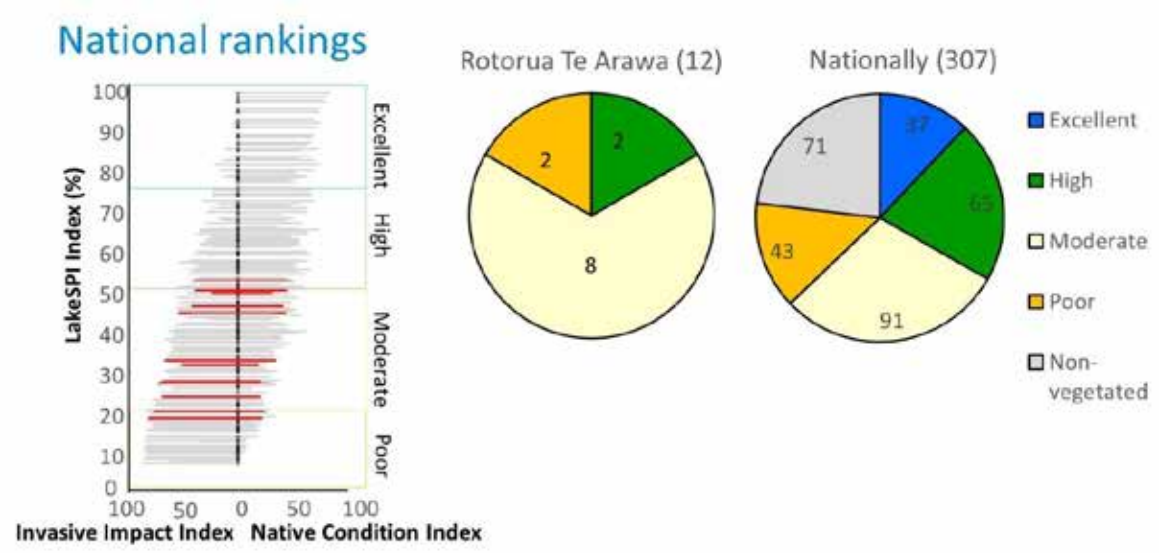
In this bird's eye view of the current state of the Rotorua Te Arawa Lakes, it shows that they are achieving about half of the 'nativeness' that they could. The darker green lakes, Rotomā, Ōkataina and Ōkāreka, score highest and lakes Tikitapu, Rotokākahi and Rotorua are scoring quite low on the Native Condition Index.

By contrast, on the Invasive Impact Index for the Rotorua Te Arawa Lakes, a darker red for those more invaded lakes shows Rotoiti, Rotoehu, Rotorua and Tarawera are all scoring quite highly in terms of the impact of invasive weeds in the littoral zone, but only 28% for Lake Ōkaro.



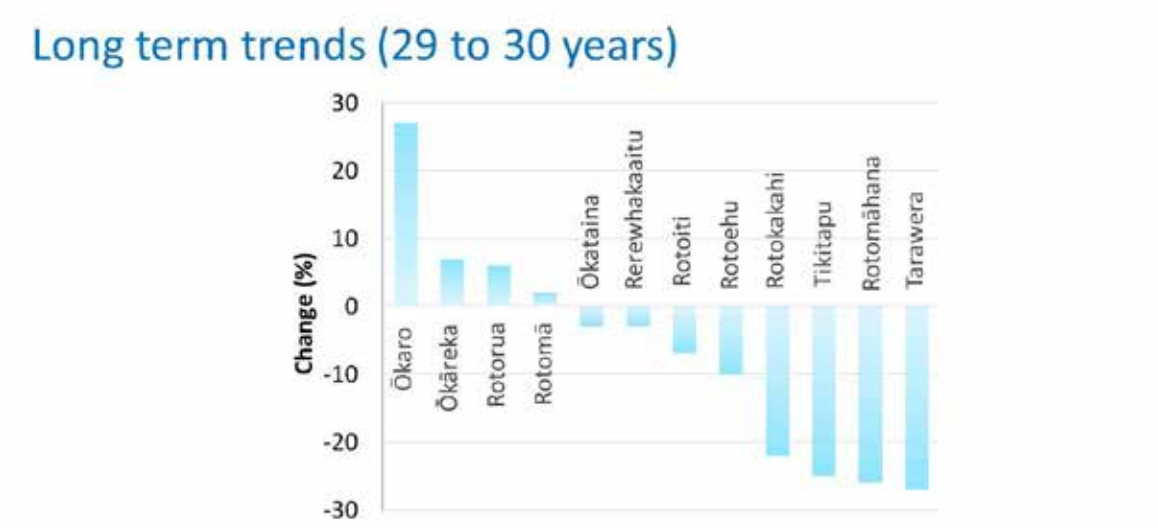


The blue bars in this graph show a slightly different view in the state of the Rotorua Te Arawa Lakes. In a regional ranking from the best lake for the LakeSPI score being Rotomā, to the poorest lake being Rotoiti. The green plotted line is the Native Condition Index and the orange plotted line is the Invasive Impact Index. It shows how the Native Condition Index is progressing about the same as the LakeSPI index, but the Invasive Impact Index is behaving in a different way. The better lakes have a lower Invasive Impact score and the poorer lakes have a higher Invasive Impact score.

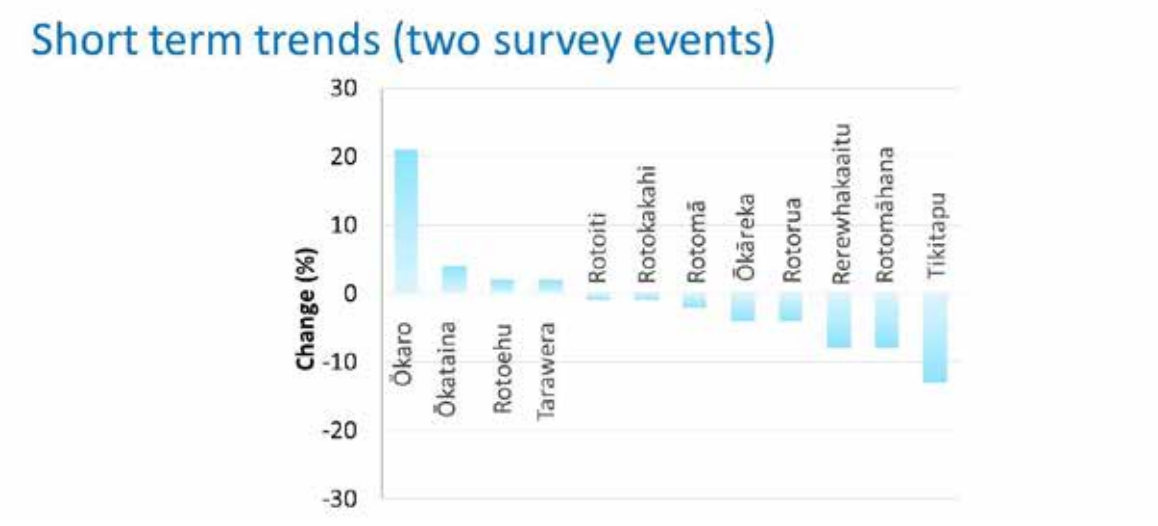


This graph (left) ranks the Rotorua Lakes as the red lines against the rest of the 307 New Zealand lakes assessed by LakeSPI as grey lines. The vertical axis is the overall LakeSPI Index, the positive horizontal axis is Native Condition Index and the negative horizontal axis is the Invasive Impact Index. For reporting purposes, results are also given a narrative description (right) depending on LakeSPI score, with high scoring lakes described as excellent, to low scoring lakes in a poor category. One category not shown for the Rotorua Te Arawa lakes is the lake with little existing vegetation which scores a default of zero and is termed non-vegetated.

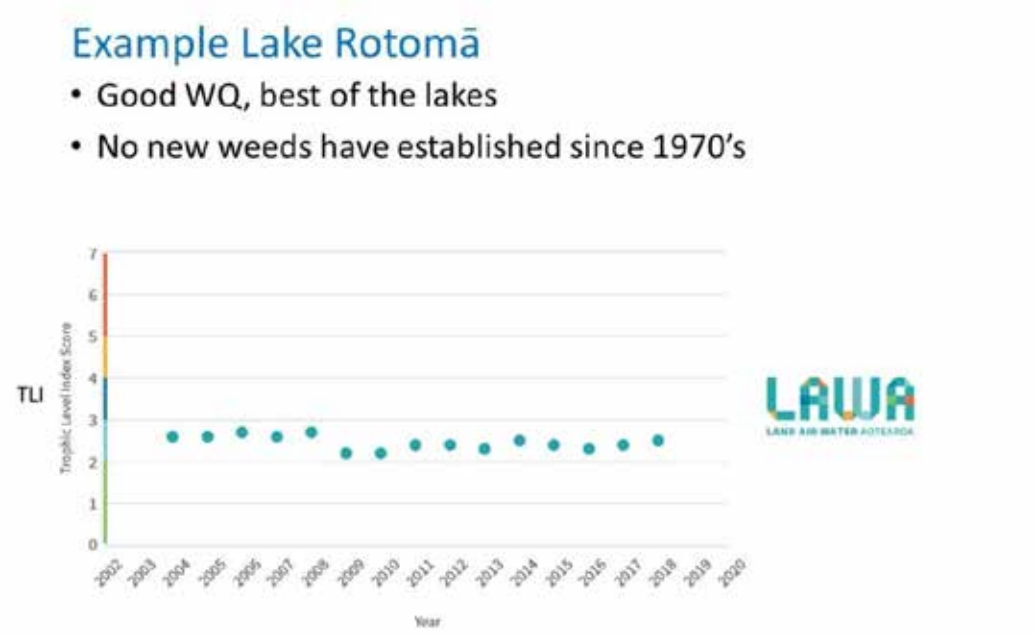
The Rotorua Te Arawa Lakes do not have any lakes in the category of excellent, but neither do they have any falling into the non-vegetated category. Like lakes nationally, most of the Rotorua Te Arawa lakes are falling into the moderate category. There are a couple of lakes that are considered high and a couple of lakes that are considered poor.



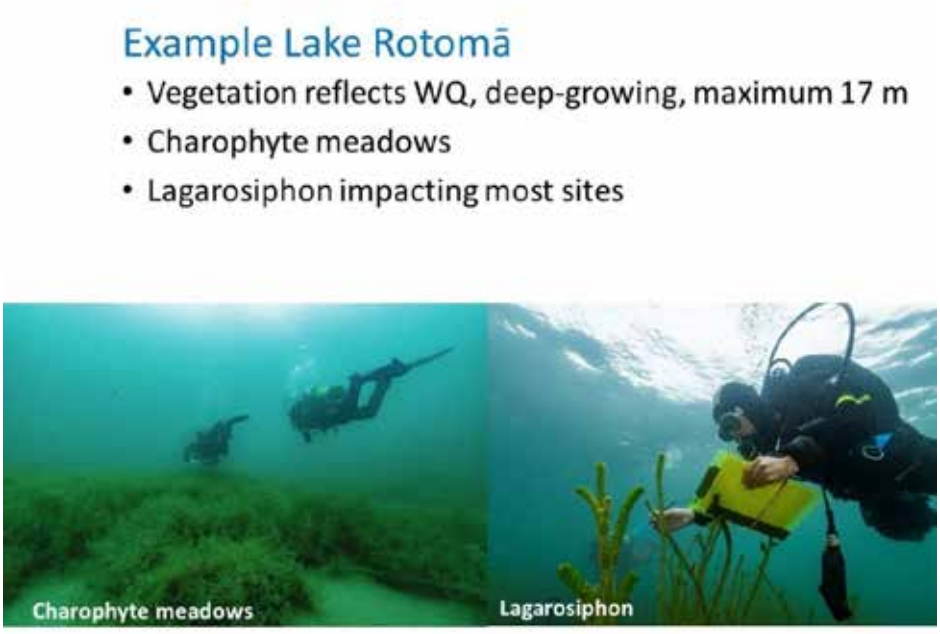
Good historical data on the vegetation of the lakes exists over 30 years and has been translated into a LakeSPI score, giving a long-term view of how the Rotorua Te Arawa Lakes have changed. This slide shows improvement in the condition in the lakes on the top part of the graph and a decline on the bottom part of the graph. Changes are influenced strongly by weed status either decreasing (Ōkaro and Ōkareka) or increasing (Rotomāhana and Tarawera especially, but also Rotoehu and Rerewhakaaitu), while changes for Rotokākahi and Tikitapu suggest strong water quality decline over a longer period of time.



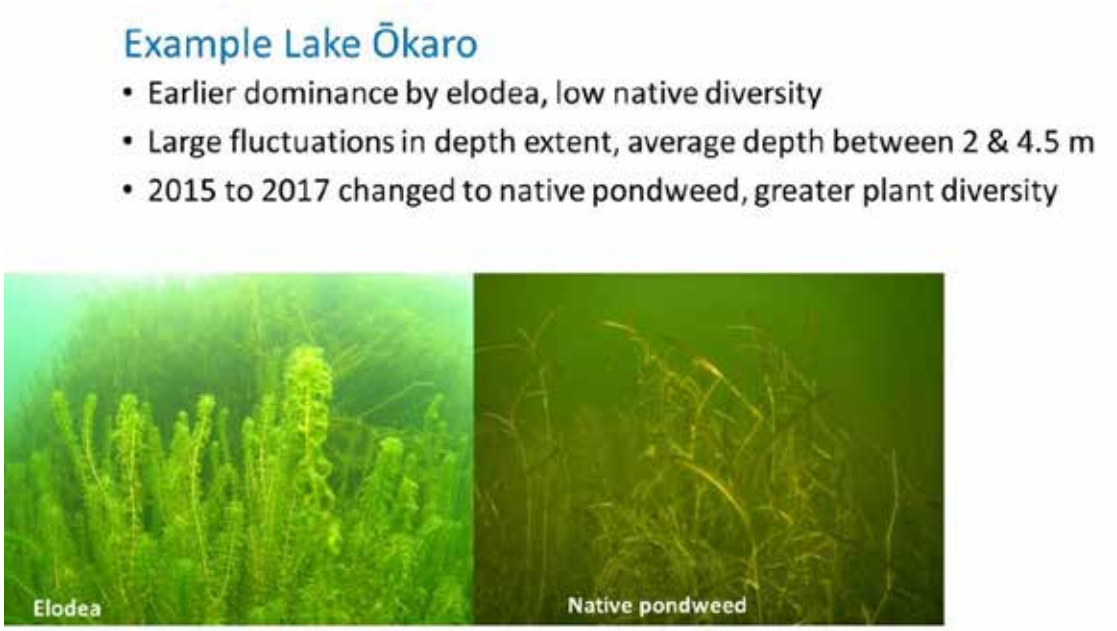
Short term trends over the last 4 to 5 years show a slightly different picture but confirm Lake Ōkaro has improved recently as the result of activities in this catchment. Many lakes have had only slight changes in the last few years, but amongst the ones that have declined are Rerewhakaaitu, Rotomāhana and Tikitapu.



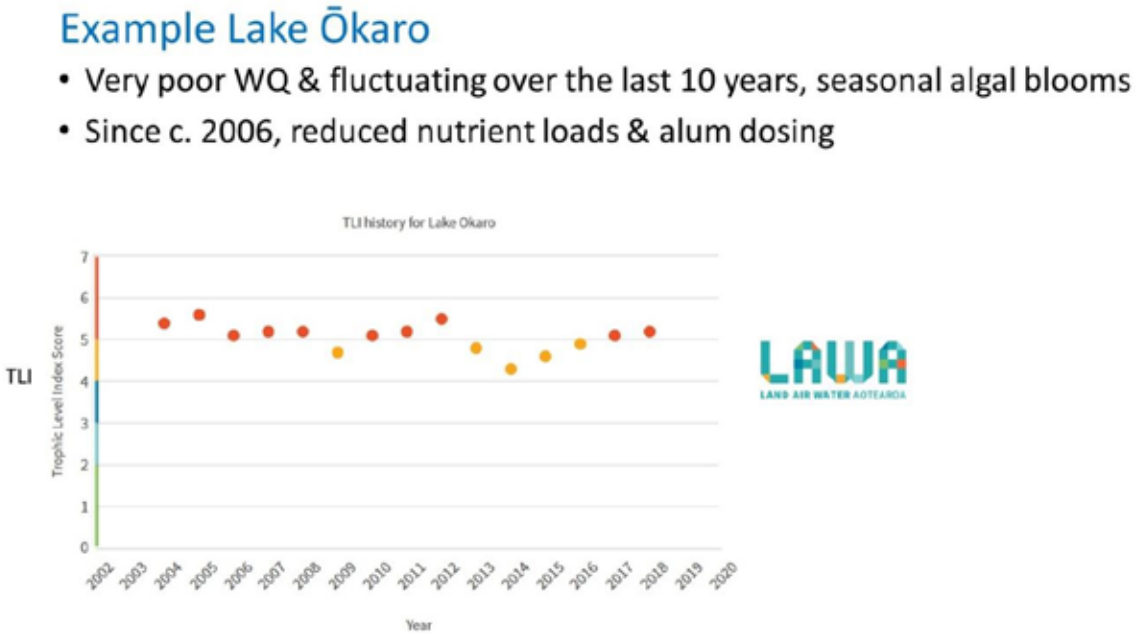
Lake Rotomā is one example. This graph from LAWA (Land Air Water Aotearoa) shows the Trophic Level Index (TLI), with a lower TLI indicating better water quality. Rotomā has always been one of the best lakes in terms of water quality in the Rotorua Te Arawa Lakes Region and no new weeds have established in the lake since the 1970's.



Vegetation reflects the water quality and deep growing submerged plants in this lake, and it is easily seen in Rotomā because of the wonderful water clarity. There are records of vegetation growing down to 17 metres in this lake, which would only occur with good long-term water quality. There are extensive charophyte meadows and this picture (left) shows two divers swimming over deep meadows and a low growing carpet of native plants. But there is the weed lagarosiphon (right) and it is present at most of the sites that we survey in Lake Rotomā.



In terms of LakeSPI, Rotomā is the highest scoring lake in the Rotorua Te Arawa Lakes; being largely stable over all the time that it has been monitored. The only changes detected have been between the Invasive Impact Index score in 2005 and the most recent two surveys. Even that change has been so small as to be hardly ecologically significant.

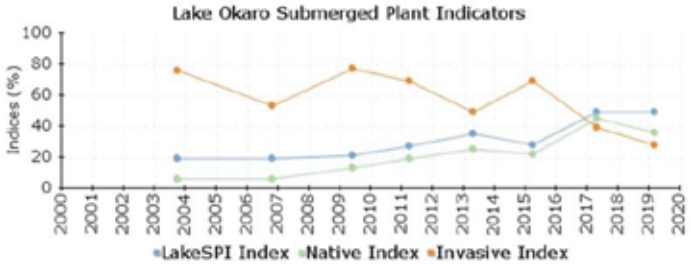


Lake Ōkaro has always been considered to have very poor water quality, fluctuating over the last 10 years. In the early days it was completely dominated by elodea with a very low diversity of native plants and it had seasonal algal blooms. Considerable works have taken place in this catchment resulting in reduced nutrient loads into the lake. Alum dosing in the lake itself since 2006 has also helped to improve this lake's condition.

There were large fluctuations in vegetation depth extent, sometimes surveys showed plants were growing down to about 4.5 metres depth, other times they died right back up into the shallows to only 2 metres depth. In 2015 to 2017, there was a dramatic shift in the composition of the vegetation. It had changed from elodea through to native pondweeds and a greater plant diversity has developed.

Example Lake Ōkaro

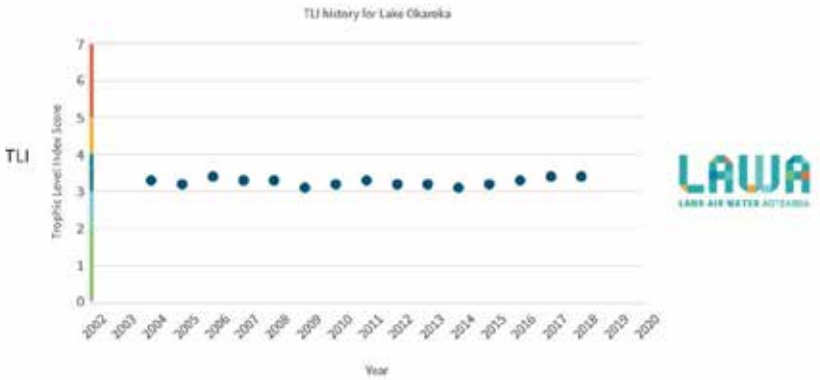
- Recently improved LakeSPI condition
- Change detected from 2009 onwards, stepwise in 2017 & sustained
- Still fluctuating vegetation depth limit (halved between 2017 & 2019)



This graph is how the LakeSPI has tracked over time, clearly showing recent improvement in the lake condition. This change was detected from 2009 onwards and a real stepwise change occurred in 2017 which has been sustained. There is still a fluctuating vegetation depth limit. In fact, the survey picked up that the depth of the vegetation halved between 2017 and 2019. This means there are still concerns but there is no doubt that a definite improvement has occurred according to LakeSPI.

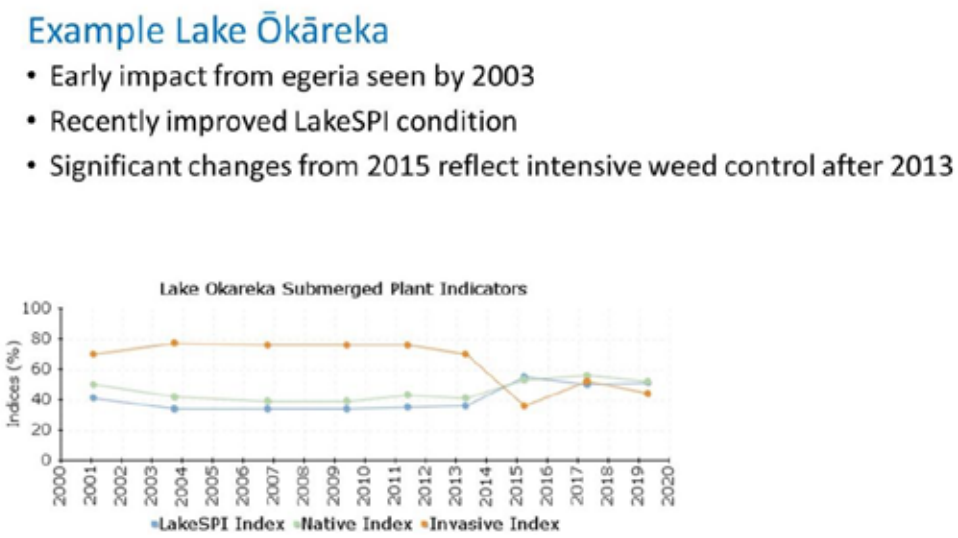
Example Lake Ōkāreka

- Average WQ, but considered to have improved
- Recent actions as sewerage reticulation & land use change

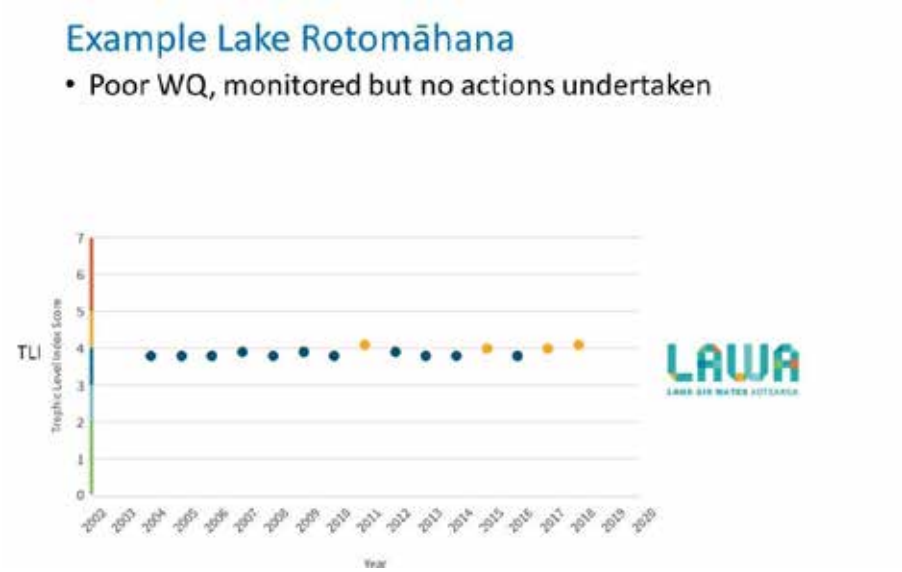


Lake Ōkāreka is considered to have average water quality but more recently an improvement has been noticed. Actions such as sewerage reticulation and land use change have occurred in that catchment.

Previously Lake Ōkāreka was dominated by lagarosiphon with big beds widely distributed around the lake. It still had some elements of native vegetation; with charophytes forming meadows down to 10 metres depth. About 2001, egeria was first recorded in the lake and hornwort was detected in 2012. At that time it was considered the greatest threat to the lake. An intensive control works programme was initiated from 2013 with widespread spraying of weed beds with the herbicide Diquat.



The LakeSPI results for Lake Ōkāreka show an early impact from egeria seen between 2001 and 2003, but there has been a dramatically improved LakeSPI in recent years with significant changes from 2015. This really reflects those intensive control works for hornwort that occurred just after 2013, resulting in improved native vegetation in the lake. So, it is possible to achieve changes in the LakeSPI index through management initiatives.

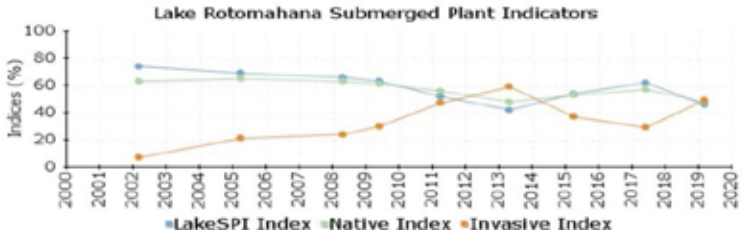


My final example is Lake Rotomāhana, which is considered to have poor water quality. The water quality of the lake is monitored but there has been no action plan or management actions undertaken. Pre-2011, the vegetation in the lake was primarily native, it was diverse and according to LakeSPI Index, it was the highest ranked Rotorua Te Arawa Lake at that time.

Charophytes formed meadows down to a maximum depth of 13 metres. But in 2007 egeria and hornwort were detected and by 2011 egeria was widespread.

Example Lake Rotomāhana

- Deteriorated LakeSPI condition long-term
- Invasive Impact increased between 2007 to 2013
- Egeria has fluctuated in abundance since
- Possible reductions in plant depth extent



The LakeSPI score shows a deteriorated condition over the long term. The Invasive Impact Index increased between 2007 and 2013 as the egeria spread around the lake impacting the littoral zone. But there have been some strange fluctuations in the abundance of egeria since that time. Paul Champion's paper mentions the boom & bust nature of egeria and that is possibly what we see in this lake. Rotomāhana is also unusual in its water chemistry due to geothermal inputs. Recently some reductions in the plant depth limit have been noticed which is a concern.

The results of the LakeSPI show that monitoring of plants in the Rotorua Te Arawa Lakes differentiates a range of ecological conditions and providing useful comparisons with other lakes nationally. The monitored vegetation is responsive to lake events and to management initiatives, and so this investment in LakeSPI monitoring in the lakes provides a good baseline for the future.

Conclusions

- Plants reflect the ecological condition of the Rotorua Te Arawa Lakes
- Contributes to diversity of indicators for measuring integrated & holistic well-being of lakes (Te Mana o Te Wai principles)

The concept that 'Plants reflect the ecological condition of the Rotorua Te Arawa Lakes' is important. It is another contributor to the diversity of indicators for measuring integrated and holistic well-being of the lakes, the Te Mana o Te Wai principles.

Acknowledgements
Bay of Plenty Regional Council for funding LakeSPI surveys
Photos taken by the NIWA Aquatic Plants Group

QUESTIONS

Ann Green, LWQS: I noticed in your Lake Okareka graph, after the spraying the invasive weeds are increasing again, and I wonder when we have good results from the monitoring whether we keep up with those programmes? It was quite a significant drop but going up again which agrees with what Doug Leeder was saying before. How do we keep those programmes going so that we do not go back to where we were?

Mary de Winton: Yes, that is a very good point Ann. You can see the response of the Invasive Impact Index to the *hornwort* eradication where the intensive management was undertaken. When it slips back to an amenity control works programme some of those gains may be lost and it is down to decision makers as to what gains they want long term? Is it important to maintain that diversity or is there really just an amenity control works required in that lake?

Christine Caughey: Kia ora, climate change is here to stay and increasing its impacts which include climate warming. Our waters are obviously part of the warming process. What modelling has been done, if any, and how is NIWA addressing the status quo. The future is coming at us very fast with our increasing water temperature, what are the impacts.

Paul Champion: That is right, we really have to look at the future and we can be guided by species that are problematic in warmer parts of the world. New Zealand has been really proactive in identifying species, like water hyacinth and salvinia, which are major problems in countries like Australia and the United States. A lot of the species that potentially would benefit from warmer temperatures and have much greater impacts have been nipped in the bud by those proactive eradication programmes.

However, there are species like *hornwort* that could become even more problematic and a lot of management effort has been put in to stop the establishment of these species from spreading through curtailing the introduction pathways. Certainly, the deliberate introduction pathways, (humans spreading weeds) regardless of the conditions, is in the management of that transfer. We are looking at the impact of increased temperatures not only on invasive species but also those threatened species become even more threatened as the habitats available to them decline, so thank you.

Don Atkinson, LWQS: Are catfish in decline?

Michael Dedual: No, I do not think that the catfish are in decline. What I was saying is that they probably have reached their maximum population now according to our monitoring. We do not have any data to assess how much brown trout for example are controlling catfish. The only thing we know is that they eat them, that is all.

Session 3: PATHWAY STRATEGIES

SESSION CHAIR – Colin Jackson, LWQS

INTERNATIONAL EXAMPLE – PESTS IN LAKES AND MANAGEMENT STRATEGIES

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TRANSCRIPT

My colleague Nicole Cartwright is coming online through satellite imagery later and will talk about Lake Tahoe specifically. This introductory picture is an artist's rendition in the late 1800's of a water hyacinth population. This density, and even much greater, is not unusual for some of the south-eastern parts of the US, and the Sacramento-San Joaquin Delta in California and indeed many lakes worldwide. The problem is what can be done to manage these kinds of non-native aquatic weed infestations?

I will discuss a little about the 'maturity' of invasive aquatic plant management. That may sound confusing. I do not mean the 'age' of us doing it; rather I mean where are we in the 'industry' and 'technologies' of aquatic plant management and how well established are the components of successful management projects. I may get to an example of a 'Feasibility Matrix' for assessing risk, benefit and costs of various management methods and practices.

Water is very personal to all of us. However when we talk about water, whether it is the bathtub, lake or swimming pool, everyone has biological, emotional and economic

connections to water. Therefore, if we put something in water (e.g. chemicals, non-native fish or 'waste') we want to know what it is going to do to ourselves, the children or the dog, or indeed, the aquatic site ecosystem.

When we propose putting a herbicide into an aquatic system we immediately have perceptions of risk from both the (chemical) active ingredient as well as the targeted problem plants. For example, in Lake Tahoe we are not allowed to use any pesticides (which includes herbicides) whatsoever at the current time. This prohibition has driven the use of mechanical harvesting (cutting) as the primary method for aquatic weed management in the 170 acre Tahoe Keys Lagoon. This restriction is based in large part on some of the publics' - and regulatory staffs' - 'perception' of risk associated with aquatic herbicide use.

Ideally, however, science based assessment of the balance between the risks and benefits would determine if herbicides should be included in the tool kit. Following such an assessment, with full consideration of available data, a consensus could be reached among stakeholders and managers so that a feasible solution can be identified and implemented.
In New Zealand there are two herbicides that are registered whereas in the United States we have almost two dozen, and the UK has a couple. We are fortunate in the US with the range of aquatic herbicides we can use under the right circumstances, giving us more options for selective control and the ability to reduce the likelihood of developing resistance.

Some global responses to aquatic invasive plants:

- *Hydrilla verticillata* (Management in Southeastern US; **Eradication** in California, Washington state and NZ)*
- *Eichhornia crassipes* (Management **world-wide**, **Eradication** in NZ)*
- *Myriophyllum aquaticum* (Management in US, NZ, AU, FR, Europe in general)
- *Ceratophyllum demersum* (Management world-wide)
- *Salvinia molesta* (Management, US, South Africa **(some infestations eradicated**)*
- *Egeria densa* (Management, US, NZ, Brazil)
- *Elodea canadensis* **(**Management in Australia, Europe, NZ, **Eradication in Alaska)**
- Alligatorweed (**near-eradication** in California; management in Australia, NZ)*
- *Lythrum salicaria** (Management: US, NZ,)
- Other aquatic weeds in irrigation systems (Management **world-wide**)*

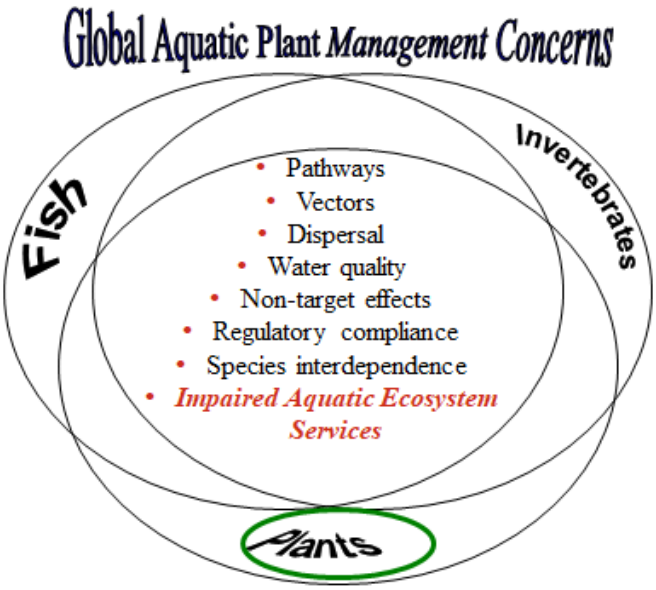
***** *Included use of biological control agents*

These are some of the global responses to aquatic invasive species internationally. South Africa represents a biological control success. A recent eradication project on *Elodea canadensis* in Alaska is still on-going but has successfully extirpated[1] populations in a few lakes. Note: we do not have any major problems with *E. canadensis* in North America where is it considered a native species. However, *E. canadensis* and hybrids (*E. canadensis* x *E. nuttalli*) are non-native and invasive in Alaska.

You can see from the species listed that wherever there is water in the world people are trying to manage, control, or eradicate aquatic plants. For example *Egeria densa* is

[1] Eradicate or destroy completely.

problematic in the US, New Zealand and even in Brazil, where it is native. In Brazil, constructed reservoirs now provide excellent 'nurseries' for this plant where it interferes with hydroelectric power production. This illustrates that just because a plant is native, it does not necessarily mean it is not a problem. By constructing habitats favouring SAV growth, even native species can cause ecological and economic impacts.

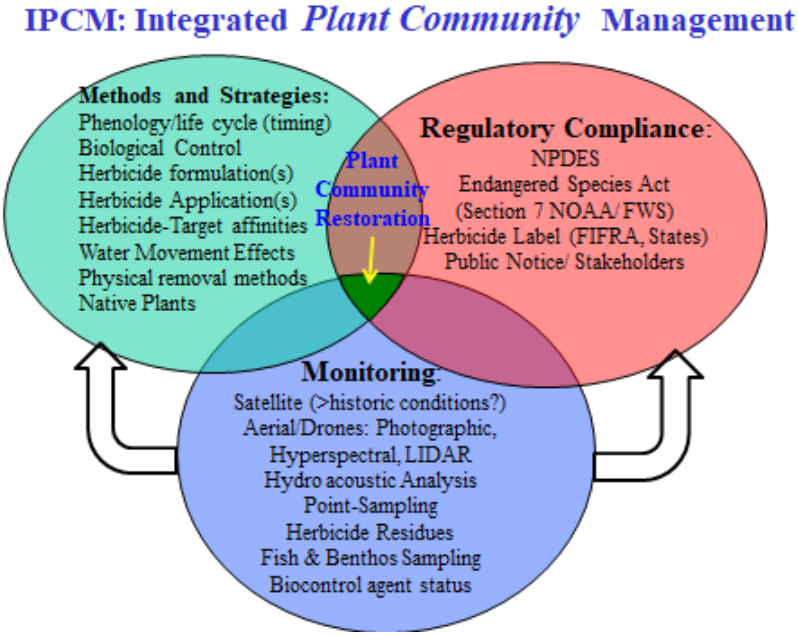


This figure summarizes typical global concerns associated with aquatic plant management, including effects on non-target plants, fish and invertebrates. These concerns all come into play so that a primary goal is minimizing effects on non-target species. Later, I will describe a new method using UV light, which may alleviate some perceived risks associated with use of aquatic herbicides.

This figure shows the common cost/risk associated with various invasion responses and management 'investments'. On the left-hand side are transport, introduction, establishment, spread and increased impacts and what it costs to manage these at different stages. This clearly shows that the most economically feasible and ecologically protective action is prevention, followed by early and effective control - preferably eradication. Unfortunately, most of the time we are already at the establishment and rapid-spread stage when actions are implemented and this is what drives up the cost while impairing the chances of successful control. Once the impact stage is reached, then increasingly more money is required just to manage a population from year to year to some 'acceptable' level. Typically, procrastination in decision making, and delay in action will result in a never-ending attempt to manage impacts. Of course, if early detection is coupled with an effective fully integrated eradication approach, this can both stop further spread and result in reduced long-term cost and impacts.

The next figure shows an example of an integrated plant community management plan for restoration using several methodologies to control invasive plants. In the left-hand green circle are the methods and strategies based on the life cycle of the plants and use of biological control, herbicide formulations and applications. For submersed plants, the

contact time and concentration of herbicides are affected by water movement. There are also some constraints and concerns when using physical removal effects such as non-selective plant removal, increased turbidity and spread by viable plant fragments. Ideally management methods are selective (either spatially or temporally) to ensure that desirable native plants are released so that the site eventually will become revegetated with beneficial plants.



However, there are regulatory constraints that must be considered. In the right hand circle are regulatory constraints and compliance requirements in the US. In the US, the National Pollutant Discharge Elimination System ('NPDES'), which was formerly used to regulate waste discharges to water from industrial operations and domestic sewage treatment facilities, was first applied in 2000 to the use of aquatic herbicides in western US states. Now an NPDES permit is required US-wide for use of aquatic herbicides. The NPDES permits typically have specific compliance protocols to follow designed to protect water quality and that is good.

Before 2000, all an applicator had to do was comply with the herbicide labelling (i.e. timing, placement, methods and rates of use and appropriate target plants). Additional permits were generally not required. Unfortunately in practice, some applicators did not follow labels exactly. (Do you always read the label, the fine print on pharmaceutical products?). Now, nearly 20 years later, NPDES permits and related compliance training are routine. Although this has added costs to aquatic plant and algae control, it has no doubt also contributed to improved expertise and professional levels in the field.

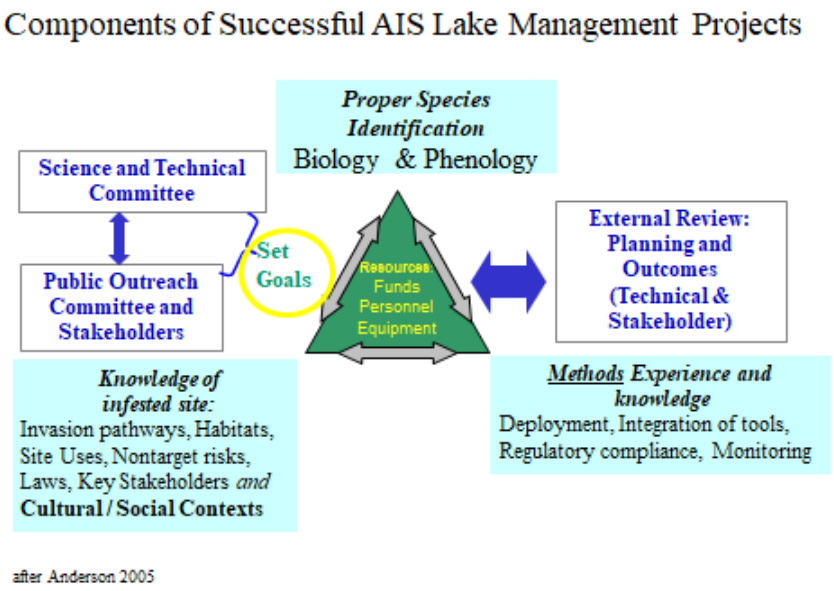
One problem still remains: Each state, and indeed, different regulatory bodies within a state can set different, often more stringent requirements than those outlined at the federal US-EPA level. For example, as I mentioned in the opening talk, the Lahontan Regional Water Quality Control Board, which sets 'discharge' compliance requirements for Lake Tahoe, has to date prohibited entirely the use of aquatic herbicides.

In the same figure, the blue circle focuses on monitoring, which is absolutely critical for two reasons. One is for NPDES compliance, the second is to ensure efficacy. Aquatic herbicide products have to be in contact with the target plant for a certain period of time at

a certain concentration in order to work. Therefore it is essential to know what the concentration is in the field, and if it persists long enough to be effective. This type of monitoring typically requires sequential water sampling and analysis, or use of dyes such as Rhodamine WT to understand the potential for dilution, distribution and movement of the herbicide.

I have included in monitoring examples, the use of satellites and drones and hyperspectral methodologies. Some of these methods are for monitoring the status of target species and are fairly new and some have been used for decades. We often use a combination of hydro acoustic ('sonar') type surveillance methods coupled with physical 'point sampling' to see what species are present on that particular body of water, both pre- and post management actions. Unfortunately fish and benthic organism sampling is not routinely done. Monitoring non-target impacts on the fisheries populations and invertebrates (primarily in the benthic environment) is very useful, especially for new sites and where sensitive (protected) species occur. For biological-control approaches, you need to monitor the status of the bio-control agents (for example, populations size, quality and reproductive success) as well as their impacts on the target plants.

Regardless of the suite of methods and strategies employed, proper monitoring and follow-up adjustments are critical for successful management of aquatic plants, whether it is for control to minimize impacts, or for total eradication. Eventually, if done correctly, there is higher probability of achieving a restored community.



This figure summarizes concepts and approaches for responding to invasive species. In all my years of working both within the US and internationally, I have found that this model, incorporating the components of successful lake management projects of aquatic invasive species pretty well describes the needed components. Starting with 'Resources' in the centre of the figure, without adequate funds, experienced personnel and equipment, nothing will happen. There may be a nice theory and discussion about what *should* be done but nothing will happen without these resources because that is the heart of the whole process. At the top of the figure is the proper identification of the pest species and an understanding of its biology and phenology: how fast does it grow, how does it reproduce, how does it spread, when is optimal time for specific actions?

On the bottom right-hand side of the figure are the methods, experience coupled with knowledge to use this information. It is essential to have trained personnel in the field. As an analogy, we can compare this approach to what we have come to expect for a rapid response to a fire. All these components are in a fire protection response mode: The skill set, resources and the equipment, understanding what type of fire (i.e. type of fuel), and the communication needed. Those men and women who are out there fighting fires as a team know what fires are like, how to respond and how to monitor it all. It takes only a few minutes to deploy firefighters from their 'stations'. We do not have that kind of response structure yet for aquatic invasive species.

The lower left of the figure is the knowledge of the infested site: What constraints are there? Where does the water come from and go? What is going to dilute the system if herbicides are applied? Who uses the aquatic site? Are there people who need to be contacted? Is it used for potable water? What are the cultural and social contexts?

On the top left-hand side is a science and technical committee and public outreach committee, which are also critical. For the last 20 years we have been using this model at Lake Tahoe with some success and almost every project that has been successful has this component of external public input and public outreach.

On the other side of that figure is an external review of the planning and outcomes. This has been critical with the projects that I have worked on for two reasons. One is that if you get too internalised you do not see the trees for the forest. The second point is that an external panel review of the planning process, as well as the results, gives credibility and may also open up other opportunities. One of the best examples is the eradication of a marine algae (*Caulerpa taxifolia*) we accomplished in San Diego in southern California. We had an international external review of our multi-agency planned project. There were 7 panellists from outside the US who gave a 60% chance of success in eradication of this particular species of marine algae. However, we were successful but the panel also came up with good ideas about how to monitor and what to look for.

The success in this marine alga eradication resulted from the presence of all the components shown in this figure. This kind of model, or some modification of it, covers everything needed for a successfully managed aquatic invasive species management/eradication project.

Note that I highlighted the need to set goals because that is sometimes missing: **clear, precise, well defined goals of the project**. If the goal is unknown or poorly defined, how do you know what you are after or when you're making progress? It is surprising how many times you find that project objectives are listed from '1 to 10' but with no clear goal at the end!

With the background understanding the need for resources, strategies and approaches, what are the methods or tools that have been used? The table below summarizes methods and tools that have been used successfully in the US and globally. The tools must fit the scale, target plants and uses of the aquatic site that is infested, and ultimately, achieve the goals of the project.

Aquatic plant management tools typically used in integrated projects:

- *Mandatory vessel inspections, decontamination, barriers* (curtains, bubble barriers, temporary bulkheads (e.g. during eradication actions)

These tool are primarily for Prevention and Containment

- *Physical/Mechanical:* (Removal or 'cover & kill'; reduction in biomass)
    - Dredging, Rotovation, Diver /hand removal, Bottom barriers of various types (synthetic, jute)
    - Harvesting/Cutting: (Various powered devices): Risk of spreading fragments; can stimulate re-growth

- *Herbicides:* Systemic, Contact, post/pre-emergent
    - Liquid, pelletized, 'precision placement', sediment -incorporated (e.g. drawdown/dewatering);
    - Containment to localize (bottom barriers, curtains, bubble systems)

- *Biological:* host-specific or 'general' (e.g. insects are selected to be host-specific; grass carp are 'generalist' herbivores)

- *New and Potential Tools:*
    - *ProcellaCOR (systemic herbicide):* use at ultra-low rates (few ppb)
    - *UV-C light* (limited by high turbidity): selectivity unknown; non-target effects unknown; UV-generated compounds unknown; similar to contact herbicide); preliminary efficacy studies in clear water are promising.
    - *Microbial community manipulations*: Poorly understood or researched; may affect nutrient availability or have direct inhibitory effects on target plants

I wanted to include some brief comments on these tools. Regarding prevention of introductions and containing new infestations, some states in the US have effective vessel inspections which you will hear about from Nicole at Lake Tahoe. (Note: Lake Tahoe spans California and Nevada so the inspections are really multistate focused.) In contrast, there are no boat-launch inspections in the Sacramento-San Joaquin Delta, a massive tidal estuary that supports endangered fish and which provides water to over 25 million Californians!

All the physical and mechanical methods listed above have been tried everywhere in the world and can work, but most do not fit everywhere. Lake Tahoe is a good example where it was suggested that we rotovate the Tahoe Keys Marina to remove invasive plants. But the likely damage to the benthos, the organism community that live in and on the sediment, would be huge. Turbidity is also a problem with rotovating and this method spreads plant propagules when disturbed. This tool has been used in localized areas where fragments are contained, such as in swimming areas in some Canadian lakes.

Aquatic herbicides used in the US encompass a range of active ingredients, formulations and a spectrum selectivity for target plants species. There are all kinds of herbicides and it is important to understand what the herbicide does in the field, how it affects the target plants and how it may affect the non-target plants and species you are also trying to protect. Herbicide can be liquid or pelletized (granular). The key is to contain the treatment 'zone' just to the local area where the target plants are located. This is more readily done now than in the past because of modern methods and materials, such as GPS-referenced precision placement, accurate pumping and metering systems and rapid analysis of water for the level of active ingredients - often within 24 to 48 hours after treatments.

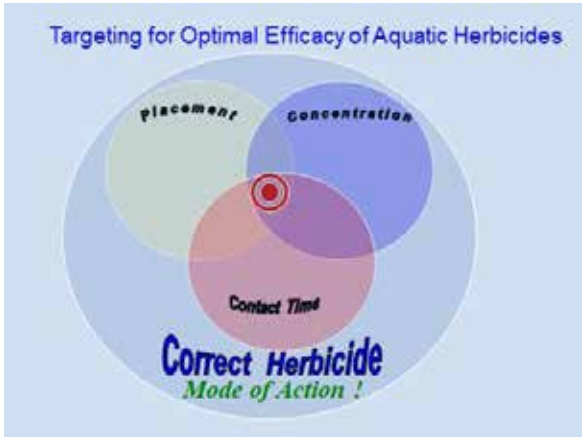
Biological control is best used for widespread infestations and where host specific agents (insects, or pathogens) can be introduced. That means the agent will only feed and reproduce on the target species. However, there are also some successes with non-

specific agents such as grass carp, for example, which can and will consume most living aquatic plants!

Here is an example of physical/mechanical removal of South American spongeplant both in lakes and irrigation areas in California. That plant was first detected in 2007 and within 2 years had infested a lot of the canals and areas in the riverine systems including the Sacramento-San Joaquin Delta.

This shows harvesting submersed aquatic plants in Lake Tahoe Keys lagoons, which is the primary management tool used, as well as some minor use of bottom barriers. This type of harvesting unfortunately creates huge numbers of fragments that are viable. The 3 dominant target plants there are Coontail, (*Ceratophyllum demersum*, known in New Zealand as Hornwort) Eurasian watermilfoil (*Myriophyllum spicatum*), curlyleaf pondweed (*Potamogeton crispus*).

The cost, to manage plants in about 170 acres, is over US$350,000 a year. This cost supports running 3 to 4 harvesters, work boats and a crew of 6 or 8 depending on the season. It is expensive, over US$2,000 per acre, and these harvesters break down, and are non-selective, so everything is taken out, including desirable native species such as *Elodea canadensis* and Leafy pondweed (*Potamogeton foliosus*). Thus the prohibition at Lake Tahoe against using EPA - and California - approved aquatic herbicides has resulted in the spread of invasive plants from the lagoons to Lake Tahoe proper and has also reduced the likelihood that existing native plants will become re-established.

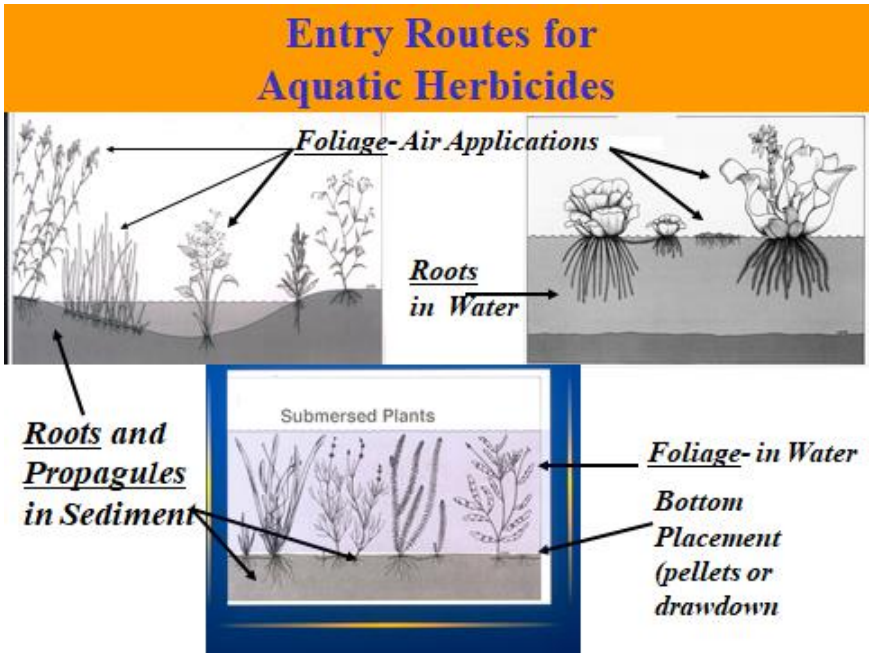


This figure depicts what is required for optimal efficacy of herbicides:

(1) the right placement
(2) the correct concentration
(3) correct (sufficient) contact time
(4) importantly, the correct herbicide

The correct herbicide requires knowledge of the mode of action. In other words, how does a herbicide work? Is it going to work on the target plant? Is it selective? Will there be resistance if used for 5-10 years?

This is important information to understand in order to develop an effective management strategy.



This diagram illustrates the various entry routes for aquatic herbicides to get into submersed plants, which are the primary type of plants that are problematic in the Rotorua Lakes. On the right hand side the foliage uptake is through contact of herbicides in the water column, or from pellets that can be placed on, or incorporated in, the sediment. If water is removed out of a system, (as with canals and some lakes in the US), then a soil active herbicide can be applied. This way the herbicide is localised where the plants are and when water is re-introduced, and as the plants begin to grow, they are affected by the herbicide.

Using this approach, the water column has not been treated at all, just the sediment where the target plants are. These methods of application really have a huge impact on where that herbicide goes, how much monitoring is needed, and how much herbicide has to be used to achieve the desired efficacy.

The following list is of currently approved **US EPA Registered Aquatic Herbicides.** The product names and year in **bold** show those approved in the past 12 years. Note that only two are approved for used in New Zealand: diquat and endothall for macrophyte control.

Aquatic herbicides registered by US EPA:

- Acrolein (Magnacide-H)
- 2,4-D (Weedar 64, others)
- Endothall (Aquathol-K, **Cascade**)
- Copper elemental & Chelates
- Diquat Dibromide (Reward)
- Gylphosate (Rodeo, Aquamaster, other product names, etc.)
- Fluridone (Sonar, multiple formulations)
- Trichlopyr (Renovate 3) (2003)
- Imazapyr (Habitat) (2003)
- **Penoxsulam (Galleon) (2007)**
- **Imazamox (Clearcast) (2008)**
- **Carfentrazone-ethyl (Stingray) (2007)**
- **Bispyribac sodium (Tradewind) (2011)**

- **Flumioxazin (Clipper) (2011)**
- **Quinclorac (2007)**
- **Florpyrauzifen-benzyl (2019) (ProcellaCOR)**

At the bottom of the list is ProcellaCOR, fully registered this year and partially last year in some of the US states. It is an interesting herbicide, used at very low rates: typically 2 to 10 parts per billion (ppb). It has a fairly fast uptake in the plants and breaks down within a few days when pH is over 7.5, so it has a very short half-life. It is a systemic herbicide that moves through the plant. We are just beginning to look at this. The first field operations with this were last year and there have been more this year (2019).

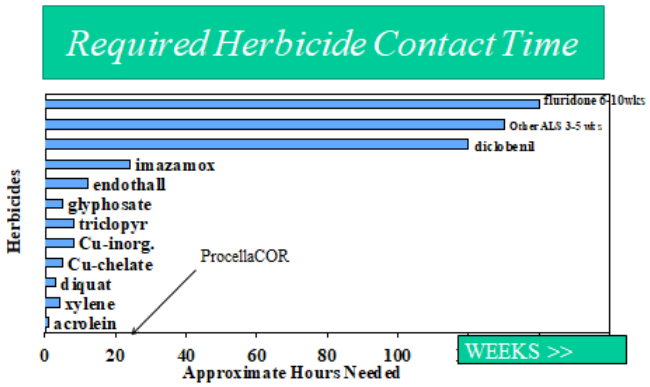
Characteristics of florpyrauxifin-benzil (ProcellaCOR):

New (2017) systemic herbicide:
Approved by US EPA; approved in some US states 2019)
ProcellaCOR EC (SePro Corp) (florpyrauxafin- benzyl)
(Group 4/growth regulator)

Main Charactertistics:

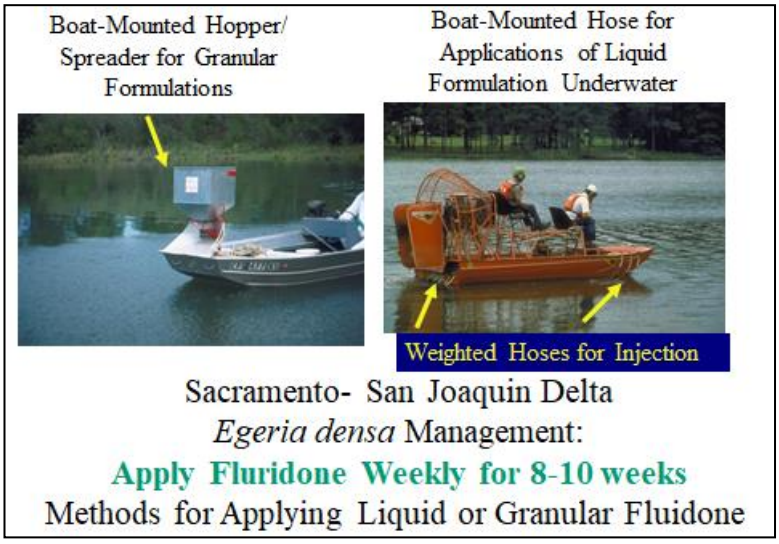
- Efficacy on *Myriophyllum* spp. *and* Hydrilla
- Efficacy on *Nymphoides cristata*), crested floating heart
- Efficacy on *Eichhornia crassipes*
- Extremely low rates: (2-10+) ppb
  NOTE: USE of new dose metric: 'PDU' = Prescription Dose Units (one PDU contains 3.17oz product)/ used on volume dose basis.
- Rapid Uptake in taret plants
- degradation (pH dependent: very rapid at >pH 8 (several **hours to days)**
- Few use restrictions
- Some selectivity (i.e. *None or minimal* effects of some native plants)
- **Highly managed product stewardship**
  >>>>ProcellaCOR is still in very early in stages in use/rate/target & combination development

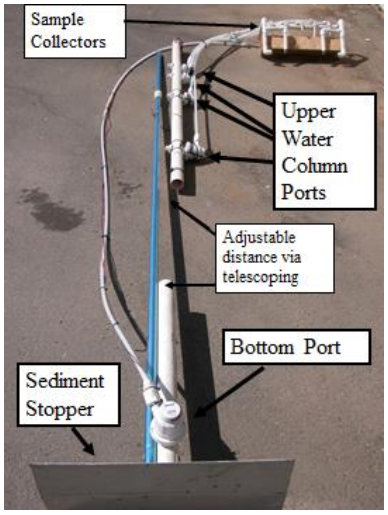
It is the first new active ingredient registered in the last 15 to 20 years and a brand new one that wasn't first used in terrestrial systems. It is a major breakthrough and very effective on *Myriophyllum* species, *Hydrilla* verticillata, and some other plant species as well.



This figure shows the required herbicide contact time with the 'target' plant. The far left is the shortest and those products on the right need contact for weeks which means multiple applications or some control release formulation to extend contact time. Diquat, third from the bottom, has a very short contact time. Acrolein is a biocide that works within hours, but as it is a general biocide so it kills everything and is rarely applied except for water conveyance systems used only for irrigation. Endothall also has a fairly short contact time required. ProcellaCOR is shown requiring 24 to maybe 35 hours depending on the concentration, and probably even shorter in some cases.

These two pictures show some of the different methods used for aquatic herbicide applications. On the left-hand side is a boat-mounted hopper and spreader for a pelleted applications. These are formulations that are small granuals or pellets. On the right-hand side is a boat-mounted system with drop hoses that can apply herbicide down to the plants usually located on the bottom instead of just general exposure to the whole water column.





We do a lot of monitoring and this type of equipment enables us to look at the movement of aquatic herbicide in the water column. It is a PVC and aluminium tube frame with tubing for collection of water samples at five different water depths using four 12 volt bilge-type pumps. The samples are labelled and tracked using 'Chain of Custody' forms and sent to the certified laboratories to analyse the level of active ingredients at any given time. The flat sediment 'stopper' at the bottom is used to prevent the apparatus from plunging into soft, unconsolidated sediments.

The importance of employing integrated control technologies

Because aquatic sites are so varied and the array of target plants is highly variable, management approaches need to be tailored to those conditions. The tools listed below should be considered as a fully integrated management approach. Not all methods are appropriate to a given site, but these control technologies are not just herbicides, and we have looked at these options quite a bit. For example, there is a lot of work being done on bio-control, followed up by aquatic herbicides, or using herbicides as initial methods followed by physical removal of small re-growth sites. We have also looked at water movement effects using dye and I will show you the results shortly. There are opportunities for using physical control to begin with and then maintaining it with low levels of aquatic herbicides. So, there are lots of combinations; however, if you take herbicides off the table, it limits what can be done, particularly to optimize rapid responses and selectivity.

Typical methods considered for use in integrated management:

Phenology/life cycle (optimize timing of management actions)

Nutrient management (e.g. adjacent watershed/ landscape inputs)
Biological Control (host-specific or general?)
Herbicide formulations (liquid, pelleted, controlled-release)
Herbicide Application/Placement(s) (water column, bottom zones, sediments)
Herbicide-Target affinities (selectiveness for target plants)
Water Movement Effects (containment? physical placement)
Physical removal methods (feasibilities? how to minimize release of fragments?)
Promotion of Native Plants (selectivity; desirable fish/invertebrate/waterfowl habitat?

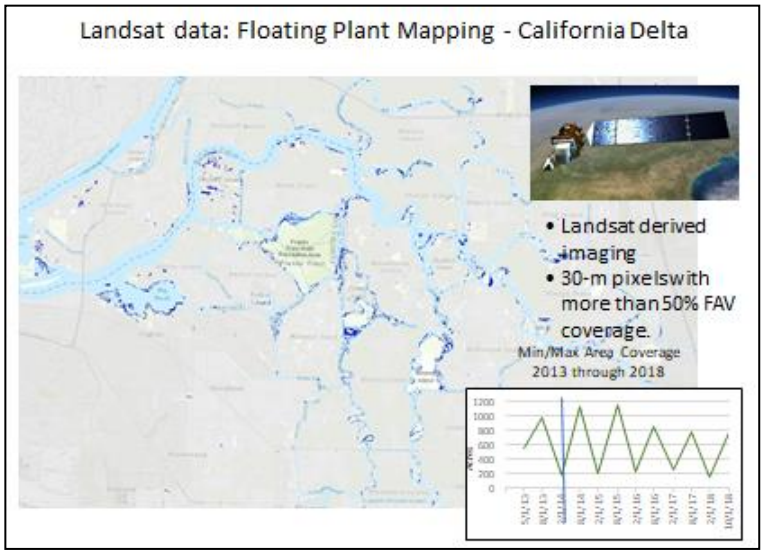
Importance of monitoring technologies and strategies

The most commonly used methods for monitoring management effectiveness are listed below. Depending on the aquatic site and goals of management actions, usually two or more methods will be needed. In fact the NPDES permit I mentioned earlier requires a list of all the monitoring protocols used, the frequency of use, and who is going to do the laboratory analysis; it is quite detailed. This includes not only herbicide residue sampling and analyses when they are used, but also general water quality variables as well.

Typical management monitoring technologies:

- Rapid herbicide assays (24-48 hour)
- Remote controlled sensing submersibles
- GPS-linked Hydroacoustic analysis
- GPS-linked videography (in clear water)
- Precision flow and herbicide dispersal modeling:
  Automatic Doppler Velocity Instruments ('ADP's)
  Tracer dye (e.g. Rhodamine WT)
- *In-situ*, physical plant condition & response assessments (point sampling)
- Bioassays using explants and surrogates (i.e. typically laboratory bioassay)

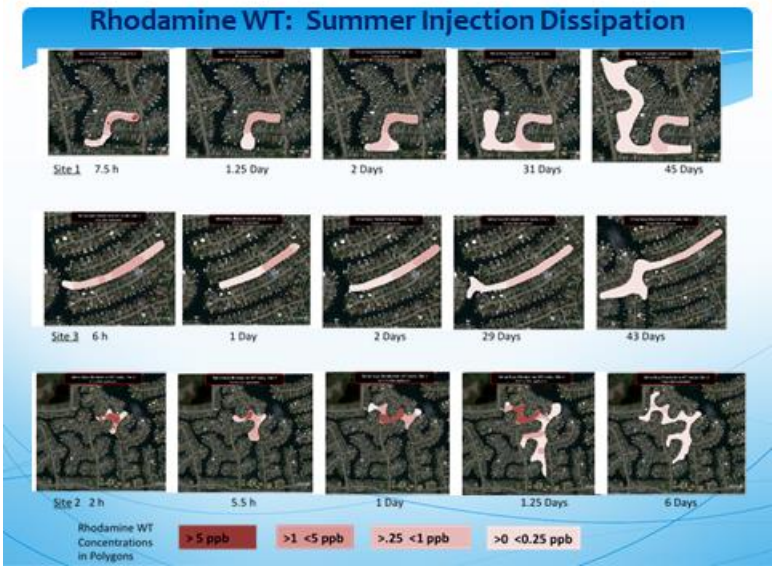
This figure summarizes most types of monitoring associated with aquatic plants management projects. We are starting to use Landsat satellite data. The only disadvantage is that though it flys over many times per week, it has a very low resolution of about 3 metres by 3 metres so there is not a lot of detail. But we are using this in the Sacramento-San Joaquin Delta to look at long-term trends in floating plant populations. The graph shows data from May 2013 to October 2018 and the pattern coverage of water hyacinth. NASA has been cooperating with California researchers and managers in looking at this kind of approach for the last 2 or 3 years now and it could be good for large scale assessments of management progress.



I am going to focus a little bit now on this tracer dye study. It is a very useful way to approximate what happens in that water column when a dissolved material like herbicide is applied. The dye is in effect a surrogate for the herbicide.

How do we know what is happening to a herbicide put in the water column? Does it move vertically, horizontally, what happens in a diel (daily) period, does the water column turn over? We use a Rhodamine WT dye to detect this. It is injected at very low concentrations (ca. 10 parts per billion) and detected with a fluorimeter which also has a very good detection capacity (parts per trillion).

For example, in the Tahoe Keys Marina, which I mentioned earlier, we put the dye in the purple areas shown on the figure to see how long the dye would stay where it was applied. Keep in mind that currently, herbicides are prohibited for use in Lake Tahoe, including this marina. The purpose of this study was to use the dye to estimate what would happen if we did utilize herbicides. We injected the dye in the system just as we would a liquid herbicide and then followed up that injection with monitoring with the fluorimeter on a continuous basis.



The results are presented in this figure. The darker the colour, the more dye, and on the top left-hand side it is 7½ hours post application to 45 days. It indicates that there is little movement out of that treated cove until between 2 weeks and a month later particularly in Site 3 where it stayed almost 30 days. The bottom one, Site 2, is a more open site and there is definite movement out of the site within 2 hours up to about 6 days.

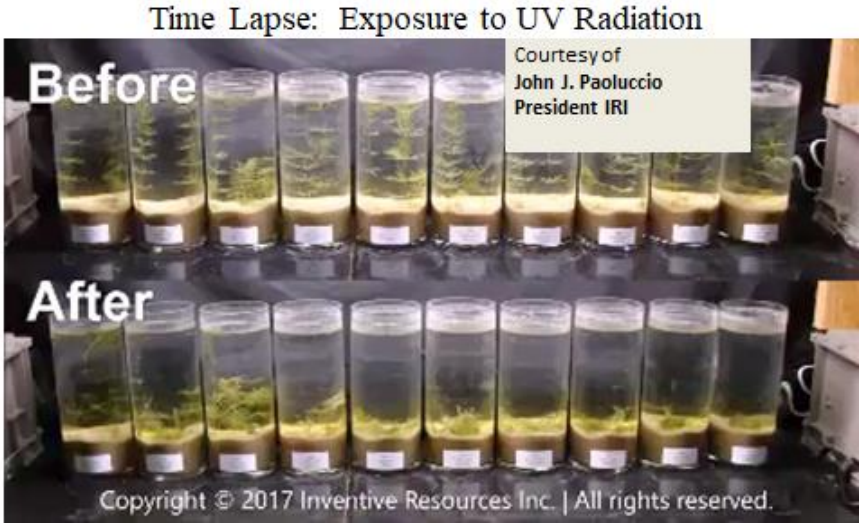
This suggests that if we were to use liquid herbicide in those more 'dead-end' coves it would probably be retained there for 2 to 5 weeks without much dilution or movement, which gives plenty of time for contact and also for dissipation and degradation of that herbicide. These are very powerful and relatively inexpensive methods to provide understanding what would happen in the field if

we actually used a herbicide. I believe that there is opportunity for this in some of the lakes here in New Zealand/ Rotorua lakes to tailor more effectively the use of Endothall for example.

A new potential tool for aquatic plant control?

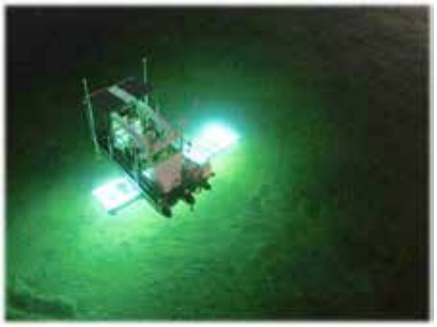
Perhaps one of the most exciting new methods being explored now is the use of ultra violet irradiance ('UV-C' light). This is the UV approach that John Paoluccio, an engineer in California, invented as a system using LED/UV C lights that emit light at a certain wave length which he found in the laboratory would kill aquatic plants.

Although UV light has been used for years for sterilization, control of algae, and generally killing germs and pathogens. UV-C light, which is a non-chemical physical treatment method leaves no residue, and can simply be turned on and off and localized. John's approach was to treat where and when you want, for such things as plants near drinking water intake pipes, at any time of year, with no residual effects and avoiding native plants and sensitive areas. His approach is that it is also better to treat plants when young, before they mature and drop seeds or fragments, which is a standard strategy regardless of methods. It may also cost less than other non-chemical methods, but economics still need refining.

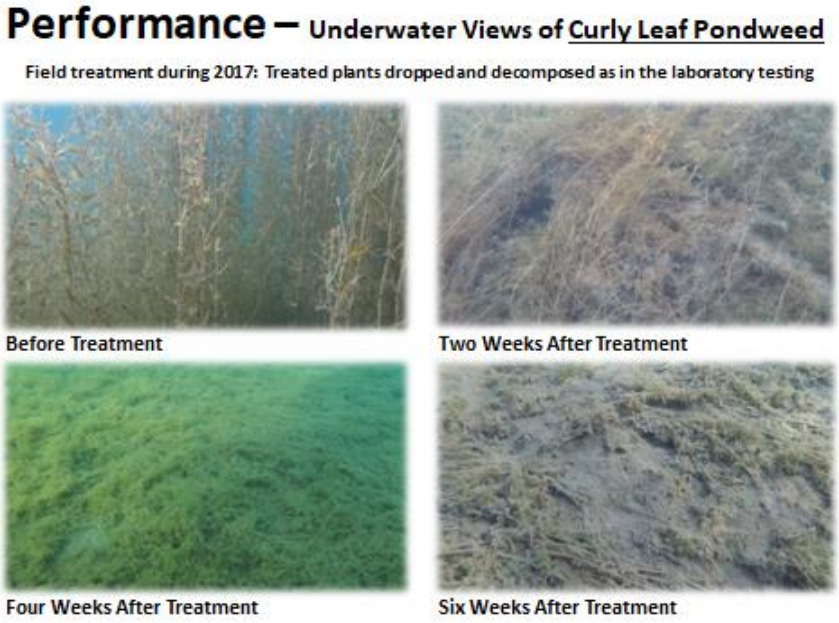


For example, this is a time-lapse video John produced in 2017 showing plants growing in his laboratory. '*In this time lapse video clip under water plants can be observed growing in individual monitored tanks. Sample A is our control or our untreated plant. Watch how the plants grow approximately one inch per day. The camera is recording a frame every 30 minutes (flash). Samples B through J were all exposed for different treatment times. Observe how the treated plants stop growing as soon as they are treated with the UVC light unit. They all begin to drop approximately 1 to 2 weeks after being treated depending on water temperature'.*

John Paoluccio shifted to field trials in 2017 in a small marina in Lake Tahoe. The example shows an offshore application at night. There is an array of UV emitting diodes that expose the plants on the bottom. John found that anywhere from 5 to 10 minutes exposure was enough at any given site.



Below shows some of the results. On the left-hand side is the before treatment of curlyleaf pondweed and 2 weeks later on the right upper side, then 4 weeks on the bottom left and 6 weeks on the bottom right. These were good results in the field.



The problem is we do not know about non-targeted effects or what it does to invertebrates that are associated with those plants. That will require further research. John does have a system where he 'frightens' the fish out of the way with noise and flashing lights before he starts the UV exposure, but there are a lot of unknowns. Another question is cost. Right now, the cost per acre for doing this is probably in the neighbourhood > $5000 because of the small scale that he can do right now. The other limitation is the time it takes to expose an acre: a few to several days, depending upon the growth stage. In contrast, typical herbicides can be applied in a few minutes per acre.

Critical Challenges for Management of Aquatic Invasive Species in Lakes

I want to close my talk by underscoring some challenges that I believe are important for any kind of management, particularly when considering putting an aquatic herbicide into a waterway. The challenges derive primarily from public perception of 'risk', and their knowledge about what true risk is, as well as what stakeholders believe to be true, whether it is true or not. Perceptions are powerful and can impact the ability to implement

effective management actions. These concepts are summarized below, which include not only risk components but effective 'management structural' requirements.

1. *Address Risk Perception and Infrastructure Components*

- Public Perception and Knowledge
  Disconnect of Risk and Benefit - Some stakeholder 'Beliefs'?
- Rapid Response - Deployment Teams (equivalent to 'fire station' staff)
- Climate Change effects on aquatic ecosystems
  (plants, fish, inverts, ecosystem services)
- Resources to sustain management (What are sources? Who pays?)
- Preventing new/reintroductions (Retail sales, aquarium/pet retailers, etc.)

2. *Implementing Integrative and Consensus-Driven Approaches*

- Create interdisciplinary teams
- Combine and integrate methods for maximum efficacy and minimum non-target effects
- Consult with stakeholders at *EVERY* phase
- Promote flexibility and adapt to changes
- Invite outside reviews and assessments
- Readjust actions based on reviews (in other words: 'Adaptive Management')

In summary these approaches have been successful in achieving aquatic plant management (and eradication) goals in several types of aquatic environments ranging from lakes and reservoirs to streams, irrigation systems, rivers and even some tidal-influenced estuaries.

Thanks very much for your time.

ACKNOWLEDGEMENTS

Some contents of this presentation and written summary were in part provided by the following individuals and organizations with much appreciation.

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Tahoe Keys Property Owners Association (TKPOA)
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Earth Science Division, Biospheric Science Branch
National Aeronautics and Space Administration (NASA)
Biospheric Research Branch, Ames Research Centre,
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INTERNATIONAL EXAMPLE – LAKE TAHOE

Nicole Cartwright
Tahoe Resource Conservation District (RCD), California
Via video link
ncartwright@tahoercd.org

Nicole has served as the Executive Director for the Tahoe Resource Conservation District since 2017. Previously she was the Aquatic Invasive Species Program Manager for over 10 years developing and implementing programmes including aquatic invasive species control, watercraft inspections and public education. Nicole received a Bachelor of Science in Biology from California State University, Chico and had her first exposure to invasive species while working with yellow jacket eradication in Hawaii National Parks with the US Geological Survey. Living in South Lake Tahoe, Nicole enjoys playing in her 'backyard', biking, backpacking, snowboarding, kayaking and spending time with her friends, family and dogs.

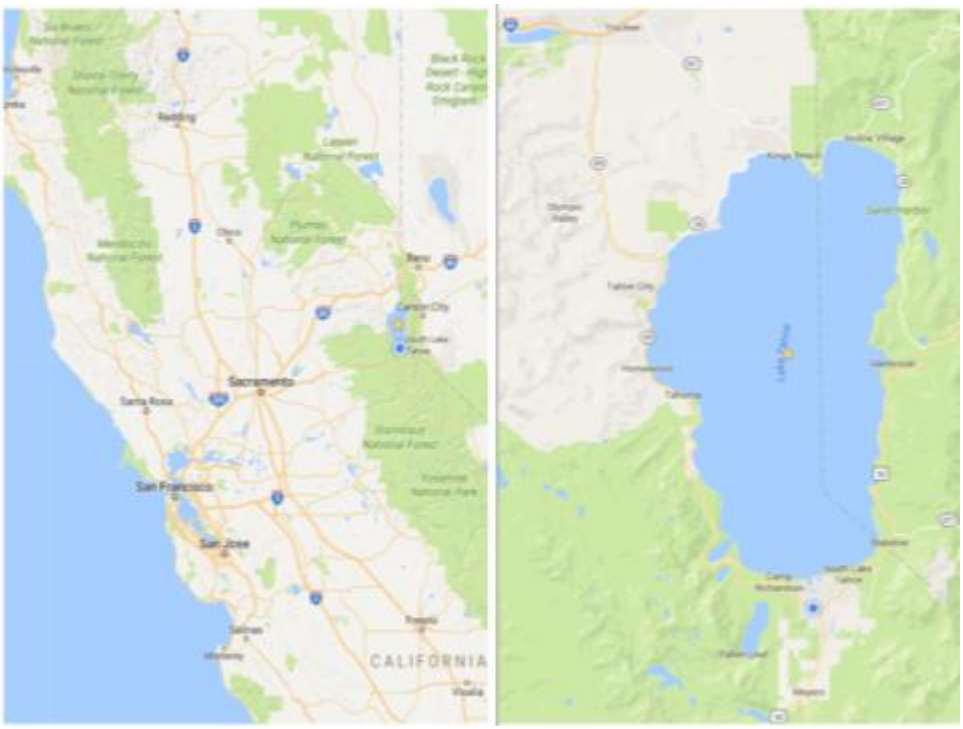
TRANSCRIPT

Hello everybody, thank you so much for having me. Lars Anderson summarised the control strategies which I also included in my presentation because my talk about our prevention programme needs the context of the larger management strategy and the partnerships that led to our very successful boat inspection programme.

I will give a background to the development and history of how we got to where we are in Lake Tahoe and touch briefly on control and monitoring. The majority of my time will be about our boat certification programme and the challenges and achievements.

I will use the word 'we', and I do not mean Tahoe RCD, I include the larger group of over 40 agencies, private businesses, stakeholders in the community,

non-profits; it has taken an army to get where we are. Tahoe RCD does serve as the co-chair for this larger committee, and the lead implementer for both prevention and control, but we would not be successful without all of our partners.



To give an orientation of where I am, Lake Tahoe is on the border of northern California and northern Nevada. The Tahoe Basin includes Lake Tahoe which is the largest body of water there**.** But it also includes Echo Lake and Fallen Leaf Lake which are two smaller water bodies. The Tahoe Basin is comprised of 5 different counties, 2 states and 1 incorporated city. We have also stretched our expertise a little outside of the Tahoe Basin into our regional partnership, which includes Donner Lake, a small lake up on the right-hand side off Highway 80, in the town of Truckee.

Lake Tahoe's elevation is about 6,000 feet, holding about 40 trillion gallons of water that could cover the whole state in about 14 inches of water, (about 0.3 metres). The entire state of California is about 264,000 square kilometres. The lake is very deep with an average depth of 1,000 feet, it is 22 miles long and 12 miles wide.

What is the Tahoe Resource Conservation District?

We are a local sector of government, considered a special district similar to the way our fire and water utility districts are set up. We are non-regulatory and locally governed with a 5-member board appointed by the El Dorado County. We are funded through a diverse background of sources, state, federal, local and private, and I believe that is why we have such a great partnership. This gives us the ability to partner with a variety of different people and be nimble and adaptive. For example we partnered with John Paoluccio, the inventor/engineer that Lars mentioned, adapting to different needs as long as we stay focused protecting all our natural resources.

We do have multiple existing aquatic invasive species in Lake Tahoe, both plant and warm water fish species. We also have one mollusc, the Asian clam, and bull frogs. We are fighting to keep those species at bay and trying to keep out a whole slew of other things with the prevention programme, even a New Zealand mudsnail and the Quagga and Zebra mussel from the Black and Caspian Seas, now widespread across the US. Spiny water flea and lots of other invasive species are quickly approaching.

How did this all get started?

In 2007 there was a scare when Lake Mead, very close to us down in southern Nevada, became infested with mussels, the first time that mussels had made it out west. Our partners all quickly sprung to action and there were letters of commitment from over 20 organisations which then jointly formed the Lake Tahoe Aquatic Invasive Species (AIS) Coordination Committee, set up to provide guidance, financial support, governance, project and funding prioritisation, and it continues to guide all of our efforts for AIS.

By 2009, only a year and a half later, we had created a management plan outlining all the priorities for control, prevention, early detection and rapid response. This plan has been endorsed by the California and Nevada governors and the Tahoe Regional Planning Agency, who is responsible for making sure that this management plan is implemented.

One of our Founding Fathers, Ben Franklin, said many, many years ago, that, ‘An ounce of prevention is worth a pound of cure’. We found through creating the management plan that the economic impact of any new introduction of invasive species in our area was estimated at about $22million per year and investing our money in control and prevention was worth every penny.

In 2015 an AIS Implementation Plan was developed prioritising species into three tiers. In 2019 (not quite finalised) the newly created Action Agenda is a 10 year plan that aggressively treats and controls aquatic invasive species by:

- preventing new introductions of AIS
- limiting the spread of existing AIS
- extirpate existing AIS populations
- Abate harmful ecological, economic, social and public health impacts resulting from AIS

It gives priority to specific sites and puts dollar figures on each project. It suggests that the total plan, would cost about $A7.4 million a year to combat, including the Tahoe Keys which has 173 acres of invasive plants, fish and clams and.

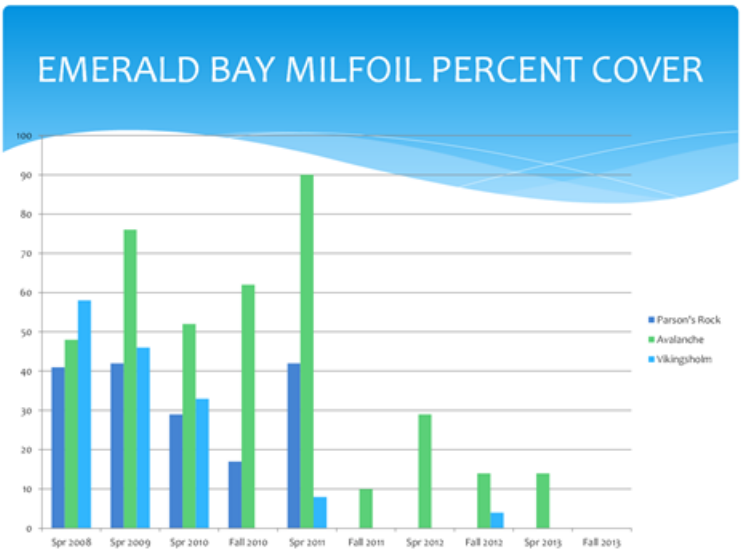
Case Study: Emerald Bay Plant Control

In Lake Tahoe we are not allowed to use herbicides but potentially a couple of years away from using them as a management technique. However we have had some successes with non-chemical methods. This photo is of Emerald Bay, an iconic location and a state park where thousands of boaters go on the lake. There is lots of wildlife and it is a really beautiful place to visit.

We first started this project in 2010 when there was an infestation of Milfoil over 6 acres at its highest peak. We started using 10 x 40-foot bottom barriers seen below. We also used diver assisted suction removal, hand pulling plants out of fallen logs and in tight crevices where the barriers could not fit. (Below left)

Below is a visual representation of its success. In 2006 on the left, it was a fully infested area, algae also growing all over the plants. By 2013 you can see how clear and clean that water is. Again a graphical representation of its success, the 3 colours representing the different infested areas within Emerald Bay. It clearly shows the decline to almost nothing in 2013.

We continue to do surveillance monitoring and spot treatments when needed.



Other Control Techniques

Lars also talked about some of the other techniques. There is a great report summarising our UV Light pilot project on our website, www.TahoeRCD.org.

We are also getting closer to a programmatic approach using electroshocking for our invasive fish. Hopefully in 2020 we will start that.

This was also a pilot project for control of Asian clams using non-permeable bottom barriers that do not allow oxygen to flow back and forth and act like a pond liner. The project was to kill clams by suffocation and was very successful but because it uses large barges, heavy machinery and lots of divers its cost is prohibitive.

Monitoring

No programme would be successful without monitoring to ensure our prevention efforts are working and to monitor movements or changes in existing species. Lake wide monitoring for existing species occurs through a coordinated effort and through a citizen science programme which is called *Eyes on The Lake* run by one of our local non-profits. It trains people to identify different species and as they are out and about enjoying the waters, swimming, kayaking, boating, they can also report on anything that they see from fragments of plants to clam shells on the beach. Citizen scientists have found new infested sites over the years and we have been able to come in and treat immediately.

This picture shows how we monitor monthly during the boating season (May through September) for new introductions of mussels in the form of veligers, which are the microscopic larval stage of the muscles.

Prevention

This programme would not be successful without prevention or without both control and monitoring. Our prevention programme was set up to:

- Protect Lake Tahoe, Donner, Echo and Fallen Leaf Lake from any new infestations of harmful aquatic plants and animals
- Implement the local ordinance on invasive species prevention
- Educate boaters and visitors on different prevention techniques.

The local ordinance was created in 2008 through the Tahoe Regional Planning Agency which is our bi-state regulatory agency. That ordinance says all boats must be inspected prior to entry. A lot of things come with that and how we crafted our programme. All the ramps around the lake have gates and hours of operation and that is the biggest leverage in being successful with this programme. (https://youtu.be/oZ82pxn9HBs)

We have learned a lot over the years. When I first started here at the Tahoe RCD I was an AmeriCorps member, which is a volunteer. I was out on the boat ramps interviewing boaters to see if they knew about aquatic invasive species and if they had heard about the devastation that these mussels were making across the US. We changed from being a voluntary inspection programme to being mandatory and everybody paying per inspection. We moved off the ramps and now have roadside inspection stations. We have reduced costs, created efficiencies and a lot of changes over the years.

Programme Evolution

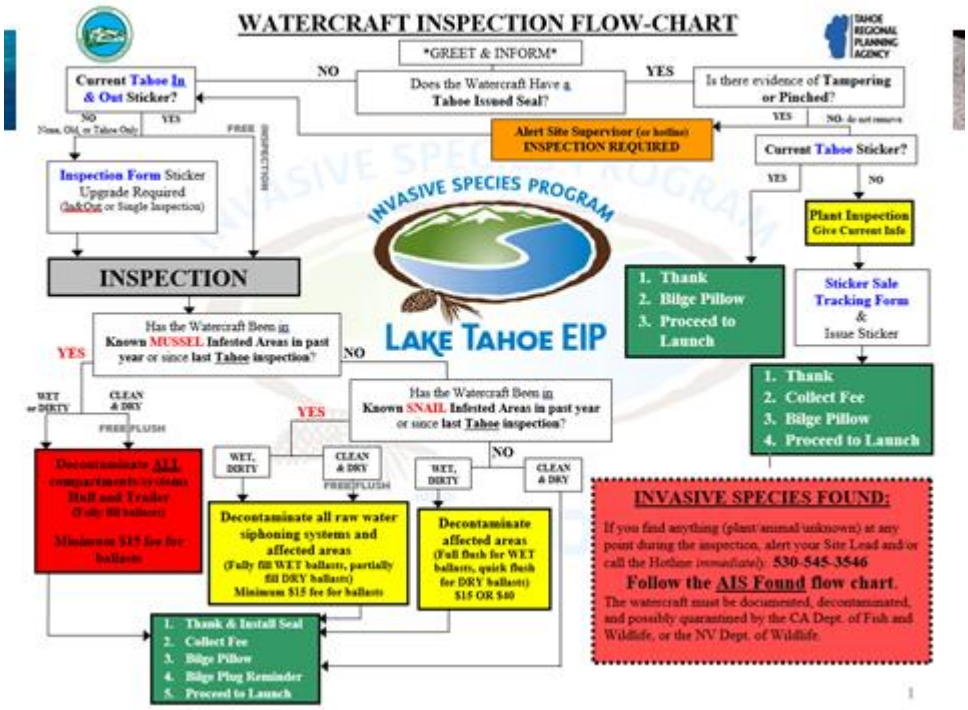
- 2008 – Voluntary @ ramps
- 2009 – Mandatory, free decontaminations, fee every inspection

- 2010 – Annual stickers, roadside stations & ramps
- 2011 – Roadside only
- 2012 – Fee for decontamination
- 2013 – Reduced hours
- 2014/2015 – Regional Inspection station (Truckee)
- 2016/2017– No changes
- 2018/2019 – Site improvements and fee increases

One thing that has not changed is that we continue to provide inspections, decontaminations and outreach for Donner Lake, Lake Tahoe, Echo and Fallen Leaf Lake, and we keep our lakes open to the public.

The process for inspection is that a boater arrives and we inspect literally everything from in and outside the boat and all systems that could hold water; bilges, ballast, deck showers, toys, sea strainers, anything that could have touched water. The inspectors are very careful, thorough, methodical and must know boat anatomy to trace lines. We have large documents and very extensive training on different boat parts and mechanics. They look for mud, water, plants or animals.

Another big part of our programme is customer service. We put a very large focus on making sure that our inspectors are trained in order to provide excellent service.



This is our Watercraft Inspection Flowchart, giving a quick reference guide to a 50-page protocol on inspections. It breaks it down so that if the inspectors in the field have questions on where they are in the process this document will help them get to whatever outcome they need. For instance, if a boater comes in and during the inspection they find water in the bilge compartment and in the engine, this flow chart tells them that it needs decontamination on the bilge and the engine. There are lots of different scenarios.

All our resources are available so please do not reinvent the wheel. If you are thinking about inventing a boat inspection programme we are happy to share all of our materials in a Word document form, so you can tailor it to your own needs.

When the boaters get to the inspection station they go through a process. There is an inspection fee and different ways to charge which we have changed a couple of times. Local boaters that do not go anywhere, staying only in Lake Tahoe, have a lower cost of $US45 a year. To those that are visiting and go to other bodies of water throughout the year that ranges from $US55 to $US95 a year for an annual pass depending on size and complexity of the boat.

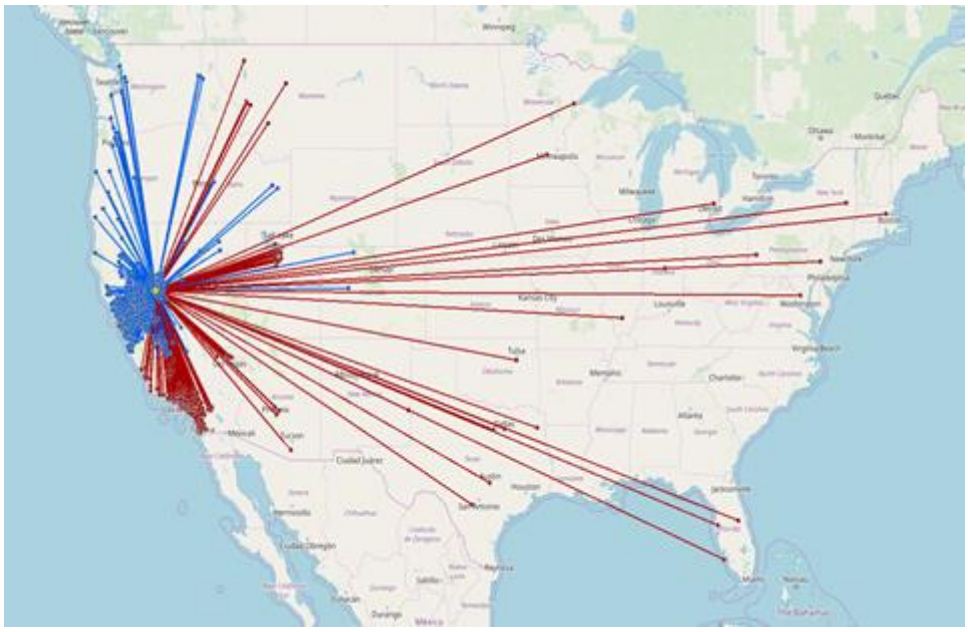
One thing that has changed over the years and it has also changed boater habits is charging for decontaminations. Previously we gave free decontaminations as a prevention measure to protect the lake. But we noticed that the boaters were not taking it upon themselves to arrive C*lean, Drain and Dry* prior to arriving at the inspection station. Once we charged for the decontaminations boaters' tendencies changed and they have become more rigorous to ensure that their boat is prepared prior to arrival.

Our inspection programmes are now set up a little differently. The red dots on that map show that our four roadside inspection stations are located at the major roadways coming into the Lake Tahoe Basin. Three of the sites are set up with semi-permanent inspection stations which are larger and can run more decontaminations, higher capacity, more water, more hoses. The decontamination unit is the metal storage container behind the boat. (top photo) The bottom photo is a mobile station that is set up with portable decontamination units.

All of our units are set up to recycle water; no chemicals are used in the decontamination process. Decontamination consists of running 140 degree Fahrenheit water through any area of the boat that has been wet or contaminated. The only chemicals used are Ozone and light chlorine to keep algae growth down in the source tanks.

Once the vessel completes its inspection it receives a sticker which says that it has paid into the programme for the year and they also receive a one-time security seal that binds their boat to their trailer which is the key for the entire programme. Once it leaves the inspection station with this wire inspection seal attached around the U-bolt on the bow of the boat to the eye hook on the winch it can go to the boat launch. At the ramp there is someone checking to make sure that the security tag is intact. At the end of the day, leaving the lake, a new inspection seal goes on. As long as that inspection seal stays intact, they can go straight back to that lake launch ramp and do not need to visit the inspection station again. If they decide to boat in another waterbody, they will have to return to the inspection station for a new inspection.

This is a map showing where we see our boaters come from. All the blue lines are boaters coming from non-infested waters. All the red lines are coming from infested waters. **Our threat is very real and growing every year** as more and more water bodies are infested.

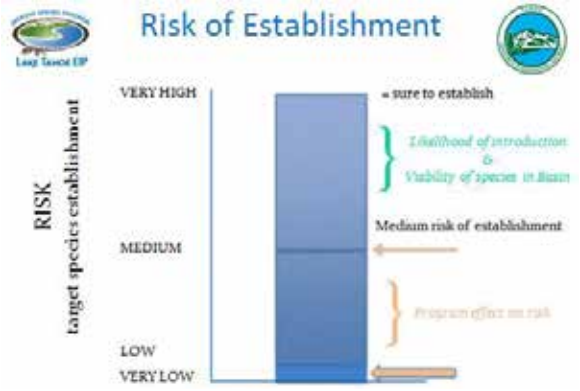


Outreach

We have had some very crafty messages over the years. The most important part as far as bringing stakeholders along is that we have stayed consistent with our messaging - ***Clean, Drain and Dry*** has never gone away. The boaters are more and more used to the process and messaging and now support our programme. That has been the change over the years. In the beginning everyone thought we were taking away their freedom but we have been able to soften that edge a little bit.

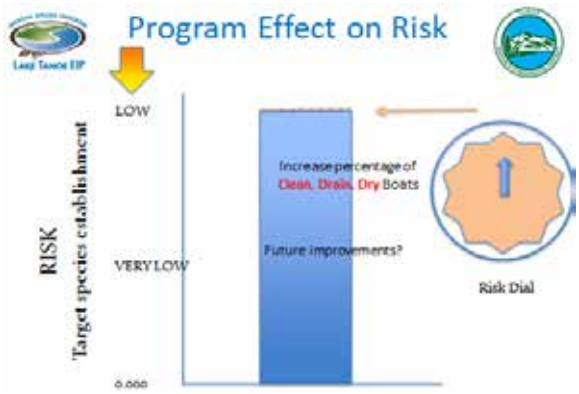
What the impacts are

People say that, 'Mussels can't survive in Lake Tahoe'. We have done a lot of studies and they can. Based on their biology, our temperature and our location our conclusion was that the risk of Quagga mussel establishment at Lake Tahoe, without any prevention measures, and given current practice in the use and management of Tahoe Basin waters, was 42.6%.



In a graphic form you see all of our efforts from the programme, and what that is doing to reduce our risk. That darker blue piece at the bottom is really what we have done with science and our programme on the impact of risk. The risk of quagga mussel establishment at Lake Tahoe is 2.8% when programme prevention efforts are taken into account.

Then I take that very low risk, 2.8%, and blow it up so we are at a low risk and we would like to get to a 'very low', if not 'no risk'. What we are trying to increase is the percentage of boaters coming **clean, drain and dry** and then any other future improvement that we can do.



We have been working a lot with the boating industry to actually change how they make

and craft engines and visual inspection points on ballast tanks, to help make spreading invasive species less and less of a risk across the United States.

Challenges

- Multiple jurisdictions/landowners
- Inconsistencies within jurisdictions
- Various user groups
- Funding
- Confusion when rules and regulations differ throughout states & west
- Boater buy in
- Restricting access

With anything there are challenges. We have multiple jurisdictions and land owners that we have to get on the same page. There are lots of inconsistencies within jurisdictions with regard to rules and regulations.

We have various user groups; Donna Lake is a sleepy lake, lots of early fishermen and a couple of wake boarders.

Then there is a celebrity golf tournament on Lake Tahoe in the middle of July.

Dealing with different user groups and ensuring good communication is vital. Funding is always an issue, and I have not touched on that, but the inspection programme itself is funded 50% by the fees that we collect and 50% split between the state of California and the state of Nevada.

There is confusion with rules and regulations throughout the different states and the west, so it is important to ensure that communication and outreach is consistent. Boater buy-in is always challenging but getting better. Because we now have an inspection programme, restricting access becomes an issue. Some people want to boat at 4 o'clock in the morning to get the best fish on their line, and sometimes that is not possible anymore.

Achievements

Since the programme started, we have had no new aquatic invasive species detections. Our last invasive species invasion was either the Asian clam or curly leaf pondweed, but that was well before the programme started. We can safely say that it is working well and we will continue to do so. Last year we celebrated 10 years of implementing the Watercraft Inspection Programme. I take great pride in coordination with our partnerships and it is one of our greatest achievements, our ability to partner, to leverage everybody's certain roles, leadership and regional coordination. Recently we completed a mobile

application for both the inspection process and the seal inspectors so that all the information is more real time than it ever has been. It was always on paper and now keyed in to a computer/mobile device so we are really trying to upgrade our technology and abilities.

Thank you and I would like to acknowledge all those who contribute to the work that we do:

- California Division of Boating and Waterways
- Town of Truckee
- Tahoe Regional Planning Agency
- California Tahoe Conservancy
- U.S. Fish and Wildlife Service
- Nevada Division of State Lands
- Bureau of Reclamation
- Tahoe Fund
- Truckee River Fund
- Lake Tahoe AIS Coordinating Committee

QUESTIONS

Colin Jackson, LWQS: Thank you that was a great presentation and a very effective programme, impressive that after 10 years there have been no further incursions. A point of clarification, you said that in 2007 there was an incursion at Lake Mead and you said that was very close. Can you just confirm how close that was?

Nicole Cartwright: It is within an 8 to 9 hour drive of Tahoe at the southern tip of Nevada and Southern California.

Colin Jackson, LWQS: So you are talking 'close', Lake Mead is near Las Vegas on the other side of the state, 8 hours away and you are really concerned. We have Lake Taupo that we can ride to on a push bike in half a day. You also talked about the water temperature for decontamination at 140 degrees, presumably that is Fahrenheit, about 60 degrees Celsius. So, no chemical, just 60 degree Celsius water?

Nicole Cartwright: Yes, correct.

Christine Caughey, LWQS: Thank you for a wonderful presentation. A question in relation to the UV light and other techniques of killing them off, what happens to the rotting weeds re: nutrification of the substrate of the lake and the water in terms of new life coming out of it? Has there been research monitoring done?

Nicole Cartwright: Yes, fabulous question, with the UV light project specifically, because it is such a new technology, the only way we could get permission to implement it in 2017 and 2018 was to do very rigorous monitoring. We evaluated changes in dissolved oxygen, temperature and turbidity. We also looked at macro invertebrates, plankton and periphyton. Our sampling was not very large but the results showed that there was no significant impact on any of those. If anything, turbidity increased and the water quality improved.

With bottom barriers, there has not been as much science but they are permeable, so oxygen is still flowing, which means our macro invertebrates survive. Some years ago, there was a study looking at the survivability of macro invertebrates underneath permeable bottom barriers and the results were also good. What happens to the plant themselves? When you pull back a bottom barrier after its been in the water for 8 to 12 weeks, depending on temperature, the plants disintegrate, they are so weak and made up of mostly water, decomposing and turn to a liquefied dust. The same with the UV light treatment. In the time lapse videos (Lars Anderson's presentation) of the underwater treatment site you see a plant collapse, curl up and then it washes away. So it is not changing the actual water quality or clarity of that particular site. I hope that answers your question.

Paul Champion, NIWA: More of a comment really, we have a campaign very similar to yours, *Check, Clean, Dry*, with a whole range of different decontaminant methods than were shown there, particularly for an invasive algae called Didymo. But we want to expand it to a whole range of species and like you, we found 60 degree Celsius water was the only thing universally acceptable, apart with freezing which is not really achievable there. It is great that we have got a similar approach. Thanks.

Nicole Cartwright: Thank you for that and a great point. There was a lot of science prior to us starting that highlighted that 140 degree Fahrenheit or 60 Celsius is the tipping point for

most species, whether it is plants, mussels or clams, it really does kill the gamut. Freezing is a great option but hard to do here.

Warren Webber, LWQS: We have had a few preliminary meetings with various local agencies to discuss how we might introduce a boat certification process, not quite as elaborate as what the Lake Tahoe scheme is running. We thought about paper-based systems with voluntary declarations by the people launching their boats or the possibility of a smart phone app in which people could do voluntarily declarations. You mentioned going through a paper-based system at one point, what was your experience with that and what would your comment be about us introducing a paper-based system as a start point? Thank you.

Nicole Cartwright: Great question and thanks for bringing that up. For some years we assisted lakes that are just outside of our reach, Stampede, Prossor, Boker, smaller lakes and more remote, with a self-certification programme. There were inspection sheets available at the boat launches for boaters to fill out and then put a slip in their wind shield that said, 'I did it', and then they filed a portion in a drop box that was collected by officials. We had fairly good compliance with that and a great way to collect data for those particular lakes. We asked ourselves questions like "Should we be more concerned and get a more rigorous programme?" What we found was that the boaters were not going very far and staying to those lakes. For the Tahoe programme, there was nothing wrong with paper which we used for 9 years, filled out by our inspectors, not by the boater, but nothing wrong with paper in that sense.

MITIGATING MARINE INVASIVE SPECIES THREATS TO FIORDLAND: A PATHWAY MANAGEMENT APPROACH

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Robert is a Marine Biosecurity and Biodiversity Officer at Environment Southland. He has a MSc in Marine Science from the Otago of University, where he studied the interactions between fish, invertebrates and algal habitats inside the East Otago Taiapure. He worked as a Coastal Scientist for the Bay of Plenty Regional Council and Brisbane Airport as a Water and Biodiversity Officer. More recently he worked for the California Department of Fish and Wildlife as a Marine Biologist undertaking monitoring and management of California's Marine Protected Areas.

TRANSCRIPT

Kia ora everybody , thanks for having me. It is a change of pace from what I do day to day compared with what you do in the lakes . I have been in my role for 5 months now so fairly new to it. I will give you a quick rundown on Southland, marine Biosecurity and *Undaria* incursions in Fiordland which have driven the need for a Fiordland Regional Marine Pathways Management Plan . I will then go over the rules and components of the plan, highlighting some of the challenges of implementing pathways plans in remote areas.

Southland is a large area, over 3,000 kilometres of coastline, islands and a large part in remote national parks including Fiordland National Park, Stewart Island and Rakiura. It has very little human impact, mostly recreational or commercial fishing. This makes it a very hard place to protect.

The reason why we have a Fiordland Marine Pathways Plan is because of the Fiordland marine area, pristine, remote and so different to the rest of New Zealand. Fiordland never fails to impress visitors. It is an enormous and stunning landscape but most of us never get to appreciate the magnificence that lies beneath the surface of the water. It is a unique and very special marine environment, significant not only nationally, but globally.

The inner fiords are sheltered; mostly native bush all the way down to the sea. Underneath is just as complex and magical as above the water. The outer coasts are extremely rugged, wind-swept and not many people venture into these fiords. People venturing in are either brave or very crazy and mostly work there in the crayfishing industry. I was there last winter and it was blowing a gale (110 kilometre winds), sideways sleeting wind and snow inside the fiords. That is the environment we work in.

Under the water are very distinct species. They have a phenomenon called 'deep water emergence' caused by the tannin stained freshwater layer from such a high rainfall in Fiordland that it brings species, usually found at 100 meters, into diveable depths for spearing. For example, Fiordland Black Coral (*Antipathella fiordensis*) living in a symbiotic relationship with a Snake Star (*Astrobrachion constrictum*).

In the very upper fiords are unique food-webs such as the white sea urchin whose main food sources are terrestrial in origin such as leaf litter from the forest.

What is the commercial value? Tourism is a huge driver in Fiordland, but also there are important commercial and recreational fisheries of blue cod, hapuka, crayfish and paua.

Fiordland has a unique management regime with the Fiordland Marine Guardians (FMG) which was formed in 1995 to manage fisheries. It has a board whose members come from different backgrounds and agencies that have a shared vision:

> '*That the quality of Fiordland's marine environment and fisheries, including the wider fishery experience, be maintained or improved for future generations to use and enjoy'.*

Over the years this has changed and FMG now deal with a multitude of threats facing Fiordland such as biosecurity, biodiversity and marine pollution, not just looking at fisheries.

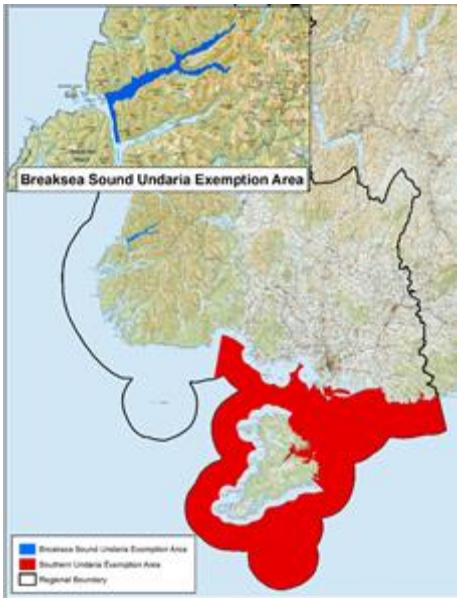
Timeline:

- 1995: Guardians of Fiordland's Fisheries
- 2003: Fiordland Marine Conservation Strategy
- 2005: Fiordland Marine Management Act
- Present: Fiordland Marine Guardians active

I work under the Southland Regional Pest Management Plan which went into effect in July 2019. This Plan drives all the marine Biosecurity management work that we do and the goal is to effectively and efficiently manage and eradicate pest animals, plants and marine species in the Southland Region. We do not have much of a fresh water focus in our Pest Management Plan. Lagarosiphon is listed but that is as far as it goes. Mostly freshwater invasive species are managed by DOC because they are under a DOC estate, in the National Parks.

There are 7 marine species listed in our plan. Six are listed as exclusion and found in New Zealand but not necessarily in Southland. One species listed for progressive containment is *Undaria pinnatifida,* found in Fiordland, and the main species that I work with. This is because it is highly invasive, outcompetes and smothers natives and has negative effects on Fiordland marine ecology

Undaria pinnatifida



The two species we are most worried about are *Undaria* and *Sabella-spallanzanii,* and the map shows were they are found in Otago and the closest pathway we have.

Sabella-spallanzanii

Many boats come to Otago for both recreational boating and commercial fishing purposes as a stop off from Tauranga. *Undaria* arrived in Breaksea Sound in 2010. Since then work to eradicate *Undaria* has been ongoing through a joint agency response between DOC, Environment Southland and Biosecurity NZ (MPI), sharing costs and resources for operational activities. Environment Southland does not have a huge rating base and as you know pest or biosecurity responses are always very expensive, especially in Fiordland where our management technique is weeding the garden but with divers. It is a big and expensive task and a lot of work.

In 2019 there was a new incursion found in Chalky Inlet at the southern end of Fiordland, whereas Breaksea is in the middle. We are currently working on a programme to:

- Move into a long-term management programme for *Undaria* in Southland
- Moving out of response phase and into a containment phase.

That is a big change for us from when the Fiordland Pathways Plan first started in 2012ish to where we are now, in our implementation of the Pathway Plan and the way we manage invasive species. We have moved from just *Undaria* to a whole gambit of species of marine bio-diversity in our zone.

These photos show what we do for an *Undaria* response. Expensive divers, staying in a boat for a week and spending up to 15-16 hours underwater just looking for *Undaria*. Clearly there are lot of costs, which means that for what we are trying to achieve it is not as good as we would like. We are now investing more in science and technology tools to effectively manage and contain *Undaria* rather than eliminate it with the methods that we have now.

The Fiordland Marine Regional Pathways Management Plan was proposed in 2012 and became effective in 2017. A long process mainly driven by the Fiordland Marine Guardians, similar to what the LakesWater Quality Society achieved here for the Rotorua Te Arawa Lakes. In Southland FMG and Environment Southland drove the process, supported by Biosecurity NZ, DOC and Ngai Tahu.

The Pathways Plan was established under Section 95 of the Biosecurity Act 1993 which allows Regional Councils or other agencies to propose an action under the Biosecurity Act. The process that Environment Southland went through was extensive. There was two years of informal consultation with stakeholders. The good thing about Fiordland is there are not many users and it is quite easy to consult as everyone knows everybody in Fiordland. One of the challenges was connecting to the recreational users because there was no real body that we could talk to. They drive into Fiordland over the Willmott Pass into Milford Sounds, fish for a day and then we never see them again.

Then a proposal is given to Environment Southland Councillors and formal submissions and hearings with stakeholders and finally implementation. We are still in the implementation phase with last year being the first year that cost recovery for noncompliant vessels went into effect.

The Fiordland Pathways Plan

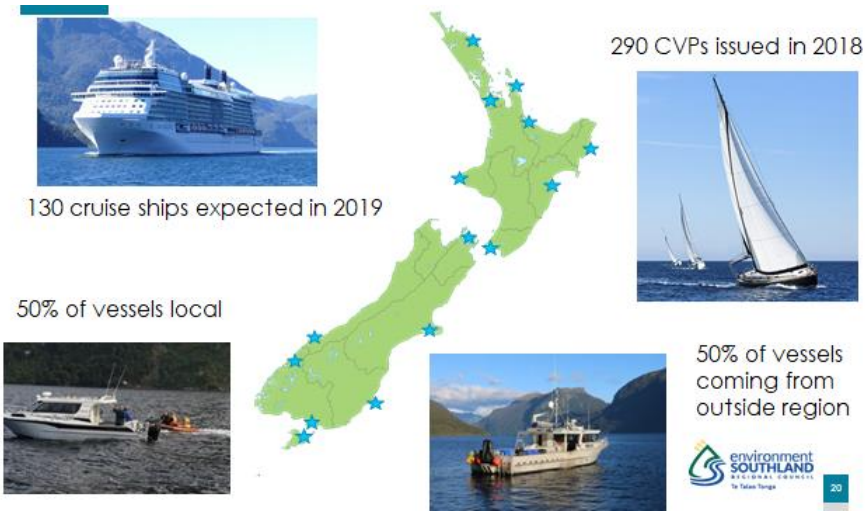
- Marine pest exclusion programme
- Aims to manage movement of vessels into Fiordland
- Four main components:
    - Requiring vessel owners to hold a Fiordland Clean Vessel Pass (CVP)
    - Rules: Clean hull, clean gear and residual seawater standards.
    - Communications plan
    - Compliance and enforcement programme

The Pathways Plan is primarily a marine invasive species exclusion programme that manages the movement of vessels into Fiordland. The aim of this plan is not to restrict vessels but to manage them and know where they are coming from. This is achieved through four main components.

Clean Vessel Pass

The first is a Clean Vessel Pass (CVP). Any vessel that enters the Fiordland Marine area (defined area under the plan) must own a CVP. It is free and administered by Environment Southland. Every year a vessel needs to get a new pass but it does not necessarily go with the vessel, it goes with the owner or the person in charge of the vessel.

The CVP collects information on the size and type of vessel, its use, its destination within Fiordland, what time of year it is in Fiordland, where it has come from, its activities in Fiordland and when it was last cleaned and antifouled. In Bluff Harbour our commercial vessels are hauled out every 2 years. All this information will enable Environment Southland to easily identify high risk vessels coming into Fiordland and enable compliance with the plan.



This is last year's numbers for CVPs in 2018. Approximately 290 passes were issued, 50% for local Southland vessels, 50% for vessels from outside the region, coming from Nelson, Marlborough, Otago, Wellington, Lyttelton and Northland. Less than 5% were international private vessels. We previously did not know how many vessels were coming into Fiordland and it was a rude shock to know just how many vessels were coming from outside our region with pieces of marine species on their hulls. This really showed how important it was for us to understand the risk profile in Fiordland.

As an aside we have 130 cruise ships expected in 2019. That is one a day going through Fiordland. They have their own Biosecurity and exempt from our Pathways Plan. We have a Cruise Ship Deed of Agreement through the Resource Management Act with Southland, and collect fees off these boats to be able to go into Fiordland. This pays for much our marine Biosecurity programme and a lot of other initiatives in Fiordland.

Plan Rules

Rule 1 - *Hold a current CVP*
Rule 2 - *Clean vessel standards*:

- *Clean Hull*: no more than a slime layer and goose barnacles
- *Clean Gear:* visibly clean and free of fouling (including fishing and mooring lines)
- *Residual seawater:* treated or visibly clean and free of sediment

Rule 3 - *Carry records of actions taken to meet standards*

The second component of the Pathways Plan is that we have 3 main rules. The first one is to hold a CVP if going into Fiordland. The second one is clean vessel standards. A lot of our boats do not spend much time out of the water, especially our commercial operators, so we have a clean hull standard. No more than a slime layer is allowed on a vessel, so this picture is a vessel that would be non-compliant with the standard. Every single boat, especially a travelling boat, will have goose neck barnacles so this complies.

Clean gear is vital. One of our biggest risks is the gear that comes with the vessels. We have a lot of commercial operators who store pots in Bluff or Stewart Island which have *Undaria* and they come to Fiordland and drop those pots back into our water. *Undaria* loves to grow on moorings, fishing gear, or anything like that. We want to clean and dry, but in my opinion it should go further, and treat as well as clean and dry.

There is a residual seawater standard. Ballast water is the hardest thing to get compliance with because there is a rule that discharging this water must be done offshore, certainly not within the Fiordland marine area.

The third rule is the key for compliance. They must carry records that show they met the standards, including when they were last antifouled, cleaned and hauled out of the water.

Communications Plan

The third component is the most important as we move forward. We use several different methods to communicate about the Fiordland Pathways. Some examples include: advertisements placed on radio, signs at boats ramps around Fiordland, stalls at boat shows, marine pest ID workshops to raise the profile of Biosecurity marine pests and advertisements in boating magazines and websites.

Compliance and enforcement programme

The last component is now starting to ramp up. We are still in the implementation phase of the Pathways Plan, but the plan is only as good as our enforcement. We currently have a monthly hull inspection for all boats that live in Bluff and regularly move to Fiordland. Commercial divers are contracted to survey each vessel that has a

home port in Bluff, Steward Island or Rakiura. There are joint agency compliance monitoring trips twice a year. Unfortunately these are the same time every year because we use DOC's *Southern Winds* in January and April and most operators know we are around and radio each other. The first thing I need to do is mix up the time of year. Currently Environment Southland is exploring further monitoring and surveillance options for the rest of Southland's secondary ports and boat ramps and mooring areas.

We check all boats we find, asking for their CVP and inspect their hulls. If they do not have a pass it costs $175 per inspection. If heavy fowling is on their vessel we put divers in the water and their costs are claimed from the vessel owners. Last year was the first and we had 15 vessels for cost recovery. We also issued a Notice of Direction to leave Fiordland because we had a suspected *Sabella* incursion on a vessel. For us the big stick is that they have to leave Fiordland. Many boats, especially recreational yachters, come down to Fiordland for a couple of months so ordering them out of Fiordland to Bluff to get cleaned wrecks their whole trip.

We also have the option of flying in a FAB dock, a low maintenance, cost effective and transportable dry docking solution that wraps around the vessel, which we then treat with chlorine. But we priced that out: 6 people to fly in with the FAB dock because it is very heavy to lift, and helicopter flights are about $5500, staff time is another $10,000, and then the treatment. All in all, about $25,000 worth of cost recovery if we find a vessel that has an invasive species. That does not include a fine, just the costs for us to do such work in such a remote place as Fiordland.

Challenges

- Communications- mixed messages
- Infrastructure to clean boats
- Compliance with clean vessel standards
- Uptake of CVP slow in some groups
- Records carried by commercial, not so for recreational
- More monitoring and compliance for early detection

These are the main challenges and takeaways from the Plan. Communications are difficult with mixed messaging, a major issue for boaties outside the region. Marinas, especially in the top of the North Island, tell operators that they only need a certificate to

say they have been cleaned in the last 2 years and they do not need a clean vessel pass. Such a certificate is not acceptable down here in Southland.

There is need for better infrastructure to clean boats in Southland and especially in other areas of the country. We currently have one facility in Southland at Bluff that is only for commercial vessels so we are investing $300,000 this year to get a vessel haul out facility for recreational vessels. Many places in New Zealand have haul out facilities that we consider insufficient to clean vessels properly. It is up to every region in New Zealand to improve their infrastructure so we can rely on having clean hulls on all vessels at all times. There is a direct correlation between the amount of fouling on a vessel and the amount of invasive species on it.

We have had good compliance with clean vessel standards but uptake of CVPs is very slow with some groups. 90% of the people that we catch in Fiordland without a CVP are recreational boaters that have trailered their boat over the Willmott Pass into Milford Sound, or come through Doubtful Sound. They skip between these areas, in and out of the Fiords. They are probably low risk to us because most of their boats are out of the water 90% of the time, but still a big risk if they come from Bluff. When their boat is left in Bluff for an extended time, it accumulates a whole bunch of foul and then they drive over to Fiordland to launch their boat. It is highly likely that they have an invasive species. The same thing goes if they are coming from Otago.

Record keeping of cleaning and antifouling is carried by commercial vessels. Not so for recreational. We are aiming to increase our compliance with the plan each year. We also need more monitoring and surveillance for early detection of any new incursions. At present we are looking at a Southland wide monitoring surveillance plan, on all high-risk sites as well as vessels. We have a lot of moorings in Fiordland which are not resource consented. Anyone can put in a mooring requiring only a name and type of mooring. There are many unknown moorings gathering our invasive species.

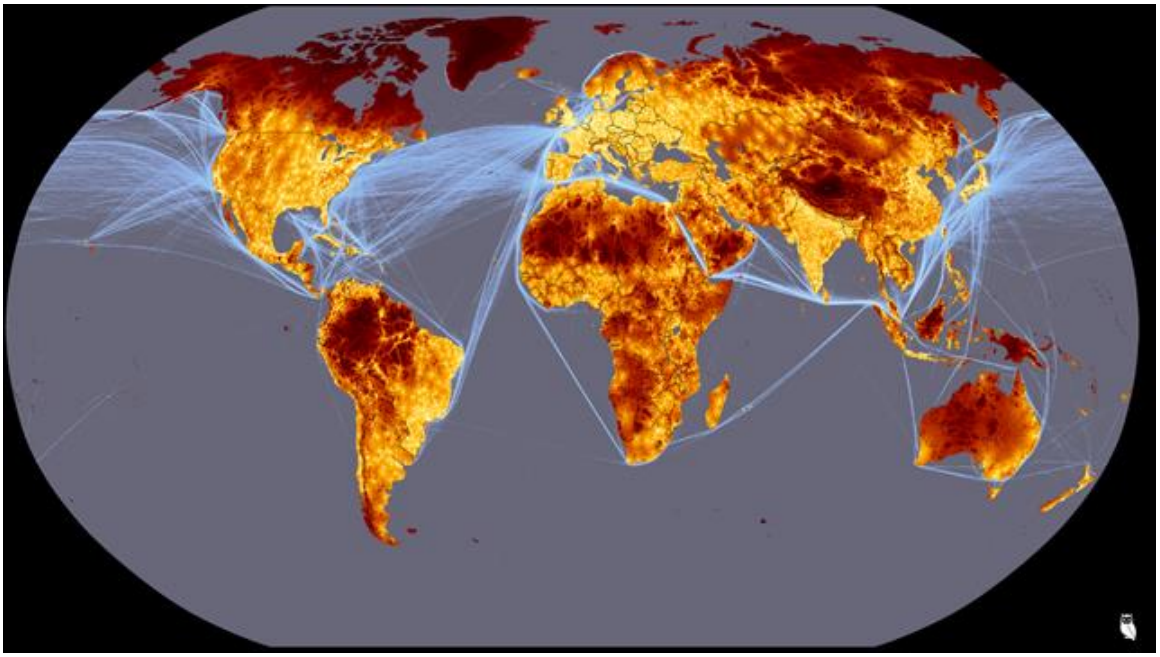
What is next for the Pathways Plan?

We want to work with partners and other councils in the rest of New Zealand on a national pathways framework with a clean vessel standard and vessel registration. Improved cleaning and antifouling facilities are needed nationwide to ensure we have clean hulls on all vessels. Many people in marine Biosecurity have called for a boat registration or a pathways plan in which we know when vessels are coming to Southland, and from where, and likewise for all other regions. Movement in invasive species is always on boat hulls and gear so a national frame work showing the movement of vessels from region to region would be really helpful especially in Southland.

Takeaways

- Marine Biosecurity is very complex, as with Biosecurity in general.
- Prevention, early detection and engagement with the public and users are our best tools.
- The Fiordland Marine Pathways Plan has helped, in that we did not know previously which vessels were coming to Fiordland. Now we have contacts and systems that allow us to gauge when vessels are coming into Fiordland and the risk profiles of the different people. We can now target our messaging to different marinas because we know they are coming to Fiordland.

- Clean hulls need to be the norm! Every single boat in New Zealand needs to be clean. That is the only way we are going to ever stop the spread of marine invasive species around New Zealand.



This world map highlights why we need biosecurity. New Zealand as an island nation is particularly vulnerable to invasions. Some statistics:

- 58,000 flights with nearly 4 million visitors
- In 2018 there were ~2500 records of individual ships entering New Zealand

Acknowledgements

I would like to acknowledge that this Pathways Plan would not have been possible without the work from many people, especially Derek Richards, Shaun Cunningham and Richard Bowman from Environment Southland and working with Dr Reka McLeod from the Fiordland Marine Guardians who was the one that has been instrumental in pushing this along. We are not done yet!

- Derek Richards
- Richard Bowman, Environment Southland
- Ali Meade
- Dr Rebecca McLeod, Fiordlands Marine Guardians
- Jen Brunton
- Richard Kinsey
- Shaun Cunningham, Environment Southland
- Dr Chris Hepburn
- Various stakeholders

QUESTIONS

Colin Jackson, LWQS: Thank you, Robert, that was a great presentation. A point of clarification, you said you had 15 boats that you found dirty, out of how many that you checked?

Robert Win: 80

Lars Anderson, USA: We have been doing it in the West Coast for the last 15 years. It looks like the divers are hand removing it. That is really time consuming. You talked about wrapping boats and using chlorine which we have also considered. Have you ever looked at acetic acid as a treatment, because we found it works in the labs at least?

Robert Win: That is one of our control options that we have been looking at, but *Undaria* is not found on boats, it is on a natural habitat or a rocky reef. It is very wide spread in Fiordland over 100's of acres and we need a large-scale treatment device. We would us a lot of acetic acid for that kind of treatment. When I heard you talking about UV I thought that could be something.

We are looking for novel tools at the moment. *Undaria wakame* is a food source in Japan, and we are working with Ngai Tahu and University of Otago to develop a commercial business. They talk about $5,000 a tonne to export in shipping containers, 20 tonnes per container, 200 to 300 tonnes of raw *Undaria* to full up a container. They believe it is possible and they can remove 2 tonnes of *Undaria* from the around the east coast Dunedin area. It shows how dense it is and how much foliage is around.

Session 4: PATHWAY STRATEGIES CONTINUED

SESSION CHAIR – John Gifford, LWQS

CLEAN BOAT PROPOSAL FOR ROTORUA LAKES

Don Atkinson
LakesWater Quality Society Chair
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John Gifford

Tena koutou katoa, I am a committee member of the LakesWater Quality Society and have the honour of chairing this session. The background is to discuss clean boat proposals which the LakesWater Quality Society has been thinking about. The Symposium title is *Float Your Boat, Certify* and we are interested in broadening the discussion about what management strategies can be used to prevent the future incursion of aquatic invasive species into the Rotorua Te Arawa Lakes.

Reflecting on headline statements that have been mentioned here today; 'An ounce of prevention is worth a pound of cure', 'We need resources, funds, personnel and equipment' which Lars Anderson touched on as key levers needed to make successful programmes come to fruition. Robert Win's statement, 'Clean hulls must be the norm', are just some of the ideas that are increasingly important.

Our LakesWater Quality Society journey over the years has had strong emphasis on control strategies for invasive weeds. Our 2017 symposium was called *Trouble Makers*. We highlighted that new invasive species were in the lakes, specifically the incursion of catfish, originally in Rotoiti, now found in Rotorua.

The '*Stop The Trouble Makers'* public forum in 2018 not only identified the troublemakers, but started debate on strategies needed to stop these invasive species arriving in our lakes. Now, in 2019, we have moved on to '*Float Your Boat, Certify'* with a strong evolving theme emphasising the urgency to be proactive, taking action more effectively and much faster.

Most speakers have expressed the importance of collaboration, a process which has already started in the Rotorua area with existing stakeholders having fruitful and effective discussions. That idea of collaboration is vital; Nicole gave a poignant observation on the depth and breadth of collaboration taken to develop an effective programme in Lake Tahoe.

Our next speaker, LakesWater Quality Chair Don Atkinson, has been very proactive in encouraging some sort of certification process for boats. His message has been that, 'We have been fixing up the house but we have left the back door open'. This highlights the fact that even though remedial and restorative work is happening, we have not contained the future risk of more invasive species in the lakes.

TRANSCRIPT

Thank you very much John. The concern that LWQS has about catfish has driven our Society for some time. Our initial focus made us consider the possibility of invasive pests spreading to clean lakes. At present catfish are only in two lakes, but there are 12 lakes in total. If we do nothing, we can guarantee that we will have 12 infected lakes. Do something solidly now and we can at least contain the present level of invasion, maintain 10 clear lakes, and continue to work on suppression and eradication. That is the objective we have put up for us all to focus on. The reality is that we have other pest fish - perch, rudd and carp - all within close distance. 'Close distance' is Wellington according to our US friends; for us in Rotorua it is a 'bike ride' to the Waikato Catchment; they are on our back door.

I would like to recognise and congratulate the people who have been involved in the Catfish Kill Programme; William Anaru from TALT and Grant Wallace and his team of local supporters. Together with the Regional Council contractor they have caught 68,000, which is an enormous number of fish! The 'cat is out of the bag' in Rotoiti and Rotorua, we just cannot afford to let this go beyond these lakes.

The curse of weed is everywhere; in fact it is surprising that not all of our lakes are infested with the full range of invasive weeds. Lake Rotoiti is probably the highest use lake and has the worst invasion. That directly reflects human activity is associated with movement of weed.

It is on our boat trailers, in our anchor lockers, in our bilges, in our motor cooling systems, in and on our gear. These may not be quite as difficult pests as the shellfish we have been hearing about today, but the consequences of these pests are enormous and we just cannot turn a blind eye.

Proposed Regional Pest Management Plan

- *Generic Rule for pests listed in the Exclusion, Eradication, Progressive Containment or Sustained Control programmes of this RPMP*

- ***Rule 6***

    1. *For all pests listed in the exclusion, eradication, progressive containment or sustained control programmes:*
    2. *No person shall move or interfere with any article or substance left in place by an authorised person for the purpose of monitoring, controlling, or eradicating a pest listed in this RPMP, and*
    3. *No person shall move, or allow to be moved, any live pest listed in this RPMP, or any machinery, vessel, organism or goods that are contaminated with any pest listed in this RPMP, and*
    4. *No person shall keep, plant, propagate, distribute or release any pest listed in this RPMP or assist in their maintenance including tending, feeding or sheltering them.*

- *This is to protect production, environmental and public values that can be adversely affected by pests.*

When we started to focus on catfish, the proposed Regional Pest Management Plan was out for consultation; a bit of luck for LWQS and probably a pain from Regional Council's point of view. But they have been very cooperative in allowing us time to flesh this through to get an understanding of the issues.

- ***Rule 7***

- *To avoid the spread of aquatic pests, the following provisions apply:*
    1. *No person shall leave boat trailers in any water body other than for the purposes of launching and/or retrieving boats.*

2. *No person shall transport ballast water from any water body to any other location.*
3. *All owners of vessels or craft entering any water body within the Bay of Plenty shall ensure their vessels or craft (including trailers) are free from freshwater pest fish and lake weed including fragments*

- *This is to protect production, environmental and public values that can be adversely affected by aquatic pests.*

The plan has got some powerful rules around pest controls. When shifting boats and gear around, every citizen is required to make sure it has been **drained, cleaned and dried**. But the way it is written makes it a difficult rule to police. There have been no fines and no enforcement of this rule and we see that this is perpetuated in the proposed plan. We are still getting weeds transferred within our lakes and in our observation areas.

Our Submission to RPMP

- *LakesWater Quality Society (LWQS) hereby make the following submission to amend the Proposed Regional Pest Management Plan (RPMP)*

- *Specifically we seek to*

    - ***Provide an additional Provision in Rule 7 requiring 'That every boat entering any of the Rotorua Lakes be required to certify that the skipper has checked, flushed, drained and cleaned his boat, trailer and associated gear.'***

We have gone further and asked Council to provide an additional provision to Rule 7 requiring that every boat entering any of the Rotorua lakes be required to certify that the skipper has **checked, flushed, drained and cleaned his boat, trailer and associated gear**. We believe this moves the accountability directly on to the captain of the boat; it requires the person captaining the boat, or owning the boat, to take the initiative. It will engage every boat owner before he launches his boat. This contrasts with the present approach of random inspection and an educational programme that has been run with students employed by Regional Council.

- ***This rule will***

    1. ***Ensure the engagement of all public utilising boats of any category.***
    2. ***Could be undertaken through an app and/or website in a self-certifying process.***
    3. ***Could be easily monitored by wardens or the like.***
    4. ***Would need to be subject to fines, preferably instant for minor offending.***

We believe it could be undertaken by an app or if necessary, a paper format is probably not a bad starting point. This must start as soon as possible. It can be easily monitored and ultimately be subject to a fine. I am a firm believer that unless it is subject to a fine it will be ignored. That fine would be best as an infringement and most effective, an instant fine, say $200 for failing to certify.

This is a change in concept, but from our point of view, unless we engage everybody in this process, we will continue to be on the slippery slope that we have been on since the 1960s when the first weeds were introduced into the Rotorua Te Arawa Lakes. Rotoiti's record at a 93% invasive weed index is shocking and now catfish is added to that. We still have pristine lakes and we must be proactive in keeping them that way.

Initially we aimed to find the level of public support we could expect to assist in stopping the spread of pests. This programme was advertised extensively, both NIWA and Regional Council supported us with a presentation. We expected a room full of people, we got 50 and 40 of those would have been our LWQS supporters. That is the level of engagement we could attract when we were asking people to come and do something that they probably did not want to do. We realised that we had failed to engage the public and learned that we must have some teeth in our proposals for it to be effective and we must also obtain support of the community.

However, the fyke netting programme has been amazingly effective in lifting the level of engagement and understanding within the community. It has been embraced by many primary schools and people have been talking about its effectiveness. To have a voluntary programme to prevent pest spread through lake user community groups in our assessment is unachievable.

With that failure of 'Stop the Trouble Makers' we looked for similar situations around New Zealand and the world searching for best practice:

- Lake Tahoe
    - Can't deny its effectiveness
- Aquatic Invasive Species – Mandatory Self-Inspection Launch Certification Permit : Nevada and Sierra Counties.
- Fiordland Marine Pathway Rules
- Northland Regional Pest and Marine Pathway Management Plan

Today we have had the experience of Lake Tahoe so ably demonstrated in this session by Lars Anderson and Nicole Cartwright. They have taken a very strong position which has proven very effective. If their rules were put in place here, we could ensure no further invasion of unwanted species here in our lakes too. Their 10 year record of no further invasions is proof of a very successful system in place and commendable.

We have seen and heard the Fiordland Marine Pathway rules and the good work that has been done there to protect a pristine environment. The low level of boats they have coming into their environment, 280 launchings annually compared to well in excess of that on a busy day here, we face a different hurdle. There is a similar example in the Northland Regional Pest and Marine Pathway Management Plan, a marine environment like Fiordland. It shows that all around the country people are taking notice of their vulnerability and moving to provide levels of protection.

Proposed Self Certification

From our point of view what would self-certification be about?

- After retrieval you would ***check, clean, dry and drain*** your boat and gear before setting off on the road, especially in respect of weeds hanging off the back of the trailer

- Before launching confirm that your boat is fit to go and Self certify that your boat, trailer and equipment has been ***checked, drained, cleaned, and dried***. We have added 'drained' as this is about boats, and includes all of the wet points in the boat. It is essential that the whole boat is thoroughly drained.

- We anticipate that certification could be done on a cell phone or computer app.

- Where cell phone coverage is not available, a paper form left on the dashboard would suffice. A paper system may be a nice, easy start and simple for people to understand, perhaps in the first season.

- Monitored by lake wardens on land or on the lake when the app becomes available with live information. The paper situation would require the inspection of cars in the parking lot.

- The Rule needs to be an Infringement and subject to instant fines. It is fortunate that the Bio-Security Act is currently under review. We hope that

the government is listening. Bio-security legislative change which is imminent and can be done in parallel

- We will need to go through an educational phase.

Why this Preferred Option?

In summing up, existing rules are ineffective with available resourcing. The critical issue is that any system put in place must engage at least 95% of the people. We know if we adopted the Tahoe model we could expect to achieve a 100% compliance. We consider that the difficulties we have, with multiple lakes and launching ramps, the Tahoe system would be prohibitively expensive and restrictive. The Self Certify proposal is achievable and can set 95% as an initial compliance level target, which will be a great start to prevent further incursions.

There is no point in continuing to renovate the house and leave the back door open. Our lakes are iconic and not pest infested, we must keep them that way. We recognise that we have some pests, but there is much worse out there that we could be subject to.

POTENTIAL FOR CLEAN BOAT CERTIFICATION

Greg Corbett
Bay of Plenty Regional Council Toi Moana
Greg.Corbett@boprc.govt.nz

Greg has been with the Bay of Plenty Regional Council since 1995 and has worked in bio-security since 1983. Most of his career has focused on pest animals but he is rapidly learning about aquatic pests.

TRANSCRIPT

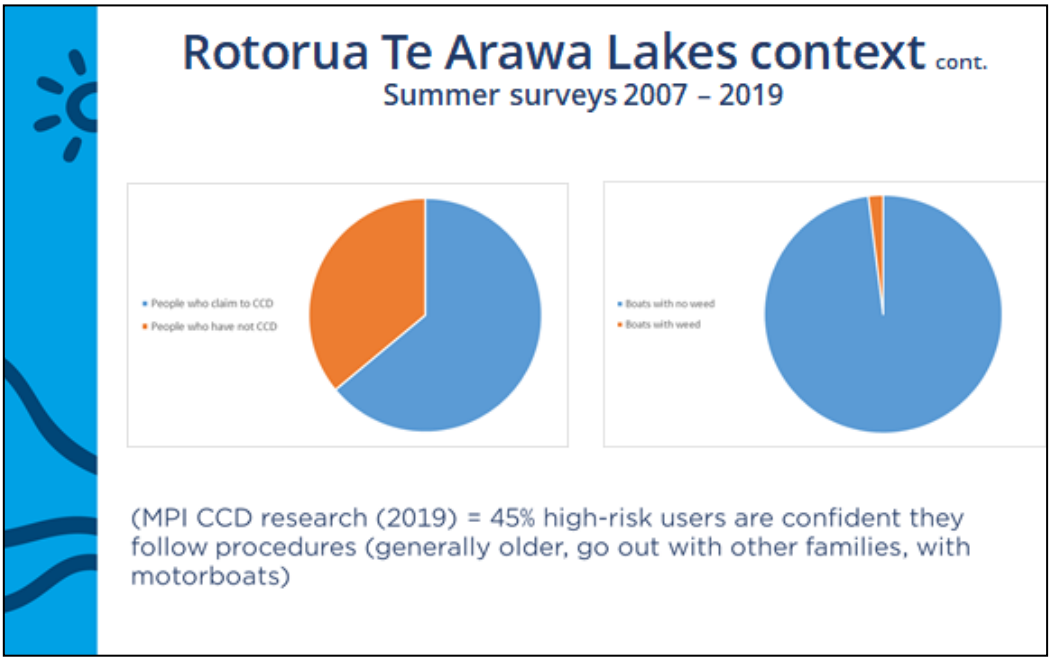
Tēnā koutou. Thank you to the LakesWater Quality Society for the invitation to talk today. I would like to acknowledge Te Arawa Lakes Trust, William Anaru and his 400 odd volunteers in the Catfish Programme, winning the Supreme Award at the New Zealand Biosecurity Awards last Monday night. It was just a fantastic achievement and a great recognition for a great job well done.

I would also like to acknowledge the Regional Councillors here this morning and this afternoon, thank you.

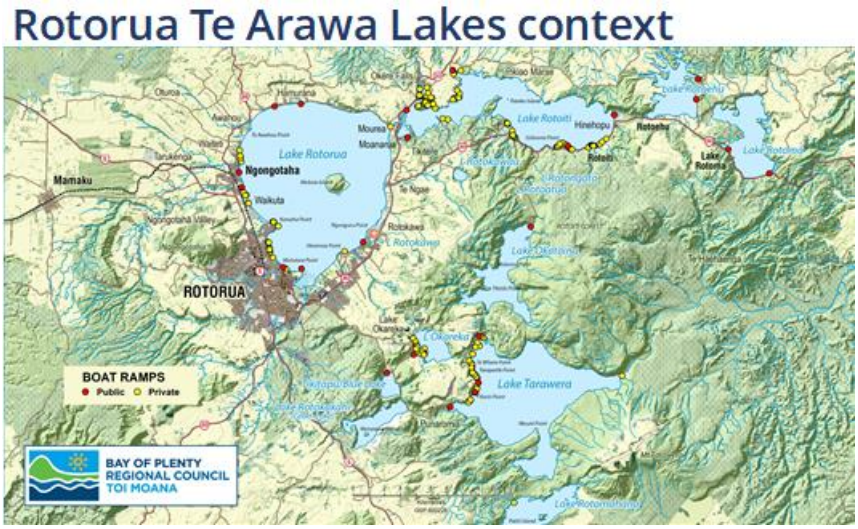
Firstly I will recap things that have already been mentioned about 'the issue' we want to manage through regulative approaches. I will then cover what we have learned about people who use our lakes and the complexities of managing bio-security threats within the Rotorua area. I will also briefly look at how we might use this information to inform and guide our future education and compliance work. Then I will look at the current review of the RPMP and the rule that has been proposed by LakesWater Quality Society which would require boaties to self-certify that they have *checked, cleaned, drained and dried* their equipment. I will finish off with our plans to implement this over the summer in the face of LakesWater Quality Society's challenge of a new rule.

The issue which Paul Champion spoke about is not a surprise to anyone here today; that aquatic pests are spread by humans. Nor is it a surprise to hear that boats, trailers and equipment used in our lakes are the most common pathway of that spread. We also know that weed fragments, if released into an un-infested lake can establish new populations, can also carry fish eggs, algae, etc. and some fish can survive out of water for long periods. Boats, boat trailers, ballast/bilge water can potentially carry fish, algae and weed fragments.

Our messaging has changed slightly since the discovery of catfish in Lake Rotoiti, in that we want people to ensure they are draining any water from their boats or equipment at the time they exit the lake.



We have learned from our summer advocacy programme over the last 12 years that we are lucky that our situation is not worse. Of the 10,000 surveys that we have done with boaties, only 64% claim that they have *checked, cleaned and dried*, but in reality it is probably lower than that. Students at the boat ramps observe that about 2% of boats and trailers were contaminated with lakeweed. As John Walsh indicated this morning, the recent MPI national survey on *check, clean, dry* indicated that only about 45% of high-risk users (people who move between waterbodies at least once a month) are confident that they follow the procedures.



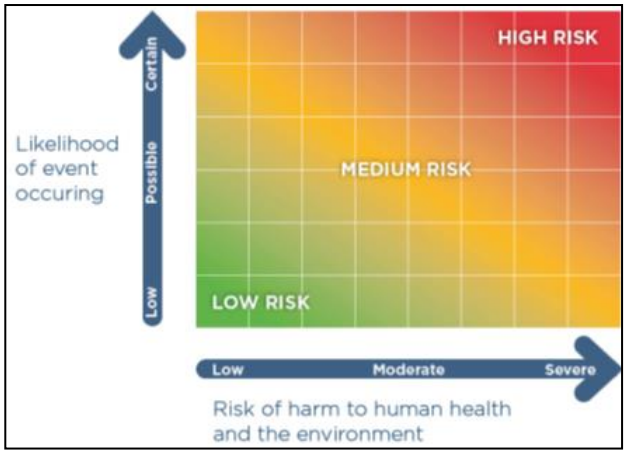
Looking at the context in our area, and taking into consideration the information on the previous slide, it is no surprise that, with the exception of Lake Tikitapu, our most heavily used lakes are also our most infested.

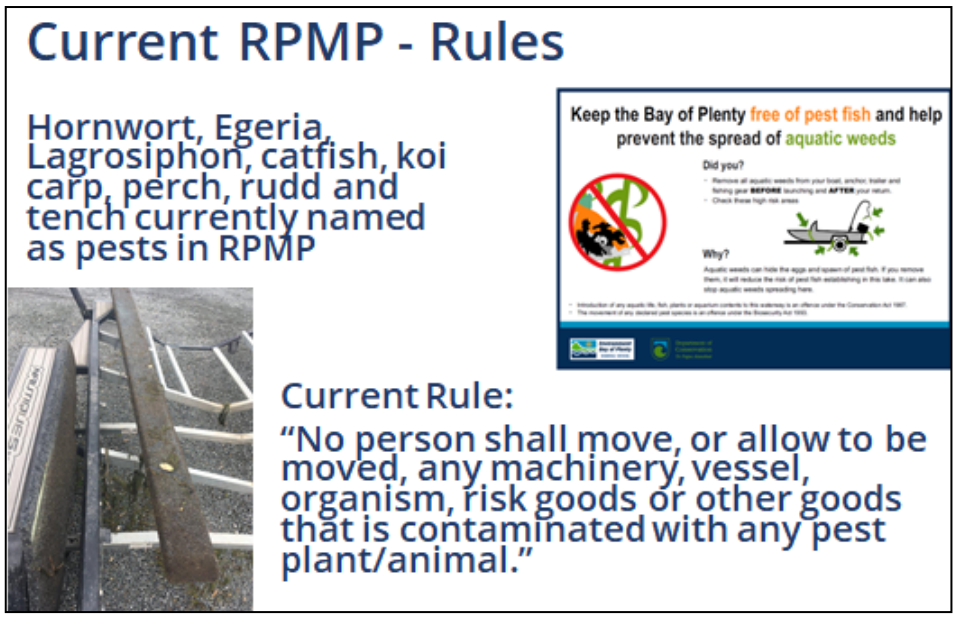
From a biosecurity point of view our lakes are complex. We have 12 closely located lakes, most of which are inter-connected with many access points. There are 200 private boat ramps, 25 public boat ramps and 7 highways leading to the lakes. Further complicating this is the fact that we are close to the Waikato system, and as Don and others have already referred to, that system is heavily invaded by pest plants and fish. It is this connectedness that provides people with the opportunity to move between lakes over very short periods. It also makes the potential management of all those movements practically impossible given reasonable resources.

This is the summary sheet from the recent MPI survey which provides some interesting insights and information on the knowledge, attitude and behaviours of people who use our lakes and rivers. Some of the wording might be difficult to see, but we will focus on the sad and happy faces. The research categorised people into 3 different groups. The people who come to play in our water (water babies), the adventurers exploring our environment (jet skiers, water skiers) and the providers (those fishing, hunting and gathering within water bodies).

The top line shows their current awareness, behaviours, motivations and knowledge; it is not a very happy sight. This information provides us with a basis to target future education and compliance work. Obviously there is a lot of work needed with all waterbody users but it appears that those who come to 'play' in the lakes pose the biggest risk.

It makes sense to guide our compliance programme using a standard risk management matrix, informed by the information from the previous slide.





What has been happening in recent times?

Our current RPMP includes all significant fresh water pests, the threats to our lakes, and a generic rule that aims to control risk of people vectoring them between waterbodies. Our approach has largely been around advocacy and encouraging people to do the right thing. With the support of MPI, we have summer students engaging with lake users at boat ramps to survey knowledge of the C*heck, Clean, Dry* processes and also keep their eyes out for people arriving with contaminated boats. We have used signage, a portable washdown unit and collateral to help educate people.

However, we have also carried out stronger compliance against 25 individuals and two event organisers since 2015 who have presented with problematic weeds on vessels or trailers. Those people that we have interacted with in a stronger way have generally been water skiers and jet skiers, which fits with the findings of MPI's research. Interestingly the MPI research identified that Bay of Plenty people have a better understanding of the risks freshwater pests pose to our native species, recreation and our economy than the general public. This probably means that some of our messaging is getting through, which is encouraging.

The Bay of Plenty Regional Council are reviewing their current Pest Management Plan and last September we released a proposed Regional Pest Management Plan and received 56 submissions, nearly half of which focussed on aquatics, 19 specifically supporting the LakesWater Quality Society submission. Their submission called for changes to some pest programmes and proposed a new rule.

The proposed Plan aims to continue with the current rule, Rule 6, and a new rule, Rule 7, which provides stronger direction to manage the risks associated with boats, trailers and freshwater equipment:

Proposed RPMP Rule 7

To avoid the spread of aquatic pests:

1. *No person shall leave boat trailers in any water body other than for the purposes of launching and/or retrieving boats.*
2. *No person shall transport ballast or bilge water from any water body to any other location.*
3. *All owners, occupiers of vessels or craft entering or leaving any water body within the Bay of Plenty shall ensure their vessels or craft (including trailers) are free from freshwater pest fish and lake weed freshwater pest plants including fragments.*

LakesWater Quality Society proposed rule:

> *'That every boat entering any of the Rotorua Te Arawa Lakes be required to certify that the skipper has checked, flushed, drained and cleaned his boat, trailer and associated gear.'*

Our Council is yet to formally consider this submission, but staff have worked closely with the Society, other partners and our stakeholders to tease out how this might work. There is general consensus that such a rule or checklist would raise awareness but applying a refreshed education programme and stronger compliance at boat ramps, ensuring that people have actually carried out the *Check, Clean and Dry* processes, may be more effective at preventing contaminated boats and trailers from entering our lakes.

If we were to pursue a certification process we probably would need to:

- Put in a Boat ID register
- Develop a 'self-certification App.'
- Ensure good Internet/cellular coverage at lake entry points
- Get the ability to use infringement notices under the Biosecurity Act

There is also potential for unintended consequences such as:

- Potentially prosecuting/infringing someone who may have *checked, cleaned and dried* their vessel but not complied with the self-certification rule
- Checking whether boaties on the lake have completed the certification process will achieve little in preventing the spread of pests, i.e. if they are already on the water and have not *checked, cleaned and dried* and pests may already have been released

What are we proposing to do this summer?

Based on the conversations that we have had with the Society and other stakeholders, we will continue our summer advocacy programme with the support of MPI. But we will also focus on compliance at boat ramps on our 'water baby' group, the water skiers, jet boaters

and those that come to play in the lakes. These interactions would be mainly around educating boaties, double checking that they know what they should be doing.

We will issue ‘directions’ to skippers of contaminated boats under the Biosecurity Act to prevent them from doing anything stupid. We will also continue to operate our portable wash down unit and provide support for boaties who are trying to do the right thing as they leave boat ramps. We are investigating the option of check lists at boat ramps in a paper form, as Don discussed earlier, to get people into the habit of what might be compliance in the future.

We will work with Council to complete the RPMP review process and we are supporting the inclusion of infringement notices through the current review of the Biosecurity Act.

Acknowledgements

I would just like to say thanks to:

- LakesWater Quality Society for their engagement in this and their willingness to work with us
- Bio-Security New Zealand and MPI who fund a lot of the advocacy work that we do over the summer months
- Fish and Game who have been working with us in the stakeholder groups
- Te Arawa Lakes Trust
- Land Information New Zealand, a strong partner in our fresh water programme
- Department of Conservation
- My team - Hamish, Lucas and Andy, the ones who actually do the work

Thank you.

FEEDBACK ON THE LWQS PROPOSAL

Jonathon West, Victoria University of Wellington: What is a direction under the Biosecurity Act?

Greg Corbett: Once we have a Regional Pest Management Plan in place, under the Biosecurity Act if someone is not complying with a rule or doing an action that could spread a pest, we can direct them to not do that, or take appropriate action to mitigate that spread. It is an offence not to comply with that direction.

Terry Beckett, LWQS: I am incredibly sceptical in the biological sense that you can actually achieve what you are hoping to achieve, especially when I look at the ducks and other birds at Tarawera traipsing between 3 lakes within an hour for instance. In a previous life I spent 20 years in the waste industry including 10 years on the board of the Waste Management Institute. We had a similar situation as far as recycling and recovery is concerned and I applaud whoever said this morning its 'awareness'. We had a huge awareness in the broad community of the need to change, but it was never backed up with regulatory legislation which allowed things like instant fines. I urge you, Greg, that you have must have that stick or it will not work.

Greg Corbett: Just to clarify where things are at; the review of the Biosecurity Act kicked off earlier this year and I am representing BOP Regional Council on some of the working groups. Infringement notices are close to my heart, they are a tool we have been missing and will be useful in many situations, not only the aquatics. I am pretty passionate about this and will be pushing hard through that Biosecurity Act review process.

Don Atkinson, LWQS: Terry, I totally agree with you. Unless we do have a stick we will go nowhere. There is an opportunity for an education phase into the lead-in while we get the stick, because the stick is not going to emerge before December this year, but it will be essential to get everybody over the line.

Troy Baisden, University of Waikato: Following up on Terry's question. I had the odd experience in my professional life of working on isotope traces and biosecurity often entered into that. The international biosecurity system has moved more and more to understanding risk management of where stuff comes from beyond the borders, beyond the check, beyond anything that you can get your hands on. We use data science to understand where the risk levels are, how are they changing and is there a new lake within range that has suddenly got an infestation? Lake Tahoe as an example is really interesting and hopeful. But on the blue versus red map we could see that most of the boats arriving at that lake were not from highly infested areas, whereas there is quite a concern here. Another way to think about that would be facing a wave of zebra mussels on the east coast. Not that we are going to have those hopefully. But have you thought about designing the system taking into account a risk management of perspective pests and gather more information on where our threats will come from and how to manage those in real time.

Greg Corbett: The real time stuff would be fantastic to get to but I am not sure where technology is on that at the moment. We have been collecting data on movements of vessels and users of our lake for a number of years but it would be better to ensure that we have consistency on how we collect that data and ask the right questions so that data can be used in a meaningful way. MPI have been working on that in the last couple of years, to standardise data collection across the whole country.

Don Atkinson, LWQS: Still to be explored though. There are opportunities like electronic gates which would come with an app, so that as you came across the Mamakus, a user of that app would trigger a response to ask, 'Have you got your boat clean?' There are opportunities in this new world where boats move around, that we can engage with them.

Sherilyn Coney, LWQS: I am talking about awareness. I have heard that the catfish can live out of water for 3 days. Is this correct?

Greg Corbett: It is correct, as long as they have still got a moist skin and sheltered from the sun they are pretty robust and can live out of water for some time.

Sherilyn Coney, LWQS: I had heard it and have spoken to a lot of people but nobody seems to know this. I am sure if boaties knew that they could last 3 days they would be much more careful about looking over their boats. I do feel this should be made much more public.

Paul Champion, NIWA: Picking up Troy's comment, I think it is important to know that all regions are talking to each other within the country and if there is a new discovery all adjacent areas are aware of it. Everything tends to focus on what is within your region. The Waikato River is an obvious source of problems but it is very dynamic. There needs to be not necessarily a central repository, but at least databases talking to each other.

We have developed a standard operating procedure for decontamination of all NIWA vessels and equipment that are used in freshwater and we presented this to the MPI led Freshwater Partnership programme. You are most welcome to use that protocol and modify it.

Greg Corbett: Thanks Paul, that sharing of information is really important and something that regional councils are collectively talking with Biosecurity New Zealand about. How do we get better in those regions that have a new incursion and ensure that they are informed in a timely manner and the other adjoining regions if they are at risk?

We are also talking with Waikato Regional Council about what a pathway management could look like between the two regions, particularly because we know that there are plenty of boat movements backwards and forwards. Obviously it is in the very early stages but those conversations have started, mirroring what is happening in the top of the North Island in the marine space.

Sarah Van Der Boom, NZ Freshwater Biosecurity Programme: I am the North Island coordinator for this Freshwater Biosecurity Programme. You heard that mentioned by John Walsh (Biosecurity NZ) this morning. The partnership involves regional councils, DOC, Fish and Game, MPI and hydro companies.

One of my roles is to roll out the *Check, Clean, Dry* programme throughout the North Island and run the training. We have advocates throughout New Zealand who run surveys and work with Phil Hume from Lincoln University. Brenda Lawson, here, who is an advocate from Taupo. The reason I mention this is that our research outcomes will be really relevant to this project. It gathers people's movements, what activities they have been doing and how recently they have been in other water bodies. The research generates a map of New Zealand and all the pathways that people have been travelling, and because of all their activities we can understand the vectors as well.

A task in this new role, only established last year, is to do a complete revamp of *Check, Clean, Dry* which we have been doing over the last 18 months, including the social research that John Walsh and Greg referred to today. We only received that research at the start of October but I can already see how useful it will be. I can get that research for you if you want greater detail because there are some absolute gems. It is about the people, their activities, their values, the barriers they identified, their levels of compliance, their motivation, its absolute gold.

I want to say something on the certification proposal, which is not in my contractor role but speaking on my own behalf. I have spent the last 20 years working in comms, behaviour change, engagement, in all sorts of different organisations. In my long experience regulation is one tool in our tool kit, but we cannot see it as the panacea that will fix all those who are not complying in your desired behaviour. In that tool kit we might consider infrastructure as one of our tools in behaviour change, comms and marketing, community action such as the Catfish Killer's activities and care groups who are working around the lakes and incentives programmes. These tools all operate alongside each other, no one in isolation is going to achieve the desired behaviour change that you are after. No matter what environmental, social or health behaviour, it comes down to the same body of tools in the tool kit.

I specifically wanted to talk about regulations. I worked with NZTA for 4 years in their behaviour change team and the learning I took away is that regulation, on its own, works on your recidivism people, those who are persistently doing the same naughty behaviour time after time, after time, after time, regulation is there to bang them, and it will help you achieve your lowest bottom line in behaviour. But having said that, the big opportunity with this proposed certification idea is that it takes 2 to 3 years before the Biosecurity Act is actually changed and there is any kind of infringement tool. Speaking hypothetically, there is a 2 to 3 year window to run your certification programme as an educational voluntary activity. The greatest gains will be achieved in that period of time and then when regulation is in place you have a legal tool to do infringements or instant fines that will hopefully be the bread mopping up the gravy on the bottom of the plate. The bulk of the change will have been achieved through early voluntary comms, social marketing, the face to face behaviour change campaign that you have been running with your voluntary certification programme. So that's all from me.

Don Atkinson, LWQS: Thank you for those comments and we take them all to heart. Just one comment back to you, in the review of *Check, Clean and Dry* can you include the word 'drain' please? That will signal to boat owners, not just fisherman, and they can start to understand that bilges, anchor wells and deep dark places must be included in cleaning a boat.

John Green, LWQS: I am interested in the concept of the back door being left open. If you take aquarium owners who have their aquariums in their homes, and they tip their aquarium out in the lake, suddenly we have catfish, *Lagarosiphon*, *Hornwort* or whatever, because those species are still allowed into this country for aquarium users. What are we doing about stopping these aquarium plants being imported into this country, because they are big industries overseas but they are very bad for our country?

Greg Corbett: Thanks John, thankfully the likes of *Hornwort* and *Lagarosiphon* are banned from sale and are not imported into the country anymore. But the fact that we still have an aquarium trade is a real risk. We have climate change and global warming, and some of the aquarium specimens that have been bought in are deemed safe present no risk at present because our climate cannot support them in the wild, but that may change in the

future. It is a real risk and something for MPI rather than regional councils to think about as they manage import standards for organic material or organisms coming in over the border. I don't know if you've got anything to say on that Paul?

Paul Champion, NIWA: Yes, MPI are doing horizon scans of what unwanted organisms are in the international trade and we are contributing. We interact with groups like the Aquatic Plant Management Society in the US to see what new species they are dealing with, likewise in Europe and Australia. New Zealand was the first country to manage the spread of weeds like *Lagarosiphon, Egeria, Hornwort, Hydrilla* and *Salvinia* by banning their sale and distribution. Every region is charged under the Plant Pest Accord to inspect all places of sale, both nurseries and aquarium outlets. So it is not a back door that has been left open, it has been slammed shut for 40 years, but good job you mentioned it.

Nick Miller, LWQS: We were talking about pest plants. Can I comment that when Elizabeth and I first moved to Lake Rotoiti, which is quite a long time ago now, the house next door was not occupied and we took a brief look through the fence and noticed they had a fish pond with a healthy clump of water hyacinth. That water hyacinth was in our rubbish bag before you could say Jack Robinson and I am very thankful that it never made its way down to Te Weta Bay.

Lars Anderson: I have a comment and a naive question. First of all I agree with the process of education and up to a mandatory inspection mode, because I do think that is what it takes to be successful, 95% is not enough, you need 100%. 5% is sufficient to get you started again.

The question is how in the next 2 or 3 years do you engage stewardship mentality within the lakes. It is there to some extent but there are 12 lakes, 12 representation groups within each of those lakes that could take this on as a stewardship effort to work within their lake to make sure the educational process occurs. It seems a natural way to do that and have ownership of property, the users of the lakes. In Lake Tahoe the long-term process to get where we are today was to educate, but it turned out that the people who live there are the ones who pushed for change. People who are short term renters do not have a clue. It is the ownership that makes a difference.

Of the 12 lakes, 2 of them are Maori, is that right? Anyway, it seems that the way to start is where you have stewardship within your lake. You can even do a competition over who has done a better job at keeping boats away that have not been inspected. Anyway, that is my naive question, could that be done as a way to start the education process?

Cr Reynold McPherson, Rotorua Lakes Council: I am a very recently elected councillor and I would like to thank Phil Thomas for tipping me off about this symposium at short notice. I am sorry I cannot be here tomorrow because we have got Day 3 of our bus tour being introduced to the various operations of Council. But I would like to pick up on the points you made about the educational programmes that are required and points that were raised by Sarah. I come from a background in the reform of large organisations internationally and a professorial role at the University of Auckland on change management. The emerging rules over the last few decades of community change models always seem to stress a combination of strategies, and this points to the strength of what is being proposed. You have to use power cohesive strategies, in combination with empirical rational strategies, in combination with normative re-educative strategies. The power cohesive is about the necessity of fines being in the background and deploying those if necessary, to sharpen up the behaviour of users and some potential users.

The second group, the empirical rational strategies, have been well addressed by the science that I have heard all day and I have been incredibly impressed by the quality.

The third, normative re-educative strategies, refers to the need for a sophisticated and sustainable re-education programme over a number of years. My only suggestion for the proposers of the strategy is have you really obtained access to, and can you immobilise all the available social systems that could give weight to this whole strategy? I think of the complex and diverse nature of our community here in Rotorua and we have pre-existing social systems, to what extent could they be mobilised and drawn in to the strategy? But across the board it seems to me you are pretty much ticking all the boxes. Thank you for a very interesting day.

Don Atkinson, LWQS: Just responding to both questions, I am sure that there is a wealth of support out there for this process and the example of the Catfish Killers and their enabling and picking up such strong community support. There is no good reason why we cannot see that type of support reflected in this type of certification programme.

Prof Warwick Silvester, LWQS: When one gets to a certain age one looks back to see things in a historical perspective. Nick's arrival at Lake Rotoiti, and I go back to 1960 when Val Chapman took the Botany class for a tour to his bach at Lake Rotoiti and we stood on his little wharf and looked down at all the weeds coming up to meet us. Val, in his inevitable way, talked about what was going to happen in the future if this went on. That was nearly 60 years ago now and what has happened. I do reflect on the way in which the LakesWater Quality Society has, as a ginger initially, become of age and generated a number of seminars in the last few years which have been very cooperative and constructive, and this is inevitably one of them. I wanted to congratulate the fact that we have got Don and Greg standing there from 2 different organisations, talking from the same song book, obviously getting on together and coming with solutions to the problem that has been there for 60 years. Thank you Gentleman, you are great.

Jonathon West, Victoria University of Wellington: Thank you both very much. It seems to me there is a question as to whether or not people agree with Lar's prognosis; that ultimately the only thing that is going to work here is a Tahoe type lock down situation where you guarantee that a boat is cleaned and properly checked before it can go in the water. If that is the end goal, the only thing that is going to work, and something that is plausible, possible and defensible in a principled way given the iconic status of these lakes. It feels to me that there are some people who may feel that way, but you want to go down this track because this is the only level of cultural change you think you can envisage to begin with. As this goes on there will be questions posed of you as to what should happen. This will be seen as a stalking horse, rightly so, and you need to be open about what you want, and why, along the way. Think about what is guiding the process that you have in mind.

Don Atkinson, LWQS: We are not playing any shadow game here; we are being up front about trying to progress the biosecurity issues forward. Ultimately if we find that we cannot get people to partake in a voluntary, or semi-voluntary way, it will be inevitable that we have to take a firmer position and it might look very much like Lake Tahoe. But I do believe there is an opportunity for the community to achieve the 95%. If we were there in 2 or 3 years, we would say we have done well. But if we are failing, and particularly if we get further major incursions around these lakes in this intervening period, there will be a hard look at what has been achieved and what opportunities have been missed. But we do have to take the community forward and be inclusive, and we are mindful of that.

Mary Stanton, LWQS: Kia Ora, I am a whakapapa to the Newton whanau. I was born on the Ohau Channel and my father was Stan Newton. The history goes back a long way. When I was a child there were only 7 boats on Lake Rotoiti and we knew all those boats and who owned them, and we looked after each other. We were very careful about what went into the water and conscious of water quality.

I look back and see our traditional methods of catching koura in Lake Rotoiti by putting bundles of fern into the lakes is now almost history. Our koros and kuias helped us by telling us what to do and not to do. We had so many maraes and still have today right around the lakes. Te Arawa will help to protect our whenua and our lakes and the environment. Please ask more speakers from the Te Arawa Lakes, I would like to see that happen more.

I live in Okawa Bay and see heaps of boats coming into the boat ramp from all directions, Tauranga, Taupo and Whakatane. When it comes to restricting and checking, how will you keep up with it? It will be a huge job? But Don I congratulate you, you have been here for so long helping with all our Symposiums and we back you always.

I want to bring up a point here about jet skis, will they be accountable? We have a huge increase on jet skis, canoeists, rafters, waka ama, all increasing, and the lakes are getting very busy. So, are they going to be a problem? We have boats, jetties, and we also have boat sheds and a lot of boats hidden in those boat sheds. How are we going to make them accountable? I hope we will be able to help wherever we can, kia ora.

Don Atkinson, LWQS: Kia ora Mary, thank you for those comments, and yes, all those boats that you mentioned will be included.

Phill Thomass, LWQS: Could I just make comment there too and thank you Mary for mentioning Te Arawa, because we always have to remember that our lakes belong to Te Arawa. And although we have not got them talking here with us today I would say that at all our stakeholder meetings, Te Arawa are a principle part of those meetings and this strategy.

John Gifford, LWQS: To add to that, the groups that are involved in the collaborative effort and the sub groups that are working on the proposals that Greg eluded to, include the Te Arawa Lakes Trust, DOC, the Bay of Plenty Regional Council, LakesWater Quality Society, Fish and Game, MPI and LINZ, a comprehensive group of stakeholders coming together, and the Rotorua Lakes Council and the Community Board. This collective coming together is a network similar to what Nicole talked about in Lake Tahoe, and worked as a successful formula for bringing about the change process.

Session 5 : REGULATIONS, TOOLS & ECONOMICS

SESSION CHAIR – Stewart Edward

LAKE PLANS, ERADICATION, MANAGEMENT PLANS & THE TOOLBOX

Hamish Lass
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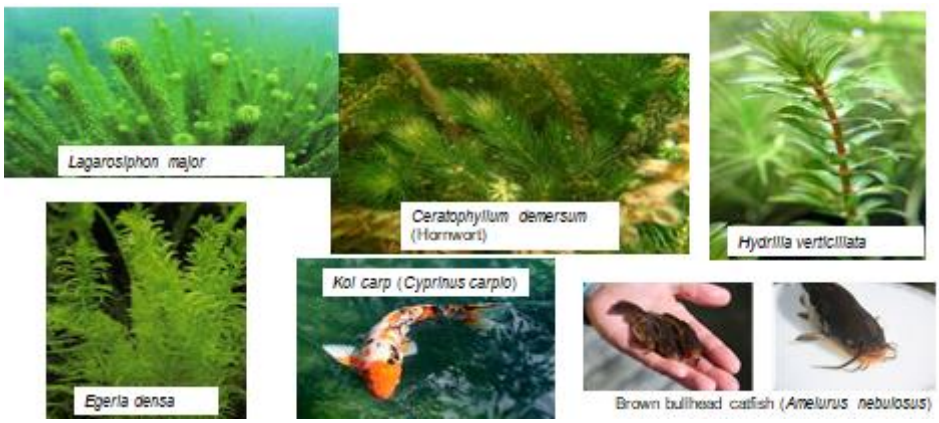
Hamish is a Senior Projects officer with the Bay of Plenty Regional Council whose focus is on the Marine and Freshwater Biosecurity programmes. Hamish's involvement within the programmes involves management of lake surveillance, summer students, lakeweed spraying, education and lakes weed cordons.

TRANSCRIPT

Morena Tatou. My presentation today is about the freshwater biosecurity toolbox that we have at the Regional Council. I will talk about the pest programme, weed cordons, surveillance incursion response, our Aquatic Pest Co-ordination Group and Lakes Management Plans.

Our Aquatic Pest Coordination Group is made of the Bay of Plenty Regional Council, Rotorua Lakes Council, Te Arawa Lakes Trust, Fish and Game, Land Information NZ, Department of Conservation and NIWA. We get together 2 to 3 times a year talking about projects that we have underway such as the spray programme, and any shared resources. We talk about student work over the summer, where they are going and potential changes to different areas like boat ramps and new ideas popping up to aid in the whole programme.

Freshwater Invasive Species

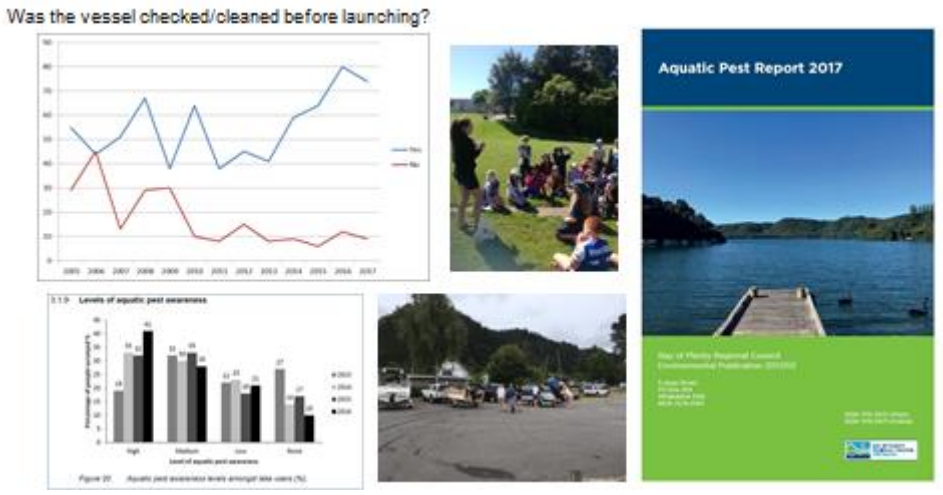


I will not delve too deeply into these because Paul and the NIWA team talked about them yesterday. But these are some of the pests that we have and do not have in the Rotorua lakes:

- *Lagarosiphon major* is in 9 of our 13 lakes and is one that most people know as oxygen weed.
- *Hornwort*, my nemesis that I have been chasing for nearly 14 years, in 7 of our 13 lakes.
- *Egeria densa* is in 6 of our lakes
- *Hydrilla* is not present in any of our lakes but there have been infestations in other regions in the North Island. Its good management in Hawkes Bay has been beneficial for its prevention in the Rotorua Te Arawa Lakes.
- Koi carp are not here although they are in the Waikato water systems and one to worry about
- Catfish are a big problem for us

We do a lot of communications and work in behaviour change, and education is a huge part of the Freshwater Biosecurity Programme. A lot of our work is over the busy summer period and in winter as well, working with MPI and the *Check, Clean Dry* programme. We rely heavily on the student programme, normally two students every summer who do an excellent job visiting all boat ramps, educating people, attending events and giving away handouts. This has been going for almost 12 years now and they produce a report, giving us really good data on changing behaviours around the lakes, the origins of lake users and where we need to concentrate on different areas. They talk to thousands of people each summer giving us valuable pieces of the puzzle.

The data (next page) shows that many people check their vessels before they go and the awareness is quite high. But we still get people doing the wrong thing, transporting lakeweed around on trailers and boats. It only takes one person to do it and that creates a whole heap of work for multiple agencies over many years.



We have a portable wash down unit which is kind of a portable boat wash. It is a good tool for awareness because it gets people thinking about what they need to do and they drive in there and get a free clean. That is Zair, one of our students at Lake Rotoma with *Hornwort* that had been blasted off a trailer.

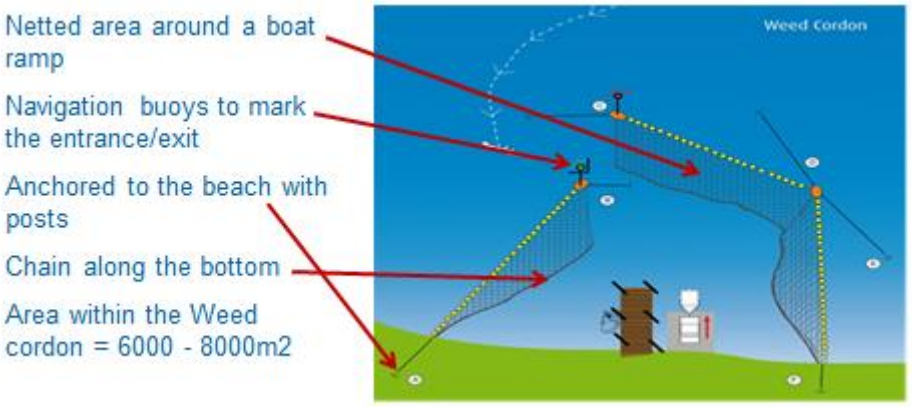
The issue we have around the Rotorua lakes is that there are large numbers of lake users that travel between lakes which is the main vector for lakeweed transportation. We have weeds in some lakes that are not in others and these lakes can be situated in close proximity to each other, i.e. less than 1km. A portable wash-down is set up at events and has intercepted vessels with weed fragments.

Surveillance

We do a lot of surveillance and are lucky that we have our own inhouse dive team and do all sorts of Manta boarding, beach searches and spot dives using underwater scooters and a side scan sonar. We check all of our high value lakes, Rotomā, Ōkataina, Rotokākahi, Tikitapu, Ōkāreka, Ōkaro, Rerewhakaaitu

and Rotomāhana that have the least amount of weeds and do analysis on high risk sites within each lake. We also keep an eye out for catfish pock marks, spotting anything that might look like pest fish, such as catfish and Koi carp. The photo on the bottom right is *Hornwort* in Lake Ōkataina.

Weed cordons – What are they?



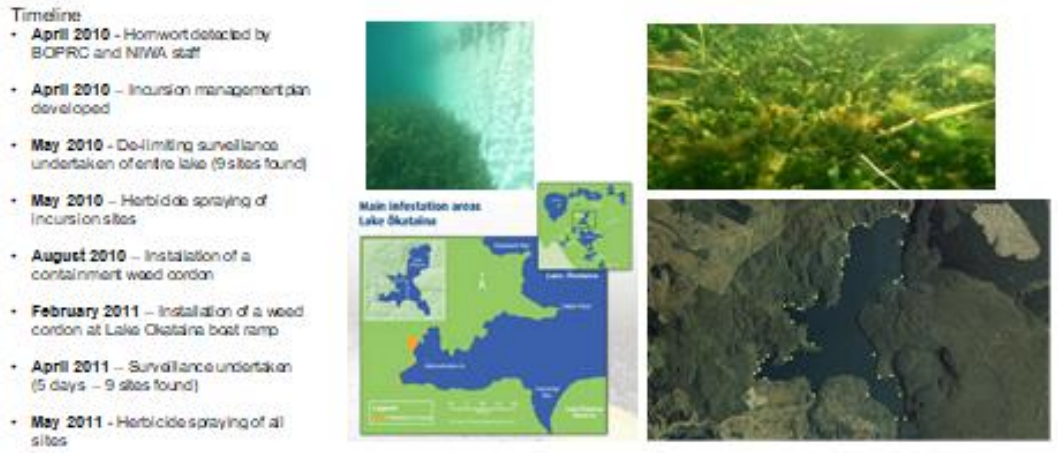
Weed cordons are a newish tool which has been in the lakes for around 10 or 11 years. Basically it is a fence around a vector point, being a boat ramp, and designed to contain any fragments within its area if someone does transport a weed on their trailer. The shade cloth netting and navigation buoys marking the entrance show people where to go in and out so they do not drive over the top of it. It is anchored by posts to the beach with a chain along the bottom to hold it down and acts as a curtain barrier to stop fragments from going out into the main body of the lake. It is a lot easier to manage a small area within the weed cordon (6,000 – 8,000m_2) rather than the whole lake.

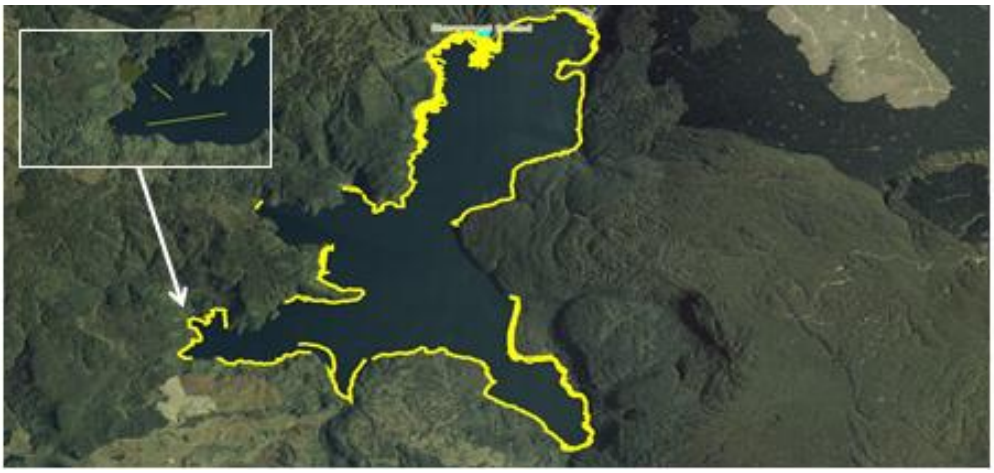
Weed cordons are installed at 8 locations within 5 of our high value lakes around Rotorua. They stop new incursions happening and also stop any weed fragments from gathering around the boat ramp and getting transported, so they work in two ways.

Incursion Response Plan

When we have a new incursion the Incursion Response Plan gives options for management. Normally they are - do nothing, containment or eradication. For Lake Ōkataina we decided to attempt eradication and within the response plan we had a weed cordon to contain the area at the boat ramp, increased public awareness and used the Biosecurity Act (Sec100 and Sec130) to aid in the plan working.

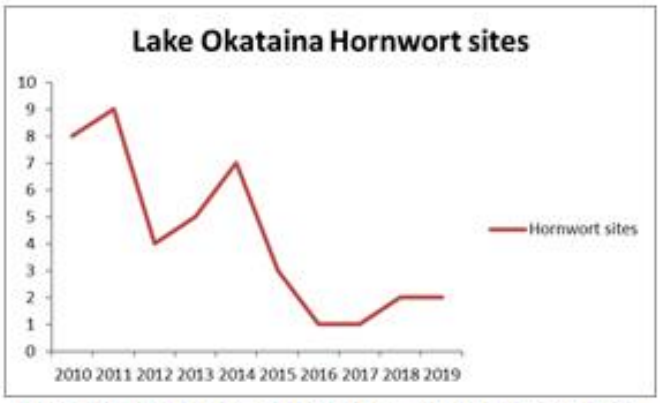
Lake Biosecurity Incursion Management - Lake Ōkataina 2010 - 2017



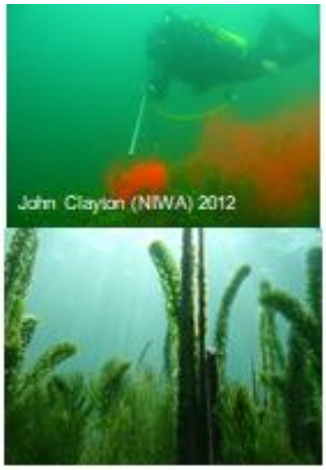


This is surveillance that was associated with the incursion response plan. It was quite extensive and the results of that plan are pretty positive. We did incursion response surveillance, then spraying, then surveillance and then spraying and it has been on-going for 9 years now. We were quite lucky with Lake Ōkataina because it is a clear lake and reasonably easy to do the surveillance. We have spent nearly 2,600 dive man hours.

We started with quite a large incursion site back in 2010, and with management, surveillance and spraying we are down to two small plants, so it is going really well. The next few years will be interesting to see. It is not often that a big lake like Lake Ōkataina potentially could have total eradication of one of the world's worst aquatic weeds. It would be an amazing story if we could get there.



Dive surveillance "man" hours = 2560 (2010-2019)

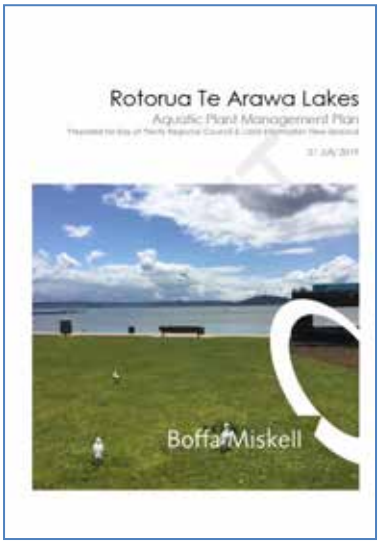


Lakes Management Plans

The Rotorua Te Arawa Lakes aquatic plant management plan vision is:

> *The eradication of invasive aquatic pest plants and restoration of native plant communities. The vision aligns with purpose of the strategy group as eradicating invasive aquatic pest plants and restoring native plant communities will:*
>
> - *Promote the sustainable management of the Rotorua Te Arawa Lakes and catchments*
> - *Allow for the use and enjoyment of present and future generations, and*
> - *Recognise and provide for the traditional relationship of Te Arawa with their ancestral lakes.*

Management of aquatic pest plants within the Rotorua Lakes dates back to the 1950s when pest plants first became problematic in Lake Rotorua. Many options were trialled, including both mechanical and chemical, of which diquat was found to be the most effective (Clayton & Wells, 1989). Aquatic pest plants have continued to spread since the 1950s with new incursions discovered within the past 10 years. Pest plant control has mostly been on an ad hoc basis and aimed at containing aquatic pest plants, due to the limited resources. Diquat remains the most widely used tool, while the weed harvester is also used in some lakes. There is an increasing range of tools available to combat aquatic pest plants. Effective control is dependent on lake characteristics (such as type and distribution of aquatic pest plant species), the overall vision, goals, targets and objectives for the lake and the cost effectiveness of each method.



The Aquatic Plant Management Plans were prepared by Boffa Miskell for LINZ and Bay of Plenty Regional Council and have very high level visions. They are developed to address the ongoing and increasing problems with lakeweed management and talk about the eradication of

invasive aquatic pest plants and biodiversity restoration back to native plant communities which is a big hurdle. The vision aligns with the values of Te Arawa and something that we have worked on for some time. They have taken a while to develop but we want to make sure they are right.

A consultation programme contributed to the preparation of the Aquatic Plant Management Plans and involved obtaining perceptions of lake values, invasive pest plant locations and management of Rotorua Lakes from government and statutory organisations, iwi and hapu, LWQS, ratepayer groups, tourism operators and recreational groups. Views and opinions from the consultation programme have contributed to the vision, goals and objectives within the plans. This document provides aquatic plant management plans for each of the 12 Rotorua Te Arawa Lakes within the Bay of Plenty region

We used a lot of information from other related projects. In mid-2016, Dragten Consulting prepared a document for BOPRC which prioritised weed control at a selection of sites throughout the Rotorua Te Arawa Lakes. Biosecurity and amenity criteria were used to create a prioritised order of sites. The project was intended to assist BOPRC with making decisions about where to best direct aquatic pest plant control efforts with limited resources (Dragten 2016).

Over the past 10 years BOPRC, RLC and TALT have created action plans for some of the Rotorua Te Arawa Lakes to restore water quality. The action plans identify tasks that should be undertaken to reduce nutrient inputs into selected lakes with specific nutrient reduction aims and trophic level targets. The documents are active, providing the ability to be reviewed and updated with changes in technology, best management practices and regulatory framework. The Aquatic Plant Management Plans have been structured to allow for potential integration with action plans at a later stage and take a more holistic approach.

LakeSPI (Lake Submerged Plant Indicators) was developed by NIWA and is used for assessing the ecological condition of New Zealand lakes. LakeSPI characterises the composition of native and invasive plants growing in the lakes and the depths to which they grow. All Rotorua Te Arawa Lakes have been assessed numerous times in the past with monitoring becoming more frequent over the past 10 years (each lake is assessed approximately every two years) (NIWA 2016a). The Aquatic Plant Management Plans use LakeSPI information which is also included as part of the monitoring and plan review section of this document.

In 2011, APR Consultants prepared a series of reports on aquatic pest plant control for amenity purposes on Rotorua lakes. The reports focused on identifying areas with high amenity values that were potentially impacted by the presence of aquatic pest plants, stakeholder's thoughts on management of aquatic pest plants and assessing the control and prioritisation options as well as associated risks (APR Consultants 2011a, b & c). Some of the findings from the reports have been used in the preparation of these Aquatic Plant Management Plans.

All these projects gave us a lot of information that we add into the Aquatic Plant Management Plans to make them robust. Each plan caters to a different lake with a distinctive goal and LakeSPI targets that guides the objectives and outcomes as well as subsequent management for that lake. The goals, LakeSPI targets, objectives and actions are based on the overarching vision. This document does not replace existing legislation

or plans, policies or statements but seeks to build on agencies existing goals and legislative requirements to achieve integrated, effective and efficient management of aquatic plants within Rotorua Te Arawa Lakes.

I will not go through all 12 of them, but will go through the eradication plan for Lake Ōkāreka.

Lake Ōkāreka Management Plan vision

The goal for Lake Ōkāreka is:

Eradication of Hornwort, Lagarosiphon, Elodea and Egeria from Lake Ōkāreka

Those are the 4 pest species that are present at relatively high densities. Lake *Ōkāreka* has a community adjacent to the lake and is a popular recreational lake for both locals and tourists. Being a moderately sized lake it would fit really well with eradication. It is larger than other waterbodies where we have done another eradication programme of *Hornwort* within the lake with spectacular results but small enough to test the feasibility of lake-scale eradication.

We did management for 2 or 3 years and have not seen any *Hornwort* or *Egeria*, which is most surprising, because the *Egeria* plants within Lake Ōkāreka were anything from 5 to 8 meters tall. We first found *Hornwort* fragments in 2012. In 2013 a delimitation survey was completed finding large areas of light infestations in the northern end of the lake. The management was very similar to the Ōkataina incursion response plan. The areas were sprayed with Diquat in 2012, 2013 and 2014 and there has been none seen within the lake since. So, it would be a really good to restore that lake back to a native plant index. The photo shows the areas that were sprayed.

- Hornwort fragments found in 2012.
- Delimitation survey completed in 2013.
- Large areas of light infestations in northern end of lake.
- Areas sprayed with Diquat to control infestations
- No hornwort seen with lake since

Possible future management

Slide 20 This shows the possible future management within the lake's management plans. The lake size is 350 hectares, not a massive lake. The potential habitat, which is the hashed area, is where lakeweed could grow within Lake Ōkāreka. The indicative costings show Endothall spray at the top is more expensive that Diquat, each year grading down, but these numbers could change. There may be a really good result at the start through Diquat control, or we may do a combination of both. There is also monitoring involved so the costs are reasonably high.

Lake size	350ha
Allowable spray per round 25%	87.5ha
Potential habitat	135ha

Control - Endothol				
Year 1	Year 2	Year 3	Year 4	Year 5
1443770	962500	481312	481312	481312

Control - Diquat				
Year 1	Year 2	Year 3	Year 4	Year 5
549500	549500	481248	481248	481248

Pre and Post spray monitoring				
Year 1	Year 2	Year 3	Year 4	Year 5
37520	37520	37520	37520	37520

In the future, we will carry on with summer students, and two more are starting soon. We work a lot with underwater ROV that we have recently bought for surveillance as well and we will continue to work with our partners.

Thanks.

QUESTIONS

Colin Jackson, LWQS: In the example there of Ōkāreka, you had, I think it was 135 hectares of potential habitat, but only 85 that you were allowed to spray?

Hamish Lass: Yes 25%, that is part of the consent allowing us to spray 25% of the waterway.

Colin Jackson: Is that alterable? If you really wanted to hit that lake and tidy it all up, is there potential to spray the whole area?

Hamish Lass: We would have to go through the whole consultation and consent process again if we wanted to get that changed which can take quite some time.

Colin Jackson: Does that mean that you have to talk with all the partners involved, as well as the Council and so it is a community interest perception issue as well as the council?

Hamish Lass: We would have to go through the whole process again, talking to all affected parties.

John La Roche, LWQS: Hamish, thank you, very interesting. You talk about spraying our boats, is that on the way in, or the way out of the lake?

Hamish Lass: Both, we set up the portable wash-down unit in Lake Rotomā and Lake Ōkāreka. It is quite a big unit and needs a big area to use, and we use it both in and out. People can come out and clean. We have set up a boat shed bay in Lake Tarawera and people drive out clean and come in clean as well. We just want people to use it. It would be great to have permanent wash-down facilities, one you can drive through free, but getting permanent wash-down set up at every boat ramp is almost $1 million each. When we look at Greg Corbett's map of how many boat ramps we have (200 private boat ramps, 25 public boat ramps) we need to win lotto a couple of times to pay for them. In a perfect world we would have a permanent wash-down facility that was free, you could drive through and it would clean the boat, but we don't.

John la Roche: In comparison to the cost of getting rid of weeds in the lake though, it would be a good investment surely.

Hamish Lass: Yes, so far over 10 years the Ōkataina incursion has been quite a lot of money, probably the equivalent of one wash-down. We have looked at it and a man from Cambridge from Wash Deck, developed the one at Sulphur Point for the marine guys and they do work really well. But there is also a lot of maintenance which adds to the costs. The Regional Council is trying to get an extra couple of million dollars' worth of funding for our Biosecurity Programme, but you know that affects rate payers.

ENDOTHALL HERBICIDE – LAKE TRIALS AND OTHER NEW ZEALAND EXPERIENCE

Deborah Hofstra/Paul Champion
NIWA
Deborah.Hofstra@niwa.co.nz

Dr Hofstra has more than 20 years of experience in freshwater biosecurity and biodiversity. Deborah leads research that focuses on solutions for aquatic weed issues, such as developing use profiles for aquatic herbicides, including Endothall, assessing the impacts of grass carp and lake rehabilitation projects. Efficacy studies have been completed on both submerged and marginal aquatic weeds using herbicides, physical and biological control tools. These studies also include assessment of the potential impacts, or benefits to non-target native plant species and communities. Dr Hofstra serves as a Director on the Board of the Aquatic Plant Management Society, and is on the Science Committee of the International Aquatic Plants Group.

TRANSCRIPT

Kia ora tatou, thank you for the opportunity to speak today. I am going to talk about endothall herbicide, and some of the lake trials that NIWA has either undertaken, or been a partner to, with other stakeholders. I want to acknowledge also that this is not just my work, my co-author is Paul Champion, and a number of the other lake specific examples were by Rohan Wells. I have put in references for additional information on each of these trials. First, I will provide some context around weed control and the control tools, why you might choose to use a product like endothall, and then I will move on to the case studies and lake examples.

Endothall is a herbicide used very effectively for controlling submerged aquatic weeds and algae and there are two different formulations - Endothall dipotassium salt and monoamine endothall. The active ingredient for both formulations is endothall acid (7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid) which is formed when endothall salts are applied to water. I am going to focus on dipotassium endothall because that is the product that was registered in 2004 in New Zealand for use on submerged aquatic plant. It is called Aquathol – this is the trade name. It is a product that has decades of use, particularly in the USA, and there is extensive data on environmental safety around its use.[1]

A key factor relevant in a New Zealand context, and particularly within this region, is that it is affective on *Ceratophyllum demersum* (hornwort) *and Lagarosiphon major*[2]. We know from studies that we have done looking at New Zealand native species that it has a low impact on our tall growing plants. For example, it will impact *Myriophyllum*, but the plants will regrow. It has no impact on our native charophytes; these are desirable plant species within our native plant community. Endothall is most often described as a contact

[1] Keckemet 1969. Chemical, toxicological and biological properties of endothall. Journal of Aquatic Plant Management, 8(1): 50-51.
[2] Hofstra and Clayton 2001: Evaluation of selected herbicides for the control of exotic submerged weeds in New Zealand: Journal of Aquatic Plant Management, 38: 20-24

herbicide[3] in the way it works on the plants, and in recent years there has also been some research into its systemic activity too[4]. Its mode of action on plants that are susceptible to endothall is to disrupt plant cells, damaging plant tissues within 2–5 days after application[2], with peak injury weeks after treatment particularly on larger biomass. Essentially the product is broken down within water and sediments. It can be dispersed as well and it is relatively short lived in the environment, - with breakdown occurring from microbial activity and also influenced by warmer temperatures.

Why control invasive weeds?

This refers back to Paul Champion's talk about the impacts of invasive aquatic plants in our lakes and the way they displace the native vegetation, which in turn alters the habitat for fauna that live in and around the lakes. It can impact on the functioning of those ecosystems and some of you may have experienced what happens when weed beds impede the use, and functions of lakes and waterways.

Why might we want to control invasive weed species? We firstly need to reflect on the economic decisions; 'What if you decide not to'? No action is also a decision, e.g. the costs of control versus the cost of doing nothing. The consequence of doing nothing might in the short term seem like an easy option to take but bear in mind that the weeds will continue to grow while you are deciding what action to take, or even deciding not to. They are self-escalating, because they are growing, and will continue to grow until that habitat is saturated, so the impacts will be accruing as well.

When the decision is made to take action and control invasive weeds - Why use a herbicide? There are a number of key factors to consider:

- What species is it?
- What is it going to respond to?
- How big is the infestation?
- What are the water body characteristics?
- Do they allow/not allow you to use a particular control tool?
- What is the desired outcome and management goal at a community level?

[3] Sprecher et al 2002. Review of USACE-Generated efficacy and dissipation data for the aquatic herbicide formulations Aquathol and Hydrothol. Aquatic Plant Control Research Program, ERDC/EL TR-02-11: 52.
[4] Ortiz et al 2019. Endothall behaviour in *Myriophyllum spicatum* and *Hydrilla verticillata*. Pest Management Science. 75(11).

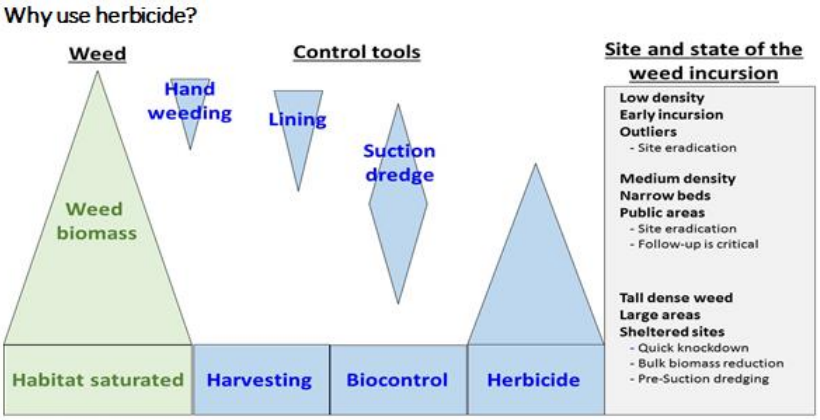


Fig. 1 Key factors for consideration when selecting an appropriate weed control tool. Weed biomass (*green, left*), site and state of the weed incursion (*grey, right*) determine the selection of control tool or tools (*blue, centre*). [Source: Hofstra et al 2018. Control of Invasive aquatic plants, In Lake Restoration Handbook]

This diagram visually illustrates the different control tools that are available and when they might be useful.[5] On the left-hand side, the green triangle illustrates weed beds. At the top there are new incursions that can be controlled by hand weeding or benthic barriers (Nicole touched on this tool yesterday for the Tahoe example), or you could use suction dredging. But once the habitat becomes saturated, at the bottom of the diagram, the options for use on submerged plants are harvesting, biological control (we have a generalist bio-control agent here in New Zealand called grass carp), or herbicides, which can have a significant impact on large volumes of weed.

Hamish Lass has talked already about some of the constraints that there are for the use of endothall once you have a consent. But before that consent process there is another process which is through the Environmental Protection Authority (EPA). Endothall is subject to a number of controls set by the EPA, such as the concentration of herbicide that can be applied, the time frames within which the water can be used by people (withholding period), e.g., for drinking, livestock or irrigation, etc. Hamish also touched on the restrictions in how much of a water body can be treated with endothall at any one time. So, there is the EPA level, and the resource consent level under the RMA which regulate the use of endothall.

Endothall Regulations

The use of endothall is subject to controls set by EPA

- Restrictions include:
    - Maximum concentration in lake water must not exceed 5 ppm (5 mg /1 L)
    - Environmental Exposure Limit (EEL) for water of 86 µg/L (0.086 mg/L)
    - (EEL is a dilution of the max. permitted concentration by 1/60th)
    - Withholding periods for the use of treated water for drinking, livestock, irrigation or preparing agrichemical sprays.
    - No taking of fish for consumption within 3 days of application.
    - No swimming within 24 hours of application.
    - Spray must not be applied to > 25% of the water body area.

[5] Source: Hofstra et al 2018. Control of Invasive aquatic plants, In Lake Restoration Handbook

- Spray must not be applied to estuaries or water bodies within 1 km of the coast (May to Aug).

- Monitoring of spray operations include measurements of pH, dissolved oxygen, % plant cover and presence of native plants in the spray area, at least 5 days prior to spray and 15-20 days after herbicide application.

- Resource consent (under the RMA) is required for all regions[6]

Endothall – use constraints

	NZ endothall dipotassium label	USA endothall dipotassium label*
Swimming	*24 h*	No withholding period
Fishing	*3 days*	No withholding period
Drinking	*7 days to 0.50ppm; 14 days to 4.25ppm; 25 days to 5ppm*	Less than the MCL (Maximum Contaminant Level) of 0.1 ppm. Drinking water setback distance from functioning potable water intakes is greater than or equal to 600 feet.
Stock use	*7 days to 0.50ppm; 14 days to 4.25ppm; 25 days to 5ppm*	No restriction
Irrigation	*7 days to 0.50ppm; 14 days to 4.25ppm; 25 days to 5ppm*	No restriction
% treatment	Up to 25% of waterbody	Not specified

Comparison between NZEPA approvals (italicised), or NZ label requirements and United States endothall dipotassium herbicide labels including withholding periods and use metrics.
*Reregistration Eligibility Decision for Endothall in the US (September 2005) (https://archive.epa.gov/pesticides/reregistration/web/pdf/endothall_red.pdf)

This diagram shows the contrast between the controls that the New Zealand EPA and the USA EPA has, on the use of dipotassium endothall. It is a point for reflection, because the same data sets are available in New Zealand, but different decisions have been taken.[7]

Endothall has been used to **eradicate** pest plants in several whole of water body treatments to date and we will look at some examples here in New Zealand. I want you to be aware that some of the studies have happened under a different regulatory environment. Going back to 2001, we had an experimental use permit and these studies were not done under the restrictions that, for example, Bay of Plenty Regional Council now needs to operate under.

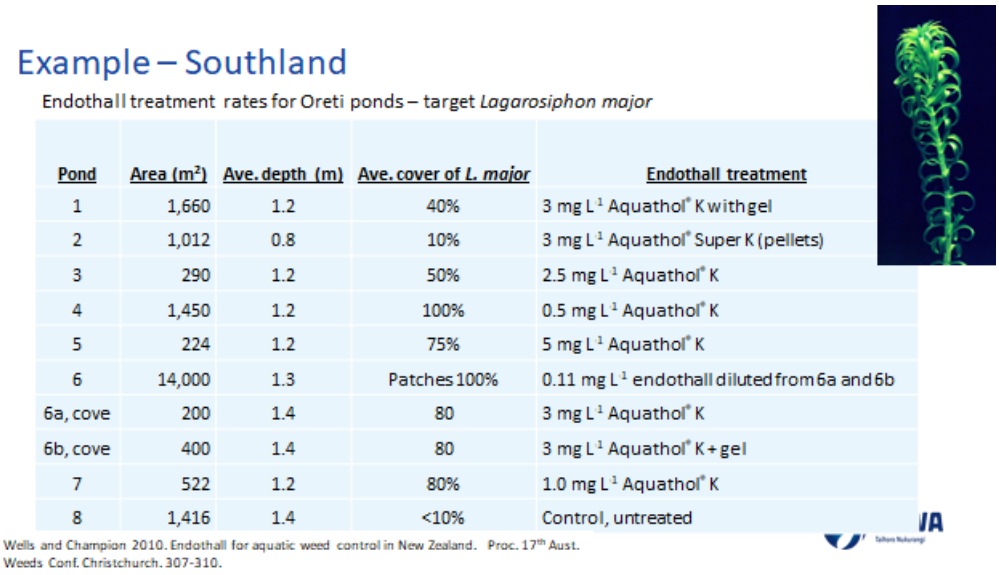
The first two examples involved Rohan Wells and Paul Champion. The first one was *Lagarosiphon major* in Southland ponds where different treatment rates were evaluated. The second one, *Ceratophyllum* in Centennial Lake, Timaru, was for eradication.

[6] Champion, Hofstra, de Winton 2019. Best Management Practise for Aquatic Weed Control, Part One. Envirolink Report. [https://niwa.co.nz/sites/niwa.co.nz/files/Best%20Management%20Practice%20for%20Aquatic%20Weeds%20Framework%20May%202019.pdf]

[7] Reregistration Eligibility Decision for Endothall in the US (September 2005) (https://archive.epa.gov/pesticides/reregistration/web/pdf/endothall_red.pdf

Example: Southland ponds

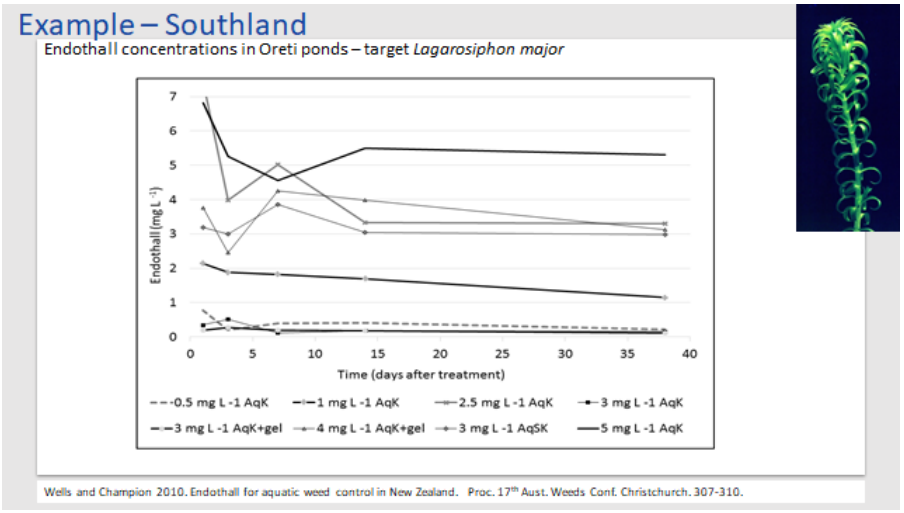
The Southland example did not start out with the goal to eradicate. Rohan and Paul conducted a field trial in a series of eight small gravel extraction ponds in Oreti, Southland, South Island to demonstrate the use of endothall to control *Lagarosiphon major* (Wells and Champion 2010).



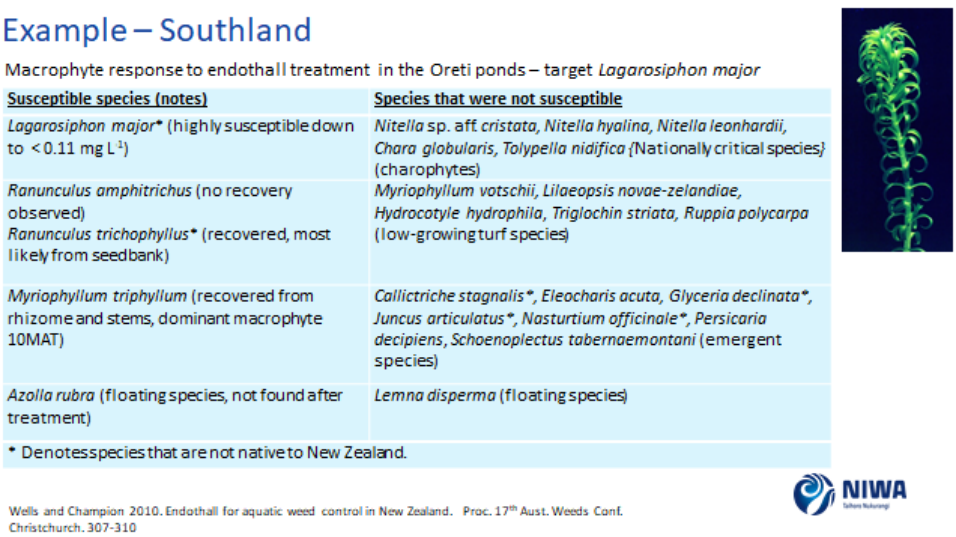
They used different concentrations of Endothall, either as the Aquathol K, which is the liquid product, or as the pellet product which is the Super K. They also put gelling agent with some of the treatments as well. The ponds were assessed before treatment, for species present, height (maximum and average), and plant cover using a 'quick survey' method (Clayton 1983). Location of selected areas of dense *Lagarosiphon major* were noted specifically to enable monitoring of Endothall efficacy on this target species. A repeat assessment was made at 53 days, 10 months and two years after treatment and compared with the pre-trial assessment. Of 3 macrophyte species recorded, only five were adversely affected and, with the exception of Ponds 4 and 8, *Lagrosiphon major* was eradicated.[8]

[8] Wells and Champion 2010. Endothall for aquatic weed control in New Zealand. Proc. 17th Aust. Weeds Conf. Christchurch. 307-310.

As the ponds were not of natural origin, Environment Southland ruled that this trial did not require a resource consent under the Resource Management Act 1993. However, herbicide residue analyses were undertaken on samples from each pond, along with temperature data to assist in interpreting results. The data demonstrated that desired herbicidal concentrations were maintained for up to 38 days. No detectible endothall residues were sampled 8 months after treatment.



It is worth noting from this study that these Southland ponds had cold water (16 degrees). The question was would Endothall work in cool conditions on *Lagarosiphon* (the most problematic submerged weed down there) under natural conditions? This study did find that Endothall stays around for longer, has slower breakdown in cooler water. The result is longer contact times and efficacy. The middle part of this graph shows that Endothall stayed at those concentrations for about 30 days. So, concentration and exposure time are two of the important things to get right in to get the desired level of control.



These are the results. What this shows is that the *Lagarosiphon* was eradicated in water bodies up to 1.5 ha, at concentrations up to 50 times less than the recommended rates of Endothall. Five years after the treatment, no *Lagarosiphon* was present. The native milfoil

had fully recovered by 10 months post treatment and dominated several of the ponds[9] and the *Myriophyllum*, another desirable native species, also bounced back. This trial confirmed that the native charophytes were not susceptible to Endothall, and this was particularly important because there was a nationally critical species present, and the study showed that it was not impacted.

Example: Centennial Lake, Timaru

For our next example the purpose was eradication of *Ceratophyllum demersum* (Hornwort) in Centennial Lake in Timaru. *Ceratophyllum* has been discovered in the South Island a couple of times and both times it has been eradicated. The national strategy is to target *Ceratophyllum* for eradication in the South Island, but there had not been any success at this site using Diquat, most likely because the waters are quite turbid and the turbidity impacts the efficacy of Diquat.

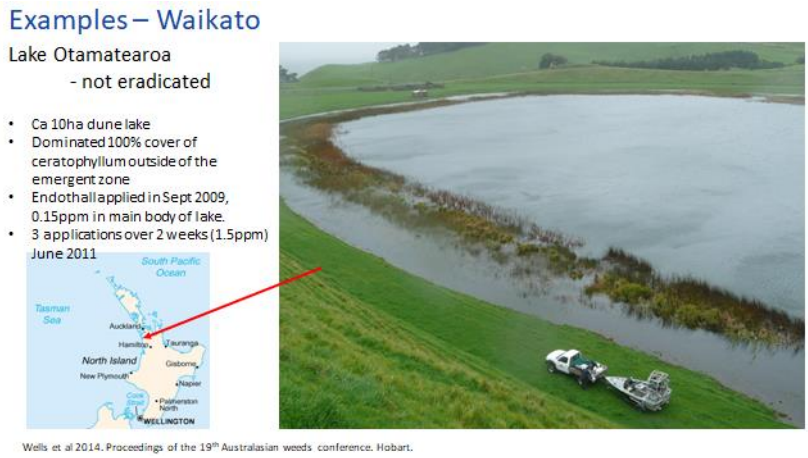
The lake is nearly 3 metres deep and is part of a stream that has a weir on it. The pre-treatment *Ceratophyllum* inspection of 18 March found scattered plants and clumps over 15-20% of the lake with several large patches noticeable from the lake edge. No *Ceratophyllum* was noted upstream of the lake but it had spread to the upper reaches of the Otipua Stream (the lake outlet) where about seven plants were found 50 m downstream of the lake. The Otipua Stream feeds into a much larger water way, Saltwater Creek before entering the sea.[10]

Endothall does not have those same constraints around turbidity in the water and a treatment was applied to Centennial Park Lake on 18 March 2008 and the post treatment scuba inspections undertaken on 19 April 2008, and subsequent monitoring over the 1, 8, 12 and 24 months to check and an annual surveillance for 5 years until summer 2013. One application removed the *Ceratophyllum* and had no apparent off target effects on any other species. In this particular example they targeted 5 ppm in the water body because the goal was eradication. *Elodea canadensis* and *Potamogeton crispus* remained in the system and we know that *Elodea*, a non-native species, is not affected by Endothall.

[9] Wells RDS, Champion PD (2012) Endothall for aquatic weed control in New Zealand. In: Zydenbos SM (ed) Proceedings of the 17th Australasian Weeds Conference. New Zealand Plant Protection Society, Christchurch, pp 307–310

[10] Wells, R.D.S., Sutherland, D. (2013) Centennial Lake Hornwort eradication using Endothall, Centennial Park Lake, Timaru. NIWA Client Report No: HAM2013-013, Project MPI13203: 14

Example: Lake Otamatearoa, Waikato



Wells et al 2014. Proceedings of the 19th Australasian weeds conference. Hobart.

This example was with Waikato Regional Council and as you can see *Ceratophyllum* was not eradicated; not a successful result in terms of the desired outcome, but some important lessons were learnt. It is a 10 ha dune lake with a large 100% infestation of *Ceratophyllum* outside of the emergent plant zone. There were two different treatment programmes put in place in different years; Endothall applied in Sept 2009 in main body of lake, and 3 applications over 2 weeks in June 2011.

It was because the spray in 2009 did not achieve the desired outcome, that a different approach, with multiple applications was used in 2011. This approach aimed to keep the exposure of the plants to Endothall at a level that would provide better efficacy. But again, it did not work. There was good reduction to start with, the *Ceratophyllum* was reduced by 95%, and there was a nice recovery of charophytes, so they became dominant. However, three years later the *Ceratophyllum* was back to pre-trial levels. Looking at the monitoring data for Endothall, the concentrations did appear to be good in the centre of the lake, so why was there not a better outcome? The poor result has been largely attributed to ground water inflow, particularly around the literal margins, therefore diluting the Endothall so that exposure was not achieved.[11]

Example: Northland, Lake Phoebe

Champion and Wells 2014 Australasian weed conference, Hobart.

[11] Wells et al 2014. Proceedings of the 19th Australasian Weeds Conference. Hobart
Hofstra and Champion 2017. Research Methods. Journal of Aquatic Plant Management

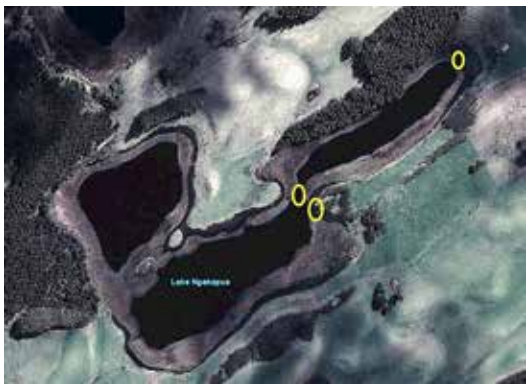
In Northland, Paul Champion worked with Northland Regional Council in Phoebe's Lake where there was a *Lagarosiphon* control programme. The Regional Council were interested in evaluating Endothall and set up an operational plan for its use. *Lagarosiphon* formed a dense band of submerged vegetation between 1 and 2.5 m deep in Lake Phoebe. Selective herbicidal control of *Lagarosiphon* was achieved using Endothall applied in three doses:

28 L on 17 April 2012
46 L on 24 April 2012
26 L on 2 May 2012

There were different applications over a period of time, with the aim of achieving a particular target concentration in the lake, which was quite low, 1.5 ppm; remember the maximum allowed was 5. There was no *Lagarosiphon* in surveys from April 2013 onwards and now there is only indigenous submerged vegetation present in this lake.[12]

Example: Northland, Lake Ngakapua

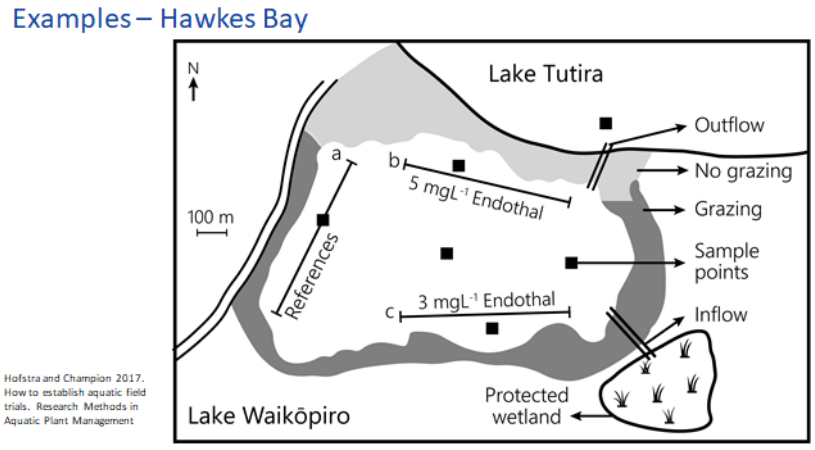
A partial lake treatment was set-up in Lake Ngakapua, with the aim of eradicating *Lagarosiphon.*



The yellow circles on the map indicate where scattered plants were present in the lake, mostly in 1.5 to 2.5 m water depth over 1 hectare, so not an infestation. Endothall (Aquathol Super K, 200 L) was applied where the circles are and along the southern shore, about a tenth of that lake area. The Northland Regional Council declared in 2018 that they have eradicated *Lagarosiphon* from that system.[13]

[12] Champion and Wells 2014 Australasian Weed Conference, Hobart.
[13] *Ibid*
www.nrc.govt.nz/news/2018/April/'Top 20' Northland lake declared free of pest oxygen weed.

Example: Hawkes Bay, Lake Waikōpiro



I want to pop back in time and talk about why we at NIWA looked at Endothall back in the early 2000's. We were looking at alternative options to provide tools for eradicating *Hydrilla verticillata* from the country. The purpose was to verify, at field scale, the efficacy of Endothall on *Hydrilla* following successful tank scale studies,[14] and provide a method with which to control *Hydrilla as* the New Zealand *Hydrilla* was not susceptible to diquat or fluridone.

Hydrilla has been recorded in several lakes, but this trial lake was small, 11 hectares. This trial was done under that experimental use permit. *Hydrilla* formed an almost continuous monospecific band around the shallow margins of the lake from less than 1 m to 6.5 m depth. It was a late summer treatment and the water temperature about 20C. We set out 2 plots in the littoral zone of the lake, at 5 ppm and 3 ppm. Water samples were taken from the treatment and reference plots, the center of the lake, and adjacent areas of neighboring Lake Tutira (there is a culvert between the two lakes) and analyzed for Endothall. We wanted to see how fast our product moved away from the treatment areas, or whether or not it did over time. Sampling was carried out immediately before and following herbicide application, as well as 1, 7 and 28 days. By day 1 the maximum concentration of Endothall outside of treatment plots was 0.282 mg L^{-1}, by day 7 Endothall was below 0.2 mg L^{-1} at all sampling points and was no longer present by day 28.[15]

The results of this trial were really good, we had about a 70% reduction in the weed beds, which was promising in the potential for using Endothall as a herbicide for *Hydrilla*.

What happened subsequently? Endothall was registered in New Zealand in 2004 and by 2008 MPI was the agency that was mandated to deal with *Hydrilla* in New Zealand and MPI set up the *Hydrilla* eradication response. In 2008, the public were coming into contact with the weed beds in Lake Waikōpiro and Lake Tutira (adjacent) along the causeway. So, the weed beds were considered at highest risk of being transferred to other sites. They were sprayed with Endothall as part of this MPI response. This time there was a better result and the target was 80% reduction, by 1 month after treatment.

[14] Hofstra and Champion 2017. How to establish aquatic field trials. Research Methods in Aquatic Plant Management.
[15] *Ibid*

*Hydrilla s*cuba assessments found no vegetative fragments of the *Hydrilla* weed beds in Lake Waikōpiro 1 month post Endothall treatment. However, viable tubers were sieved from the mud, but the introduction of grass carp meant that any subsequent re-growth from tubers would be controlled. No other off-target Endothall effects on emergent macrophytes and aquatic fauna were noted.

Summary – Endothall use in lakes to control invasive weeds

Whole of water body treatment

- Significant reduction of target species
- Eradication of *Lagarosiphon* and *Ceratophyllum* demonstrated most examples
- Failed result - Otamatearoa

Partial water body treatment

- Significant reduction of target species – locally and throughout the lakes

I want to reflect on some of what I have talked about. The difference between the successes that we have seen is whether there were whole of water body treatments, or partial water body treatments with Endothall for eradication and weed control. We have been involved in failed results with things that were not obvious at the time. But certainly, there are valuable lessons to be learnt from the Otamatearoa example.

Where to from here?

I also think there should be some conversation, or rather action items for us all, for better information exchange to develop in-lake use pattern for Endothall, learning from each other. Monitoring is so important to inform operations, the use of dye studies to understand what the water movement is and what dispersion is likely. I would personally like to see our herbicide label reflect the science and data to enable better use within New Zealand.

Acknowledgements

I would like to acknowledge the funders of this science and the other research partners and stakeholders who have been involved in, or led some of the trials I have been talking about today:

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- Environment Southland, Keith Crothers
- Northland Regional Council, Lisa Forester, Irene Middleton, Jillian Fulcher
- Waikato Regional Council, Paula Reeves

Department of Conservation, Kay Griffiths
Ministry for Primary Industries, Victoria Lamb
InGear Global, Ian Gear

Thank you.

QUESTIONS

Lars Anderson, USA: Have you done tuber counts in the *Hydrilla* trials.

Deborah Hofstra: No, we didn't do tuber counts and partly because NZ plants produce less tubers than either of the strains that you have in the US. Here we have a dioecious male plant, in the US they have a dioecious female plant and monecious plants and both of those plants (*Hydrilla biotypes*) produce much larger tuber numbers. In the past we have spent days looking at tuber numbers in those lakes, hence we know the numbers are very low and did not use this as a monitoring methods post-herbicide treatment

Lars Anderson: So part B is - what is the grass carp stocking rate, do you know?

Deborah Hofstra: I should know because I have been involved in that project so I can get that information to you, but I can't remember off the top of my head.

Lars Anderson: I would suspect the grass carp had a lot to do with the non-resurgence of *Hydrilla*, rather than a systemic endothall effects.

Deborah Hofstra: Well, here is the interesting point. Grass carp, same stocking rate in the lake immediately adjacent to it, and it was 2½ years before there was a similar reduction in *Hydrilla* in that lake. The herbicide was used to a much lower extent in that adjacent lake, relative to the overall littoral zone and extent of the weed bed. So, we know that there is more going on than just grass carp, but it is certainly a valuable point for conversation. Thanks Lars.

John Green, LWQS: Thank you, Deborah, the 25% containment that the Bay of Plenty Regional Council has for using Endothall, what's your view of that? You have given examples of small, shallow lakes, but we are dealing with far deeper lakes. If you put the 25% near the edge, does it dilute itself really quickly over the other 75% of clear water, and how effective is 25% going to be? What is the point of going ahead if it is not?

Deborah Hofstra: It is a good question for debate. My personal view is that we need to have constraints and regulations around the way that herbicides are used. A lot of the restrictions around how much of a water body can be treated at any one time is about protecting the other aquatic life in a system so that when you are removing a weed bed and it is rotting (which could apply to other methods of weed removal), you must not have large scale negative impacts on the biota in that system. That is why these constraints get put in place. What I personally would like to see is the restriction on how much is treated at any one time is based on the specifics of that lake. For example, 25% can be a really meaningful number if you were to treat all of the shallow lake where the weed bed was covering the entire lake. Which is a totally different situation to a large deep-water lake where you have weed beds around the littoral zone, and the potential for de-oxygenation or having impacts on other biota is totally different. I would like to see a system that could be regionally or locally managed and that can be informed by the nature of that water body. This is what I said right at the beginning, a key characteristic to think about when selecting control tools - What's the nature of your water body?

ERATICATION ECONOMICS FOR INVASIVE FRESHWATER PLANTS

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Carla has recently joined the Perrin Ag Consultants team as an economist. Prior to this she was an environmental economist with NIWA for over two years working primarily in the freshwater space on projects ranging from irrigation, to biosecurity and water trading. Carla has a degree in Applied Economics and a masters in Environmental Management.

TRANSCRIPT

Morena tatou everyone, and thank you very much for having me here. I will confess right now that I am an economist and freshwater science biosecurity is not my core business. I rely on the scientists Paul Champion and Deborah Hofstra who were integral to this project, if there are any science questions.

The Issue

Firstly I want to touch on what economics actually means. It is often linked to money, but to me it is more about how we decide what we do with our resources. Invasive plants in particular are a challenge throughout New Zealand and have had massive impacts on environmental, social, economic and cultural values associated with our freshwater resources. However, they can also be very costly to manage and/or eradicate, have a varying likelihood of eradication success and ongoing challenges of re-infestations/re-incursions and/or new incursions. While there is a reasonable budget in New Zealand for biosecurity there will never be enough and it is likely not practical to remove all invasive species.

Eradication Economics

So where does economics fit into decision making on invasive species including deciding what intervention to undertake at what point? There are quite differing scales in economics - micro and macro scales. When I talk about the micro scale it is about a particular lake or incursion response. When I talk about macro, I am talking about general concepts that affect the majority of incursions. We are interested in the rules of thumb that scientists hold, and how do they translate or resonate in the economics discipline?

It is important to remember that economic value is more than just the money spent on interventions including eradication. It includes the positive values assigned to freshwater bodies that are impacted by invasive species. These include Use Values such as recreation, water abstraction etc. as well as Non-Use values such as the intrinsic values associated with water bodies, including the option to use the waterbody in the future. Cost benefit analysis is a very useful economic tool which aims to help make decisions based on the trade-off between costs and benefits that can be included in a quantified monetary measurement. While cost benefit analysis is very useful, there are challenges with it in the biosecurity space; including the fact that it requires quantification in monetary

terms of all the costs and benefits to be included. It is useful in analysing specific decisions at a specific point in time, but it can be challenging to use as a macro scale, pre-emptive tool to try and understand principles common across a range of incursions, and to improve overall decision making.

There are two other specific challenges with economic analysis of invasive plants regardless of the tool used: they are **spatial and temporal variability**. As a particular incursion progresses there are different intervention options, the possible choices change based on what stage an incursion is at. For example, eradication may be an option early on but may not be a realistic option as the incursion spreads. In addition, decision-making must include the no-response option, including the consequence of invasive plant spread to other waterbodies that are at risk of being negatively impacted.

The reason I was tasked to join this biosecurity programme with Paul and Deborah was to look through an economic lens at the rules of thumb that scientists use to better understand the macro-economic elements in eradication and intervention options, and the common principles from an economic perspective. By doing this we hoped to enable more proactive, transparent decision making and provide more holistic outcomes for society. In particular, we sought to understand what common economic principles can be used to support decision making and implementation of intervention options, including eradication. Do they actually make sense from an economic perspective? These key rules of thumb will help policy makers address incursions in the future, particularly when time is such a critical element when dealing with biosecurity.

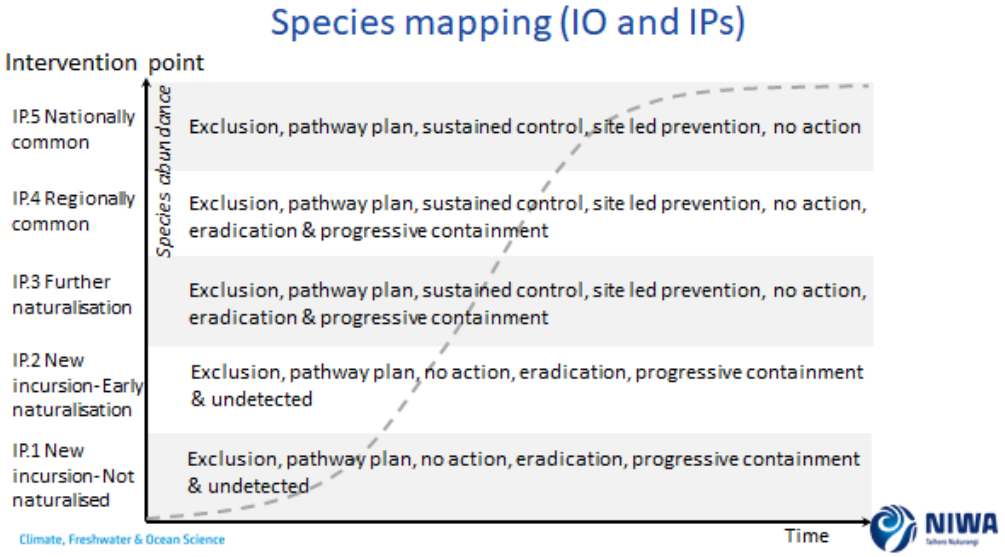
What are the impacts of invasive species? Hamish said earlier that it is easier to account for the costs when you are spending $1 million on a boat wash that goes directly out of the budget and can be seen. But what about the benefits? We know that invasive species impact on biodiversity, ecosystem services, amenity values, and significantly on cultural values. The question is how do we consider all of these values together? I will put the caveat right now that not all of these values should be monetised, but being able to quantify and/or monetise some values does help to consider cost and benefits together.

We will talk about market and non–market values, as well as cash costs and non-cash costs and how we can improve our decision making in the future using some of these concepts. The challenge in biosecurity is not just about the immediate here and now. It is about the value that we want to preserve into the future, and it is about where the potential spread and future risks are as well.

Methodology

We mapped out New Zealand incursion case studies starting at a high level and then focusing in at a deeper level - each time looking for patterns and principles to enable that improvement in decision making in the future. We looked at a range of different options of incursions across case study species, and analysed and compared estimated costs and benefits. We quickly found that there were a lot of similarities between them, and we were able to draw out what we called a basic species map to look at a high level costs and benefits of different options. We focussed on the comparison of ‘rules of thumb’, the higher-level understanding of things like ‘Is prevention cheaper than eradicating new incursions?’ ‘How does ongoing maintenance and control compare to eradication costs?’
To help with this grouping we used the intervention options defined in the New Zealand National Policy Statement which are: **exclusion, eradication, progressive containment, sustained control**, **site-led pest programmes and pathway programmes.** Throughout

the incursion lifecycle some or all of these options may be applicable and selection of one intervention option does not necessarily, but can, impact on future intervention options. What options are applicable when predominantly based on species abundance, and also on the location in the region and the connectivity between the water bodies? Intervention points were primarily defined relative to incursion size at a site. While each incursion is context-specific there are similarities between the intervention options and points for different species at a macro level. Mapping these helps to understand the costs and impacts, thereby helping make decisions that lead to optimal outcomes.



This graph shows the schematic used as the basis for the species mapping. On the y axis there are different intervention points (IPs), based primarily on species abundance, and segregated by the grey bands across the graph with time on the x axis. Within each Intervention Point there are different Intervention Options. Key differences are that eradication and progressive containment drop off as viable interventions at IP5 and will be increasingly hard as the IPs increase. Sustained control and site-led prevention are unlikely to be relevant at IP1 and IP2. As always, this is simplifying reality into a diagram. We do know that it is much more complex and factors such as costs and possible intervention options will depend on available tools, knowledge, species and site characteristic etc. however, simplifying does help identify key principles.

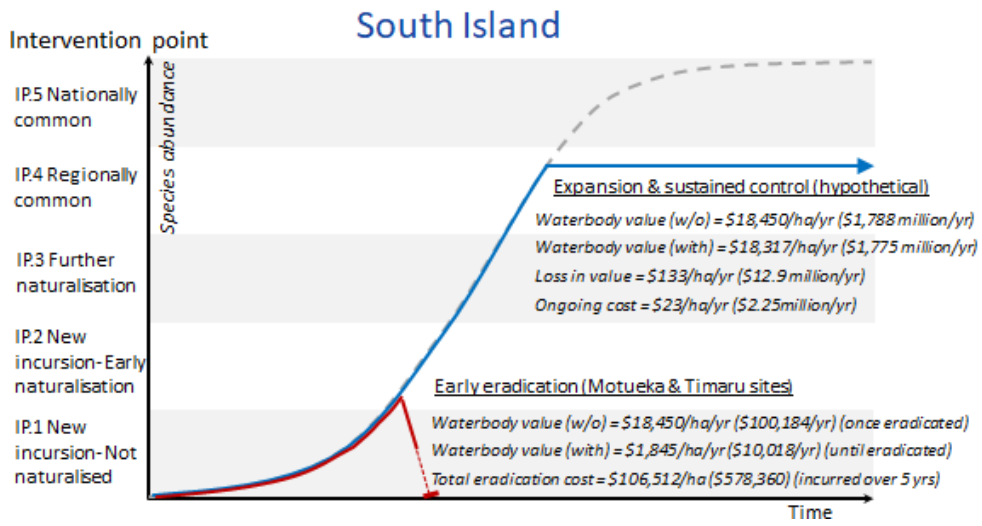
At the moment in New Zealand, there is little literature on how we understand benefits that are not monetised, for example, ecosystem services. That is, what is the value of having a clean and healthy lake? Todd McClay touched on this yesterday, but it is not as straight forward as you may think. Many things are woven into that value, including cultural, social, and environmental values. The cost side of the equation is easier and more widely discussed and these were largely based on literature and experience, including the considerable knowledge NIWA has in this space. It is important to capture the difference in costs, including initial costs up front, things like putting in the containment barriers around the boat ramps and then the ongoing costs and benefits of things like spraying for maintenance control.

I will give an example which in this case is *Ceratophyllum demersum* or hornwort. We looked at this in the South Island, Lake Karāpiro and the Rotorua Te Arawa Lakes. At

each site we looked at how the costs and benefits played out. We based the benefits on ecosystem services.

Methodology

- *Ceratophyllum demersum* was analysed across 3 incursion examples; the South Island, Lake Karāpiro and the Rotorua Lakes
- At each site, the costs and benefits of the various intervention options were analysed
- The benefits were based on best estimates of the ecosystem services provided for the relevant sites from literature
- The costs were based on estimates from literature and experience
- Values vary over time based on capital and ongoing costs, and how benefits change, based on intervention



This is the South Island example looking at eradication in Motueka and Timaru. *C. demersum* has been found in two places in the South Island. In this case these are combined as both sites were treated, with early eradication achieved. The combined sites affected approximately 5.5 hectares. These early eradication attempts were very costly. They totalled approximately $41,000 per hectare in year one and then assuming this eradication treatment was successful, ongoing monitoring cost were approximately $7,000 per year for another 4 years.

These waterbodies had a value of approximately $18,500 per hectare per year. When *C. demersum* was present the value of the waterbodies affected was expected to decrease by 90% because these were both small waterbodies with the majority of the waterbody impacted. However, this reduction in value, while large, was only present while *C. demersum* was present, and if it was successfully eradicated after one year, then the value of the waterbody is likely to recover over time.

In this scenario with early eradication, a pure economic perspective suggests that it is best to not eradicate (if you just look at year 1). But after five years, there would be no further cost due to the successful eradication outcome. However, this assumes that if *C. demersum* is not eradicated there will be no further loss in value, including effects on other waterbodies in the area but this is not likely to be the case.

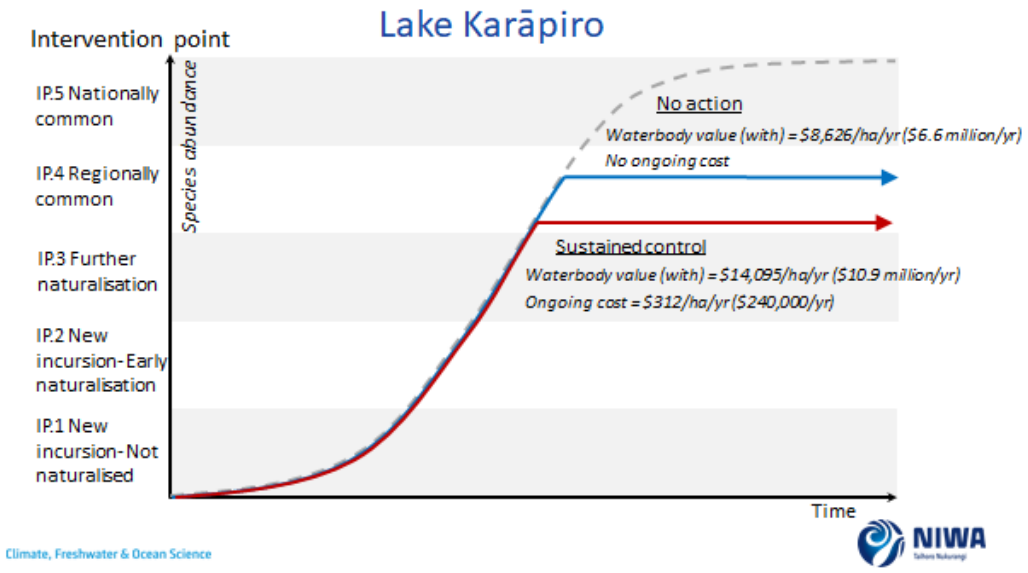
Lagarosiphon major has spread to several South Island lakes and one could assume that if left to establish, *C. demersum* would spread in a similar trajectory, even with some ongoing management. It is critical to include this risk into decision making, especially for early eradication, because if weed expansion is likely, then eradication may cease to be an option and the cost is likely to increase exponentially. In addition, with the risk of large scale expansion the reduction in benefit and costs will be ongoing.

Under the hypothetical scenario that *C. demersum* were to expand as *L. major* has, and assuming it expands to 97,000 hectares then control costs are approximately $28 per hectare in year 1 ($2.8 million) and $23 per hectare ongoing ($2.3million). The difference relates to the use of some control measures like weed cordons. It also assumes that only an area of 1,000 hectares is treated with control measures (e.g. at boat ramps) but the 97,000 hectares is infested and costs are averaged across all of this area.

If *C. demersum* is present, the base benefit of the freshwater bodies decreases ($18,450 to $18,317/ha). However, the value of only the treated areas decreases (by 50%, because the areas being treated have higher weed impacts) and the remainder does not lose value. The reason for this is that the areas treated are the high use areas and often have higher values etc. as they are, for example, shorelines, or popular recreation areas and boat ramps. The remainder of the areas with *C. demersum* are likely to retain their value for boating etc. When averaged out over all of the area, the value reduces by $133/ha annually.

In summary, this hypothetical scenario has an ongoing cost of $23/ha (averaged across all 97,000 ha) and a loss in value of $133/ha in perpetuity. Basically, this means the early eradication option would have prevented this significant loss in value ($13 million annually).

However, in this hypothetical scenario eradication is not likely to be an option. This means that in this case early eradication would have been beneficial and highlights the importance of accounting for risk and potential impacts of selected interventions in decision making.

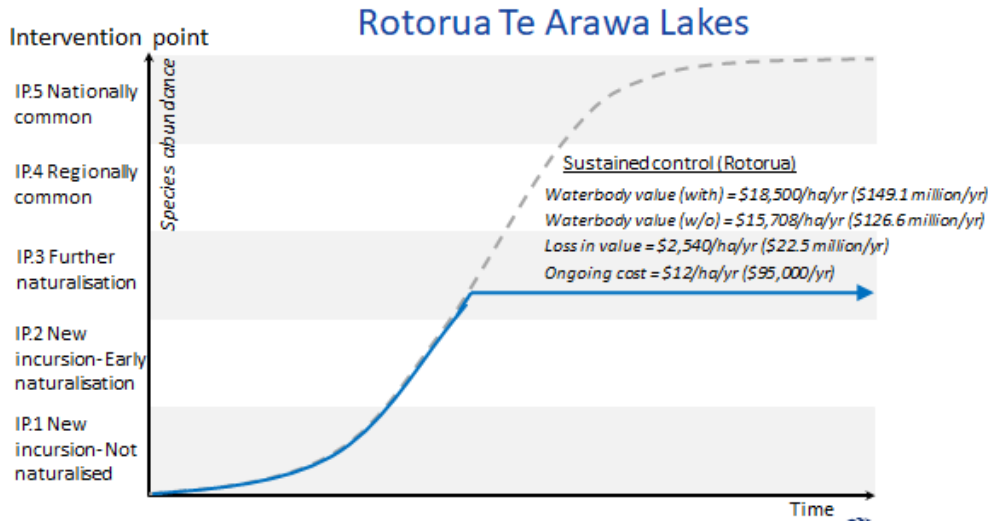


C. demersum is present in Lake Karapiro, a dammed lake on the Waikato River, and also present in other parts of the river. It is managed through sustained control on this lake which is an electricity generating lake. It also has significant economic importance to the local region as it plays host to regional, national and international sporting events, particularly rowing. The lake is approximately 770 hectares, 50 of which is considered impacted by nuisance weed which indirectly interferes with power generation, sporting and recreation activities.
The current action is sustained control which is shown by the red line, this is expected to continue indefinitely, based on the current resourcing. The ongoing treatment cost is estimated at $300/ha/year (this includes all costs around the programme) which is averaged across all the 770 ha, equating to approximately $240,000 per year.

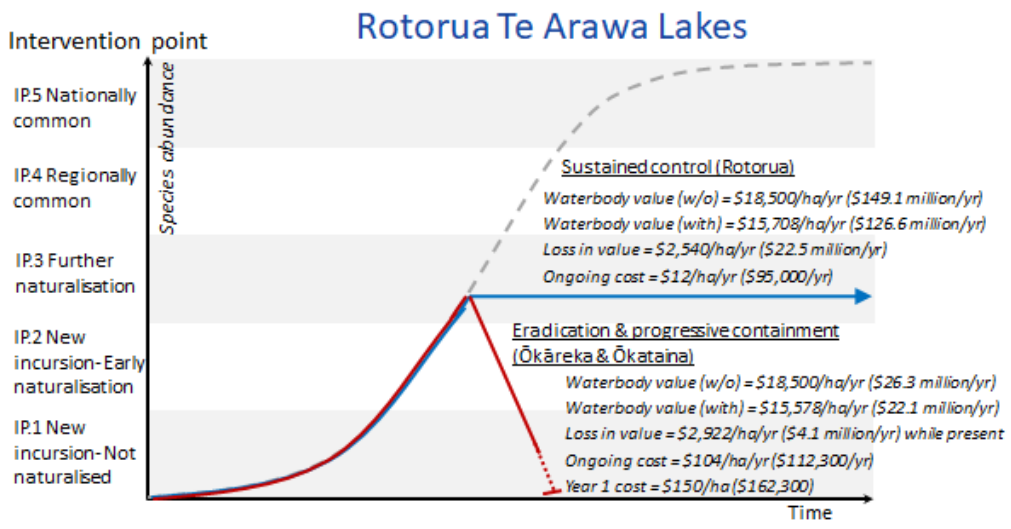
The water body has an estimated value of approximately $23,000 per hectare per year if there was no *C. demersum*. Like the South Island example, this is largely based on the estimates of Patterson and Cole, but also includes the economic benefit from the Maadi Cup which is held on this lake every second year. The Maadi Cup is the national secondary schools rowing championships and brings in significant economic benefits to the region.

If *C. demersum* is present and hence targeted for control, as it is currently, the value of the lake per hectare reduces from $23,000 to $14,000 relative to no *C. demersum.* If *C. demersum* is not controlled (the blue line) the annual treatment cost of $300 is saved; however the value reduces from the $14,000/ha/year to $8,600. This drop is due to reduction in the value from not being able to host sport events.

In this lake, eradication is not a feasible option given the scale of the infestation and the high likelihood of reincursion. While management is an ongoing cost in this lake, which has a high value directly influenced by the presence of C. demersum, the cost of this management is far outweighed by the value preserved by controlling *C. demersum*.

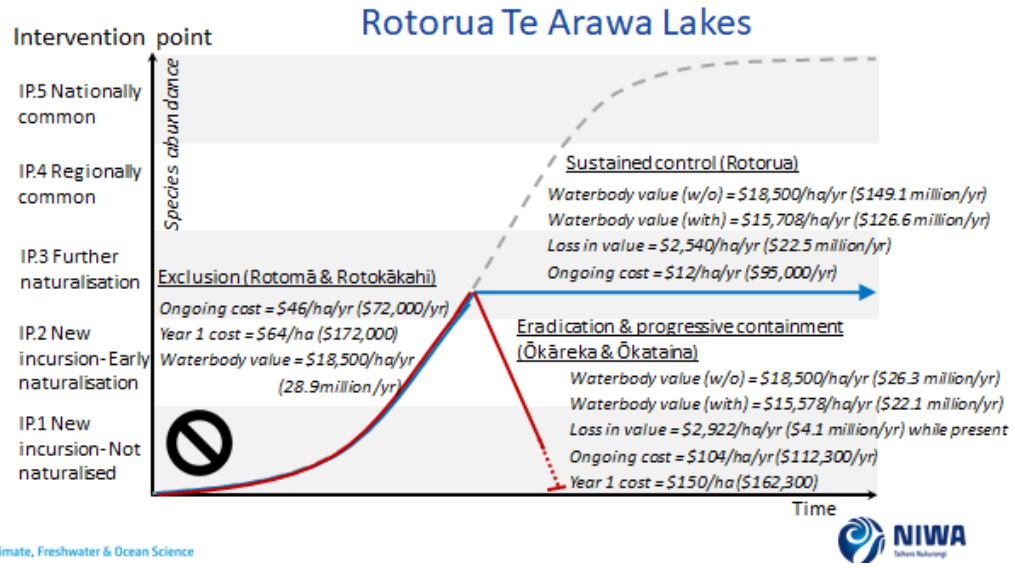


Some of the Rotorua Te Arawa Lakes contain *C. demersum* and have a range of different intervention plans. Here we focus on 5 lakes across 3 groups of intervention options for comparison. The benefits, for this example are based on a Rotorua specific ecosystem services study, and the costs are generally based on the operational plans from the regional council.



This graph compares two lakes, Rotomā & Rotokākahi, for which there is a total cost of $72,000 each year to exclude *C. demersum* from being introduced. This protects waterbodies worth $29 million per year (or $18,500/ha/yr). While *C. demersum* would not reduce all of that value, as can be seen with the other scenarios, it does reduce value. This cost is ongoing (or until the threat of *C. demersum* is removed).

Conversely, for Lake Rotorua, the blue line has a programme of sustained control and ongoing management costs of $95,000 per year (or $12/ha). As with the other sites, only areas considered to be of particular nuisance are targeted for control, however costs and benefits are calculated for the whole waterbody. The impact of *C. demersum* in this lake is estimated to be $2,500/ha/yr. The control costs prevent this from a larger loss in value.



Lakes Ōkāreka and Ōkataina (where they are targeting eradication) are shown by the red line. The cost of this intervention, approximately $104 per hectare per year, is higher than ongoing management (e.g. $12/ha/yr in Rotorua) and exclusion (e.g. $46/ha/yr in Rotoma and Rotokakahi). The reduction in value from the presence of *C. demersum* is

approximately $3,000/ha/yr (in Ōkāreka and Ōkataina). However , this is short lived , relative to the impact of managing *C. demersum* through ongoing control.

This example highlights how there are positives and negatives associated with each intervention option. The real world examples indicate broad principles such as while exclusion can cost, it prevents significant loss in value. Eradication may be more expensive than sustained control however it is likely to be done over a shorter time period.

Rotorua Te Arawa Lakes- Conclusions

- The cost of eradication and progressive containment (Ōkāreka & Ōkataina) is higher than ongoing control (Rotorua)
- Interestingly the loss in value is also higher (per ha) in Ōkāreka & Ōkataina relative to Rotorua, though this is due to assumption on proportion of lake impacted by nuisance weed
- But the cost and loss of value is shorter term in Ōkāreka & Ōkataina relative to Rotorua
- Exclusion in Rotomā & Rotokākahi has a cost but it is considerably less than the value at risk

One thing that is particularly useful to think about for the future is where the benefits apply from a multi-disciplinary approach. Government policy is moving quite rapidly in this space. The government is introducing the four capital approach, so how can these changes at a policy level help balance out some of the intangible benefits with the typically high cost of some initiatives up front. I think that is an interesting problem that science and policy and economics can help to solve.

Conclusions

Based on these examples and the rest of the analysis and examples behind the scenes there are some key conclusions for decision making on invasive management in the future. Eradication has a higher probability of success and lower cost the sooner it is initiated – *C. demersum* in South Island vs. Lake Karapiro. There is no universal point where eradication becomes uneconomic, it depends on the costs (both short and long term) relative to the benefits and consideration of possible spread risk.

Costs of re-incursion and re-infestation should be factored into analysis as should the risk of spread. While eradication and exclusion can cost, they can prevent significant loss in value. Eradication may be more expensive than sustained control however it is likely to occur over a shorter time period.

Stronger border exclusion policies require more investment; however they could be more beneficial than eradication strategies provided the cost of stronger border exclusion is less than the cost of preventing one eradication response. To assess this we looked at *Eichhornia crassipes* (water hyacinth) which in New Zealand is always targeted for eradication once detected but has a very high cost of eradication due to the required monitoring time associated with eradication sites (at least 15 years of follow up inspection). There are relatively frequent incursion sites found as well, meaning the continual cost of eradication is very high. Stronger exclusion regulation and enforcement would likely provide a positive return, especially when risk is taken into account.

Challenges

- This research highlights some ongoing challenges with incorporating economics into biosecurity decision making.
- Valuing non-market costs and benefits continues to be a challenge; however, it is crucial that these are not excluded from decision making.
- Non-market valuation needs to continue to improve as a technique.
- Benefit transfer is one way to overcome challenges in the non-market valuation space. However, this should be done with caution especially to ensure that sites are similar and that when combining studies, they are not double counted.
- Cost benefit analyses are crucial in decision making, especially for incursion specific decisions. However, care needs to be taken to try and include potential pathways and changes in intervention options through the incursion pathway.
- Real options analysis could provide a bridge to this. It is typically used in investment decisions but helps account for flexibility in changing decisions when the context or incursion factors change.
- It is also challenging to accurately define counterfactuals, or what would happen if you didn't act, given uncertainty.

Where to next?

- There is a huge shortage of studies which attempt to understand and quantify how we value environmental benefits such as the impact of invasive freshwater plants on non-market values.
- Whatever decision-making framework is utilised, it is imperative that clear counterfactual and desired states are defined and risk is included.
- Incorporate key principles into decision making and planning for biosecurity and invasive management. Hopefully understanding these types of general principles can help supplement decision-making while site specific cost benefit analyses are undertaken.
- We need to work out how we better incorporate these across science, economics and policy.

Acknowledgements

This work was supported by strategic science innovation funding from the Science and Innovation Group, Ministry of Business, Innovation and Science.
Thank you to the co-authors Paul Champion and Deborah Hofstra as well.

QUESTIONS

Don Atkinson, LWQS: Carla, a very interesting presentation. Have you applied it to our most degraded Lake Rotoehu? Have you considered that in your position?

Carla Muller: No, we didn't. We looked solely at the 6 options and part of that was access to the information I needed. It could easily be extended. At this point is the biggest challenge is understanding the costs that have gone into the programmes, because that is the hardest information to get. If we could record all of our costs in programmes around the country and then learn from them that would be great.

John Green, LWQS: Carla, thank you for that because for 15 years we have been trying to work out the economic impacts of these subjects. For the first time we have had a presentation which goes far beyond the linear cost/benefit approach and into the expenditure aspects of what we are dealing with. It surprised me because we were the ones trying to get money out of government to clean up the lakes. It was always difficult to talk to policy makers about the economic benefits that come from cleaning up lakes and their impacts on the community as a whole, which we have never been able to get our hands on to explain in simple terms in simple terms. The only way is to sit with those who live by a lake infested with trout flies, rotting weed and algae blooms and you cannot explain that in economic terms to policymakers who don't live by a lake. You are on the right track it is so much more than the monetary side of things.

Carla Muller: Thank you, you have actually sparked a few things that are useful and one is balancing the monetary considerations, and policy makers do tend to want that information. But we need to wrap it around the stories from people who are interacting with the lake, because that is where the real value and richness of the information comes to the fore.

The second thing is that a lot of estimates of benefits are general because we do not have enough information. There was no difference across the South Island because there were no better examples. We added the sporting values at Karapiro back into the mix and one Rotorua specific study bases itself on everything else. It is an area we could definitely move into. The policy context and what is happening at the government level now gives opportunity to grow this space for sure.

AQUATIC WEED TOOLBOX: CAN WE WIN WITH WHAT WE HAVE?

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Jourdan is a Biosecurity Consultant at the environmental consultancy, Boffa Miskell, which is responsible for delivering LINZ's Biosecurity and Biodiversity work programmes. Following a successful five year relationship, Boffa Miskell and LINZ formed a strategic biosecurity partnership in 2014 which has led to more innovative and effective weed and pest management in lake and river beds across New Zealand. Jourdan is part of a team which manages operations in over 200 sites across the country, including aquatic weed control operations in the Rotorua Lakes.

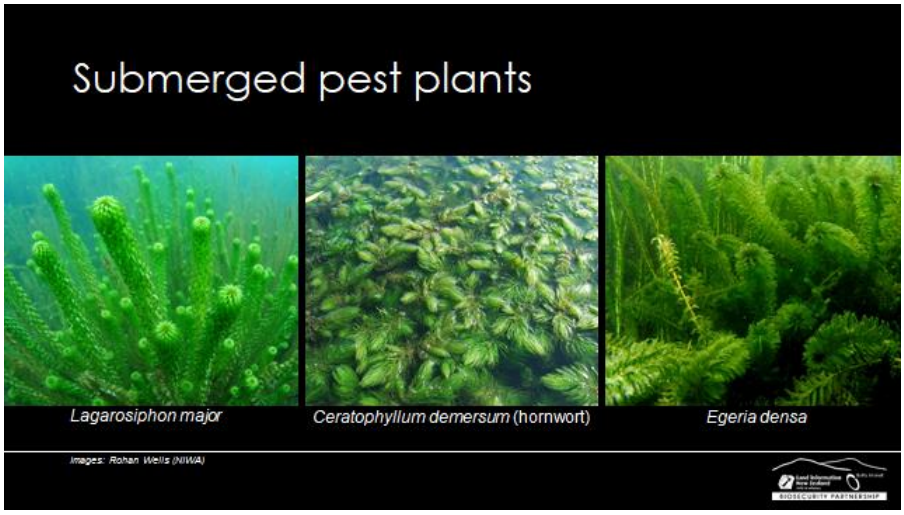
TRANSCRIPT

Aquatic weeds thrive in our New Zealand lakes and rivers. We do have a number of useful tools in the toolbox; however we have been fighting a lot of these pests for over 50 years and they are still in New Zealand and within the Rotorua Te Arawa Lakes. In this talk I will go through different options that we do have available in New Zealand and ask, 'Can we win with what we have?' This photograph illustrates why we are fighting for these things. They are beautiful lakes and we want to see them back to what they originally were.

What is Boffa Miskell's role in all of this?

We have been delivering our biosecurity services for LINZ since 2009. We formed a strategic partnership in 2014 and we are responsible for managing biosecurity operations across New Zealand on behalf of LINZ. Within the LINZ programme we deal with aquatics and terrestrial as well. We control over 200 control sites across the country. The yellow areas are our terrestrial sites, which

consist of mainly braided rivers with pests and weeds. The blue areas are the lake beds we manage, a number of the large glacial and hydro lakes in Canterbury and central Otago, as well as those in Rotorua, and Lake Karapiro in Cambridge. Fortunately we have been able to double the amount of control work we are doing this season thanks to a successful funding bid last year from LINZ, so that is going to be really helpful in the ongoing years for fighting these weeds.



I will touch briefly on the three main aquatic weed culprits as we have heard a lot about these this morning.

- *Lagarosiphon* grows down to around 6 metres depth. It is human assisted in its spread and forms really dense weed beds.
- *Hornwort* has no roots, which is quite hard because it can migrate so easily. When we do an assessment and come back a couple of months later it has moved sites. It thrives in all types of water, dirty or clean. It has been eradicated in the South Island, a key point that I will come back to.
- *Egeria* is less dominant in poor water conditions but it grows down to around 10 metres depth.

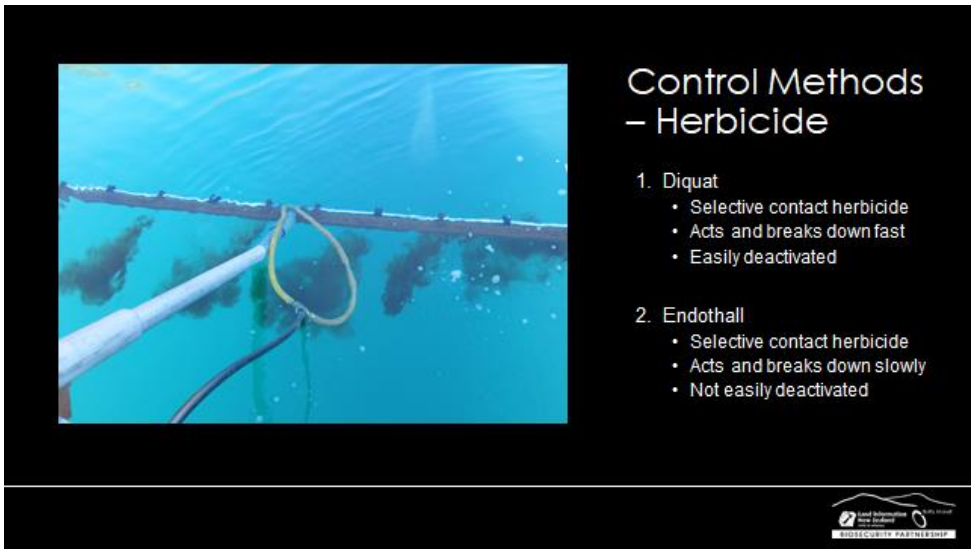
All these plants grow from a fragmentation which is good, they are not self-seeding, and otherwise we would be in a lot more trouble. But that means that any plants that are established spread through human interaction. Boats, trailers and fishing equipment are the most common vectors of movement which means that ensuring entry points are clean of weed is a key part of the management we do.

We need to start thinking about each lake as its own biosecurity border. We do not want anything leaving those lakes nor any new incursions entering them. New Zealand being so small a lot of the lakes are interconnected. We know that people travel from the North Island to the South Island with their boats, which is a real risk having eradicated *Hornwort* within the South Island.

What is in the toolbox?

We have got two approved herbicides, Diquat and Endothall. We have multiple mechanical methods and one biocontrol agent; which Mary de Winton is holding in that top photo (next page).

Throughout this talk keep in mind that there is no silver bullet when it comes to aquatic weed control. Underwater typography, water quality, sedimentation levels and water chemistry all play a part in determining what may or may not work within a control programme. A control method that may work really well in the South Island may not be as successful in the North Island. It can even be as localized as a particular method working in one part of the lake but not in another. So it is a case by case basis and we are always learning as we go through the control programme.



One of the main methods of control is herbicide application and we use Diquat which has been used in New Zealand since the 1950's. It is a selective contact herbicide and acts and breaks down really fast. The contact time for it to be effective is minutes to hours. We currently operate under the label that has only a 24 hour stand down for drinking, swimming and irrigation, which is a blessing and a curse because it is easily deactivated, which means we cannot control dirty weed with it, but it has a low environmental footprint.

The second herbicide is Endothall which has been registered in New Zealand since 2004, 15 years ago. It is a contact herbicide that causes defoliation and stem die-off. You can spray dirty weed with it which is positive. It acts and breaks down slowly and needs a long

contact time to be effective. So instead of minutes to hours, it is hours to days which is difficult to get in large open water bodies, currents, stratification in heat layers, etc. It is not easily deactivated and the current label states that the maximum stand down time is 28 days, on swimming, food gathering and water consumption. This becomes difficult to manage when Diquat is only 24 hours. Educating people not to use the lake for 28 days is hard, especially in the Te Arawa Lakes where gathering kai from the lakes is a way of life. So trying to manage all those aspects with Endothall has its problems.

What are we talking about with dirty weed?

This picture shows the weed condition scale developed by John Clayton from NIWA and goes through the scale of what weed can and cannot be sprayed:

(1) Very clean, healthy shoots ideal for Diquat spraying
(2) Slightly dirty with light brown organic deposits, healthy green shoot still visible, OK for Diquat treatment
(3) Moderately dirty, questioning whether or not to spray
(4) Quite dirty. Light brown organic deposits joining between leaves, but green healthy shoot just visible below. High risk for Diquat treatment
(5) Extremely dirty. Organic deposits completely coat shoot surfaces. Identity of species obscured. NOT suitable for diquat treatment.

With (4) and (5) we definitely would not do any Diquat spraying because as soon as the herbicide interacts with the plant it will deactivate, wasting our money.

Control Tools

How do we apply the herbicide? The airboat is one of the main methods used in Rotorua and average around 30 hectares a day of application. It is good for shallow weed beds because there is no prop and a flat bottom. We can get over areas that other boats may not be able to access, and it works well around jetties and the shallow substrate.

Another method for herbicide application in Karapiro and down south is aerial application. We can spray around 200 hectares a day and it is useful for larger weed beds. With aerial applications the elevated view allows the pilots to see where the weed is in the water.

When the herbicide hits the water it gives an even distribution.

This picture shows Lake Karapiro and in the background the large weed beds that we deal with. The herbicide trails behind the aircraft and is a lot faster than a boat and surprisingly accurate with spraying.

The weed harvester is definitely a useful tool for removing large amounts of biomass, although it can be slow and expensive. It only cuts weed down to the depth of the cutter. It is most effective where there is a lot of weed and it does not have to make long trips back to unload. Obviously weed has to be deposited on shore and there is the added cost of removal. Fragmentation is a big issue for the weed harvester and only used where the weed is highly saturated. Essentially you are cutting the lawn so you have to come back in a couple of months, but it is an option.

This mechanical cutter is another option used down south at times. It cuts weed down to 1.5m below the surface and the fragments float away once cut. It can only be used where further weed spread is not an issue, i.e. the habitat is saturated. It is a useful tool for cutting weed away from the surface to reduce the likelihood of lake users interacting with the weed, such as around boat ramps if the weed has been dirty and not been able to be sprayed, but where there could be potential for boat propellers to get caught on weed.

Excavation has limited application although it has been used down south. Obviously there is a lot of sediment disruption and fragmentation when digging into the lake beds, but *lagarosiphon* can be removed with it, but it is not used too often.

Hand weeding is an essential tool when weeds are getting down to low levels and there is minimal disturbance to the lakebed. It was good to hear the last presentation about the economics of it all. They say the last weed is the most expensive one, and we use this down south in Wanaka, Benmore and the Frankton

Arm getting down to hand weeding levels. But it involves a lot of search and destroy and is labour intensive.

This photo shows the diver being towed behind the boat trying to cover a larger area. When surveying large areas it is hard to spot that one plant. But it is a useful tool and our divers tell us if there are any new incursions. There were some found in Lake Whakatipu in Queenstown, where *lagarosiphon* or *hornwort* have been eradicated, and our divers finding new incursions was really helpful.

Bottom Lining is another control tool used down south. It involves laying a hessian mat over the water beds, similar to a potato sack. The advantage is that it does not disturb weed that is easily fragmented. Once it is in place there is little or no requirement to follow up with hand weeding and the hessian itself biodegrades after about 18 months. It can only be used with *lagarosiphon* but not appropriate for floating weeds like *hornwort*.

Another advantage of bottom lining is that the native plants can grow through the hessian layers but not exotics. On the right-hand side of this photo some turf community is starting to re-colonise through the hessian netting. A disadvantage is that it is very labour intensive and expensive per hectare, but it is getting to that tail end of control after herbicide spraying and then supressing that weed.

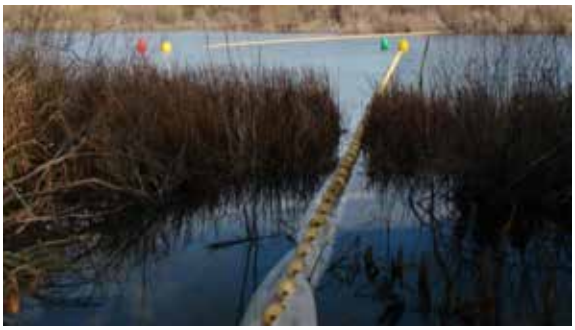
Another advantage is a small incursion, such as *lagarosiphon,* is unable to re-establish because it is unable to put its roots through the hessian back into the sand. We can put divers in to check if there are any maintenance issues, and it is easy to remove unwanted species.

But every lake is different and we get examples like this where lots of debris sit on the bottom. Obviously we would not be able to use hessian matting in this scenario. So again it is a case by case basis and we need to weigh the pros and cons as we go through the control options.

Suction dredging is another tool we use post treatment of herbicide spray where biomass is too great for effective hand weeding and the conditions do not allow for bottom lining. There is also potential if the substrate is not suitable for laying hessian matting and where herbicide treatment is not possible. It is basically a big underwater vacuum cleaner and we suck up those individual plants and deposit them on the small boat behind. It is similar to the cutter in the sense that we are removing the plant out of the system completely but we use it less now that bottom lining is an option for us.

Lake lowering is a control tool that has been used in the past. It can be used in hot summer temperatures to dry out weed, or frosty conditions to freeze it. It is often not effective as weed lies on top of itself and protects weeds underneath so the lake needs to be low for long periods of time for it to be effective. A disadvantage is that all the plants will die in that long period. Generally it is only applicable in hydro lakes but energy companies usually do not want to lower their lakes by 6+ metres for several months.

Grass carp have been highly effective in enclosed water bodies to control *hydrilla.* The risk is that they eat both native and exotic plant species indiscriminately. Once they are released into a water way they are challenging to remove. This is really an indiscriminate biocontrol.



Weed cordons are not so much a control tool, but a tool to reduce the movement to stop plants entering a waterway which is potentially weed free, similar to a biosecurity boarder. They can be used in two ways:

(1) To stop plants entering a lake that is weed free. When launching a boat any weed falls off and is contained within the weed cordon. The control effort will be within the cordon.
(2) Cordons can also be used to prevent weed leaving a lake that is weedy itself. The idea being that by reversing the trailer in its not picking up a whole lot of weed before leaving the dirty lake.

New Tools Herbicides

NIWA has been exploring two new options for herbicide tools –

ProcellaCOR and Flumeoxazin

Both of these work at extremely low concentrations. Where Diquat and Endothall work at parts per million, these operate on parts per billion, so the amount being put into the water is really low. It is unknown if these herbicides will be effective in New Zealand lakes until we do real world testing. NIWA has done lab tests with these herbicides and they have been successful. However, in order to get EPA approval to do field trials we need to prove they are safe, which cannot be done until there have been field trials. So it is a little bit of a tail wagging the dog in this scenario. If anyone does have any tips or tricks of how to speed up the EPA process talk to Paul Champion, I am sure he would love to hear.

Can we win with the tools we have?

Yes we can, we have enough tools to solve our weed issues but there is not enough money to leverage the tools that we do have to use them to their full advantage. We require new innovations to be successful with the current level of funding, and potentially using those new herbicides.

Because these plants are all spread through fragmentation, the key is education to all lake users moving between water bodies to ***Check, Clean, Dry***. If everyone stopped using the lakes tomorrow then the risk of spread would drop to zero. But if everyone is a biosecurity advocate getting the message out there we will easily be able to get on top of this problem.

Acknowledgements

Thanks to Marcus Girvan for putting this talk together
Tracey Burton from NIWA for providing photos
The Aquatic Pest Coordination Group which consists of LINZ, Bay of Plenty Regional Council, Te Arawa Lakes Trust, Department of Conservation, Rotorua Lakes District Council and Fish and Game.

Thank you for listening.

QUESTIONS

Terry Beckett, Lake Tarawera Ratepayers Association: A general question in a national sense about managing weed, is there an issue in the Rotorua Te Arawa Lakes area with the fact that technically Te Arawa own all the submerged weeds in the lakes?

Jourdan Lethbridge: It is not an issue at all, we work really closely on the Lakes Coordination Group and Te Arawa are very supportive of the programme itself, and especially with the Catfish Programmes.

Greg Corbett, BOPRC: Yes, a point of clarification with the Te Arawa Lakes Settlement Act, Te Arawa do not own the weeds, they are still the responsibility of the Crown.

John La Roche, LWQS: Jourdan, what happens under the hessian mat to the *lagarosiphon*, does it die?

Jordan Lethbridge: Yes, using them in the South Island where they are all old glacial lakes there is a higher level of sedimentation. Once we put the hessian mats down the sediment starts to infill and it blocks out all the light and that will kill the plants. Because the hessian matting does biodegrade it will disintegrate over 18 months or so. But I am not sure how fast it would break down in Rotorua because the water up here is a lot warmer compared to down south. We have not tried it up here yet.

Mary Stanton, LWQS: Kia ora, this is not a question, this is a thank you. We have seen you operate in our Te Arawa Lakes. There was a time when we said we are going to lose our food basket and we worried about that. But having approached David Hamilton at the time about lakeweed and all the problems and what you have spoken about, I know that there was a lot of work done behind the scenes and particularly at the University of Waikato training all these students. So, what I want to say here is that we have seen the outcome of this happen in the Te Arawa Lakes. Thank you very much, it is improving our lakes. I know it comes at a cost and I hope we will be able to find funding for further generations, kia ora.

Session 6: *LAKE RESTORATION*

SESSION CHAIR – Kevin Winters, Bay of Plenty Regional Council

PRIORITIES FOR AQUATIC WEED, PEST FISH & PEST ANIMAL CONTROL & NPS FOR FRESHWATER

Hon David Parker
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In his earlier years, David was a managing and litigation partner in South Island law firm Anderson Lloyd. He was also involved in many businesses, including innovative bio-tech export start-ups A2 Corporation, BLIS Technologies, Botryzen and Pharmazen, as well as in more traditional industries. He is an experienced CEO and company director. He was elected to Parliament as Labour Member of Parliament in the former electorate of Otago in 2002. David was appointed to Cabinet in 2005, and served as Minister of Energy, Climate Change, Transport, State Services, Attorney-General, and Land Information under Helen Clark's Government. In Opposition, he served as Deputy Leader, Shadow Attorney General, and in Finance, Economic Development and various other roles. His focus has always been, and remains, on delivering prosperity and fairer economic outcomes for all New Zealanders.

TRANSCRIPT

Thank you for those welcoming words. I am sorry I am late; you will be pleased to be living in Rotorua today, not Wellington. It was a very delayed departure today, not because the plane was not ready, but because they had to maintain extra-long separation distances between everything that was landing and taking off for the reasons that Wellington is famous for.

Can I acknowledge Don Atkinson the Chair of the LakesWater Quality Society and your committee for the work that you have done through the years? Is Mayor Steve Chadwick here? She was a former colleague of mine in Parliament and it is always good to catch up with her. I am presuming Doug Leeder could not be here because he was at the same meeting that I was at last night. Can I pay my regards to the other members of the Te Arawa Lakes Trust. I know that Todd McClay is not here but I also mention him as the local MP.

It is a pleasure to be back here, I spoke in this building not long ago. I am here in lieu of Eugenie Sage who sends her apologies; she has a commitment somewhere else. I was surprised to learn from my briefing notes that your LakesWater Quality Society has been active for 60 years. That is a long time and I know that since your inception the Society's initial focus was on aquatic weeds but increasingly has focused on water quality, discharges and the very complex catchment management and land use issues, which contribute to the water quality issues that you have in the Rotorua Te Arawa Lakes.

I know that your symposium is focused on preventing the infestations of pest fish, which I hate with a passion, as well as weeds and improving water quality. But I thought I would also address freshwater ecosystem health more generally. It is a matter of some contest at the moment nationally with our proposed new regulations for freshwater, national environmental standards being promulgated and updated in the National Freshwater Policy Statement on freshwater management. There really is a need for change; the latest data shows that twice as many rivers are declining as improving in water quality according to four of the most accurate indicators including the Macro-Invertebrate Community. In addition there are too many rivers that are in a static but degraded state.

Over the last couple of months we have been consulting on what we should do as a country. Firstly to stop the state of our waterways getting worse, then to achieve material improvements within 5 years, and finally to restore waterways to a healthy state within a generation. What does a generation mean? I just want an upward track for the community to give people the time needed to get back to what we enjoyed some decades ago. We think our policies are strongly supported by the people of New Zealand; indeed, we know this from polling in both rural and urban areas. Just about everyone wants their ecosystem to be healthy and their rivers and lakes to be swimmable so that people can pop down to their local river and put their head under without the risk of getting crook. I have been using that phrase for years but I do think it sums up for most people what it is that they aspire for their rivers and lakes.

Although I do not think you have to justify these issues in monetary terms, it is also vitally important to the economic futures of our tourism sector, our farmers and exporters that we maintain the integrity of the New Zealand brand in general. I came back from China yesterday morning. I was there for trade and visited the International Importers Expo and the New Zealand stands. It was so evident that New Zealand sells its products to the world in reliance upon those brand values. It is important that we preserve and enhance the natural capital on which that brand is built. Our brand goes broader than that. It encompasses things like fairness, freedom from corruption, egalitarian society, doing the right thing in the world around things like nuclear-free and standing up for human rights. They are all part of the brand. There is no doubt in my mind that part of that brand relates to the quality of our environment, it is on all the packaging.

I was interested to hear from Fonterra while I was there, and unprompted they said to me that they maintain a premium, even for their commodity products, of around 5% over a lot of their competitors. That is grounded in their brand values, and their brand values go further again than the environment, but they also do rely upon the environment. So protecting these natural values is also of economic importance to our country.

The proposals that we have include an updated National Policy Statement which will look at addressing those longer-term issues, together with National Environmental Standards that are the main regulatory tool to stop things getting worse. By and large, the debate through the submission period that has just ended has been respectful and passionate. There are many different views as to how far and how fast we need to go, but interestingly there is near universal agreement on the goals that we have set which I find very pleasing. Thousands of New Zealanders turned out to the meetings and there have been a very large number of submissions, about 17,500. It is hugely important to people. There has been very little criticism of the fundamental concept of putting the water first, which we are giving greater expression to through Te Mana o Te Wai.

We have heard from consultation that it takes time to get back to perfection, not that we are trying to get back to perfection, rather to reasonable standards in some areas. We have also heard that you cannot give Te Mana o Te Wai without Maori rights and interests being addressed. I am very aware that Maori want to make progress on these important issues, and so do I. Cabinet recognises that allocation issues need to be addressed and that will start with Nitrogen allocation, something that you have been grappling with here. We intend to address allocation issues in a phased way after we address the issue of water quality and we are very grateful for the cooperation shown by everyone including Kahui Wai Maori, one of the advisory groups, who have agreed that we need to halt the decline on water quality as the absolute priority. They have been very generous in their willingness to initially uncouple water quality issues from allocation issues which are in some ways inextricably linked but both difficult to resolve.

To resolve these issues we need to get the balance right between providing water and discharge allowances for developed land and for the needs of under-developed land that is disproportionally held by Maori. It is a pretty intense period for officials to analyse those 17,500 submissions on our water quality proposals and to then consider the options. I am absolutely delighted and relieved that we have got an advisory panel that is dedicated fulltime to the task of landing this, chaired by the former Chief Planning Judge in New Zealand, David Sheppard, who is a very efficient and very capable judge. I used to appear before him years ago and can attest to that. Also, somewhat acerbic if you are mucking around in court, so we will get an outcome.

I also want to acknowledge the ongoing support that we have had from the Local Government New Zealand Regional Sector Water Subgroup. These are very challenging issues and I have found Doug Leeder from the Bay of Plenty Regional Council to have been very supportive. He has given wise counsel on the way through and indeed some of the requests that we have already had from regional councils give recognition to the first RMA Amendment Bill that is on its way through the House. I am confident that by the middle of next year we will have practical, workable regulations and an approach which will halt the degradation of our freshwater and get us on course for improvement over the next generation.

I have a lot personally invested in this because I believe very strongly that it is my birth right as well as yours to inherit water as good as it was given to us by prior generations and I am determined to see this through. We have to be practical in the question of whether we have too many attributes listed. Can we effectively implement them all? I am determined to meet those three ambitions which are to halt the degradation, make material improvements within five years and get us on track for fixing it up over a generation.

In many ways the Rotorua Te Arawa Lakes programme is ahead of the game. You already have community agreed targets to achieve by 2032. There is nothing in the proposed new regulations that would undermine your work towards these targets. On the contrary there are aspects that I expect will support your progress, for example, the Proposed National Policy Statement intends to broaden the focus to a more holistic view of ecosystem health, potentially adding more measures to those which you currently monitor and help us all understand better the attributes of these different lakes.

There is a live debate as to how many of these additional attributes are needed to achieve ecosystem health, but we do not want to overload the system with unnecessary complexity or compliance costs. The proposed NPS for wastewater, which is separate

from the one in respect of rivers and lakes, will add weight to your focus on upgrading wastewater treatment and sewerage reticulation schemes. It will underpin regulation which will have to be adhered to by every council in the land. I am aware that you are also doing some of the things that are in the NPS for freshwater standards to improve practices that reduce contamination.

There are essentially two parts to the NES (National Environment Statement) we have proposed. They aim to stop the quantity of risky practices that we know can be problematic, and we have proposed some strict rules around that. Then we will try to bring forward best practice to the existing quantity of those risky practices.

I am also aware that we need to get more granular at a farm level with farmers through farm environment plans and there are proposals that would strengthen the on-farm planning system not the regulatory one done by regional councils. I look forward to reading some of the submissions from this region. I am not promising to read all 17,500, but representative samples on all sides of the debate so that I get my own head around them.

At the same time, we want to continue to support and invest in voluntary locally led action to improve our waterways. Regulation is important but its only part of the answer. In this region you have shown what can be achieved with local initiatives supported with investment. To date the Crown has provided $47 million towards the Rotorua Te Arawa Lakes Programme. This is a huge tax payer contribution and I know it is valued locally, but I do reinforce that it is an enormous amount of money. In fact this model is not able to be replicated throughout the country. It is unlikely that the generosity that is been shown by taxpayers in respect of the projects here and in the Taupo catchment will be repeated anywhere. It comes at the cost of hip operations and there is a limit as to how much money we can get to assist people to stop polluting.

However the programme has supported initiatives such as the alum dosing to bind phosphorus in the water to limit algae growth, together with the ongoing harvest of lake weeds. But everyone agrees that the long-term sustainable improvements will come from things like better sewerage reticulation in lake side communities, and better management of land to reduce run-off into the lakes.

These are behind the improvements that we have seen, and importantly you are achieving real reductions in Nitrogen losses to the lake. I understand that the Incentive Fund has meant that around 3,800 hectares of land has moved to lower Nitrogen uses such as forestry or different farming types. That is great and having an effect here but there is a lot more than 3,800 hectares in New Zealand and we cannot pay everyone to remedy these problems. This has resulted in removing about 30 tonnes of Nitrogen from entering Lake Rotorua which is about a third of the 100-tonne reduction target. In addition, about 80% of gorse cover in the catchments has been replaced by lower Nitrogen land use. I am telling you what you already know so I apologise for this, but it is quite nice to remind ourselves of your successes. This 80% reduction in gorse cover has generally been in favour of forestry or regeneration of native bush. I am sure we all look forward to seeing more of these long-term changes.

However, your focus today is more on the issues of pest fish and weeds and although those issues do not fall within my responsibilities, they fall within Eugenie Sage's, I am happy to talk about that. To demonstrate the Government's commitment to improving the quality of the Rotorua Te Arawa Lakes the budget doubled the Land Information New

Zealand base line funding for aquatic weed control to $240,000. Lake and river beds are held by the Crown and the department that does that, largely by historical accident, is the Department of Land Information. They only have the money to contribute to these weed control efforts if they get it voted by governments, and we have increased that. What that means in respect of the Rotorua Te Arawa Lakes is an increase in the amount that can be spent to control weed growth. LINZ controls about 75 hectares of lakeweed in these lakes every year and the main lakeweed targets are *Hornwort, Egeria*, and *Lagarosiphon*. *Lagarosiphon* is a curse down south as well in Lake Wanaka but not yet in Lake Wakitipu so control efforts can help stop it spread. The Bay of Plenty Regional Council has recently received consent to use a new herbicide Endothall in the region. This is important because the efficiency of the weed controls is an important factor in how much can be done every year. Central Government funds most of the lakeweed control work done in the Rotorua Te Arawa lakes, but we are grateful for the contributions of the Bay of Plenty Regional Council, which contributes where possible.

In respect of pest fish, responses to new incursions of any weed or pest species are always very challenging. Lake Taupo has had to cope with the arrival of the brown bullhead catfish for almost 20 years. I understand that although they are predator of koura, which are of course a taonga species, the worst fears that they would eradicate koura have not been realised. Research into control options is critical to support any decisions on the most appropriate response, and I know that the Bay of Plenty Regional Council, together with the Te Arawa Lakes Trust, and community members are putting considerable efforts into trapping catfish but regrettably, they are now also found in Lake Rotorua.

Species eradication is of course preferable, but in large freshwater environments it has not been feasible with technology to date. Most importantly the sources of new incursions must be addressed. I have no time at all for people who deliberately release these things which I am told is part of the problem. Maybe occasionally through ignorance, but sometimes it is deliberate and appalling. The nearby Waikato River catchment has several other freshwater pest species like Koi carp and thankfully these have not yet reached the Rotorua Te Arawa Lakes. We have to do our utmost to ensure they do not. This requires vigilance, especially with boats and fishing gear and therefore I commend the Society in promoting its **Check, Clean and Dry** proposals for the Rotorua Te Arawa Lakes and the intent of its Clean Boat Certification proposal which is obviously the focus of today.

I am advised that it is too early to say what the most appropriate response to the incursion of brown bullhead catfish in Rotorua lakes is. We need more information, but we have not yet found a pathway for eradication. Prevention of course is always the better approach. I am pleased to note that for one freshwater pest in particular, containment efforts are still successful. Didymo, for example, is still confined in South Island waters, since its arrival about 20 years ago and there are certain fish diseases as well as invasive species which have not crossed Cook Strait going the other way.

We have all got to help our biosecurity agents, public support is absolutely critical as we aim to keep these incursions from spreading. I am also hopeful that one day there will be a technological solution to these issues.

In conclusion, I want to celebrate the cultural and societal values that we share in relation to healthy freshwater. I sometimes tell the story that one of the reasons that New Zealand already has a very very strong environmental ethic, even though we are not perfect, is the fusion of two cultures. The Maori holistic world view, which is so well encapsulated by Iwi

saying, ‘I am the river and the river is me, the river is my ancestor'. I own the right and the obligation to pass on to the next generation water as good as I inherited it. It is a lovely ethic which we increasingly give reflection to in our statuary instruments.

Populations from the United Kingdom at the time of colonisation came from cultures where there was successive privatisation of access to waterways. Maori found willing partners in the men and women who came from Scotland and England who wanted to escape those class stratified societies where there were private privileges in water, compared with the communal attitudes to water in Maoridom. These two cultures have already influenced each other in a way that is already reflected in our law and our values in New Zealand. This is fantastic because we have got to the position where we all agree we want the same thing, to be able to swim, fish, to gather mahinga kai and to enjoy our freshwater, trying our utmost to curb these adverse effects from pest weeds or invasive fish species. We all want to hand to our children the qualities that we experienced as children and that our parents also enjoyed. We also need clean water to drink, we all agree that we also need to have water put to economic uses to support a successful economy.

I am confident that given that there is so much we all share as people whatever our ethnicity and whether we are living in rural or urban areas, that over a generation we can work together to overcome some of these challenges and leave the environment in a better state rather than oversee its degradation.

Thank you.

QUESTIONS

Ian McLean, LWQS: Kia ora David and welcome. You mentioned that governments have been generous to the Rotorua Te Arawa Lakes, and I agree, with the $47 million in the Deed, and the 4th Labour Government was particularly generous in that, so thank you.

David Parker: I opposed it at Cabinet actually because I thought it set a poor precedent, but luckily, I was over ruled.

Ian McLean: The numbers have changed a bit, as I understand that now represents about 20% of the total costs of the amount that has been spent on the lakes so far, maybe 25%, but in that range. The total cost had been very much larger.

Looking at the proposed NPS there is much more emphasis on rivers and streams than on lakes, it is relatively quiet as far as lakes are concerned, as I read it. The work on the rivers in catchments will of course be of immense benefit to the lakes, but there is still other work that needs to be done and a lot of work in the Rotorua Te Arawa Lakes, in particular the local biosecurity aspects. My question to you, apart from thanks, is will the Government be prepared to examine on their merits proposals from this area which are designed to innovate and develop ways of dealing with local biosecurity measures which will benefit the whole country?

David Parker: I think the answer to that is, ‘Yes. Who could say no to that?’ I could get a dollar out of my pocket and keep my promise. But the question is how do you fund those things? I do not know the answer to that. I do know that any government must first meet

the costs of wage increases, health and education, the needs of an aging population and improving medical technology, the core responsibilities of government that relate to law and order and justice and corrections, and armies, which we spend a lot less on than most countries. It may surprise some to know there is very little discretionary spending within the control of any one government and we prioritise that very carefully.

In fact this Government are trying to prioritise that in accordance with the Living Standards Framework that has been developed by Treasury that we are implementing via our Wellbeing Budget approach. I have been involved in those budget processes for a fair bit of time through the last Labour Government, this Government and also whilst in opposition in the 9 years intervening.

I have reached the view that sometimes we spread money around too thinly and I was really pleased that last year we chose to focus on a few issues in the budget. We met all those other pressures, but the most significant thing we did in the last budget was the package for mental health addiction services and family violence. That will have an enduring effect, partly because it is of a scale that will turn the dial, even though it takes a while to build the services capability and society to deliver those changes that will have an effect.

The other area we chose to fund significantly was the land use support package and it does focus mainly on rivers and nutrients rather than on pests, but that is the priority that we chose. What will be the priority in that next budget, I don't know?

In addition to all of that, we have created a little bit of flexibility through the Provincial Growth Fund which was an initiative of the New Zealand First Party. I sit on the Investment Committee and did not realise what a liberating pool of money that has been for the Government and for ministers. I have been at this for 17 years now and forever meeting groups of people like this and seeing the challenges and opportunities that exist in society and so do all of my parliamentary colleagues. Although parliamentarians get it in the neck a bit, they are generally a hardworking and clever bunch of people. Their analysis of what difference can be made in society is every bit as good as the analysis that comes through the necessarily complex processes that are run by government departments as to their priorities.

This $3 billion Provincial Growth Fund has enabled us to do things that are not of the scale of the big initiatives that we back in a Central Government budget once a year, but they make a difference. Shane Jones is good at getting media attention, but he has a very nuanced view of the world. Through the Provincial Growth Fund we have funded environmental initiatives such as the hydrogen economy in New Zealand, and mostly little increments of money to get the private sector motivated to come along.

We are pushing towards automation in agriculture to assist land owners to higher value land uses that are less polluting. Where is the money for those little initiatives coming out of? The Provincial Growth Fund. We are trying to deal with inter-generational welfare dependency in some very deprived communities that have got very complex problems in families. A completely different series of initiatives are needed to give pastoral care to kids from those families who want to break that cycle of dependency, but go home to dysfunctional families and need support to get to work, and help finding alternative accommodation. So, support to do what they want to do, which is to get ahead. We are doing that through the Provincial Growth Fund.

We have done works around river restoration in some areas. We have assisted Iwi to meet their economic aspirations while they assist the country to meet our water quality aspirations. A bit of a quid pro quo going on in New Zealand.

So, it is possible that if we are re-elected and we re-establish a fund like that, and I personally would be supportive of doing it, some of those little initiatives that you find so hard to get funded through traditional streams of funding can be done through that. It is run by a wise group of people supported by some very good officials creating a bit of flexibility in the system that we have not seen in New Zealand for decades. I have seen more meaningful change in that pool of money than I expected to see and find it really gratifying, because we are all trying to make a positive difference.

Professor David Hamilton: Minister, thank you for the talk. There was one thing I wanted to pick up on and that was the 5-year target for a halt to degradation. Specifically, for me as a scientist, I do not find that target realistic. The reason being that we have seen some of the legacies of the past through the Lake Rotorua process where in the mid 2000's we clearly identified what the problem was and yet it has taken many years to put something into regulation. We are still talking about Nitrogen targets in the similar capacity to some of these ecosystems in the future without having bedded down any strict protocols or ways to be able to do it. So how is this 5-year time line going to be attained and who is going to be responsible for meeting it? What are the consequences of not meeting that 5-year target?

David Parker: Well I am depressed to hear you say that David and I am determined to push it as hard as I can. I have to sell a bit of hope here. Someone commented after we launched these proposals the opposite to what you said. They said that unless we showed some progress within a reasonably short period of time the status quo will become the norm for the generation behind me. If we lose this political moment to push, and these things only come around once every 10 or 20 years, then in 10 or 20 years the status quo will be accepted by a larger proportion of the population and it will be a degraded one.

How are we trying to turn the dial within 5 years? In truth there has already been some good work started by regional councils, and we will serve that to the extent that we are able. But we have a new plan-making process that we are legislating through a bill that has already had its first reading in Parliament, which changes the process for water plans. It requires them to be notified by 2023 and in place by 2025. That is challenging for regional councils and they say it might not be possible everywhere. I had a discussion with regional councils chairs yesterday on this very issue, and they said, 'Oh well, it takes us that long to consult with communities and to agree a pathway forward'. I sometimes think we consult too much and it can be an excuse for delay. On the other hand they might be right, that it is impractical to do properly for every water body within that period, so we will have a look at the consultation period.

In the meantime, there is the strictest provision ever in New Zealand against the increase in some risky practices, such as winter grazing practices that we have in parts of the country, and that is a hard line. There are also very strict rules against further degradation or loss of wetlands including estuarine wetlands. Again something that is appalling that we have allowed those to be nibbled away in recent decades. I would claim it is progress if we immediately halt the loss of wetlands which we are proposing to do, and that is progress that you are going to see within 5 years.

Kevin Winters: We have known that wetlands have been lost through the last 20-25 years and yet we know that they play a significant ecosystem function. Why have we not been able to put in place no net loss of wetlands through that time?

David Parker: It has primarily been a failure of local and regional government in my opinion. They have had the authority to do that since the RMA was passed. Why is that? Well there are lots of reasons including the difficulty to change a plan within the democratically elected term of a regional council, which is something that central government should have fixed for regional government earlier. It is lamentable.

When I talk about wetlands I generally go straight to whitebait because people identify in a cultural sense with whitebait. Not all wetlands have whitebait but they know that we used to have more whitebait than now. I cannot answer your question but the failure for that rests on people with hair that is your colour and mine. It is our responsibility and it is our collective failure: central, regional and local government level and scientists and people that have not been strident enough in their activism. I think we all bear that responsibility.

Kevin Winters: Thank you, David, thank you for your wisdom, we are all in this boat together.

FUNDING STRATEGY FOR THE NON-DEED ROTORUA LAKES

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Guy Salmon leads Ecologic, a think tank working at the interface of the environment and the economy. His work focuses on research, policy advice, and consultancy where this can improve environmental outcomes. He has had a nine-year involvement in the consensus-building Land and Water Forum, and two years ago, advised the Rotorua District Council in its successful application to the Freshwater Improvement Fund for Lake Tarawera.

TRANSCRIPT

Kia ora koutou, the topic of this talk is about the 8 non-deed lakes which comprise Lake Tarawera and seven lakes which flow into it. Apart from Lake Okareka, they have not been funded under the previous Deed funding. We will look at the challenge of what the funding needs are for making further progress on these lakes?

Generally, these lakes are less degraded than the Deed lakes but they are heading in the wrong direction. Prevention is better than cure is a little phrase that has been used a lot at this symposium, I think rightly so. There have been some actions taken on these lakes but there is a political perception, and also a perception amongst planners I spoke with in preparing for this talk that these lakes are less urgent and have the expectation that they are not going to cost a lot of money.

There is a risk that these lakes are not going to get the attention during that critical window of time, before downward trends start to become irreversible, and we have

evidence that that is now approaching. We obviously need more knowledge but today I will give you a preliminary view and acknowledgement of several significant areas where more science must be done before we can ask anybody for money. None the less I think there are one or two things that can be done now.

Environmental strategy is generally a question of bringing together specialist knowledge from different disciplinary fields, none of which I am an expert myself. It is about social science needs as well as biophysical science. The dreaded economics comes in here and also sociology to the extent that there are some social licence issues which are important.

We need to be clear about our objectives and base lines. In environmental policies an awful lot of good intentions are expressed, but that is not the same as clear accountable time bound objectives which are essential. Strategy making is a process of weighing and integrating various perspectives from different fields, and the most challenging part is dealing with uncertainties. In some cases you make a judgement that the consequence of ignoring or doing nothing about an uncertainty is going to be irreversible and, in that case, the precautionary principle needs to kick in.

This is particularly important with lakes because of the irreversible nature of the trends which they face. In other cases it is a question of recommending further research and thinking about a framework for adaptive management in which we can learn as we go, something which, unfortunately regional councils have not been good at in the past. It is encouraging to see in the latest plan change for Lake Rotorua that there is a regular review provision built in, which is going to help us do that.

When I step up to the task of writing an environmental strategy, from a funding perspective it has a high bar, and the Minister has emphasised aspects of this which are important. Firstly, public money is scarce and has a lot of demands. The Minister talked about hip operations being traded off with water and this is a reality that we have to acknowledge. Secondly as the Minister also said, the first duty that we have is to ensure that those releasing contaminants are meeting their responsibilities. It is not for the Crown to step in and say, ‘Oh hi, we are going to excuse you from that responsibility and pay out a whole lot of money’. Thirdly we should be very concerned about the effectiveness and efficiency of any funding strategy involving the use of public money, and whether it is going to achieve the objectives which we have set.

So, having made those slightly sobering comments about the strategy process let me touch on the water quality context. In a way these presentations are in the wrong order because this afternoon we have several important presentations about the water science, an update in fact on when I last was engaged in this region when advising the Rotorua District Council on its funding bid for the Freshwater Improvement Fund which was successful. A bit more science, but the underlying messages are still similar to what we were facing at that time.

Lake Tarawera’s water quality is dominated by the influence of the 7 other lakes and land uses in its wider catchment, those connections are really important. We have a good record from 1989 of water quality trends at the lake outlet. However, the lake has consistently failed to meet its TLI target, or even to move toward it. In fact, evidence suggests that it is getting worse. There are more frequent algae blooms, there are deoxygenation episodes which could release nutrients from the lake sediments which, if they are allowed to continue, could throw the lake into a trajectory toward tipping points. The decline is being driven mainly by an inflow of phosphorus into the lake. Some of that

phosphorus comes from geothermal sources and there is nothing we can do about it, but that means that we must concentrate on reducing phosphorus levels down from human influenced sources.

There are five things we know about improving water quality:

- We need to focus on the catchment, what runs off and through the land, including the ground water flows
- We need to achieve all the little improvements that we can across the whole catchment.
- We cannot say, that this particular contribution is too small to worry about, most will be like that
- In order to evoke that willingness to act we need to have an ethos of all hands to the pumps, equitable burden sharing, everyone pulling their weight to keep the momentum going
- Also focus attention on the co-benefits of our actions

It is interesting and exciting to see how far ahead the farmers in Tarawera's wider catchment have been compared to elsewhere in the country. It is important that we do not give them a sense of being let down if other players in the catchment are not pulling their weight as well.

The wallaby issue is having a damaging effect on Lake Tarawera's water quality, but an even bigger and more drastic effect on our biodiversity. This is something we ought to be looking at in the immediate future for actions. It is mainly on DOC land and the issue is that wallabies are present in very high numbers and they browse the forest floor intensively, much of the understory is bare, slips become exposed under storm conditions and cannot heal themselves because they are constantly being grazed down. As a result of the processes triggered off by the wallabies there is a considerable amount of particulate transfer of phosphorus into the lake.

The science behind the idea of controlling the wallabies was canvassed quite exhaustively in the previous LakesWater Quality Society's earlier Symposium and there is a lot of good documentation on their website www.lakeswaterquality.co.nz. There is also broad support from stakeholders around Rotorua for controlling wallabies.

But there are two issues, and this is where I come to social licence:

(1) There is a degree of concern about aerial drops of 1080
(2) It is not only the wallabies that are browsing these catchments but also deer and pigs which are disrupting the ground, and deer and pigs are valued by people in this area for their hunting.

Most of the foreseeable actions that we need for water quality are already being backed by good funding commitments, either things that have already been budgeted or where funding is clearly in prospect. But at the moment the wallaby control is a bit of an orphan. It is important to have all hands to the pumps to keep momentum up – and there is an obvious visible gap among the potential contributors – residential property owners, farm property owners and DOC.

The main land owner involved is the Department of Conservation and they have not got funding to help this happen. That is a problem because it has a partnership with the two

Regional Councils, Waikato and Bay of Plenty, and they are not getting a sense that the Department is pulling its weight. Getting action on wallaby control from DOC would have big co-benefits for them, not just in terms of biodiversity around the lakes, but also curbing the alarmingly rapid expansion of the wallabies into those huge tracts of land in Te Urewera and the Kaimai Ranges. Once the wallabies get into those areas, it becomes an unmanageable and irreversible problem, and it is really important that DOC faces up to this and deals with the wallabies.

There are also co-benefits for Rotorua which is a big tourist destination, a lot of its economic growth prospects are driven by tourism. We have this amazing opportunity for a new New Zealand Great Walk around Lake Tarawera, which is not yet complete, but the vision is there and the end goal is in sight. The contribution that we could make to enhance that experience by wallaby control, both in water quality and the visual experience of walking in the forest would be big and well worth pursuing.

I come to those social licence issues that I mentioned a moment ago, firstly the aerial use of 1080. This is something I have been following quite closely for a number of years. There is an initial and perfectly natural suspicion and concern about the whole idea of dropping toxic baits from an aircraft. But as groups learn more and more about the reasons for doing it and the lack of alternatives for large scale control, they move up the learning curve and attitudes are changing. The most recent, dramatic example of this is on the Raukumara Range where a group has been formed, led by Iwi. There a budget for helicoptering kaumatua up into the ranges to show them what is going on and common sense is rapidly gathering that we have to change our mind about 1080. That is very promising in New Zealand at the present time, where despite all the concerns and debate, we can move forward and engage people well and help them understand what is at stake.

In locations that are particularly sensitive, such as where Hapu might be insisting on it, or other social reasons, we may be able to do aerial pre-feeding and then follow up with hand-set 1080 baits for a high level of control with ground placement. In an ideal world, it would be desirable to control deer, pigs as well as wallabies. But there are local groups who really value their ability to hunt deer and pigs. 1080 baits could be used with a deer repellent.

So we might be best to be pragmatic, take an adaptive management approach: focus on knocking down wallaby numbers in the meantime, monitoring the effects of these efforts, and then later on, if it turns out to be necessary, having a discussion about deer control.

Some final thoughts, this picture is of the members of the Land and Water Forum. Everyone thinks of it as an engagement between environmentalists and primary producers, but as someone who has served on it for 9 years, the influence of the Iwi

representative was enormous. In many places a green voice does not cut through but somehow the Iwi did and that was magical.

There is something to be said for the relationships that have been built here between the LakesWater Quality Society, the Te Arawa Lakes Trust and the local authorities. That kind of willingness to all work together across these ethnic boundaries that sometimes are difficult for us is really important. Talking with the people from the Maori community here, I was struck by how far down the track they are in coming to grips with all this. There is an opportunity for the Te Arawa Lakes Trust to take a lead role on solving this wallaby issue.

There is still much work to be done in public engagement and consultation. But the funding package is needed in part to help with that and it is important to get started and build on the great track record of effectiveness.

The last thing I will say is this, Rotorua is a pretty special place. I have worked in so many different parts of New Zealand where I look back on years of activity and not seen a lot to show for it. But here in Rotorua there is something about the social consensus around water and the inter-relationships between the groups, there is something about the long-standing effectiveness of the LakesWater Quality Society as an NGO and its willingness to come to grips with quite complex things, rather than just slogans. All of these things have placed you in an incredibly good position, so if I was David Parker and was thinking where to spend the money, Rotorua has got a lot going for it.

Thank you very much.

Lake Restoration in New Zealand – Making the Rotorua Te Arawa Lakes the Model for Reliable Success

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Troy Baisden specialises in understanding the flow of nutrients, water and carbon through terrestrial ecosystems and resulting impacts in freshwater. He spent the last decade at GNS Science's National Isotope Centre, ensuring New Zealand has access to challenging isotope techniques combined with the 'big-picture' understanding required to apply them to the nation's most important environmental issues. He holds a PhD from the Department of Environmental Science, Policy and Management at the University of California, Berkeley. He is also an Investigator in the Te Pūnaha Matatini Centre of Research Excellence on networks and complexity, and from mid-November 2016, he took up the role of Bay of Plenty Regional Council Chair in Lake and Freshwater Sciences at the University of Waikato. In the role of Chair, Troy focuses on land-to-water nutrient management at catchment scales, and BOP's vision of a mountains-to-the-sea research programme driven by community and Iwi aspirations.

TRANSCRIPT

Tēnā koutou, tēnā koutou, tēnā koutou katoa. Ko Chesapeake te awa. Ko Moosilauke te maunga. Ko Troy Baisden toku ingoa. I have begun by offering a short introduction or mihi. I come from the Chesapeake Bay Region, the world's biggest estuary, and I did my honours degree at Dartmouth, which has a mountain called Moosilauke, on the sides of which the term 'acid rain' was coined. This also describes why I entered science.

I have spent much of my time in New Zealand working on climate change, which has a great deal of overlap with water quality issues. Although I keep trying to develop pointy-headed tools to solve these problems, I realise that my education prepared me quite well for looking at the engagement that stands behind successful science. We listened to discussions of economics this morning, which should teach us to beware of applying economics over here and science over there, with a gap in the middle where we throw words back and forth. We need to join the two and connect with everybody in this room in order to be successful.

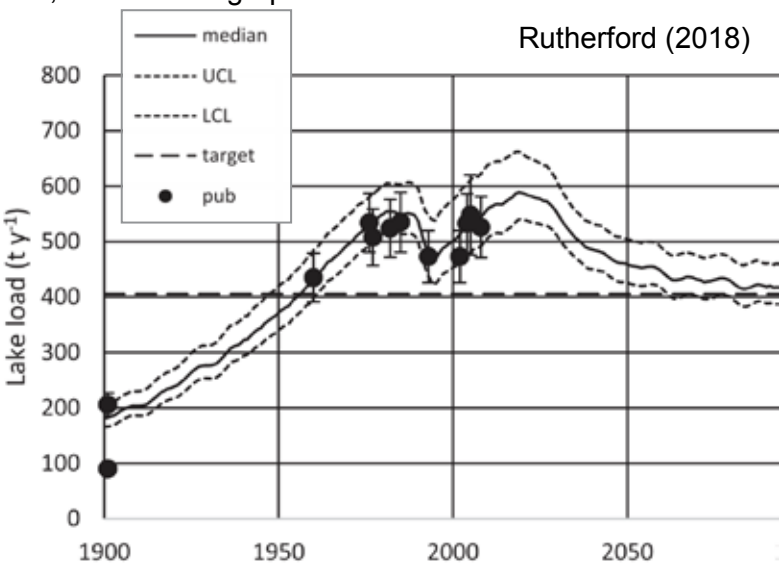
What is the right science? What is the value of (more) science?

That is what I want to talk to you about today. What do we do locally, and what should Minister Parker be thinking about if we want to achieve reliable success with freshwater reforms? Obviously it requires science, and everybody here has emphasised that access to science has been one of the most critical factors in what has been achieved so far in Rotorua. Professor Hamilton and those before him deserve a lot of credit for what we have to work with now.

The ingredients for success I have identified are: knowledge, engagement, strategy and action. I welcome additions to this list and I will go through each of them. Then I will focus

on whether the criteria I have listed for success are changing. When we look in the rear-view mirror, versus looking forward into the future, I think the answer is yes there is change we must consider.

My list of factors for success begins with knowledge, which starts with history. One of the success stories of Rotorua was a history of environmental monitoring of the water quality in the lake back to the 1960's. That prevented a lot of debate and contention that could have gone on forever and allowed people to move on. Ultimately it allowed science to project forward what you see here, which is the graph for reductions over time.



Rutherford (2018)

You can also see a period of reductions in the 1990's from wastewater treatment that achieved noticeable reduction but it accelerated again with agricultural intensification within the catchment.

We also know that there was some fabulous economics work done in this catchment by Suzi Kerr from Motu to develop what catchment N cap and trade might look like. There was similar work done in the Taupo catchment. Rotorua tends to be more realistic and comparable to the rest of the country. Some years ago when I talked to environmental economist Suzi Kerr, she said that they found what they expected in this catchment when they designed carbon trading while working on her PhD at Harvard. I therefore find it fascinating that the conception of cap and trade systems as a mechanism in environmental economics to efficiently limit pollution was designed to suit the approximate scale of Rotorua catchment, where the people in the system can gather together in a room. Importantly, it was also assumed that the framework for quantifying the pollution was scientific and robust.

The Emissions Trading Schemes (ETS) used for greenhouse gases may seem complex and fallible due to markets operating at national and global scales. Nevertheless, the scientific framework underpinning greenhouse gas accounting provides a robust example that nutrient management in lake catchments should emulate: we know the difference between carbon budgets leading to a world with 1.5°C versus 2°C of warming. The framework supporting Plan Change 10 in Rotorua is similar, and we should aim more widely for such frameworks driven by quantitative knowledge of catchment nutrient budgets.

That gets directly to my next point that the ability of people to engage with one another, and the **community desire** to achieve something has to drive success. There is also an important level of **discourse**, experts coming in, people in the community interacting with them and understanding, counsellors, officials, and people representing the way forward within organisations like the LakesWater Quality Society. Then we need consensus and often that represents **political consensus**. We come down to things that are hard and probably still contentious. One of those is achieving **equity,** which is an issue for

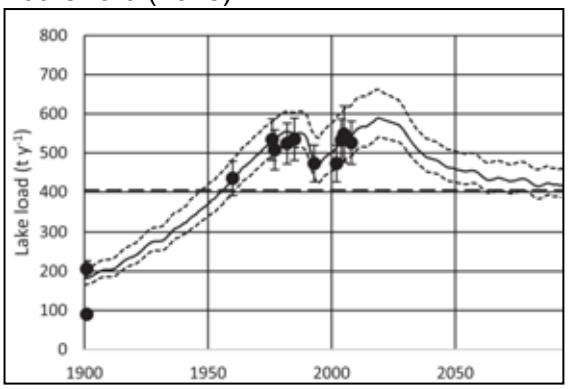
allocation, and for treaty settlements, and for issues of Iwi rights and interests. All these matters come down to **trust** to go forward; trusting the farmer across the fence, trusting people across the catchment and trusting people with completely different identities. It depends whether you can look them in the eye.

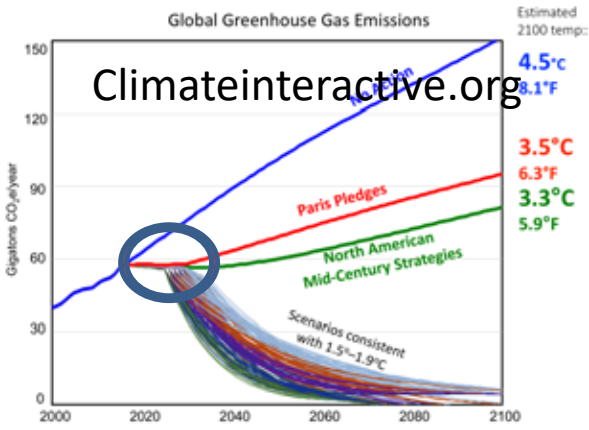
How do we develop an extended peer community?

There is a concept called **'post-normal' science**, and that is the intersection of issues like climate change and water quality where our catchments or the people involved are so big and the uncertainties so large and the stakes so high, that they work differently to the previous way we have done science.

It also comes down to **strategy**. I acknowledge Minister Parker's comments that there is potential to include things like attributes and indicators and the possibility of something resembling more closely an accounting framework. We are fortunate in Rotorua to have had an accounting framework. There is also a strategy around that framework. It is well scoped and enables us to be agile and flexible about the adaptive management and the five-year cycles of scientific assessment that are embedded in that process.

Rutherford (2018)





Strategy enables us to be risk aware so that uncertainties are well considered. In these figures, the Rotorua framework is on the left and the right one represents climate change, where we have been and where we want to go. Climate change is international, but provides a similar problem when you think about the Paris framework for climate change. It divides the problem up between countries to be dealt with quite differently, as we might delve into the water quality problems in our nation via regional councils and catchments, or freshwater management units to deal differently with unique circumstances in each place.

The reality of climate change is that we are struggling with the problem as a diverse set of people on the planet, but there is a very clear framework. Can you imagine if we had focussed internationally on climate health in the same way that we focused on ecological health as the core framework? Clearly, we would have a lot of trouble if we did not have an accounting framework for greenhouse gases that gets us to 1.5°C versus 2°C. Wherever possible, we need a freshwater framework that joins together attributes. Currently, policy proposals contain an unstructured consideration of too many attributes. We struggle to know how to focus on exactly the right ones, and to have a consistent set of measurements and methodologies across all attributes proposed for freshwater management.

It comes down to action?

Action is what happened in Rotorua. The key ingredients of action coupled everything I have talked about, knowledge, engagement, strategy and frameworks. Knowledge and engagement make each of those a process, rather than something that stands alone. Strategy and frameworks, you could argue either way, but the net effect is the other ingredient for action, investment. No matter how we cut it, $250 million has been allocated and mostly spent. It is a lot of money, and often the first time you do something is more expensive than the last. An important consideration is that $250 million is a lot of money, but according to the figures I have come across, the primary sector around the lakes generates around $200 million per year. Rotorua's tourism economy is close to $1 billion per year, so $250 million is not a ridiculous investment when we consider that it has been over 20 years.

It does mean that we need to keep our eye on the ball as things change over time. Implementation needs repeated scoping, risk management, flexibility and engagement – things that are often considered the soft parts of product management, but are the most important.

Guy Salmon highlighted the other side of project management which is setting time – bound goals and trying to achieve them. I try not to refer to them as deadlines where we need to maintain goals because trying to maintain them as deadlines can lose people along the way, and undermine the need for review. This is where **adaptive management** should be considered more deeply and has been a very important part of Rotorua's leadership. Similarly, the processes managing water quality in Taupo (RPV5) have a 10-year review cycle.

The concept and implementation of **adaptive management** was developed through a major initiative of the United Nations Environmental Programme in 1978[1]. It is well established and interacts well with what I am about to introduce – so called **'post-normal' science**.

There may be an issue though that the future is different from the past. Before we can focus on that, let's focus on what has been very successful here in Rotorua:

- N & P accounting framework including ROTAN
- Evaluation of economics by Motu Programme
- Development & negotiation of integrated framework
    - Who is responsible for what reductions?
- Discarded unnecessary complications (e.g. groundwater age)
- Community acceptance & desire

First on this list is development of the nitrogen and phosphorous accounting framework, including the ROTAN model. Second, Suzi Kerr and Motu were attracted here to develop the economics to support nitrogen cap and trade using a national funding source. The development and negotiation of the integrative framework may not be seen by all as successful, but it represents a significant success in working through allocation issues, which are typically the most difficult part the overall problem. A particular challenge turns out to be setting up a framework for limit-setting that is also compatible with allocation as

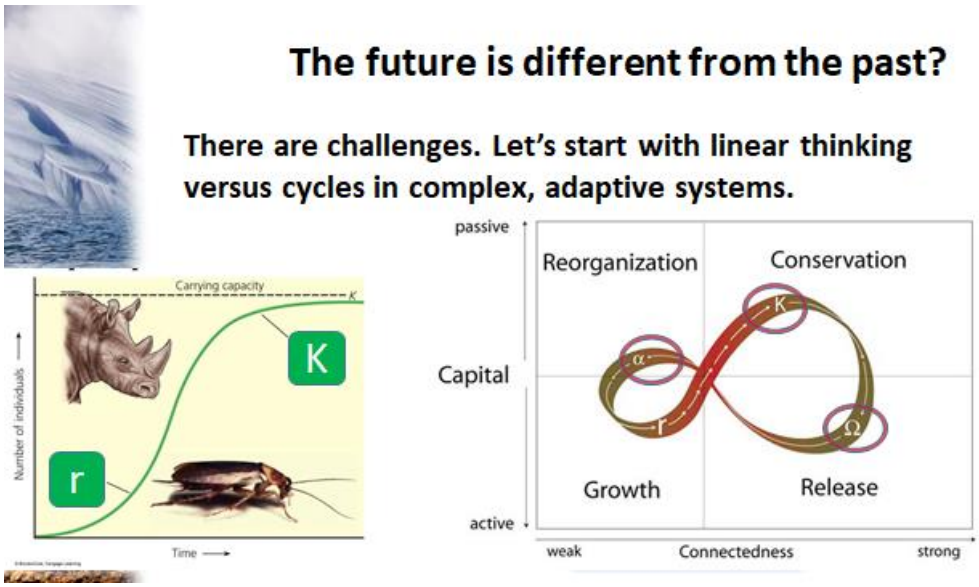
[1] Holling, C.S. (ed.), 1978. Adaptive Environmental Assessment and Management, New York: Wiley, p.377

well as Iwi rights and interests. Success there is notable, but still pending and therefore potentially imperfect.

Choices to make the framework manageable were an important outcome of the Motu-led work. Some of the unnecessary complications were discarded along the way including the notion that ground water age, though it is an interesting feature of the systems here, it may delay the ultimate responses of the system. According to Motu, the inclusion of groundwater ages increased the complexity of the trading scheme by an order of magnitude, yet resulted in only 6% more efficiency in outcomes from the system. It was a good decision to abandon it. Avoiding such barriers enables the biggest part of success – community desire and acceptance.

Yet there is potentially a very large challenge, which can be posed as a question: Is the future different than the past? The first thing to say is that the future is not necessarily the future we expect based on our understanding of the past. Scientific models can encapsulate very different processes. Scientific models that many of you already understand can describe the differences between two modes of system where the future is different from the past.

We will use the example of a system showing exponential growth transitioning to a system at carrying capacity. Ecologists represent the growth and carrying capacity stages with different organisms. The fast growth stage is often represented by an uncharismatic organism – such as a cockroach – and referred to as 'R' strategy. So, the front of the graph with the 'R' strategy depicts the concept of exponential growth. Those of you with a science background will recognise that, and also see the graph levels off at the 'K' strategy, representing organisms that live successfully at stable carrying capacity. There is a transition after the exponential growth, where the graph levels off at stable carrying capacity, and this illustrates a simple case where the future is not the past.



Moving toward more realism, one of the most interesting but perhaps least useful concepts and complexity science in the last 20 years probably has been a fabulous book

on 'Panarchy'[2]. Essentially, it explains so much, but in a way that is very hard to use for anything. However, with that said, I think there is one really important part of it. We do not actually stick at a carry capacity, represented by the 'K' in the slide. In the real world, we tend to go bouncing around once we get there, just when we expect to be able to take in the view and enjoy it. We find that, actually, the world doesn't stabilise for us.

On the characteristic figure representing a 'panarchy' you see the same sort of concept of 'R' and 'K' on a different axes, and you see cycles describing the idea that we actually go through a period of release. It is what an economist refers to as *creative destruction*, defined by Schumpeter as a necessary step in innovation. I am often told this is something we do very poorly in New Zealand. It may explain the New Zealand paradox, or why our economy lags behind our economic peers, when we appear to follow many prescriptions that create allow economies to succeed.

Ultimately, we should be able to proceed from creative destruction into innovation and success during a phase of re-organisation. That is what I want to focus on here: and I argue that there is a good case to be made with freshwater at the moment, in both Rotorua, and nationally; we are going through a cycle of re-organisation. We need to think hard about what has changed as we go there, and what is different from the past.

So, that describes key areas for focus that allow us to figure out where we are. If we think about there being a reorganised set of economic drivers, we need to ask, what are the new processes of growth?

In a Q&A published recently in the New Zealand Herald[3], I said that we are genuinely at a tipping point. This is something the Minister recognises in the freshwater reform package. However, what we lack in that package is a sense, and if I were to ask a question this essentially would have been it. It is that there is a process of trying to understand the turning point, but not a process of trying to understand, 'How do we afford this in the future, if we do not have that $250 million that has been spent in Rotorua?"

The answer partly lies in the opportunity to consider as we go forward what the Government's initial response will be and what we do in each region. The simple answer is that we perhaps are at a point where the profit-only motive of corporations has come under serious question. However, the main reason for that is that both investors and consumers are driven not to the lowest price anymore, but want something quite different. We can dismiss claims that the price of food will go up. That is one side of the tipping point that makes it very difficult for us to afford the restoration that we would like to have.

Instead, if we said governments are trying to cut rates and taxes because that is what we want in the democracy, we need to find investments somewhere else. The reality is that investors do have cash; however, they struggle to invest it. What we need to provide for them is certainty to support that investment. That investment can achieve value from consumers that will pay for health and environmental credentials. As the Minister mentioned when you go overseas, those credentials are on every product in a good store.

[2] *Panarchy: Understanding Transformations in Human and Natural Systems*, Lance H. Gunderson (Ed.), C. S. Holling (Ed.), Island Press; 1st Ed. Edition (December 1, 2001)

[3] https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12278288 (Unfortunately this is in the premium section, but I am happy to send a copy to anyone interested.).

Given the success so far in Rotorua, a big challenge we face is potential for external disruption of this localised success. Perhaps central government, fresh water policy or a whole bunch of other factors (it could be the farming lobby nationally) could drive us to less effective action and disrupt our ability to remain on target with our time bound plans. We need to work towards establishing a framework that closely resembles the Trophic Level Index (TLI) that everybody in this room will be familiar with. Instead of a forest of attributes it represents a very simple integrated index that has two drivers, nitrogen and phosphorus. It has two measures of impact, chlorophyll a and Secchi depth, that represent algal blooms and perceived water quality – in forms that quantify what we want to see achieved and what we worry about.

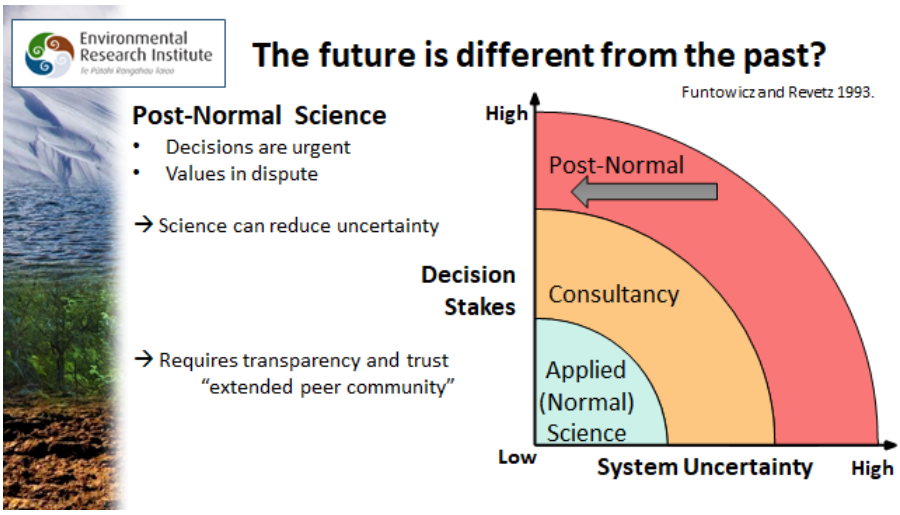
I come back to the point: imagine an international example if we tried to define climate change solutions using a confusing, nebulous concept of climate health, rather than having an accounting framework for greenhouse gases that simply describe what it means to have a 1.5°C world versus a 2°C world.

An interesting aside to this came out yesterday and is well worth some attention. The Parliamentary Commissioner for the Environment[4] released a new report looking at New Zealand's environmental reporting system. It calls into question serious deficiencies in the system we have. There are two points I will highlight here. First, the system reports simply to report, it does not report in a way that leads back to action. Second, it harvests data, but it does not invest in the data that we need to manage the environment. A feature related to this second point is that the national system is an indicator framework, not necessarily an accounting framework. That is fine as long as we realise that indicators, suitable for trend analysis, should not be used in the more predictive manner an accounting framework can be, to set policies imposing limits.

Moving on, let's talk about **Post-Normal Science**. This is an area where audiences and particularly productive officials may learn to fear in the same manner 'wicked problems'. I do not advocate putting 'wicked problems' on a screen in New Zealand because people immediately think of problems that cannot be solved with time-bound plans. In the case of Post-Normal Science, the research community has learned how to do this well over the last 20 or 30 years, and that includes some of the institutions that I have been in.

The key idea of Post-Normal Science, if you have not heard of it, is the idea that 'normal' science operates at a low level of stakes and a low level of uncertainty, and once we move beyond that we tend to bring in consultants. The reality of problems like water quality at a large catchment scale, and for that matter climate change, is that they have high stakes and high uncertainty. They also have a few other features; often decisions are urgent, or even overdue, before you are making them, and even worse, values are in dispute when this is occurring. Those are the challenges. The obvious role for science is simply to reduce uncertainties. That is what the grey arrow in this diagram signifies.

[4] https://www.pce.parliament.nz/publications/focusing-aotearoa-new-zealand-s-environmental-reporting-system



I have put up this diagram many times before in the two years I have been working here in Rotorua and around the university to make the point about reducing uncertainty. It has not entirely been taken up. I suspect people often wonder why I am not just getting on with the science. But that is a key point, getting on with science to reduce uncertainty tends to require targeting what uncertainty needs to be reduced, and how, but understanding what decisions need to be made using science. This therefore requires that transdisciplinary – not economists in one corner, and scientists in another corner, and affected people in another room. It requires everybody to come together into an extended peer community that is actually achieving discourse and discussion, and then consensus about where we go. That is what we need more of and how we generate transparency and trust about the information that we use to make decisions. That is also how we end up avoiding being in a polarised post-truth environment that is dominated by short term media news cycles. And, wouldn't most of us agree, that's not where we want to be?

The second side of all this deals with the need to recognise Te Ao Māori (the Māori worldview). That is perhaps the most urgent example of values in dispute. I come to it last, not because I have left it to last, but because I do think it is most important and partly represented by the lack of representation of Te Arawa Lakes Trust in this room. If we go through a list of what matters here:

- Te Mana o te Wai
- Mahinga kai
- Mātauranga

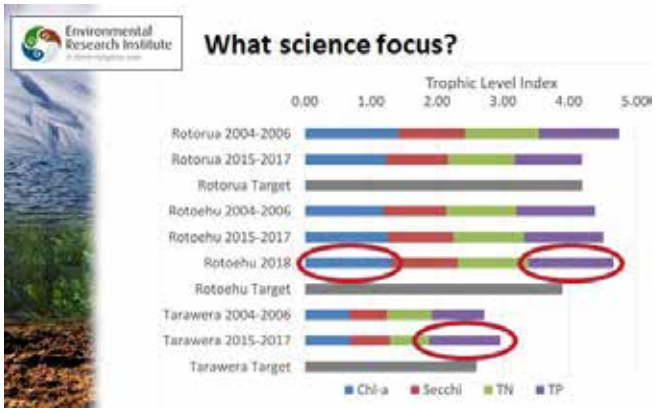
These are all processes or ways of thinking, which we think are important. And ultimately it comes down to the people making use of these concepts, often phrased as: 'He tangata, he tangata, he tangata'.

One of the challenges of getting recognition and engagement in the room is not just having the invitation but being truly compatible. That means having a number of speakers, having a pepeha (introduction), in a way that enables sitting down in discussion. But the other thing that is important is that the Te Tūāpapa o ngā wai o Te Arawa, the cultural values framework of Te Arawa, is a pretty simple document. Many of you may know it; it is a great starting point. If you are having a winding argument that you cannot understand, then it is a good foundation to come back to, to appeal to common values. For me it was

very clear, in working with Te Arawa Lakes Trust, to inform what I am trying to achieve. There are a lot of things in all this that may not make sense, as with anything that has history embedded in it. To begin finding sense, trying to understand the values driving action and debate is important.

Guy mentioned that Māori, once they are engaged and become a significant presence in the freshwater debate, can be really valuable. That is an important point. As we go forward there is a struggle between land ownership, forest ownership, and environmental stewardship that Māori feel. That is what this type of framework deals with. It sets in place a strategy driven by values for achieving that.

I will talk briefly about three areas of science focus for my programme and the areas I will be working on with the Regional Council. This graph breaks the Trophic Level Index down into the different component parts, chlorophyll A, Secchi depth, total nitrogen and total phosphorus. We can see that Rotorua is doing well and meeting its targets. We can also see that Rotoehu is not, and that is our challenge.



We can also see which parts are driving the problem and why we have algal blooms and we can see a relatively large phosphorus signal there. We can also see what Guy mentioned in this, although now we are focusing on slightly different data than the Council is producing, we continue to see an issue with phosphorus. Looking first at Rotorua, we will not be talking about this today, and it is an issue because one of the problems we have is lack of action. This lack of action results from drawn out processes in Environment Court, but that does not mean we should be sitting on out hands.

I would like to emphasise that in Rotorua we need to think now about reductions to 2032, because the clock is ticking. Farmers generally do not believe that they should be walking off the land and that the process of achieving this should entirely be land use change. I do not believe it either. I believe that it is possible to achieve a certain level of nutrient reductions on farm[5]. We need to support people in doing that. We need to be able to verify what works and encourage more of that. However, the reality is that it does not happen in two years. It tends, especially with nutrients, to take 10+ years.

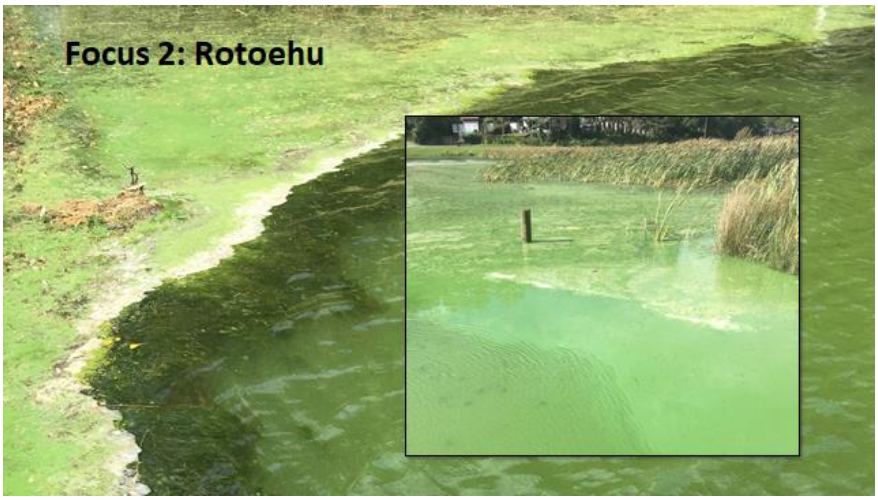
We can only buy so much

with

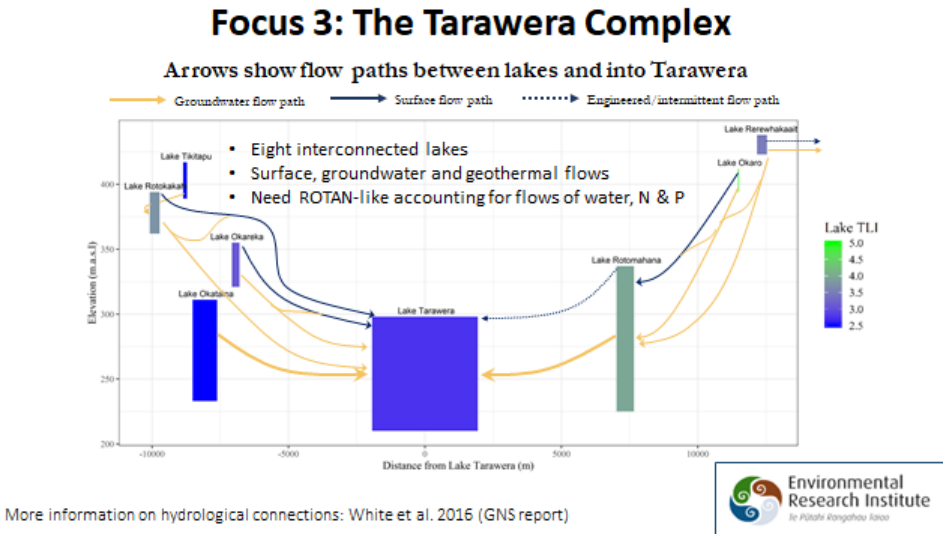
In the meantime, we have bought a bit of time with alum. I want to point out as an American that alum is something you can buy in the supermarket as a food additive. It is the reason why American pickles are crisp. So, as well as a natural chemical that goes into things, it is not as hazardous as some people make it out to be, although I would not swallow a whole jar in one go.

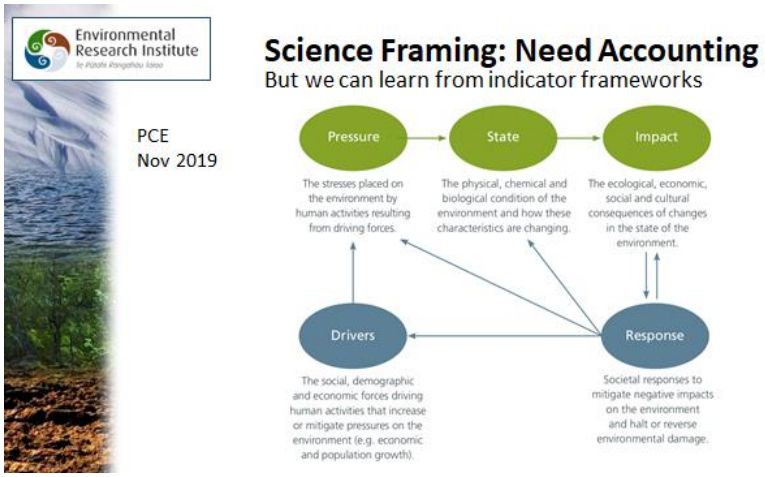
[5] https://theconversation.com/six-ways-to-improve-water-quality-in-new-zealands-lakes-and-rivers-95049

On the other hand, I would not swallow this water at all. This is a recent picture of Lake Rotoehu and it is not what we want to see. There are a number of factors in here and Chris Eager will focus on this later today giving the scientific details in his MSc thesis. He will describe some interesting details about the unique chemistry of Rotoehu, and why the alum addition stopped working. Andy Bruere may now be able to address this with a consent that allows alum to be added elsewhere in the lake to get us back out of this problem.



Another big problem to solve will be the development of an accounting framework that supports our management of the Lake Tarawera complex, essentially the eight lakes that flow together. This figure shows the flows between the different lakes and the relative Trophic Level Indexes. I will not spend long on this because it will be the feature of Chris McBride's talk later on today. The key point is that Lake Rotomahana takes in a lot of its flow eventually reaching Lake Tarawera, mostly agricultural areas, particularly dairying with higher levels of intensification. Every time you go through a lake it has a high level of nutrient removal. For a long residence time lake, it is fair to assume that in the order of 80-90% of the nutrients that go into it, sediment out within that lake. They are removed, to the benefit of downstream water quality. That is a relatively easy part of accounting for us to include and we will.





I want to return again to the Parliamentary Commissioner for the Environment's framework. Indicator frameworks should contain a feedback loop to ensure that what we are measuring and reporting on is being responded to by policies. However, the Parliamentary Commissioner for the Environment pointed out that the current national system does not include the drivers of the problem, such as the socio-economic forces or how people make decisions, and it does not request responses from the government or other policy agencies, such as regional councils.

The key issue for everybody to think about as they read this report is that it could potentially lead to a situation where, as we go around this loop and request that only central government responds, it could marginalise regional councils. That could occur in both monitoring and policy processes, if the development of the response to this report is not well considered. One danger is that well-resolved accounting frameworks for nitrogen and phosphorous, implemented by regional councils where Rotorua's PC10 provides the best example, could be supplanted by a fuzzier indicator framework mandated by central government.

On the upside, the PCE has made an effective request to review the appropriate levels of funding needed to address all the issues around indicators. That goes beyond water quality but it is certainly a good thing to highlight. It also goes into issues around biosecurity as deserving considerable new funding so that we get ahead of problems, rather than trying to fix them after they have got out of control, like wilding pines.

To conclude, what are the concepts contributing toward reliable success in our use of science?

Firstly, make sure that we use the right framework. Returning quickly to the greenhouse gases example, we know exactly where the emissions trading system went wrong. We have that full-on accounting framework and it feeds directly in to indicator processes. We have that same kind of framework for Rotorua. Let's make sure we keep it and extend it into Tarawera. Ultimately, this comes down to the people and their decisions. We need to get them on board and keep them on board. We need to embrace diversity and do that because equity matters. We need to consider the so-called 'extended peer community' that I discussed. That is not just different academic disciplines and science talking to each other, which is very much in that literature, but also includes what is often not in that literature – the 'peer community' that is represented in this room. There is nobody who is more expert in driving progress forward than the people in the area themselves.

We need to manage our risks: we have had a considerable focus on pests and climate change is another obvious risk that we need to leave head room for. One thing that continues to amuse me is that we do not plan for volcanic events in any way. Yet, this seems like an obvious place to do so.

We also worry about risks that represent external drivers, such as policy from Central Government, the politics and divisions that are present nationally. We need to represent an understanding of uncertainty, as it affects risk, and as it affects decisions. If we understand the risks that affect any particular decision, it is easier to target that within our models, than it is to make sure we understand *all* the uncertainty within our models.

We also need to understand the risk of not communicating well. This includes issues of transparency and trust around communication. One way to represent that is to break down what we are trying to achieve, even if it involves very complex models, into something that can be represented in a spreadsheet or table, a format that people can understand and carried though in policy and planning.

We need to proceed in a systematic way using adaptive management cycles, and that includes scientific assessment at each turn around adaptive management cycles. We need to embrace re-organisation; I explained what I meant by that. We can actually plan for that and accelerate it. But again, the success of innovation processes does depend on the creative part of creative destruction.

Finally, we need to understand the new economics of investment. This includes replacing value with values, and consider values in ways that will help us understand: 'Where does our next $250 million come from?'

Thank you.

There was a brief interlude where Hon David Parker apologised for leaving to catch his plane back to Wellington and was encouraged to take up a right of reply.

David Parker: Your comment on the absence of limits in the ETS was the original design compliant with the then Kyoto Protocol which envisaged an international market for those limits, and therefore had fundability between the New Zealand carbon market and international ones. When Kyoto too fell apart, the market was not immediately closed to offshore units, and the overcapacity left in the world's system because of oversupply of emission rights caused by the American absence from the final agreement meant that Kyoto and Russian hot air had nowhere to go but to the New Zealand system. The New Zealand system now does effectively have a cap, it might not be a strict enough cap, but it is effectively a defector cap caused by the limits to free allocation by sector, excluding agriculture, which is a big hole in it at the moment. It was meant to be closed by 2013. So, it is getting closer to that purer form that you identify and was designed with the help of Motu.

Troy Baisden: That is a perfect answer and I did not mean to be criticising the ETS in that way. I completely agree with his comments, because ultimately those so called Russian hot area units undermine trust and transparency if you understand that issue. (Or in other words, they undermine a framework that does quantitatively relate greenhouse gas emissions to economics through treaties and policies.

Session 7: LAKE TARAWERA RESTORATION

SESSION CHAIR – Warren Webber, LakesWater Quality Society

TARAWERA: EIGHT LAKES IN ONE

Chris McBride
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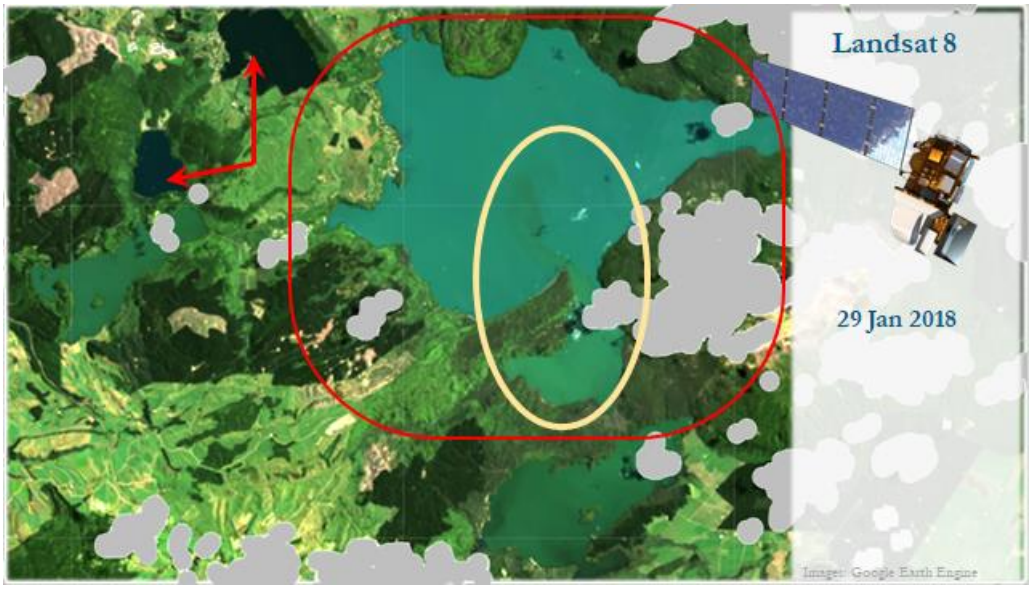
Chris McBride is a Research Officer at the University of Waikato. He began studying the Rotorua Te Arawa Lakes in 2003, and has since developed a network of autonomous lake monitoring stations throughout New Zealand, including six of the Rotorua Lakes. These web-enabled systems use high-frequency measurements to further our understanding of water column processes and long-term change. Chris also works on the application of aquatic ecosystem models for supporting management of lakes in response to pressures including diffuse and point sources of nutrients as well as climate.

TRANSCRIPT

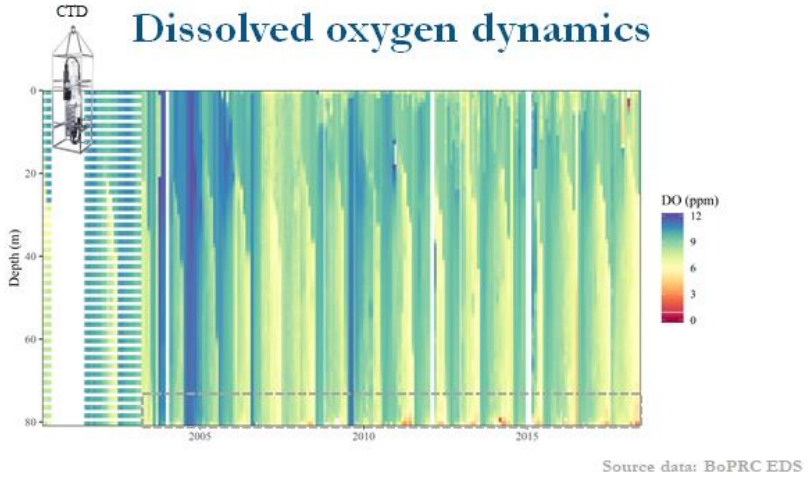
Kia ora kotou, thank you to the LakesWater Quality Society for the opportunity to present at another great Symposium. Thanks to Troy and Guy for giving a really nice overview earlier today on some of the aspects of the Tarawera catchment complex that I will address in this presentation.

The title is Tarawera: Eight Lakes in One. For those of you for whom numbers, graphs and maps do not particularly float your boat, I apologise in advance, because we are about to wade through a fair few of them, but I will start with a nice picture taken from space.



You will recognise Lake Tarawera and a few of the other lakes in the catchment complex. This is a true colour image taken from the Landsat 8 Satellite. Tarawera is famous for its picturesque qualities and blue water. What is noticeable is that the colour is different to the neighbouring lakes of Tikitapu and even Ōkāreka, which are darker and bluer in this image.

If you focus a little harder you can see a plume of green water that represents an algae bloom which has evolved in the Wairoa arm and moving out into the centre of the lake. This is a recent image (2018) and it is events like these that contribute to community perception that there is ongoing decline in the quality of Tarawera. However when we think about these events we also need to be mindful that Tarawera is a unique lake in terms of its oligotrophic water quality but frequent populations of cyanobacteria and occasional blooms have been observed in the lake for a long time, we will get to the drivers behind later.



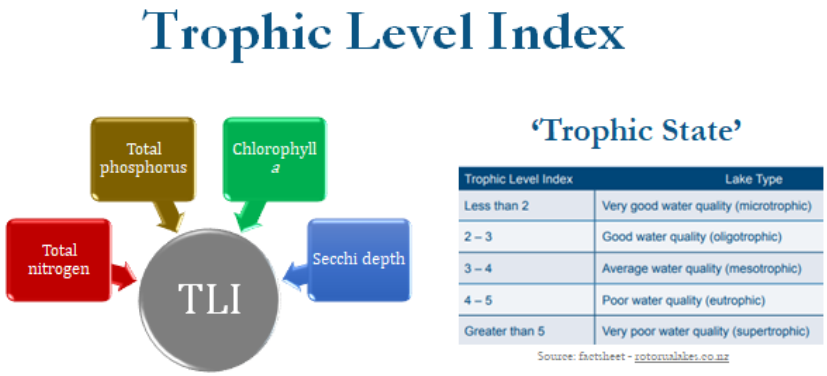
Guy mentioned earlier the oxygen dynamics in the lake were a potential cause for alarm. We measure this is by taking regular vertical profiles with a CTD instrument, which is shown at the top left, dropping it through the water column. On this graph the Y axis is the depth of the water column and the colour is the level of oxygen in the water. This is a multi-annual plot, from about 2000 to present. A red spot represents low or no oxygen in the water and we can see at the bottom in the latter years of the plot we see some hypoxic or anoxic water (shown in orange /red) in the stratification period in late summer / autumn. This is definitely something to keep an eye on because oxygen is a key indicator of water quality and lake health.

Also worth noting is that Tarawera has a very large basin of about 80 metres depth, not just a little hole as might be in some lakes at the maximum depth. Although that low oxygen band does not extend very high in the water, it could potentially represent quite a large area and potential for internal nutrient loading if that trend continues or worsens.

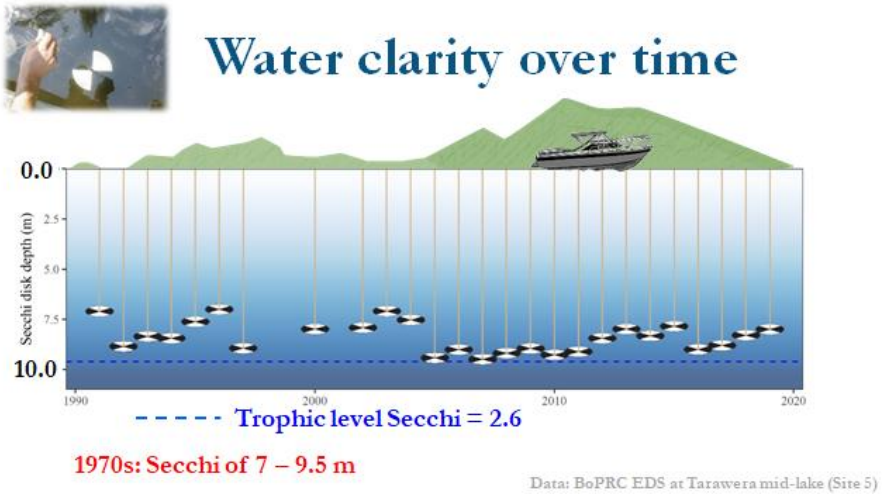
With those things in mind, I am going to talk about:

- What is the state of water quality in Tarawera
  - Is it changing?
  - Does it need restoring?
- Overview of the eight Lake Tarawera ‘catchment complex’
  - The Tarawera Lakes ‘conceptual model’
- Nutrient loading. What is the role of:

- Land use
- Connected lakes
- Geothermal sources
- What restoration or protective measures are needed?
- Where do the opportunities lie?
- Modelling and measurement tools



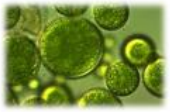
We are all pretty familiar with the TLI and its 4 component variables: nitrogen, phosphorus, chlorophyll *a* and Secchi depth. The target for Lake Tarawera is 2.6 which was set to be roughly consistent with water quality in 1994.

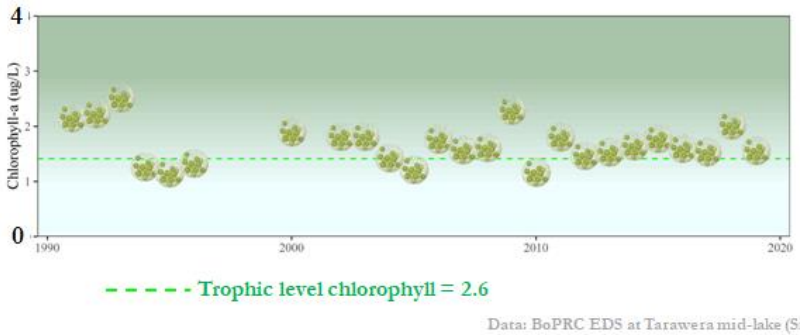


How has water quality changed over the monitoring record that we have? We use one of the simplest and most consistent things to measure clarity over time, called a Secchi disk. It is dropped down through the water and measured at the point it disappears. Each line and Secchi disk on this plot represents one annual average measurement with the surface of the lake at the top, clarity of 10 meters at the bottom and so we can track change through time. What we can observe from these annual average Secchi depths is that there is no obvious long-term trend in declining water clarity.

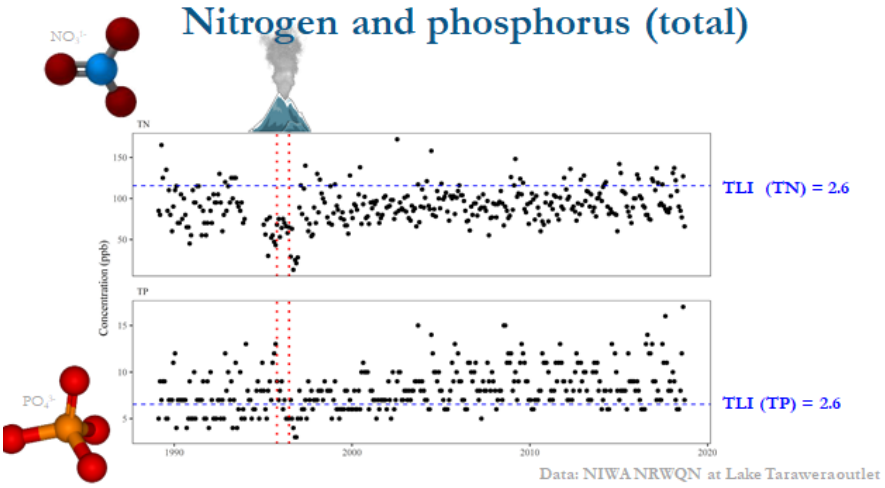
What the dashed blue line represents is the equivalent clarity for a Trophic Level Index of 2 .6 which is the TLI target . We can see that since the early 90's and to the present , clarity is slightly below where we might expect a lake at a Trophic Level of 2.6 to be. In the 1970s there

were two years of monthly samples with annual averages of 7 and 9.5 metres, which is consistent with the clarity that we observe at the moment.





If we look at the annual averages of chlorophyll and phytoplankton or algal concentrations in the water column the equivalent target value in the green dash line shows no particular striking trend in long-term increase in algal concentration . Although those monthly samples do not necessarily capture the frequency and magnitude of blooms , they are useful long-term monitoring data.



Nitrogen and phosphorus drive algal biomass and we have this high quality record from NIWA's long term National Rivers Water Quality Network where they collect monthly samples at the outflow of Lake Tarawera, consistent with mid lake water quality from our analyses. Nitrogen is below the equivalent value for a 2.6 TLI and pretty stable for at least the last 20 years. Over the last 10-15 years the phosphorus values lie comfortably above the equivalent 2.6 TLI and there is evidence for an increasing trend. We need to remember that in the mid-1990's there was an eruption of Ruapehu which spread a lot of ash over the region and it acted as a flocculent and sediment cap to some extent . This would explain the dip in phosphorus in that time.

Summarising , water quality phosphorus is quite elevated , nitrogen is slightly below what we might expect for a TLI 2.6, and Chlorophyll *a* and Secchi are slightly above . On the right the figures translate the measurements into the equivalent Trophic Level component

Water quality summary

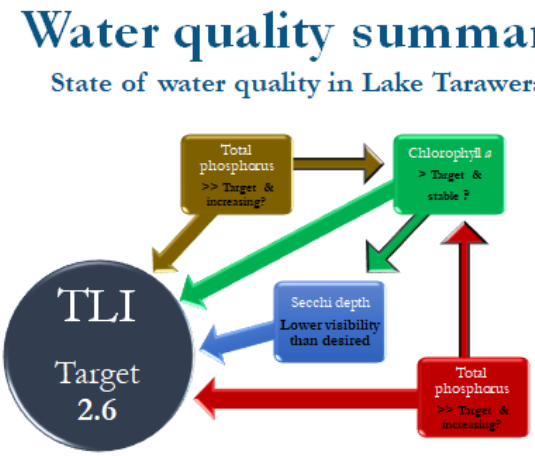
Observations (2014 – 2019)

	Value	TLI = 2.6
TP (ppb)	9.7 >>	6.5
TN (ppb)	97 <	116
CHL-*a* (ppb)	1.7 >	1.4
Secchi (m)	8.4 <	9.6

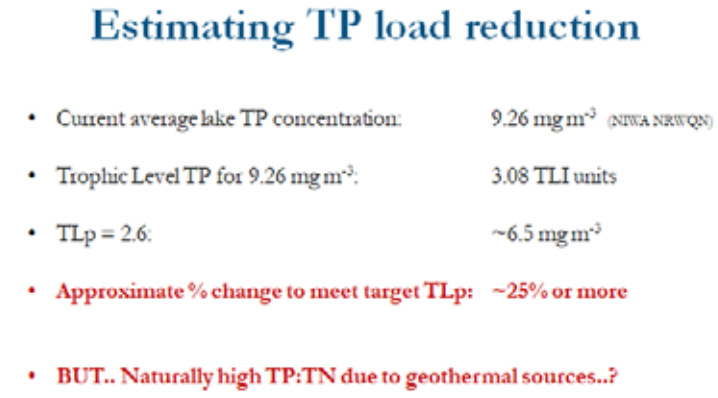
Trophic state

	Value	Target
TLp	3.08 >>	2.6
TLn	2.37 <	2.6
TLc	2.80 >	2.6
TLs	2.77 >	2.6
TLI	2.76 >	2.6

variables giving an indication of where each component sits. Each component variable impacts the TLI or the target value equally, but nitrogen and phosphorus impact chlorophyll and clarity, and chlorophyll also impacts clarity. So, nitrogen and phosphorus are the key drivers for managing targets.

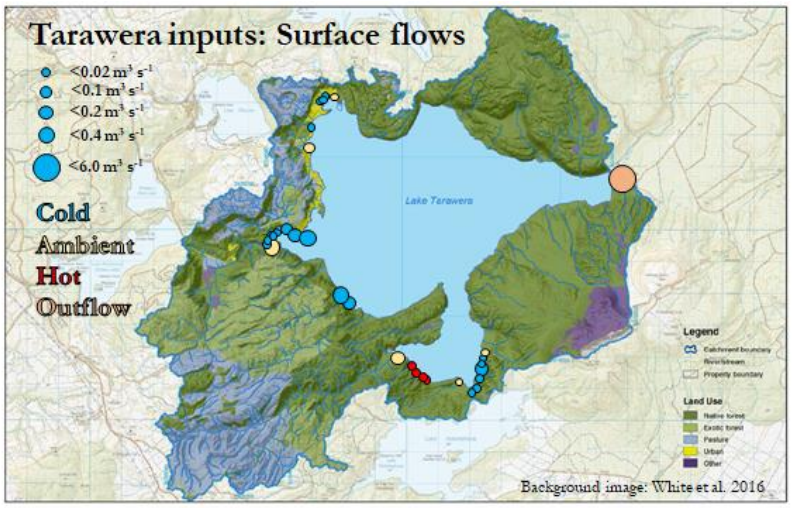


If we think hypothetically about what type of phosphorus load reduction we might look at in order to meet water quality targets for Tarawera, i.e. to reverse the observed evidence of decline, the current lake wide average concentration annually for the last 5 years is slightly under 9.5 PPB (milligrams per metre cubed) which is a Tropic Level Index of 3.1 or thereabouts. If we were to assume that the four component variables should be in balance then we might expect a phosphorous value of around 6.5 PPB, a substantial proportional reduction.

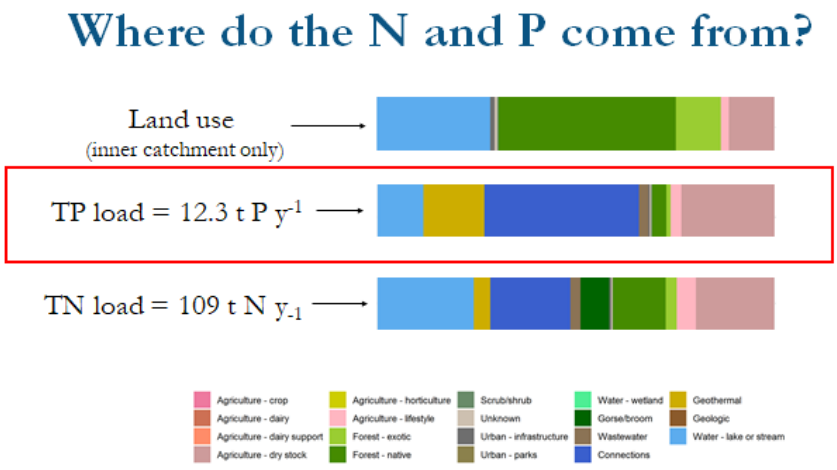


If we then assume that load is proportional to the in-lake response, which is consistent with the well-established mass balanced models, we might expect in the order of a 25% or slightly more load reduction being required in order to effect change in lake water quality. However, we do need to be mindful that when we talk about a TLI it is an aggregate index

of a whole bunch of lakes with their own individual characters. Tarawera is unique in that we have a large natural geothermal supply of phosphorus loading into the lake. So we might expect slightly elevated phosphorus relative to nitrogen in Tarawera's natural state and that is probably what drives the occurrence of cyanobacteria where we might not otherwise expect it for a lake of that quality.



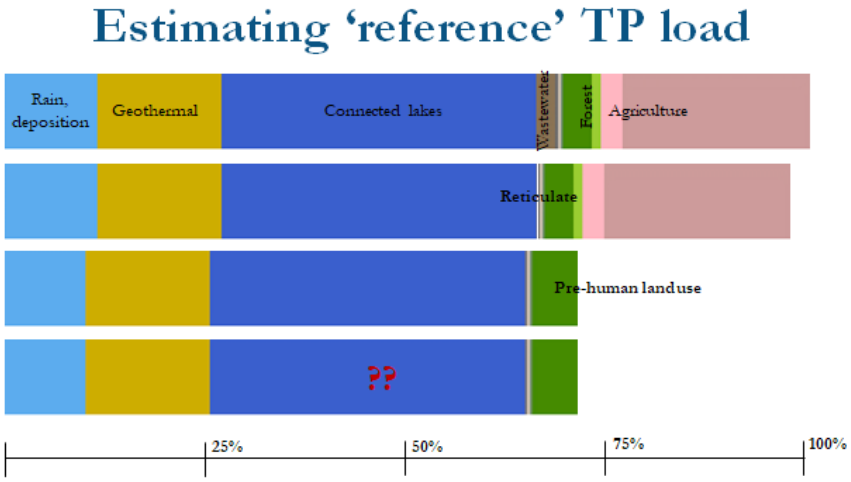
The most important thing is that we have a good understanding of nutrient and sediment inputs into Tarawera . We are lucky to have had Terry Beckett for a number of years now maintaining a great programme of sampling and measurement of the inflows . This map describes the major inflows , mostly on the west and south of the lake , with substantial geothermal springs to the south , and very little surface flow in the eastern catchment.



We recently completed a regional scale nutrient budget study looking at catchment loading to all 12 of the Te Arawa Rotorua Lakes and this is a proportional summary of the results for Lake Tarawera. The top bar is land use, middle bar is the TP load of about 12.5 tonnes from the entire catchment complex. The bottom bar is TN load, about 110 tonnes. The proportional contribution from the sources is represented by colours.

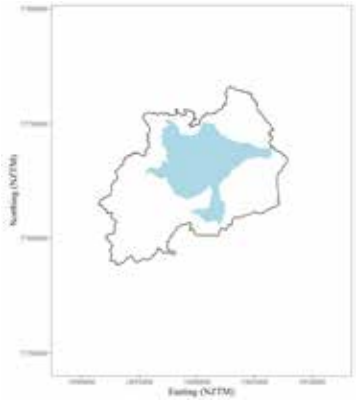
This is a breakdown of the phosphorus contributions to overall loading to Tarawera (next page). There is rain and atmospheric depositions , (wet and dry deposition). The natural geothermal input shown in yellow is that which goes directly to the lake bottom but does not include the geothermal water that might come via other lakes e.g. Rotomahana). The large blue bar is the estimated load from those other connected lakes which is a very

substantial component of the total load. Brown is wastewater; the small green bar is the forest which represents a small load but a substantial portion of the catchment area as you can see from the top bar in the previous slide. The agricultural load is the pink towards the right.



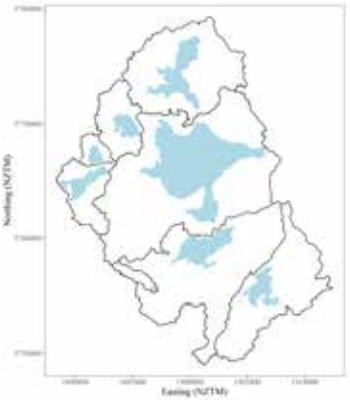
When we work towards managing a catchment -lake system we want to understand the present nutrient loads and get a good base line in what we call the reference load -or pristine load, or pre- human load. A first step towards estimated reference loads is to hypothetically reticulate wastewater and make an immediate reduction to the load.

If we assume we use our catchment models to convert all agricultural land use in the catchment that is the interior surface catchment back to forest, then we reduce about 25% of the total load to the lake. What is more complicated is estimating what the reference load for the lake connectivity might be and I am going to provide a bit more detail in the next few slides .

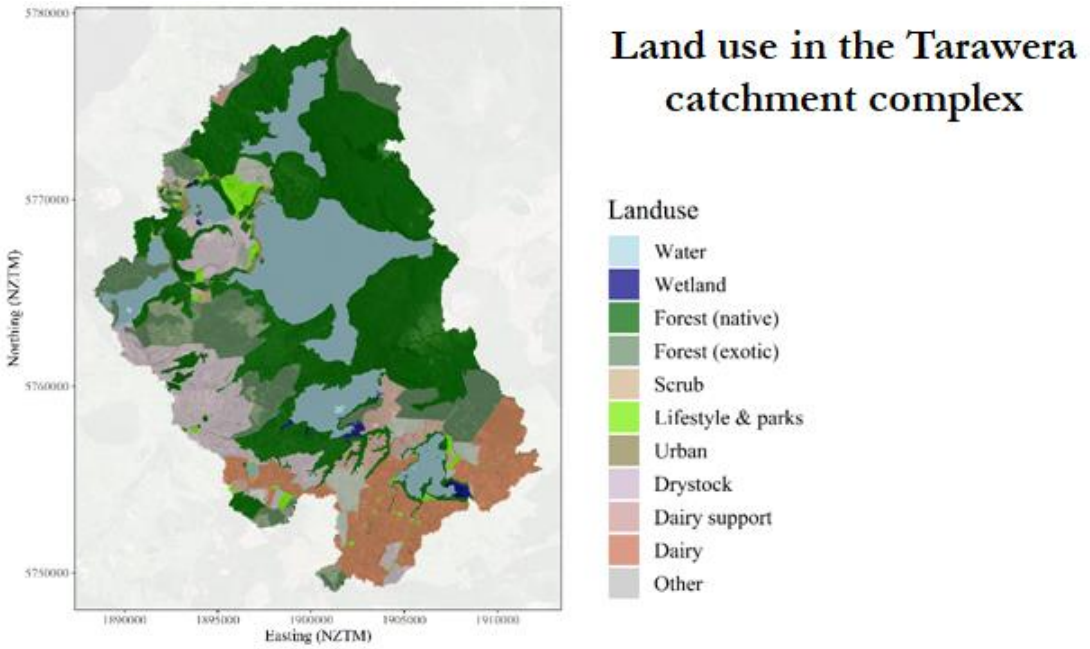


Here is Tarawera with its surface catchment.

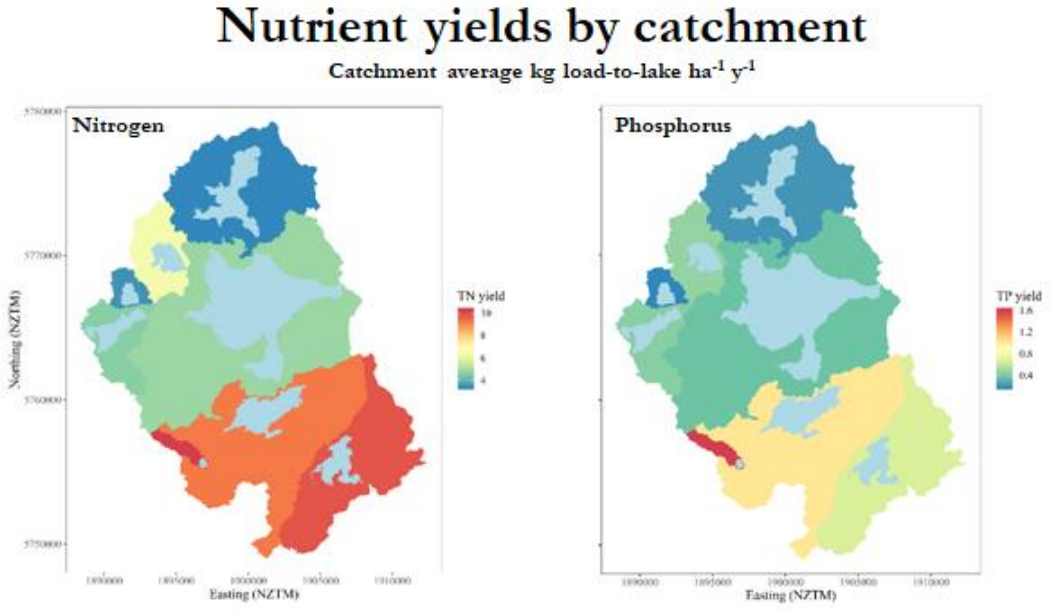
Add 7 additional connected lakes with lots of catchments, some of which are substantial lakes and provide flow into Tarawera.



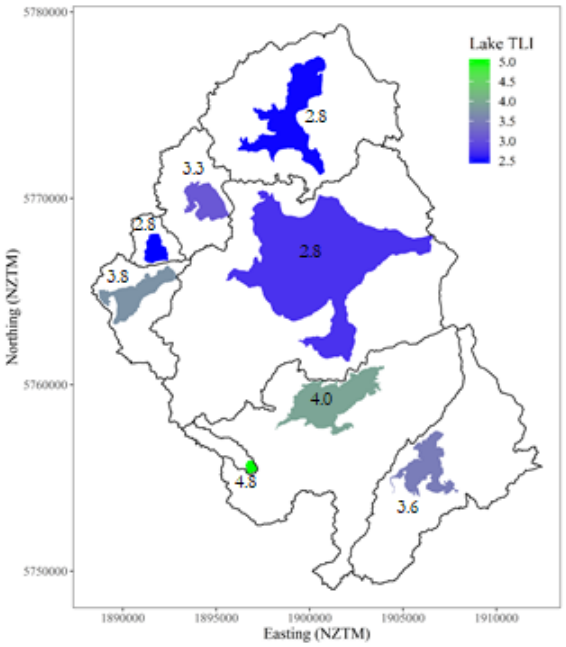
That is what it looks like from space showing varied land use across one big complex catchment.



If we colour code those land uses it looks like this. In the south of the catchment there is intensive pastoral land uses and also to the west (dry stock land). The surface catchment of Tarawera itself is predominately indigenous forest with some exotic forest. The Ōkataina catchment to the north is forested as well.



The variety of characteristics in those catchments give quite different nutrient yields and these two plots show the average catchment wide nutrient yield to the lake for each of the eight catchments . The kilograms of phosphorus per hectare of catchment area are delivered to the lake on the right, nitrogen for the left, clearly a dramatic difference among those catchments which are all connected together and, in some senses, interdependent.



Water quality of 'connected' lakes

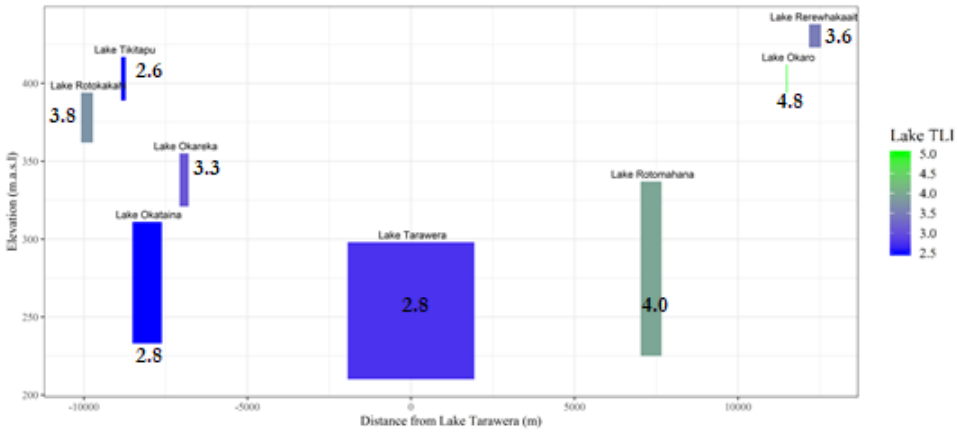
Trophic Level Index	Lake Type
Less than 2	Very good water quality (microtrophic)
2 – 3	Good water quality (oligotrophic)
3 – 4	Average water quality (mesotrophic)
4 – 5	Poor water quality (eutrophic)
Greater than 5	Very poor water quality (supertrophic)

The results of all this are a suite of lakes with quite varying water quality and this is a summary of what their TLIs are. Each lake has its current TLI for the last 5 years printed next to, and shaded in colour to represent TLI. Bright green would be a very productive lake like Okaro, with a TLI of 4.8, whereas the blue lakes lie in that oligotrophic band of around 2 to 3 - Tarawera, Ōkataina and Tikitapu for example.

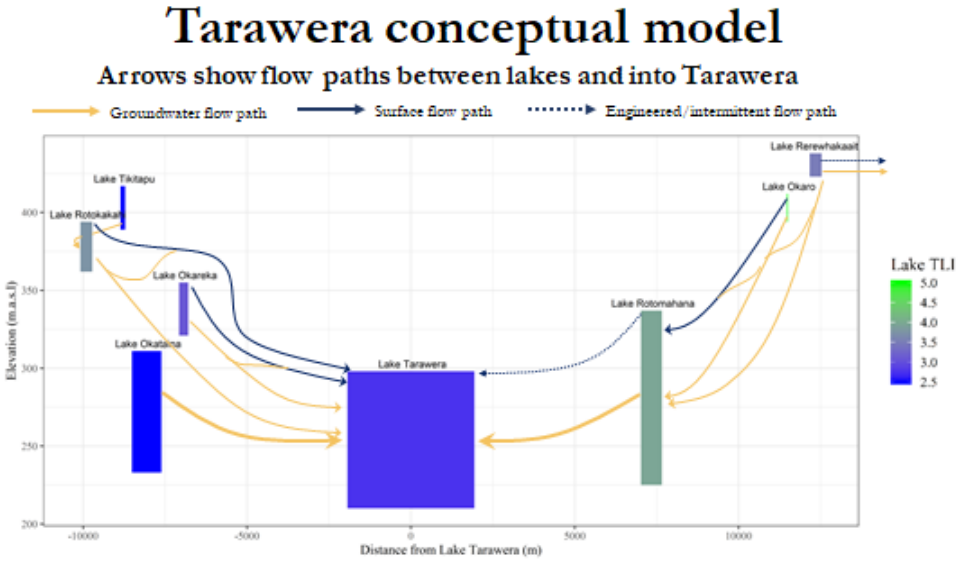
This is a conceptual model of the Tarawera catchment complex, introduced by Alastair MacCormick who was formerly with Bay of Plenty Regional Council . We can take the aerial view of the catchment complex and tip it over and look from the side. The Y axis on this plot represents elevation , the position in the landscape . Each coloured block is a lake . The vertical dimension of the block is the lake depth and the area of each block is scaled to the volume of the lake, so it gives a sense of the relative scales in size and volume. We can start to visualise how all these lakes fit together and from there we can get a good idea of the hydrological connectivity among these lakes.

Tarawera conceptual model

Lake colour represents TLI

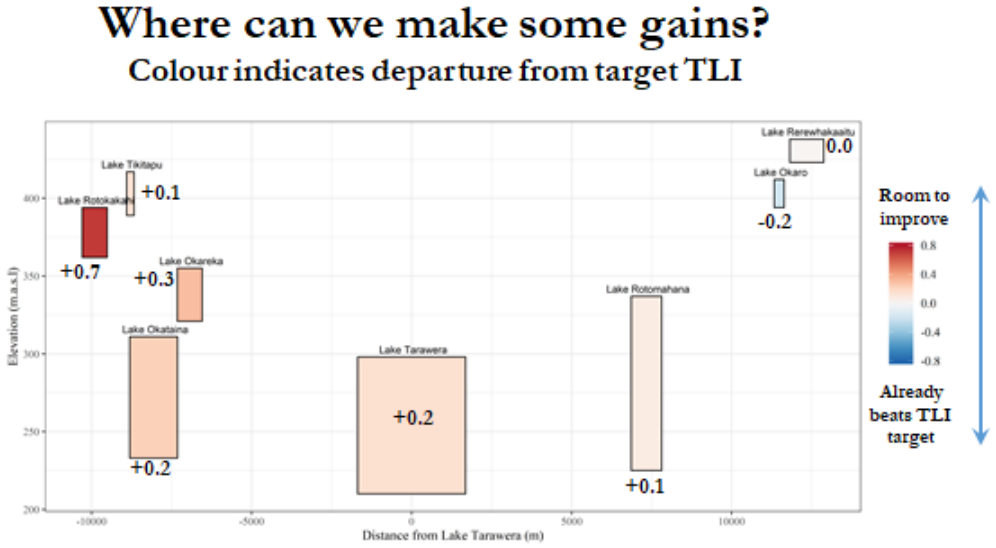


Conceptual model idea: Alastair MacCormick

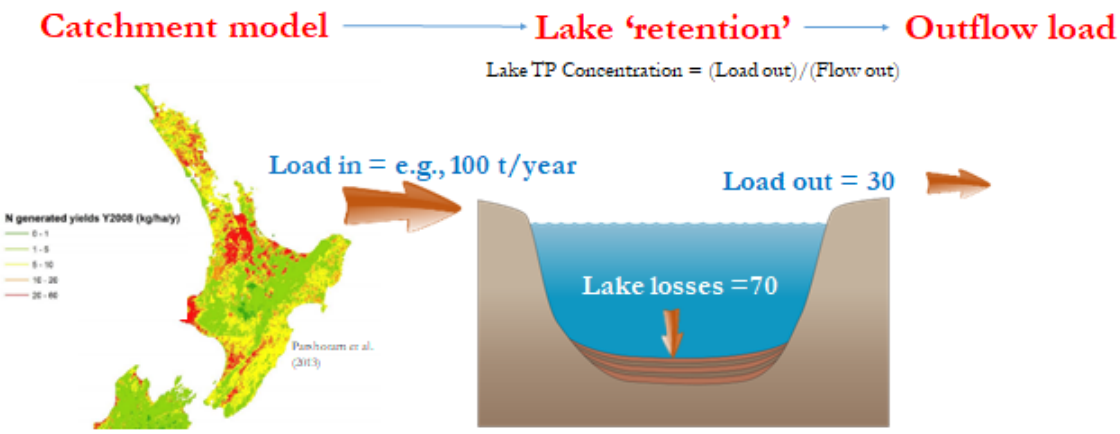


More information on hydrological connections: White et al. 2016 (GNS report)

On this plot all the connections between these lakes look a bit of a tangle, but the blue lines represent direct surface connections, a stream flowing from the outflow of one lake into the other lake. The brown arrows are subsurface or ground water connections. This conceptual model of the catchment complex gives us a schematic diagram of how management efforts in one area might percolate through the catchment system towards Tarawera. Below is the same idea but with the lakes this time colour coded by their departure from the TLI target, showing how different the TLI is in this lake compared to its target. Red represents a lake that is above its water quality target, or worse water quality, and blue shows a lake that is below or exceeding its water quality target. This is another way we can look at the catchment as a whole and think about where we have the most potential to make management impacts that could flow down through to the other connected lakes.

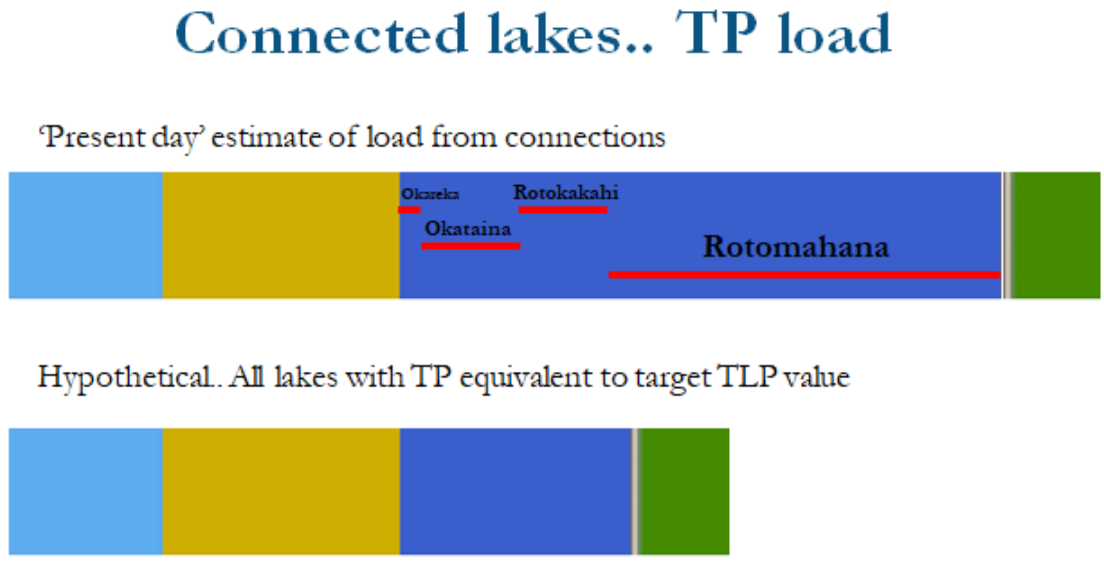


On the next page is a concept Troy introduced to think about those pathways of connectivity and lakes as sinks of nutrients. We have a catchment model that estimates a load for an upstream lake catchment that is going to be passed into the lake water body.

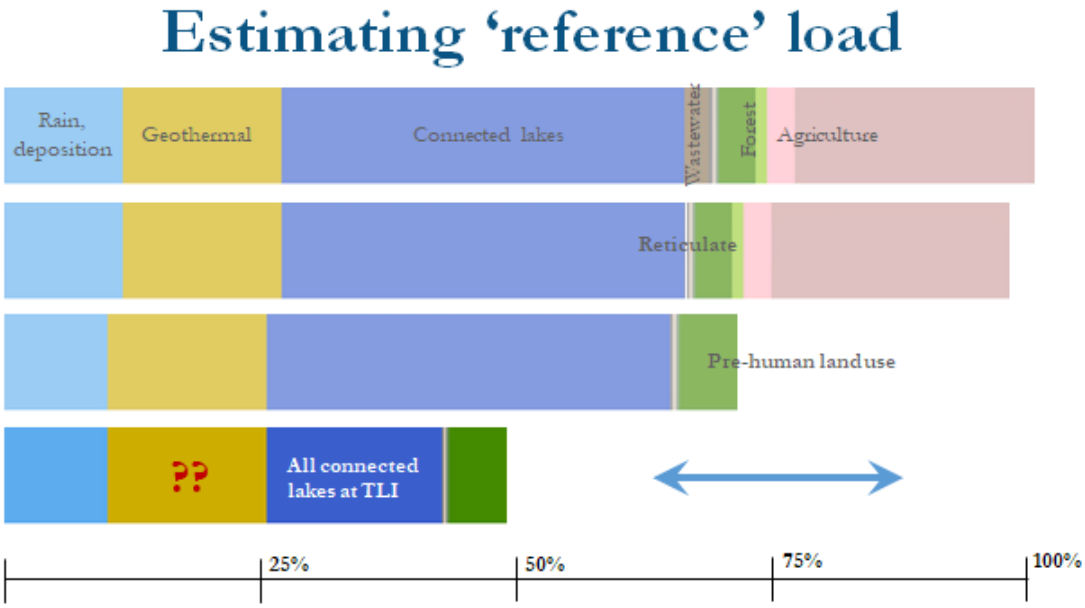


But some fraction of that load is retained in the lake before it is passed downstream into Tarawera. We need to think about what the net effect downstream is for a reduction in an upstream catchment, as well as considering the importance of the improvement to the load and the upstream catchment itself.

Here we have a breakdown of the relative importance of the 4 lakes that have an actual direct hydrological connection to Tarawera based on recent monitoring data over the last 5 years. We can see that Rotomahana is the largest contributor of phosphorus by some margin, and the other lakes contribute substantial loads to the lake as well.

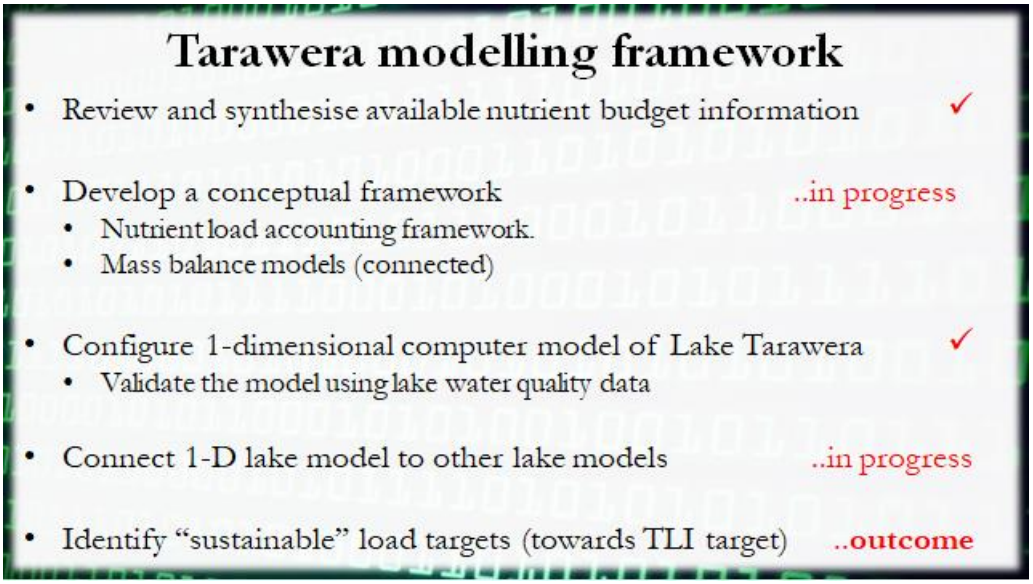


If we use our mass balance models, percolate them through that conceptual network and think about what the reference load for phosphorus might be in an undeveloped state, for a hypothetical scenario with all lakes equivalent to their TLI target, we end up with a phosphorus load to Tarawera of somewhere around half of the present phosphorus load from the connected lakes.

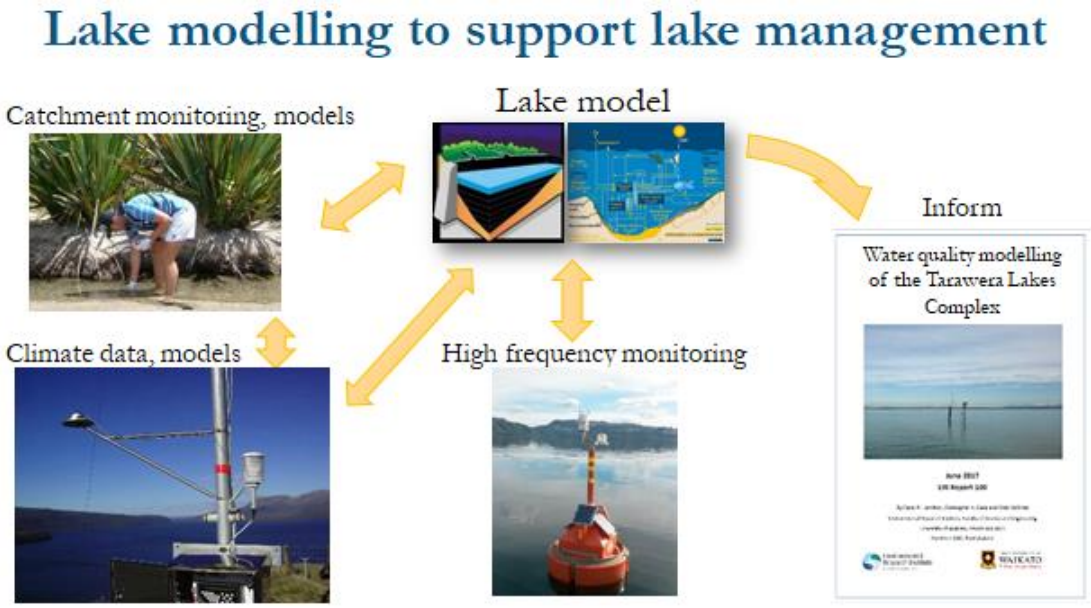


Putting it in context, this slide shows us finally arriving at our estimated reference load for Tarawera phosphorus, and it is around the 50% mark of the present-day load. There is a reasonable degree of uncertainty around how big those geothermal loads are and that is an avenue for research presently. Nevertheless we have quite a bit of head room, so to speak, space to work in to achieve load reductions to manage towards targets and water quality in the lake.

One of the main tools we are developing to guide that management process is this modelling framework for the Tarawera catchment and that consists of reviewing and synthesising available nutrient budget information, some of the results of which I presented today. We will develop that conceptual framework and how all those lakes fit together, percolating the nutrient budget estimates through the network towards Tarawera and connecting those mass balance models together.

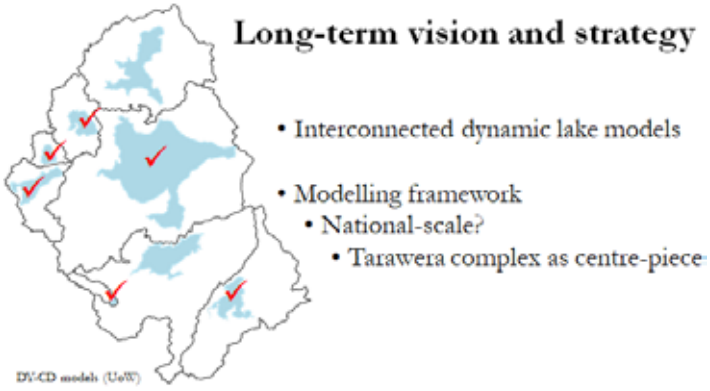


We also used some slightly more sophisticated tools which are the 1-dimensional time resolved computer models and we have recently completed a pilot study establishing such a model for Tarawera and validating that using lake water quality data, including data from the monitoring buoy stations that have been mentioned.



We are also working on connecting that 1D model with other 1D lake models that are being developed at present and in the past. The end goal of that mega model, or meta model if you want to call it that, is to identify sustainable load targets within each connected catchment and also across the network as a whole. The way the modelling supports that is by integrating and synthesising a whole range of different information data and monitoring relevant to the lake; catchment inflows, discharge, nutrient concentration, climate information . We can even incorporate climate models and future climate projections. We can incorporate the data from high frequency monitoring stations and it is all absorbed into establishing the lake model and then using that lake model to test hypothetical future management scenario simulations with the goal of a kind of iterative management process. We developed these models and will use them going forward.

This is the state of model development for the greater Tarawera catchment. There are a few more ticks since the last time I presented about this project. We have established and nearly finalised reports on most of the lakes within the catchment. We also have a proposal to do this type of modelling at the national scale, for which we would use the Tarawera complex as a centre piece for development. Its hydrological complexity is a stress test for a simulation platform on a national scale.



In Summary:

- Lake Tarawera water quality does not meet its TLI target which is roughly equivalent to 1994 water quality. There is some evidence of decline, certainly enough to warrant paying close attention to trajectories and considering management of catchments inputs in some detail.

- We need to consider the naturally elevated phosphorus loading from geothermal sources and do some more research to tighten up estimates so that they fit within our modelling framework and give us more confidence in our results. That elevated phosphorus load may contribute to the nitrogen fixation that has been documented as an important source of nitrogen in Tarawera and the prevalence of cyanobacteria for an otherwise clear and healthy lake.

- We need to track and manage **both** nitrogen and phosphorus loads, maybe even reduce phosphorus loads. I have concentrated on phosphorus today because I do not have time to go through both N and P in the same level of detail. But because we have a high natural level of phosphorus, any increase in nitrogen will likely result in very efficient algal production using up the new nitrogen source.

- One of the take home messages is that there is capacity for improvement in loading to **Lake Tarawera and its connected lakes** through , for example , reticulation and land use practice. The Tarawera catchment and particularly the connected lakes have a substantial downstream impact on the quality of Tarawera.

- The lake modelling framework will be used to guide an adaptive management process as we move forward.

Thanks very much.

QUESTIONS

Roland Burdon, LWQS: How do you partition the estimated contributions of load between connected lakes and agriculture, given that the effect of agriculture would presumably is largely through the connected lakes?

Chris McBride: That is a good question and something I meant to touch on in some earlier slides. The big blue bar in the nutrient loading scheme, the plot which showed the different colours and different sources represented the connected lakes incorporating all the potential sources to those connected lakes. It includes geothermal sources and pastoral or agricultural inputs to those lakes. Although it is not clear from the slides that I presented today, in the report from which those Tarawera estimates were taken, there is a breakdown for every connected catchment. We have looked in some detail at the contribution of all sources to each of the connected lakes, and that information is there, but impossible to go through it all in the time we have today.

John Green, LWQS: Lake Rotomahana looked like the lake causing the phosphorus problem, have you got the ability to check the geothermal activity in and around Rotomahana and has it changed somewhat putting in greater loads into Tarawera?

Chris McBride: Yes, another good question and it is open for research from our perspective. I mentioned towards the end of my conclusions that I am interested in getting tighter estimates of geothermal loads and sources, both to Tarawera and to the connected lakes, and an idea of how those might have changed over time. It is important and not something we have a great deal of information on at present. I am probably not the best qualified to speak on that, a scientist from GNS might have more information than we have at our fingertips.

WAIORA – THE SIGNIFICANCE OF CULTURAL MONITORING IN LAKE ŌKATAINA. A PARTNERSHIP BETWEEN NGATI TARAWHAI AND TE ARAWA LAKES TRUST

Cyrus Hingston
Ngati Tarawhai Iwi Trust
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Cyrus is the Chairperson of the Ngati Tarawhai Iwi Trust, he works with Ian Kusabs on the monitoring of koura, partnering with Te Arawa Lakes Trust on cultural volunteering, particularly for Lake Ōkataina. He is supported today by Delia Baira who is mokopuna of Anaru Rangihuia.

TRANSCRIPT

Kia ora, my job today is to talk about the Waiora cultural perspective which is a bit of a misnomer, and the significance of cultural monitoring in Lake Ōkataina is going to be done by my relation Delia Balle who is a mokopuna of Anaru Rangiheua. As a brief outline I am going to speak about the Waiora Project which Ngati Tarawhai Iwi Trust (NTIT) and Te Arawa Lakes Trust (TALT) undertook. Then I will talk about who Ngati Tarawhai is and their history and give a brief outline of the Iwi and Hapu involvement with the lakes, pre European times, the value we placed on Tauranga Ika or our fishing grounds, our native fish, koura and how we fish them. I will give an example of the impact on Maori with the introduction of exotic species and how the lakes were managed and then look at the value of the work we did on the Waiora Project.

I got this job on the Waiora Project in a backwards way. I was the Chairman of the Ngati Tarawhai Iwi Trust, but the person who put in an application for the grant and was supposed to do this work resigned from our Trust, so it was left to me to take it up, and then I found myself involved in a hands on process and now I am here in front of you. Yeah, I won lotto.

In 2018 Ngati Tarawhai secured a grant from Te Wai Maori to monitor the koura population, their sex and size in Ōkataina over a 12 month period. They are a Trust that was set up to advance Maori interests in freshwater fisheries. Part of their role also is to

advance the protection of the habitat and ensure water quality and abundant species. I was very fortunate to work with Dr Kusabs who has been monitoring koura for the last 14 years in the lakes. For the last couple of years he worked in Ōkataina so we went out and helped him.

Our Iwi Trust wanted to see how healthy our lake was. We also wanted to reinvigorate our links to Lake Ōkataina as an Iwi and it gave us the opportunity to research our history, our relationship with the lake, regain old skills and knowledge, acquire new skills regarding scientific research and then we could share our findings with our Iwi members. So those were the goals for Ngati Tarawhai.

Lake Ōkataina is in the middle of all the other lakes of the Rotorua district. Our lake is surrounded by native forest, and the name Ōkataina comes from Te moana i kataina e Te Rangitakaroro (The sea that was laughed at by Te Rangitakaroro) and that has been shortened to Ōkataina. Te Rangitakaroro was one of our ancestors, he and his relations were basking in the sun on a rock drying themselves off after a swim and one of them said, ‘Oh what do you think of our sea? He laughed at the lake being called a sea, a ‘moana’ rather than a ‘roto’, a lake.

Who are Ngati Tarawhai? Ngati Tarawhai claim mana whenua, mana moana of Ōkataina. But different Hapu or subtribes of Ngati Tarawhai lived around Ōkataina and we are not a big tribe, but we are noted even today for tohunga whakairo, our master carvers who were unique as a tribe and were commissioned by other tribes to carve waka or canoes, and later on wharenui. Examples of their work can be found in the Museum of Cultural Arts in Bonn, Germany, Clendon Estate in England, and at Te Papa, the Auckland War Museum and in the Rotorua Museum before they shifted it all into storage.

Around 1887 for various reasons most of Ngati Tarawhai had moved away from Lake Ōkataina. There was a 10-15 metre rise and fall of the lake over time, the arrival of Europeans, Iwi members looking for work and the Land Wars which Ngati Tarawhai took part in. So the Iwi dispersed and also their beautiful carving. Following the eruption the last of them had moved and in 1921-23 2,900 acres around Ōkataina was 'gifted' to the Crown as a scenic reserve. Basically the idea was we gifted it before it was taken from us under proclamation. Because the Iwi had all moved away, at Ōkataina the urupa of our tupuna were being raided by people taking their taonga or disturbing them. It was hoped by gifting the land as a reserve, it would protect the area.

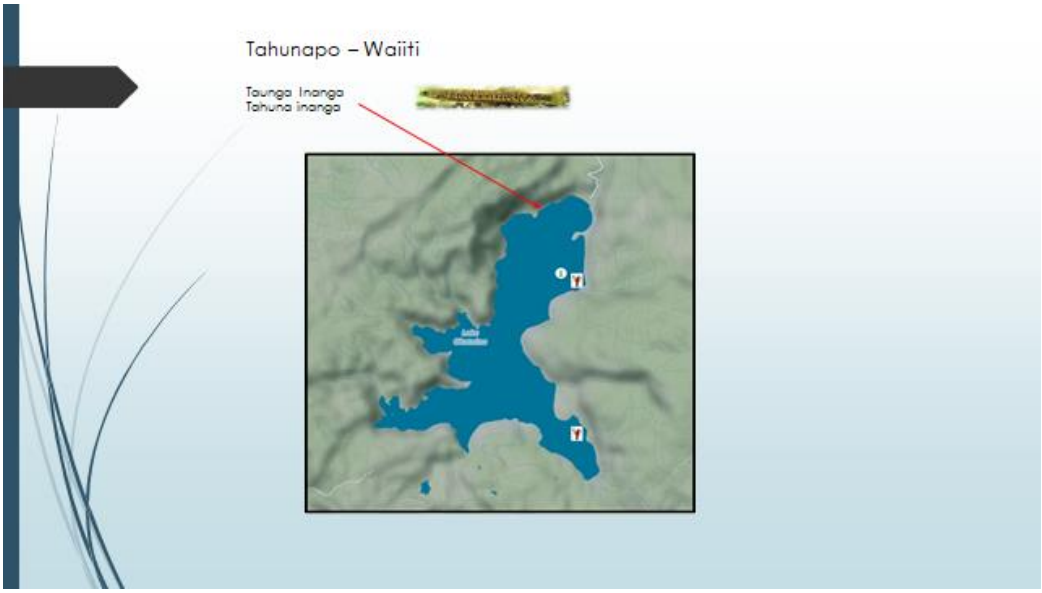
Lake Ōkataina Scenic Reserve Board oversees the DOC reserve now and it has Government appointed Ngati Tarawhai members with a couple of members of neighbouring tribes, Ngati Rongomai and Ngati Pikiao as well. The Ngati Tarawhai Iwi Trust, of which I am presently chair, is a post settlement entity established to administer and manage the assets that we received in the Te Arawa Affiliate settlement from the Treaty of Waitangi claims.

I am now going back to pre-European times to talk about the relationships Maori had with the lakes. Ihenga, one of our tupuna, discovered Rotoiti, a small lake, which came about on a hunting expedition with his dog, Potakatawhiti, who ran off and came back wet and vomited up inanga, or whitebait. Tracing the dog tracks, he found a small lake which he called Te Roto Iti i Kitea ai e Ihenga (the small lake that was discovered by Ihenga) and a narrow version Rotoiti. He discovered that area and his descendants found the lake to be teaming with food that they found appealing, kākahi - freshwater mussel, koura, inanga, toitoi and kokopu, the most famous was koura.

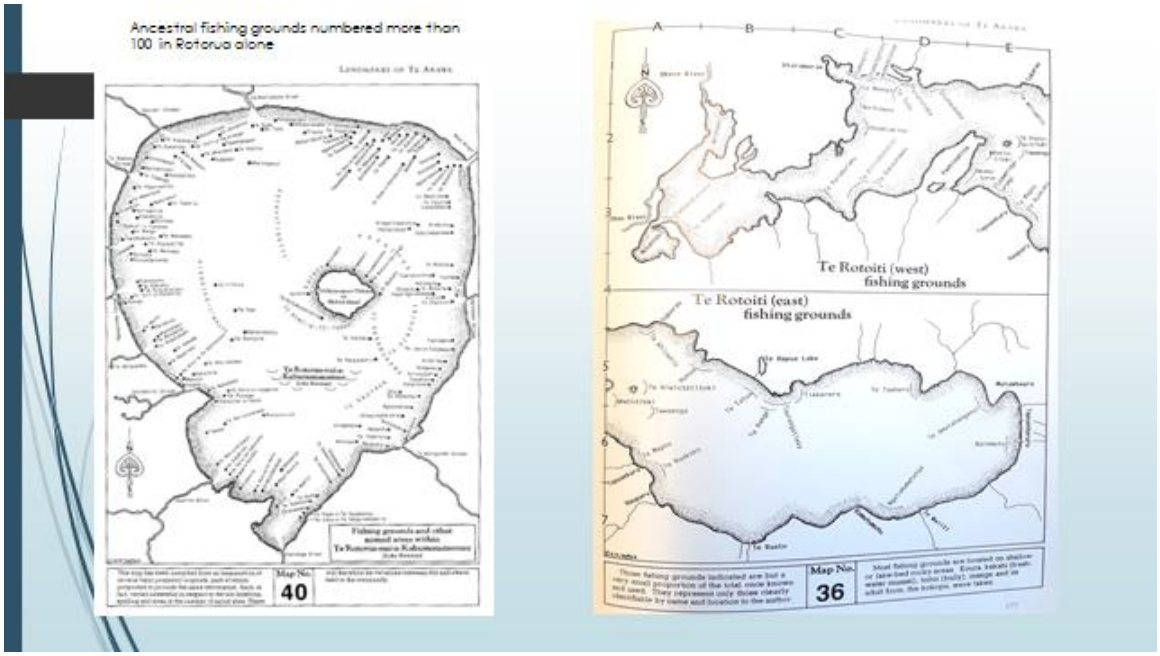
Te Amohau was asked to consider being made Maori King. His reply was ‘He paraoa me te koura taku kai’, (I have only bread and koura to feed the multitudes) because he knew that if he was made king he would have to host many visitors to the area. From that you could see that he doubted whether it was possible. Tauranga Ika are fishing grounds and highly prized, mainly because they are a major source of sustenance and they are jealously guarded. Often those fishing grounds were named after ancestors or an event; Hineawa, Te Manuka, Te Tiro which were part of the Waionu Block in the Rotoiti and Ōkataina areas. Te Manga (Waiteti) was famous because of the size and number of koura there. Kaiore and Taramoa Te Roro o te Rangi, Tamakari, Morewhati over at Mokoia. Taunga Ika, or fishing grounds were a source of pride for the Iwi that owned them because their pride and prestige, their mana, came from their ability to host their guests by providing delicacies, which the koura was regarded as, so they were highly prized.

In 1873 at a hui at Tamatekapua where 500 rohe (food baskets), which would be approximately 500 sacks of koura gathered and presented for them to eat. At the opening of Taurua Marae in 1960, there were 30 sacks of koura for the guests. Pakanga or battles were fought over the fishing grounds at Te Manga out at Waiteti, Ngararanui woke to see his brother Tawakeheimoa fishing on his grounds so he went out and they started fighting over it. He turned his brother’s canoe up and his brother separated and there was on-going sibling rivalry. At Waiiti, Te Rangihaemata and Te, Rangipaekura there was a battle that started the fight between relations, two sub-tribes from the same ancestor, fighting among themselves and led to Ngati Tarawhai taking over the Ōkataina area. That fight was over a taunga inanga, a whitebait fishing ground.

A rahui was also imposed by the owners of those fishing grounds, the management of stocks ensured that they were sustainable. A rahui may mean that rather than using dredging to collect koura for the next couple of seasons we will gather koura by hand so that the stocks have time to replenish.

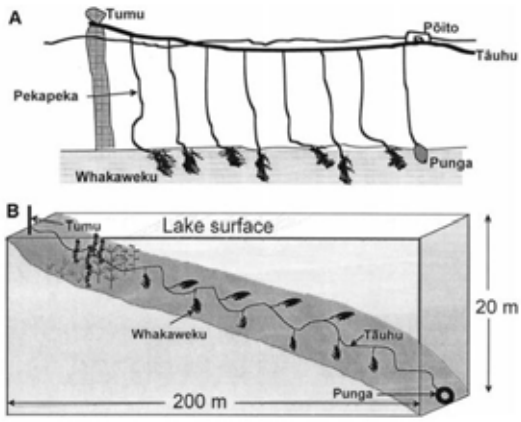


This is a map of Ōkataina and in this area Tahunapo and down here Oruaroa a Rangi, Otangimoana, is where we placed our taunga inanga, or tau koura as our uncle Willy Emery calls them, for our work. I have also highlighted in red the place where Waiiti, the whitebait beach, or fishing ground, was and our battles with Ngati Kahuupoko started.



These maps are taken from Don Stafford's 'Landmarks of Te Arawa' and are the ancestral fishing grounds on Lake Rotorua, and there were over 100 that were given in the Native Land Court. When local Maori were claiming areas that they owned on land they cultivated their mahinga kai, places of cultivation, where they fished, caught fowls, had their gardens, those were all named to support as evidence their claim to a particular bit of land.

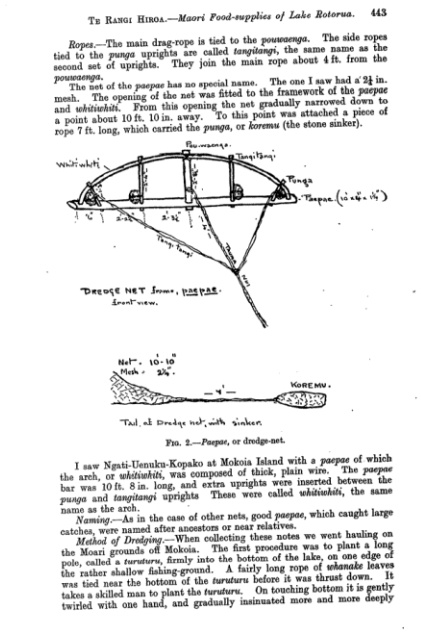
Don Stafford put all those on the maps taken from the minutes of the Native Land Court. I added this to show it was not higgledy pigeldy. They planted posts which were named. Some of them had heads of enemies placed on top or named after ancestors, events or battles that took place to signify that this is our area, 'Don't touch'. These two maps of Rotoiti show the names of their fishing grounds. Rotorua has a number of Iwi all related who made claims for the area which was highly contested. There are a number of fishing grounds they sighted and the boundaries marked which were more detailed than in Rotoiti and the other lakes.



There were different methods to gather koura such as diving to get them by hand. Paepae is a dredge to catch koura, or koura tauas as our uncle Willy Emery called them. He showed Ian Kusabs how to utilise this fishing method for scientific purposes so he could gather the fish. We have a lot to thank our uncle for. The tau koura is similar to a long line, but instead of hooks there are food bundles on the end of the line and they stay in the water for a few months and then pulled out with the koura. To catch koura at night you go with a rama (torchlight) and gather them with a small net or by hand.

This is a diagram of me te ao hou, tau koura, what it looked like in the old days and below the new method we use. Previously there was a post driven in with a line hanging out with other lines dangling in the water and the fisherman went alongside in the canoe and pulled up the koura when they wanted them. Nowadays the long line is kept down permanently with an anchor. Some people use engine blocks, others use a tyre filled with concrete, to keep them down and a hook to pull them up.

Here we have the modern equivalent of our monitoring, in a boat and pulling the ropes up using what we call the whakaweku, the fern bundle. You pull it up shake out the fern and all the koura drop out. These old photos were taken in the 1900's at Lake Rotorua from a book by Sir Peter Buck, who was a noted anthropologist and politician, and who researched fishing methods of the Maori.



TE RANGI HIROA.—*Maori Food-supplies of Lake Rotorua.* 443

Ropes.—The main drag-rope is tied to the *powaenga*. The side ropes tied to the *punga* uprights are called *tangitangi*, the same name as the second set of uprights. They join the main rope about 4 ft. from the *powaenga*.

The net of the *paepae* has no special name. The one I saw had a 2½ in. mesh. The opening of the net was fitted to the framework of the *paepae* and *whitiwhiti*. From this opening the net gradually narrowed down to a point about 10 ft. 10 in. away. To this point was attached a piece of rope 7 ft. long, which carried the *punga*, or *koremu* (the stone sinker).

Fig. 2.—*Paepae*, or dredge-net.

I saw Ngati-Uenuku-Kopako at Mokoia Island with a *paepae* of which the arch, or *whitiwhiti*, was composed of thick, plain wire. The *paepae* bar was 10 ft. 8 in. long, and extra uprights were inserted between the *punga* and *tangitangi* uprights These were called *whitiwhiti*, the same name as the arch.

Naming.—As in the case of other nets, good *paepae*, which caught large catches, were named after ancestors or near relatives.

Method of Dredging.—When collecting these notes we went hauling on the Moari grounds off Mokoia. The first procedure was to plant a long pole, called a *turuturu*, firmly into the bottom of the lake, on one edge of the rather shallow fishing-ground. A fairly long rope of *whanake* leaves was tied near the bottom of the *turuturu* before it was thrust down. It takes a skilled man to plant the *turuturu*. On touching bottom it is gently twirled with one hand, and gradually insinuated more and more deeply

This is an example of a paepae, or dredge, that was used.

Koura were either steamed, put in a hangi or dried as a method of preserving them. In the 1800's, when the tourists came to Tarawera and the Rotorua District, the dried koura was tied up on strings – toitoi - and put around their necks and as they walked they chewed them.

Introduction of Exotic Fish Species to Rotorua Lakes District

The introduction of exotic species had quite an impact on the Rotorua Lakes District. In the 1870's it was decided to introduce exotic fish species, it was felt that it was a good idea to introduce carp and trout, as a sporting fish and to grow the tourist sporting industry. In 1872-73 Prussian carp was released firstly into Lake Taupo, Rotongaio and then later into the Rotorua Lakes District. By 1877 the carp numbers were thriving, some weighing close to 2 lbs. We know them as *morihana* named after Robert Morrison , Howard Morrison 's tupuna , who released the carp in the Rotorua district . White fish (European Cisco) were also tried in 1880 but they did not do so well.

In 1892 the Auckland Acclimatisation Society, supported by the Rotorua Rod and Gun Club, introduced trout into Lake Rotorua, firstly brown trout into the streams and then rainbow trout. They loved the conditions here and the koura and inanga. When the exotic species were first released into the lakes local Maori were asked not to hunt or net them to allow them to thrive. After 4 years Maori were complaining that the trout were devastating the stocks of inanga and koura. At the same time the Auckland Acclimatisation Society was receiving complaints about Maori illegally catching, spearing, netting and selling trout in Rotorua. Maori said they will net them as long as they can and destroy if possible, because of the negative impact they were having on koura and inanga. A ranger was appointed by the Auckland Acclimatisation Society under the Animals Protection Act.

In 1897 13 Maori were arrested and charged under the Fisheries Conservation Act for using a net to catch fish. They used the defence that the Treaty of Waitangi expressly referred to in the Fisheries Conservation Act 1877 that they reserved the rights of Maori their ancient rights to fish and that netting in the lake was an ancient custom and the indigenous fish was relied on by Maori for food and they had been very seriously diminished since the advent of trout.

Their argument was upheld. However regulations for trout netting were made outlining the size of mesh nets, when fishing was allowed and costs of licences to net fish. After negotiations and arguments Maori living within a 1-mile area of Rotoiti and Rotorua were given a discount on their license paying 1 pound instead of 3 pounds.

In 1908 a bill was given to the House of Representatives by Lawrence Birkes, civil engineer, detailing the work that had been done around the lake shores clearing stumps, logs, koura posts and other obstructions which were a menace to the launches on the lake. The report also said shag (kawau) were very abundant on the lakes, and eating the trout. The white headed river shag was destructive to trout fry, the black coat shag lived mainly on koura as well as toitoi, carp, and other trout foods. In order to keep the numbers of shags down a reward of 1s per head was offered. From 1 July 1907 to 31 March 1908 711 heads were caught in Lakes Rotorua, Rotoiti and Rotoehu. The report acknowledged the valuable work that was being done by Rotorua Rod and Gun Club.

There you see a daily catch in Rotorua in those times and a photo taken at Rotoehu of two shags who were seen as stopping the increase in population of trout.

Environmental, cultural & economic effects

In 1892 a bill was introduced into Parliament to allow fishing licenses at a reduced rate for Maori due to the hardship caused by the loss of their native fisheries. Inanga **(**whitebait), were destroyed. The koura populations were seriously diminished and there were reports of overuse, semi-starvation, and Maori suffering from the inability to go out and fish, or not having the means to get a license to catch trout as a substitute for the loss of inanga, whitebait and koura.

From a cultural perspective, the introduction, or invasion of an exotic species into the Rotorua Lakes District and its impact, had huge environmental, cultural and economic effects for Maori. Between 1892 and 1908, just 16 years, the native fisheries were destroyed. The culture, knowledge, history and skills pertaining to whitebait, inanga and koura similarly were lost. The boundaries, the fishing grounds, the koura posts that were basically the property of Maori were taken out so that they would not impede on fishing.

There was a loss of economic assets of the whanau, the hapu and Iwi. Our cultural values around mana and tapu were also affected. Mana as I said earlier, our ability to host and provide delicacies for guests, was greatly impacted by the loss of koura and inanga, so there was a loss of mana. As far as tapu was concerned, following the invasion of Mokoia in 1823 by Ngapuhi, the kawau, or shags, were regarded as being tapu by the people of Lake Rotorua, because when Ngapuhi made a surprise attack early in the morning, it was the kawau who raised the alarm for the people on this island. After the devastating massacre they were seen to be in mourning by

the way they hung in the trees looking at what had happened. That is why they were revered as our tupuna, as our ancestors, and seeing a bounty put on them had an impact on our people.

I like trout but if you look at it from the impact that it had on the systems and values that were already in place, trout had a negative impact on the environment and our people. The environment had changed in the interests of special interest groups.

The Waiora Project has been of immense value to Ngati Tarawhai. We have engaged our people, our rangatahi, whanau, hunga mahi koura with scientists. It has helped us reconnect with Ōkataina, research our cultural history and we have learned old skills and shared that knowledge and gained new skills around research and science. We want to continue monitoring the lake and this has allowed us to be proactive and involved as kaitiaki of taonga, especially with other exotic species that are rearing their ugly heads.

QUESTIONS

Te Taru White: I have a comment more than a question. It is very good that we have two of you here from Te Arawa because it quadruples our Te Arawa representation and that is always nice. The point of your presentation is the legitimacy of our heritage around Lake Ōkataina and the knowledge that can be drawn from that. How is it applied in the context of caring for our lakes, because we heard from the Minister that there was a fusion of two cultures and from that we get the benefits of the knowledge systems of both cultures?

When you talk about kaitiaki of taonga, the value constructs that underpin that are exactly the conversations we have around these tables. The care of our lakes from a scientific research point of view and looking at it from a taonga Maori point of view. I know that the Te Arawa Lakes Trust has built a cultural framework that encapsulates Te Mana o te Wai and in developing that document it captured all the views of the different hapu around the lake. It will be a very useful document held by Te Arawa Lakes Trust, but how can it be fused into the conversations that everybody has around this table. I find it disappointing that we struggle to get to these hui and yet we have valuable documents and knowledge that should be in the discussion. So where are you going with that particular document? Sorry Delia to put you on the spot but I think it is important to that hear this.

Delia Balle, Te Arawa Lakes Trust: Kia ora koutou, I am Ngati Te Arawa, tribal affiliations to Tohorangi and Ngati Pikiao, so my associated roto are Tarawera and Rotoiti. I am here today supporting Cyrus as a Te Arawa Lakes Trust partner with Ngati Tarawhai in the cultural monitoring of Ōkataina.

The answer to Te Taru's patai, or question, is what frames my part of the presentation which I did not get to speak to, but it has come up in the questions, and how did I know Te Taru was going to ask that?

The title of Cyrus's presentation is cultural monitoring and I guess the question on everyone's minds is what is it? When working with Ngati Tarawhai through this project it was quite obvious that cultural monitoring is continuing the traditional practice of kaitiaki of taonga. Our people have always monitored their lakes as it was a means of sustenance on a daily basis and we were alerted to changes because we lived there. We were connected and when it declined the inability for us to continue to practice that tradition affected us for many generations.

Te Arawa Lakes Trust has been working for the last 2 years to develop a cultural health framework which is now in its final stages. What is a cultural health framework? It is a framework that allows Iwi to monitor lakes for hapu. We do acknowledge that the scientific monitoring is of great use to hapu. We have been trying to align side by side the science and matauranga, but we have learned that undertaking cultural monitoring around the lakes is an interweaving of both. Not comparing the two but really interweaving.

Our people use science on a day to day basis and perhaps the TLI is not the most useful measure; the number of micro-organisms that exist in a litre of lake water. What our people have learned to measure is whether or not their species are present. Cyrus listed a number of those food sources that were traditional and some are still present, some are endangered. It is that measure of species that we use to measure the health of our roto.

The cultural health framework is based around Te tuapapa and we have our author, Alva, here today. She has worked hard in developing that for Te Arawa Lakes Trust. The

framework sets the values in place of us as Te Arawa staff to undertake all the responsibility for looking after our lakes with our hapu. It underpins the objectives in developing this cultural health framework. Whilst in that process and working with our hapu they expressed a common indicator of our lakes, and that is koura. So under the Te tuapapa framework koura has been an overarching strategy to measure the quality of our lake water.

'Te mā o te wai e rite ana kia kite i nga tapuwae ā te koura'

'The quality of the water is such that you can see the footsteps of the koura'

That has worked in well with structuring the framework, but we are progressing with the Te Arawa health indicators' framework which we have named Tahi. We are quite excited about how that is coming along. Perhaps at the next symposium we might be invited again and we can share with you how that is progressing.

T A H I

= **T**e **A**rawa **H**ealth **I**ndex
koura as a common indicator
+ taonga species
across all Te Arawa lakes

= **T**e **A**rawa **H**apu **I**ndex
indicators and sites of
importance to hapu

FARM ENVIRONMENT PLANS IN THE WIDER TARAWERA LAKES CATCHMENTS

Simon Park
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Simon is a consultant and project manager who works with farmers, scientists and councils to help improve on farm practices and water quality. Simon has been involved in the Rotorua Lakes Programme since 2006 covering policy development, farmer engagement, science reviews and farm plan roll out.

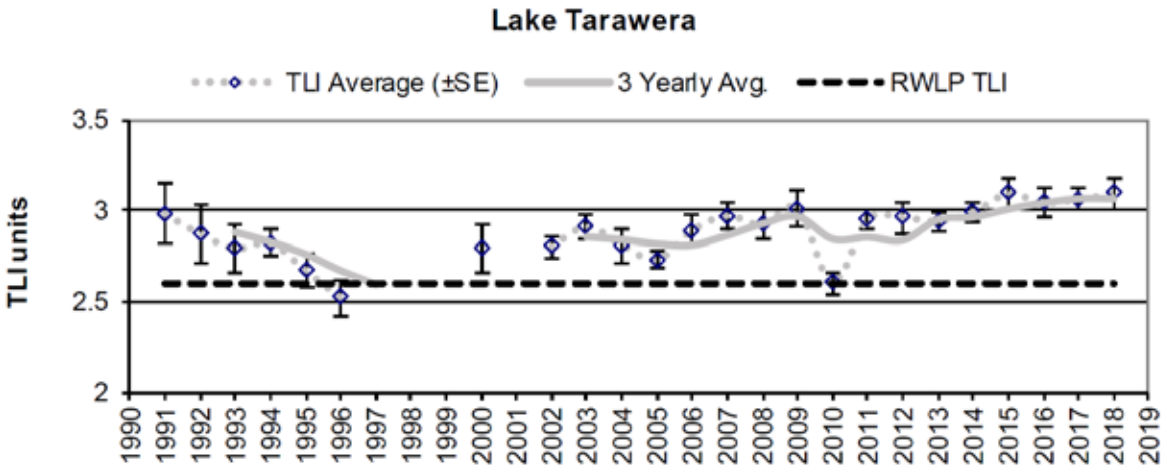
TRANSCRIPT

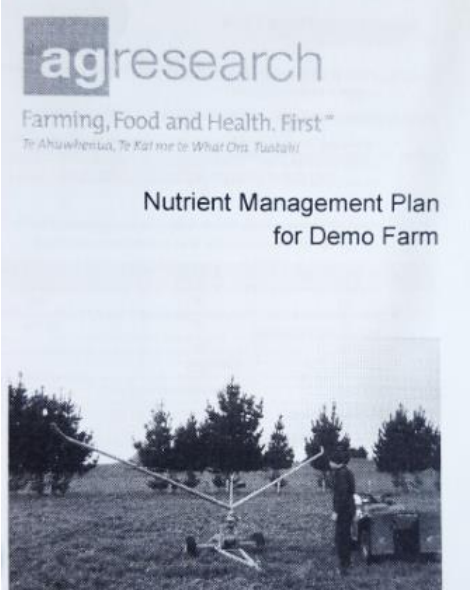
Kia ora. Thank you for your kind introduction and it has been a privilege to work in this area for a number of years and to meet so many good people. In particular people like Chris Sutton, my co-author, worked with me on this Tarawera Farm Plan Project for 2½ years. There have also been a lot of other people and organisations involved. I am paid by the Bay of Plenty Regional Council to facilitate or project manage this farm plan process, but we could not have done it without the support of the Project Rerewhakaaitu Farmers, with Chris as Chairman of that group. Mac and Linda Pacey at the back of the room have also been involved from the outset. We have had Fonterra and Beef & Lamb on board and it has been a very collaborative effort.

In a quick outline I will cover off Lake Tarawera's water quality trends in the TLI results and briefly why we use farm environmental plans to help address some of these water quality problems. There will be a background on Project Rerewhakaaitu, information that Chris has pulled together over time, and about the Farm Plan Project itself, what we were trying to achieve, what methods that we use. I will give a brief summary of the Nitrogen and Phosphorus loss results that were generated out of the farm plans and Overseer analyses and finish with a couple of examples of farm environmental plans and brief conclusions. Chis will have a few words to say as well if there is time.

Here is a picture you have seen earlier today showing the complex interconnected lake system with 7 lakes feeding into Lake Tarawera itself.

The figure below gives several lake water quality trends summarised by the TLI, where the heavy dash line is the target TLI. Over time there have been some unders and overs for Lake Rerewhakaaitu, but it has been pretty good overall. There is a little uptick in the most recent result but that has been true across most of the lakes and is mainly a climatic driven factor. Lake Rotomahana is tracking close to its TLI target but when we come to Lake Tarawera, as Chris McBride covered in some detail, there is still a big gap between the lake TLI and the target of 2.6.





Why farm plans?

Farm plans have been around for over 50 years with the origins in the United States. That carried on here in New Zealand to meet catchment and farm environmental goals, especially a focus on soil conservation to tackle excessive erosion on our pastoral farms. They have now expanded to cover multiple environmental objectives and there are many types of farm plans around the country now. They are very much a customised exercise, not just a 'tick in the box' exercise, reflecting the bio-physical aspects of the farm and the aspirations of the farmer. Farm plans are also involved in industry goals, quality assurance and linked to marketing overseas. Troy covered that in the way our clean, green environment is leveraged in the marketing of primary produce.

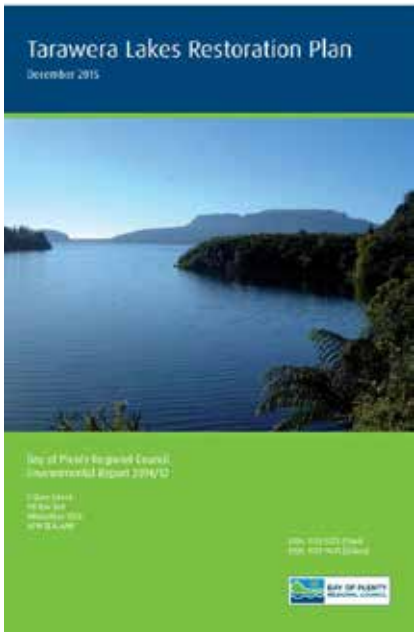
Farm plans have been well used by the Rerewhakaaitu farmers and here is an example of the AgResearch version, a nutrient management plan from an earlier project. They are specifically in the Tarawera Lakes Restoration Plan, Actions 2 and 4 refer to the inner and outer lake catchments and there was money budgeted by the Regional Council to assist the roll out of these farm plans. We also hear that Central Government will make farm environmental plans compulsory, giving then an even higher profile with a mandatory freshwater component as well.

Project Rerewhakaaitu had its initiation in the early 2000's around a couple of sustainable farming projects, initially to build farmer confidence in the science and focussing on Nitrogen mitigation and field trials. For the second sustainable farming fund effort, Project Rerewhakaaitu looked at phosphorus loss and there were some interesting experiments using smelter slag to absorb phosphorus in streams. They looked at critical source areas, parts of the farm that generate a disproportionate amount of phosphorus run off.

From there it moved to a farm and catchment planning approach from 2009 onwards and

AgResearch were heavily involved in working with the farmers to develop farm nutrient management plans. There was also auditing and reporting on the number of actions and the progress that farmers had made through that time.

In 2015 the group became a formal incorporated society with Chris as the Chairman and they had a lot of input to the Tarawera Lakes Restoration Plan. It continues to work with the Regional Council and industry on restoration plan actions, including assisting and encouraging farmers to take part in this farm plan project. There is ongoing interaction of potential rules, helping to give effect to the National Policy Statement on Freshwater Management.



The Tarawera Lakes Restoration Plan has actions focusing on the inner lake catchment, where Action 2 relates to the management of farm plans, and for the outer catchment lakes an equivalent undertaking to roll out farm plans. For the whole catchment there is a raft of actions and a key one is to generate information that could be used in ground water modelling. We have already seen some of the results in Chris McBride's work. Another action is to inform the farming and wider community what is going on and this farm plan project is contributing towards that.

The objectives of the Farm Plan Project were to recognise some of the existing good work and promote ongoing good nutrient practice on farms focusing on industry farm plan templates as the vehicle for that, as well as Overseer nutrient budget modelling. It was also to provide summary data for modellers to use to understand the wider lake nutrient catchment processes.

- **2016 preparation:**
  - BOPRC liaison with Project Rerewhakaaitu, industry
  - Target 50 FEPs + aggregated N and P Overseer data
  - Farmers agree to use 'industry template' FEPs
- **2017 FEP roll out:**
  - Fonterra's Tiaki and Sustainable Dairy Advisors
  - B+LNZ: 2 Land & Environment Plan (LEP) workshops
  - BOPRC: Perrin Ag & AgFirst 1:1 follow up on LEPs
  - Farm data confidentiality forms
  - Selected Overseer file reviews by BOPRC
- **2018 project completion**
  - Complete FEPs & Overseer
  - Fonterra and B+LNZ aggregate Overseer data
  - Results presented to farmers

The project began with lot of talking and working out how to do this in agreement with the farmers. The target was to generate 50 farm plans and to aggregate the nitrogen and phosphorus Overseer data. There was no need for individual farm data going into modelling, rather aggregate averages for each catchment. The farmers also agreed to use

industry farm plan templates. We had a lot of input from Fonterra, who trialled and refined their Tiaki Farm Plan System through this project. Fonterra are now rolling out Tiaki farm plans around the country with about 1,500 completed by early 2019. Beef & Lamb supported with two Land & Environment Plan workshops, getting farmers to be hands-on with the land and environmental plan template that Beef & Lamb have developed. Council engaged Perrin Ag and AgFirst to do one to one delivery for the dry stock farmers.

Farmer data confidentiality was most important; each of the dry stock farmers signed a form. Fonterra had its own process in guaranteeing confidentiality. There was some review of the Overseer files to make sure they were up to spec, but because we were using trusted advisors through Perrin and AgFirst, we were confident with the robustness of the nutrient loss information that would be generated. In 2018 there was the wrap up of the project and the data analysis and results presented to farmers at the end of that year which has subsequently been presented to Council, the Rotorua Te Arawa Lakes Strategy Group and to the Massey Fertiliser and Lime Conference.

Results – Drystock Farms

- 16 farms, 6829 ha total, 5549 ha effective, ~350 ha each, rain 1300-1600mm/yr
- Systems: sheep, beef, dairy grazing, deer and combinations
- N & P loss rates, effective area only, Overseer v6.3.0

Catchment	kg N/ha/yr	Kg P/ha/yr
Tarawera	22	3.7
Rotokakahi	18	3.9
Okaro	23	2.0
Rotomahana	16	1.3
Rerewhakaaitu	32	1.2
Rangitaiki	34	1.1

Soil Order	Pasture		Fodder crop		Combined	
	kg N/ha/yr	Kg P/ha/yr	kg N/ha/yr	Kg P/ha/yr	kg N/ha/yr	Kg P/ha/yr
Recent (69%)	22	2.2	90	1.5	23	2.2
Allophanic (6%)	18	0.5	-	-	-	-
Pumice (25%)	26	1.6	106	2.4	28	1.7

These are the results of the 16 dry stock farms, not quite 7,000 hectares in total, roughly 350 hectares each. It covered a huge breadth of farm systems within the rather simplistic title heading of ‘dry stock’ which is always what you find in these analyses.

There are relatively tight bands in the middle column of nitrogen loss showing kilograms of nitrogen per hectare per year. These are all Overseer 6.3 numbers which has been overtaken since then by Overseer FM, but numbers should still be roughly the same, with some differences reflected in the different land use patterns. In the Rerewhakaaitu and Rangitaiki catchments the nitrogen loss is a little higher, probably reflecting some more intensive dairy support type of dry stock farming in those catchments. The relative range in phosphorus loss across those farms is also a little higher and reflects differences in soil type. Some souls are much more prone to phosphorus loss than others, depending on how tightly those soils hold on to phosphorus, which has either been added through fertiliser or animal excretion returns.

There are also differences within the farm system, including whether fodder crops are part of the farm operation, or not. Even though most dry stock farms have relatively small crop areas, the loss per hectare can be several times higher than it is for regular pastoral based farming. So there is scope to look at fodder cropping within dry stock farm systems to see if the nutrient loss can be reduced.

Results – Dairy Farms

- 32 farms, 5352 ha total area, results below for 3 catchments (3390 ha eff.)
- N & P loss rates, Overseer v6.3.0

Catchment	Dairy effective area only		Dairy support area only		Total area	
	kg N/ha/yr	Kg P/ha/yr	kg N/ha/yr	Kg P/ha/yr	kg N/ha/yr	Kg P/ha/yr
Rerewhakaaitu	64	1.7	51	3.7	58	1.8
Rotomahana	51	1.3	34	1.8	46	1.3
Rangitaiki	57	2.5	35	3.8	54	2.5

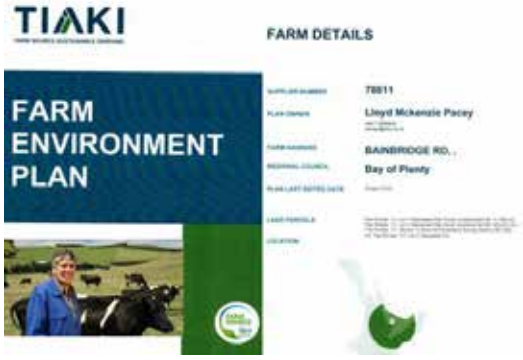
- N loss range mid-30s to low-90s, most in 40-60 kgN/ha/yr band
- Over 1000 individual actions in total

Observed higher risk N loss activities

- Undersized effluent areas
- N use in May, June & July
- Winter cropping and winter stock management

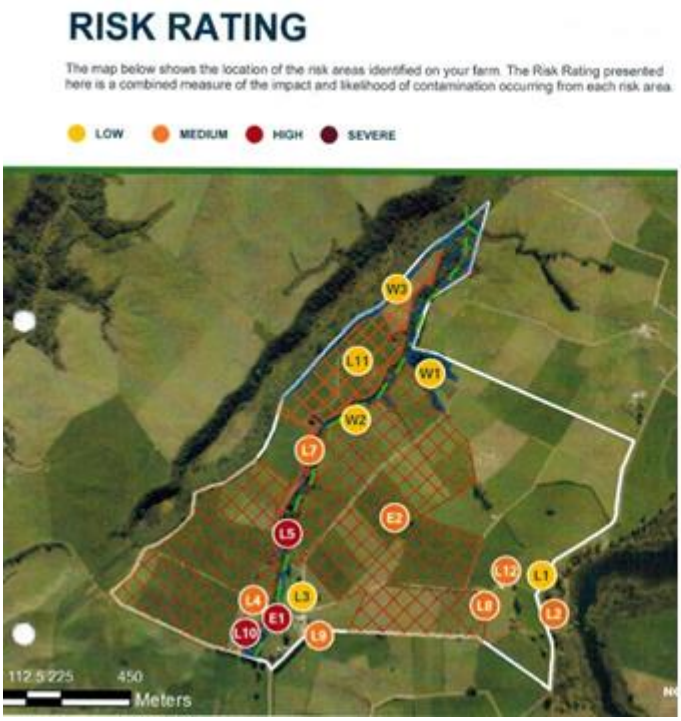
These are results for 32 dairy farms which were all Fonterra suppliers and this helped in getting the project worked through Fonterra and their dairy farm advisors. Results are just presented for 3 catchments because although more were covered, confidentiality may have been compromised in the smaller catchments. The results showed a relatively narrow band of total nitrogen loss and some bigger proportional differences in phosphorus again, reflecting soil and rainfall differences. Dairy support was done partly within the dry stock analysis and partly within this one, so there are some slightly different numbers and a bit of variation depending on which catchment.

Fonterra thought that overall the N loss range compared to national data was relatively moderate. But they were keen to emphasise that in total there were over a thousand actions identified across these 32 farm plans, over 30 actions per farm plan on average and that's kind of where the rubber hits the road, you know there are practical actions identified through there. They identified more traditional high-risk activities of nitrogen loss, particularly winter management around fertiliser, pasture and crop management, and also a handful of undersized effluent areas.



With Mac Pacey's cooperation these slides are from his Tiaki Farm Plan and show the detail that a farmer needs. After the first couple of pages there is the summary and specific actions. The farmer then has a ready reference on what the main actions are within the farm plan and bound by time to when the farmer has undertaken to deliver them.

There is also a detailed farm map, some areas might apply for the whole farm, but often they have quite specific spatial issues, little hot spots, or critical source areas. They all have a code to assist the farmer and a colour ranking of the relative risk of nutrient loss. This is a very sophisticated system that Fonterra has developed with onsite photos and references for the farmer to follow up for further guidance.

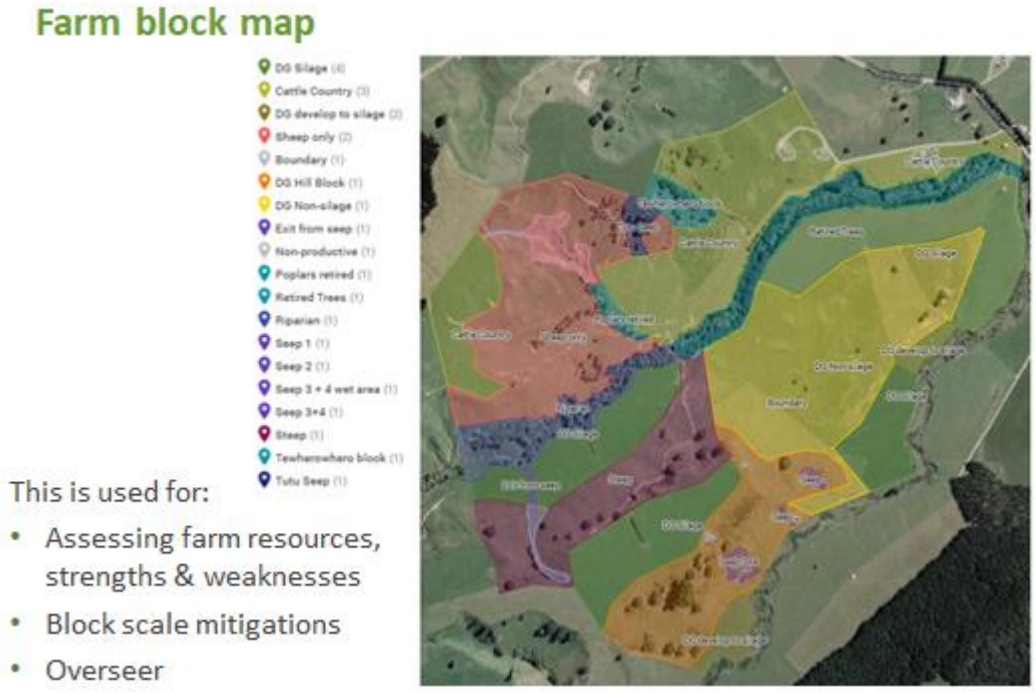


- 16 location specific actions are shown
- 2 nutrient actions apply to the whole farm
- Each action has photos and advice on good practice

The farmer separately gets a nitrogen report from Fonterra, a process that might be changing at the moment, but that can be clipped in to the Tiaki Farm Plan, along with any soil tests or other relative information that the farmer needs to use.

This is the dry stock farm plan example for Dick and Gaylene Brough's farm in the Rerewhakaaitu catchment, prepared by Perrin Ag on behalf of the Broughs.

This is their farm map broken up into blocks that have relatively common management and topographical features and these go into Overseer to predict the nitrogen and phosphorus loss from each part of the farm. It is used to address the farm's natural resources, strengths and weaknesses, and its potential for productivity improvements as well as environmental enhancements.



There is a lot of detail in these farm plans and specific action advice for the farmer to follow through. There are also more general things around nitrogen management and getting into specifics of critical source areas.

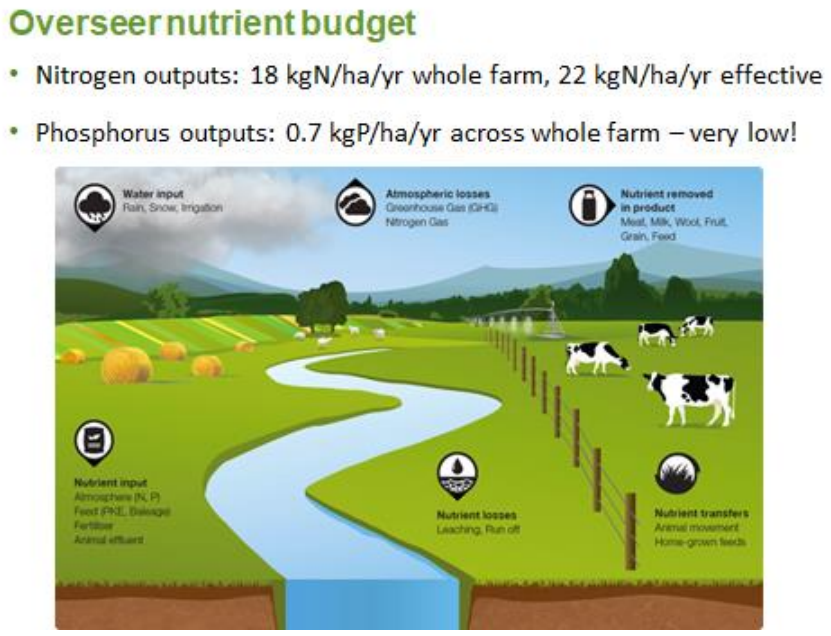
Management of the farm - key FEP actions

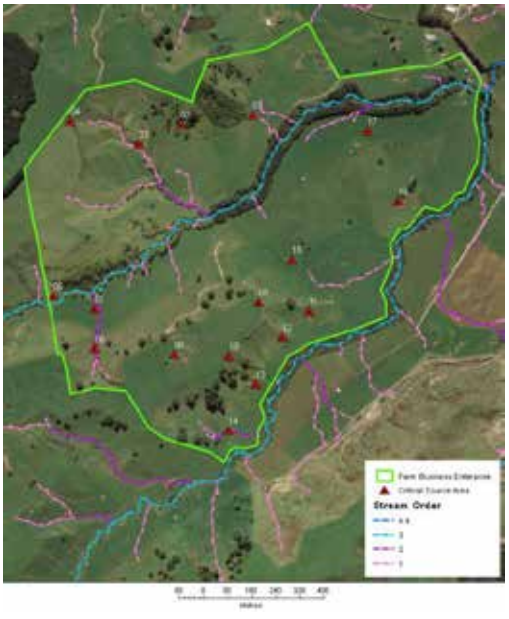
- *Where a silage stack is placed in the paddock on grass, it will be sited well away from ephemeral flow paths*
- *Any new troughs will be sited to avoid ephemeral flow paths*
- *Cattle will be prevented access from the relevant CSAs identified in Section 9. Until permanent fencing is completed, this will be with temporary electric fencing*
- *Mature cattle or dairy animals will be avoided on contour over 15°, these blocks are designated Sheep only, DG Hill Block and DG Steep. These blocks will be reserved for animals under 24 months of age, or sheep*
- *An agreed weed control programme will be maintained on land > 15° to prevent the re-establishment of broom and other noxious weeds*

- *Nitrogen fertiliser will not be applied in the months of May, June or July*
- *Phosphate fertiliser applications will be avoided May to August inclusive, and will not be carried out within 3 days of a forecast heavy rain event*
- *A whole farm soil test will be undertaken by a professional in February 2018, and thereafter bi-annually to establish trends in the soil tests*

- *Fertiliser on all parts of the farm will be applied as part of a fertiliser recommendation plan from a reputable fertiliser company*
- *Fertiliser will be applied as per the Fertiliser Association's 'Code of Practice for Nutrient Management'*
- *A plan will be developed for any spraying to protect the bee hives on the property*

This is Overseer's nutrient budget, a screen grab from the Overseer site, but it shows that even though it might be represented by just a couple of numbers of nitrogen and phosphorus loss for this farm, Overseer is pulling together a large number of inputs, bio physical inputs and farm management inputs and showing in a simplistic way 18kg of nitrogen per hectare, per year for the whole farm, and 0.7kgs of phosphorus. There is a lot of work that goes into developing those figures and within Overseer there is a range of mitigations and some flow into the farm plan actions.





The critical source areas are mapped out and on this farm there were 17 identified for action, and there is a table appended to the farm plan with detailed actions about the issue and what the farmer can do about it. (Next page)

Number 2 refers to something called the Tutu Seep which is about retiring this little hotspot.

17 CSAs and related mitigations – the first three

Table 2: Critical Source Areas (CSA) for 238 Republican Road, Rerewhakaaitu

CSA	Issue	Mitigation	Timeframe	Benefits
1	Seep from retired trees running through paddock	• Create small duck pond where seep leaves bush, novaflow below and then recontour a meandering flow path. Exclude stock while pasture is re-established	Current	• Duck shooting dam • Water protected to exit point at stock excluded creek • Retain in effective area, increasing productivity of an historically wet area
2	Tutu Seep with receding gully head, and water flowing through paddock	• Fence around seep and accompanying water way, down to southerly fence ○ Retirement fence to extend to take in steepest contour and large proportion of remnant Tewherowhero trees. ○ Remaining paddock will be cattle in summer only, sheep all year round. ○ Remove Tutu and replant with natives.	Jul 2020	• Prevent seep creeping up hill face • Prevent edges of seep exit being further broken down and eroding • Protect water course (goes underground after retirement area) • Opportunity to increase native retired/ regeneration area • Summer grazing for cattle with shade
3	Wet stream head – basin to retire	• Contact BOPRC to see what financial and planning support is available. • Re-align existing fence in south-east corner to become part of the stock exclusion fence ○ Fence to approximate area outlined on LMU map to take in steepest contour and wet spots. ○ Consider some plantings – natives plus poplars to stabilise steeper faces ○ Designate paddock as predominantly sheep paddock, cattle in summer to remove seed-head	Jul 2018 Jul 2020	• Preventing degradation of wetland area • Protect water course – almost all fenced from here to stock excluded creek • Habitat/biodiversity

3 of the 17 CSAs

from Brough FEP appendix

On the lower left shows the little slump where there is some seepage and potential erosion, a phosphorus loss hot spot. There is an undertaking that it is going to be retired and planted. These critical source areas are part of an appendix to a typical version of these farm plans. Each of these has a photo with an action identified against it, which is very comprehensive in terms of farm planning.

The Brough's Farm Plan also addressed production goals and stock classes, but also had personal goals relevant to the Brough family, native trees with family legacy links. There was also a reminder to update FEP's every 3 years or so.

There was a list of ongoing work but there was a flood in the middle of the farm plan project that delayed things. On the bottom-left is the giant tomo on the margins of the study area by State Highway 5 - but these things can happen as projects evolve. Fonterra is doing ongoing follow up, although they are very busy around the whole country trying to deliver these Tiaki Farm Plans. Beef & Lamb is committed to continue to support where they can and of course the Regional Council has incentives for some of these works that meet Council criteria in terms of retirement, planting and fencing and so forth. Bottom-right is one of the land management officers with the Broughs. The modelling work is ongoing as Chris explained earlier. I also think land use rule thinking may be overtaken by Government's Essential Freshwater package.

Conclusions

- Getting 48 FEPs out of 51 within a voluntary project was pretty good
- Projects evolve and delays happen, you have to be adaptive as you go through, there are hiccups occasionally. Maintaining good communications with the Project Rerewhakaaitu Farmer Group was essential to the effective delivery of this project.
- Farm Plan templates from the industry proved themselves to be pretty adaptable and pragmatic.
- There were a few challenges around collating confidential farm nutrient data, so there must be a trust between consultants, council and the farmers.
- We generated some useful data to go into the University of Waikato modelling that was not linked to earlier nutrient data. Catchment modelling will inform potential rules
- Implementation is obviously critical and an ongoing exercise and keeps farmers pretty busy.
- It is important to build on positive environmental ethos within the farmer community. We were lucky that there had been a lot of work already in these lake catchments led by the farmers.

Thank you.

I would like to introduce Chris Sutton who is Chairman of Project Rerewhakaaitu that I had the pleasure of working with him. He was once a dairy farmer, but is now a bull and dairy grazer.

Project Rerewhakaaitu

Chris Sutton

Thanks very much. To Te Arawa, (the previous presenters) we did give feedback to the action of Healthy Waterways and agree with Te Mana o te Wai to the point that we expect to see some rivers not white-baited in and lakes without trout, otherwise we are just saying the words, aren't we? That is the way we look at it. We put a submission in and have no fear of the action of healthy waterways because it is that we have already done a lot of it. We looked at it, read all the reports and everything else and sat down at Mac's place and only got about halfway through all the questions that we answered, so we have no fear there.

To LakesWater Quality Society, thanks very much for the Symposium several years ago that I attended, I stood up and said that I was a dairy farmer and asked a couple of questions of a keynote speaker. There were only two dairy farmers in the room and it got the attention of Bob Parker and Mike O'Connor from AgResearch. I was shoulder tapped and that was the genesis point for Project Rerewhakaaitu. From there on in it was taken up by the farmers and they ran the project with the facilitation of Bob Parker and the comfort of having scientists that could sit there and explain it in plain English to us.

I will now highlight some points from the slides you have just seen:

The Action list from the Tarawera Lakes Restoration Plan

The most important action in the Lake Tarawera Restoration Plan is:

(Action 10) *Informed community on science*

LakesWater Quality Society should take credit for that because had I not attended, or had farmers not been picked on, then maybe this Project may not have evolved.

Also congratulations should go to Simon Park who managed to tick off with our help Actions 2 & 4 and Action 5 is the next action that had to be done.

(Action 2 & 4) *Farm management plans in the inner and outer catchments by 2020*

(Action 5) *Develop rule to limit land-use change that increase nutrients in the Tarawera System*

The committee wanted those Actions 2 & 4 done in 2016. AgResearch had done a first set of plans within about 3 months and audited them 3 years later. They saw 15-16% reduction in N and P, also 90% of the actions that were committed to were carried out.

We have done more plans, and upgraded the plans, and Simon has delivered that within time, within budget, partly paid by Fonterra, Beef & Lamb NZ & BOPRC. The commercial value of their plans was about $7,000 to $8,000 and the industry has contributed quite a bit of their own money. It is not easy to do a plan of the size that they are today. We over delivered because the Restoration Plan says that a farm environment plan should only be a couple of pages, and one page should be a map, and not necessarily Overseer.

Mac has a folder that is about 'yay' big and that is because Simon and I sat down with Fonterra and they gave us a nice coffee table book, and we said, 'No, it has to be a working document where we can put things in and out.' So, if the Government decides that a farm environment plan should change for whatever reason, we just open the folder and put it in. Fonterra sends Mac annual information, an upgrade to a section of his plan and he slides it in, it's quite simple. It is at the point that he will get an App soon and be able to change something on his farm, hit the App button and it will print off a page, and he will put it in his folder.

What we look at is open, upper mind awareness. We can show you a whole lot of physical things, but it is upper mind awareness that is the asset. In the last 6 years we have seen 4 dairy sheds shut down, 2 farms completely gone out of dairy into beef and dairy support and 2 half farms gone into dairy support. That knocks Chris's fancy little coloured land use map around a wee bit, but a lot of that happened in May. The farmers are making decisions understanding their plan and how they interact with the environment. It is something that started here and happened out there. When Todd McLay was up here telling you how he was herding cats in a back room with a $10 million carrot incentive, we were putting into place with AgResearch the initial farm nutrient management plans that saw that voluntary reduction.

Congratulation to Simon for convening it, it was not easy, there were dynamic happenings, the project grew, and there were times where I was asked to attend to put the uncomfortable questions that enabled us to move forward and meet targets.

Thanks very much.

QUESTIONS

Troy Baisden, University of Waikato: I thought a good question for focus might the variability in phosphorus results from the different farm plans in run off and there are not many soil mapping units in the region. It is all a bit much of a muchness as far as I am aware, although I admit I could possibly look a bit harder. I am curious to know if what has been mapped is sufficient, or it needs more spatial detail, or breakdown of what the soil units are. I am particularly interested in whether the Rotomahana mud is adequately mapped and whether it captures fine sediment run off?

Simon Park: In the aggregated analysis we saw Rotomahana mud showed the highest phosphorus loss, but because we do not have the individual farm plans to look at in detail, it is difficult to go too much further with that. But there is certainly scope to look a little closer, perhaps as a case study cooperating with farmers to see what the soil parameters are and how much difference there is in phosphorus loss. But Rotomahana mud in combination with topography and slope makes a big difference in phosphorus loss.

Te Taru White, Te Arawa Lakes Trust: I want to acknowledge the fact that farmers are really trying, you can see that within your programme. But I would be interested to see the cultural health programme that you are bringing out, how this would fare in part of the monitoring. Is that something you have on your plan? I heard Chris make some acknowledgement of Te Arawa, is that something that could work?

Chris Sutton: We have a committee of 15 and on that we have Barnett Vercoe but because we have Barnett does not mean we have Rerewhakaaitu 1A2B, and it does not mean we have Ken Raureti and the history that Ken loves to tell, and I love to hear those stories. We have approached Ken about coming out. In our history we are a settlement area, we were ballot farms and had a relationship with the (Forest Service) woodsmen in the early days, well before I got here. Mac and Linda tell us they used to go up the mountain and clear the Wilding pines and things like that.

So, it is time that the community had the discussion around the stories that Ken talks about. It would bring a wholeness to the environment around us, holistically, which is pretty much what we are talking about in the Action for Healthy Waterways. It is going to be timing appropriate. I know it happened with the Tarawera Sewerage Steering Committee and I expect Nicky to move out our way. She has a copy of our feedback to the Action for Healthy Waterways. We had the opportunity to talk about wastewater, which is sewage and grey water. We know where that goes, and we do not want it there either.

Thanks very much.

Session 8: LAKE ROTOEHU RESTORATION

SESSION CHAIR – Stuart Corson, LakesWater Quality Society

THE WAITANGI SPRINGS GEOTHERMAL INFLOW AND THE BIOGEOCHEMISTRY OF ROTOEHU

Chris Eager
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Chris.Eager@NIWA.co.nz

Chris has undertaken research in freshwater, estuarine, and marine environments, primarily in aquatic physical, biogeochemical, and geochemical processes. His Masters research work at the University of Waikato under the supervision of Dr Adam Hartland and Professor David Hamilton explored the geochemical and biogeochemical processes associated with the geothermal alum dosed Waitangi Springs which is a major inflow to Lake Rotoehu. Throughout 2018 and 2019 Chris continued to work with Professor Troy Baisden in a technical role assisting with work throughout the Rotorua Te Arawa Lakes and engaging with BOPRC Lakes Technical Advisory Group. Chris has recently taken up a permanent position with the Coastal and Estuarine Physical Processes group with NIWA Hamilton.

TRANSCRIPT

Thanks for sticking around. Hopefully I will not bore you with the chemistry. This was my MSc thesis work that I carried out at the University of Waikato a few years ago, primarily to look at one of the remediation methods that we use to remove phosphorus from the largest inflow into Rotoehu via the Waitangi Spring, which is a large geothermal input to the lake. Many people have been involved with this, so it is not all entirely my work. I will give an introduction about the lake itself and a little about the Waitangi Spring and then cover my thesis work characterising the Waitangi Spring inflow and the biogeochemistry in Te Wairoa Bay.

Lake Rotoehu is one of the major Rotorua Te Arawa Lakes. It is shallow (13.5m max, 8m mean). It is polymictic, overturning frequently, and has a relatively small catchment and frequent cyanobacterial blooms, and well known for those. It has a very large geothermal influence in comparison to some of the other lakes (69% of Ionic input), and this equates to a large amount of dissolved salts making their way into the lake from the geothermal input. Another, management issue is that it has a subterranean outlet, so it is difficult to manage

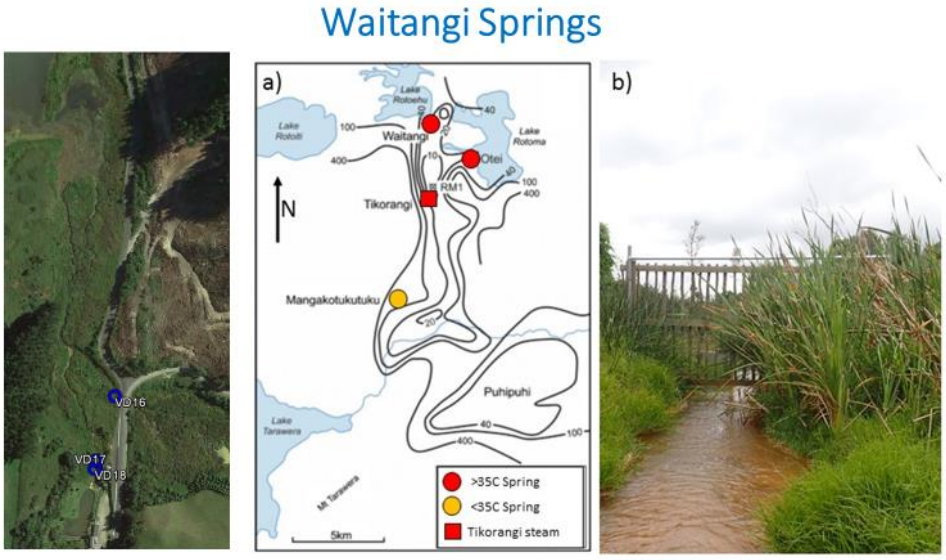
the lake level. There have also been multiple lake remediation methods undertaken; such as trying to de-stratify the lake using aeration devices, weed removal, and alum dosing for removing the phosphorus loads reaching the lake.

This is the Waitangi Spring and you may have bathed in its waters. It has elevated levels of bicarbonate, potassium, sodium, chloride, boron, silica, iron and ammonia and low sulphate amounts, which is quite different to other geothermal inputs in Rotorua. This spring does not have the eggy smell that we get coming into Rotorua from the sulphur component, or it is not as elevated.

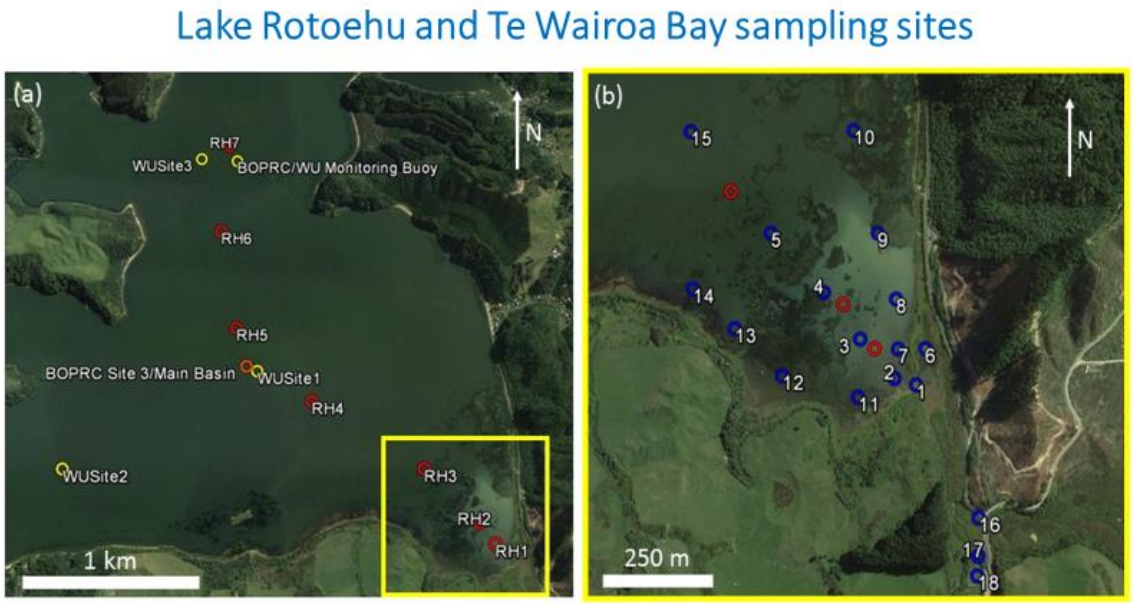
Waitangi Springs

- Elevated HCO_3^-,K, Na, Cl, B, Si, Fe, NH_3
- lower SO_4^{2-} by geothermal standards, Unlike many geothermal inputs to Rotorua

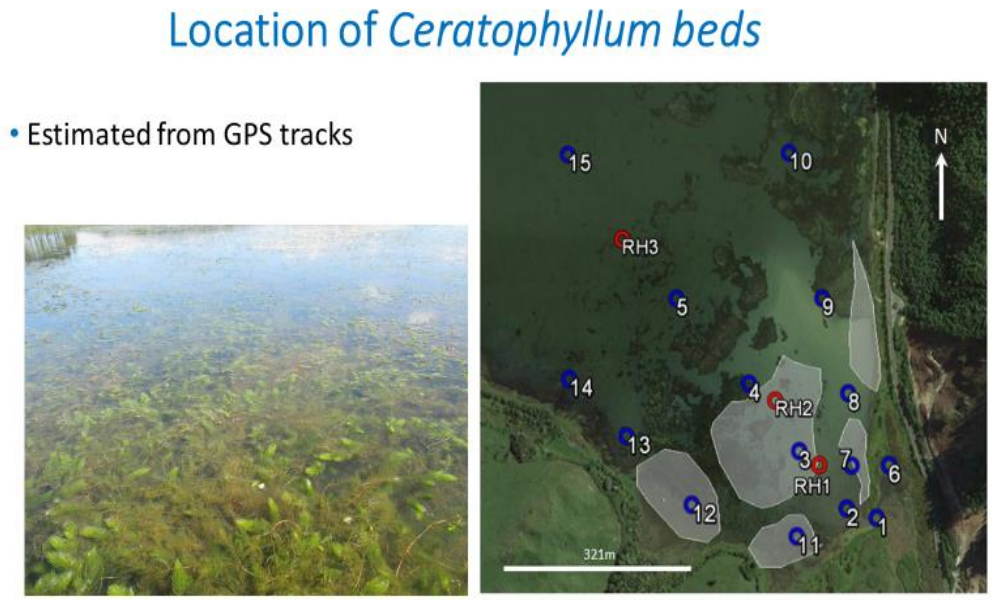
In the middle plot (below) we can see the geothermal resistivity associated with the area around Rotoehu. The geothermal field is called the Tikirangi Field and extends south from the Okataina caldera rim which intersects Lake Rotoehu all the way to near the eastern edge of Lake Tarawera and around Rotoma. In the photo on the left the blue dots indicate some of my sampling points just south of the bathing spring. We did an alum dose at number 17 and 16 is a wetland complex with ground water coming in from Lake Rotoma which is adjacent to it. On the right you can see that the bed of the stream is quite red from the iron that is flowing from the spring and is oxidising, precipitating, and coating the stream bed. It is this iron floc which plays out to be one of the issues with our alum dosing.



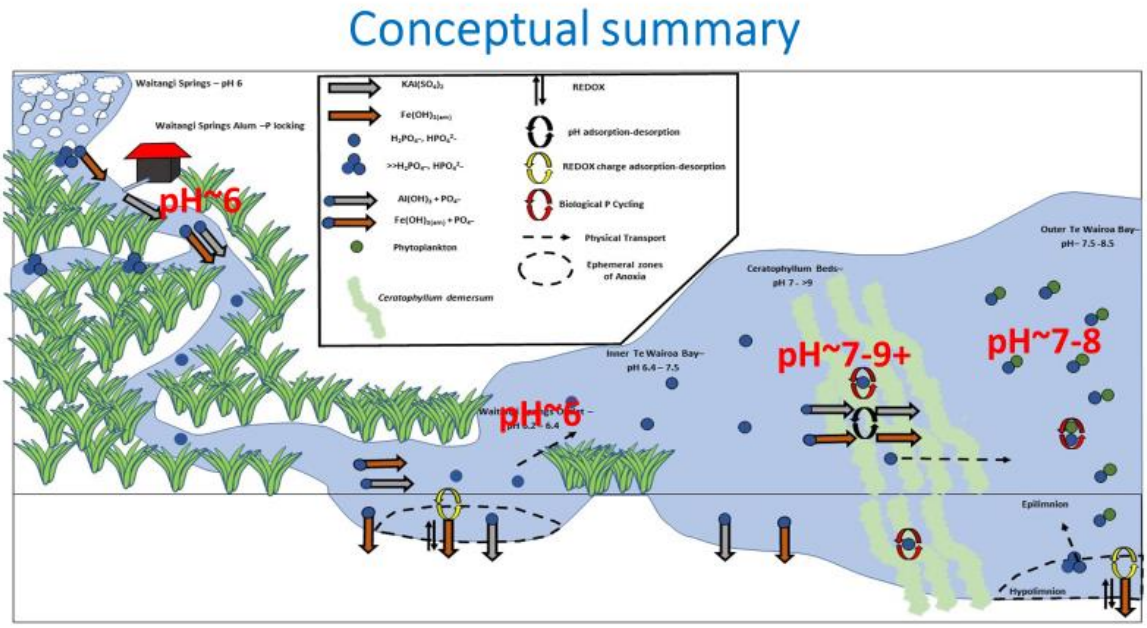
These are more sampling sites in Lake Rotoehu and Te Wairoa Bay. The red dots in the figure on the left are coring areas that were taken in a transect from out in the main lake basin all the way into the yellow square which is Te Wairoa Bay, and the main focus area of the study. The sediment cores were used for geochemical measurements; furthermore note the location of the BOPRC monitoring buoy. In the right hand figure is a closer look of my sampling area within Te Wairoa Bay. The blue dots are where I sampled water quality, physico-chemical and geochemical variables.



This Google earth photo (below right) shows a lot of *Ceratophyllum*, which is an invasive macrophyte in Te Wairoa Bay and the photo on the left is what it looks like, very dense, and a huge component affecting the biogeochemistry in the bay. I undertook my sampling from a kayak to estimate the location of the *Ceratophyllum* beds by GPS which enabled me to map out where the beds resided. This photo displays their locations during my sampling.

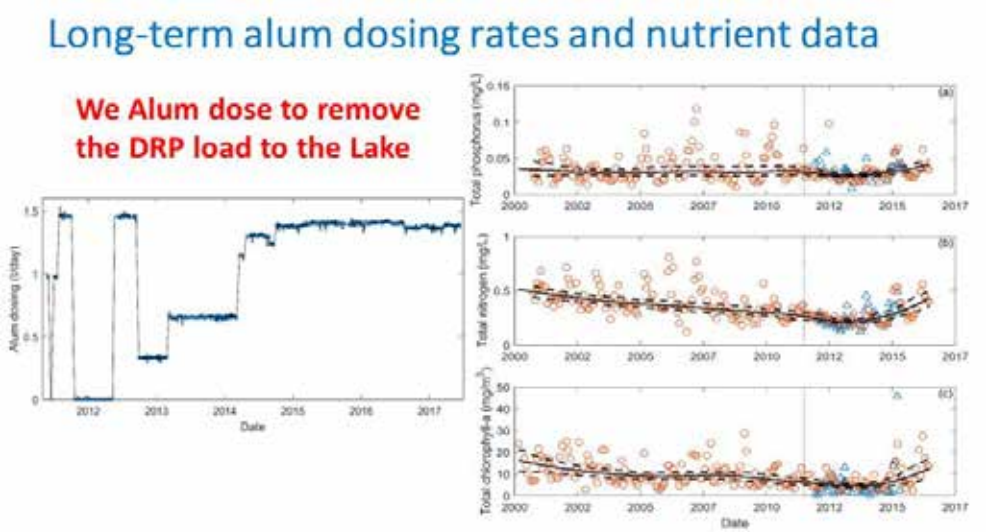


This is a conceptual summary of the Waitangi Springs system to give you an overview. In the top left of the cartoon we can see the alum dosing building. The aluminium binds to the phosphorus in the water and it is meant to hold on to it but that is entirely pH dependant. At pH 6 it is effective and as it goes down in pH it still binds the phosphorus but in a soluble form. At pH 6 it turns into amorphous goo similar to the red staining that you saw on the bottom of the stream in a previous figure, although this was the iron (ferrihydrite) component within the stream. Both aluminium and iron are very similar in their aquatic chemical behaviour and transition between a soluble form and a solid form between low (pH<5) and circumneutral pH (pH 5-7). At high pH (>pH8) they become soluble again, and this can affect how it holds on to the phosphorus and the available nutrients that we are trying to sequester from the water column.

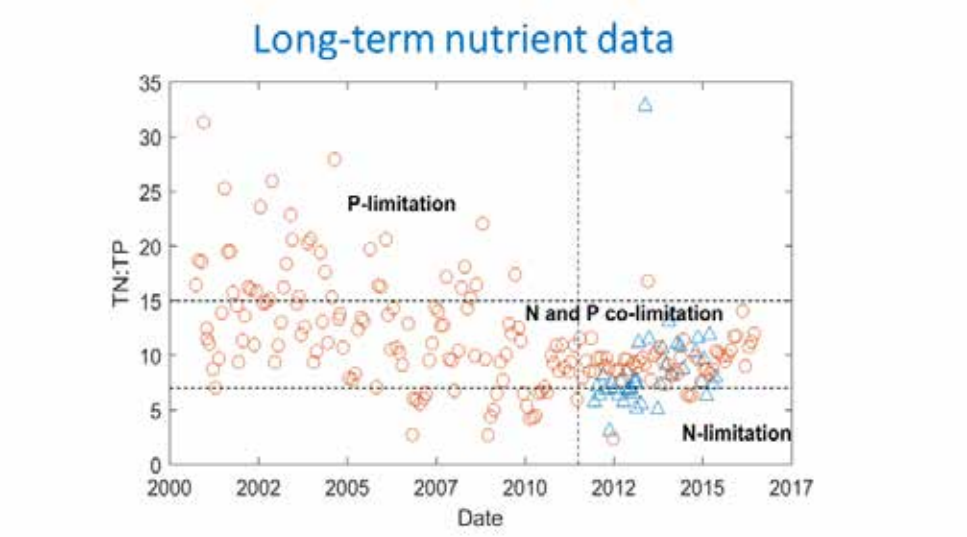


As the alum is added at pH 6 it undertakes this amorphous change and does what is called flocking through coagulation. It forms small particles which are then deposited on to the bed, providing a mineral locking mechanism for the phosphorus. Many lakes, such as Lake Okaro, have been capped with alum and often dosed on a yearly basis to add absorption capacity for phosphorus in the lake. Unfortunately there is a lot of *Ceratophyllum* and that has provided a net potentially preventing alum from making its way out into the lake. We were hoping that we could reduce the phosphorus load in the stream (which is high, upwards of 40ppb), and when it does make its way out to the lake it would provide extra phosphorus binding capacity. We attribute a lot of the success in the alum dosing programme in Rotorua (at Utuhina and previously Puarenga) to a similar process, putting it into the stream and as it makes its way to the lake it provides extra absorption for phosphorus and helps improve the water quality.

The graphs of the long-term alum dosing rates at Waitangi and nutrient data from Lake Rotoehu (next page) show that around the time we started dosing in 2011 we saw a marked decrease in total phosphorus, total nitrogen and chlorophyll *a*. We thought that we were making a big difference, but I will remind you that we had multiple remediation effects in place. Then around 2015 it started to increase again, and other people will hopefully elaborate about why that might be (Max and Andy).



The total nitrogen to total phosphorus data (below) shows that the lake was P limited before the dosing programme began, and it moved into N and P co-limitation, and we were nitrogen limited at one point. You will notice an increase back to P limitation which could have an effect on the ability of algae to grow. We are all familiar with these algal blooms that we get there.

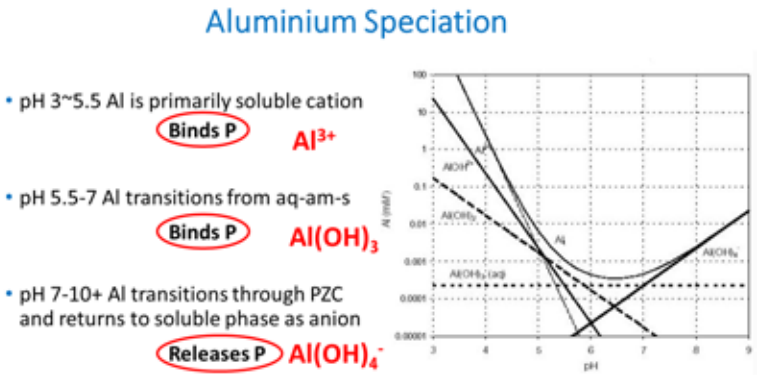


My Research Questions

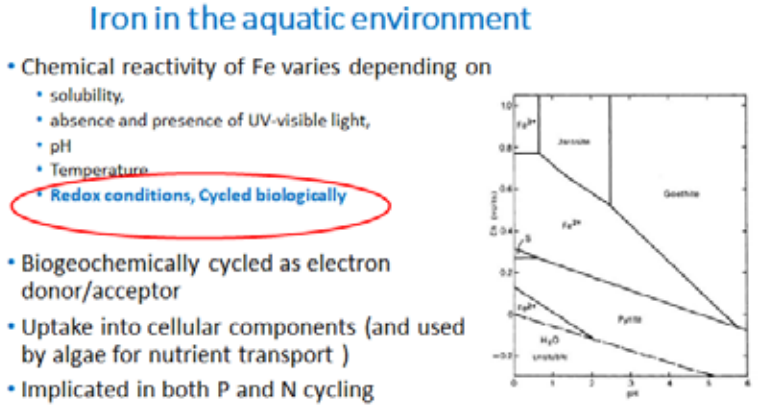
- How do the Al and Fe-P binding adsorption isotherms fluctuate spatially and temporally in Te Wairoa Bay?
- How do the *Ceratophyllum demersum* beds alter the physico-chemical environment with respect to the Alum plume?
- Can we characterise diel fluctuations within Te Wairoa Bay?

Aluminium in the aquatic environment is chemically reactive, soluble at low pH and has some chemical behaviour based around the presence of UV visible light. It is pH dependant in its chemical form and also affected by temperature. It is geochemically cycled primarily through geological processes of weathering of aluminium bearing minerals in the soil, so it is not biologically cycled. It can be biologically taken up but it has to be in the appropriate chemical species (form). It is implicated in phosphorus cycling through adsorption or desorption. This means phosphorus can stick to or be released dependant on the charge of the aluminium ion.

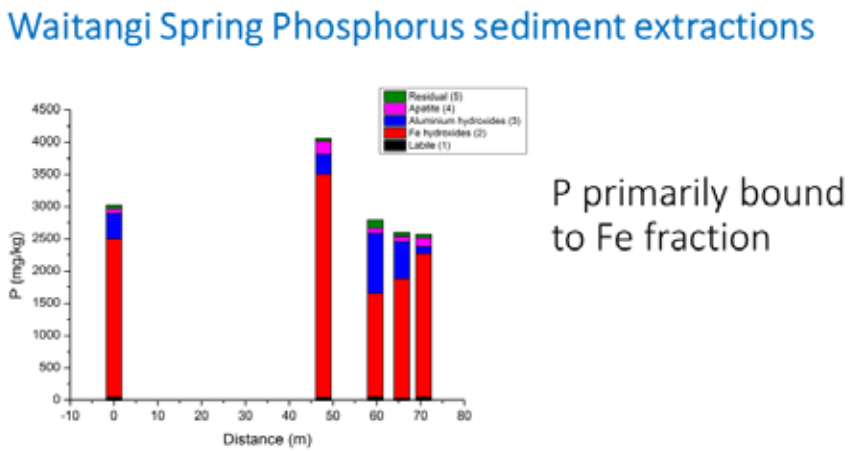
At low pH phosphorus binds aluminium strongly because it is positively charged and the phosphorus is negatively charged, so those opposites attract. At medium pH around neutral it binds P, but it becomes amorphous again and that is where we like it. It can then transition into a mineral which gets buried in the sediment locking the phosphorus up. At high pH it can transition back into a soluble form and release phosphorus back to the water column.



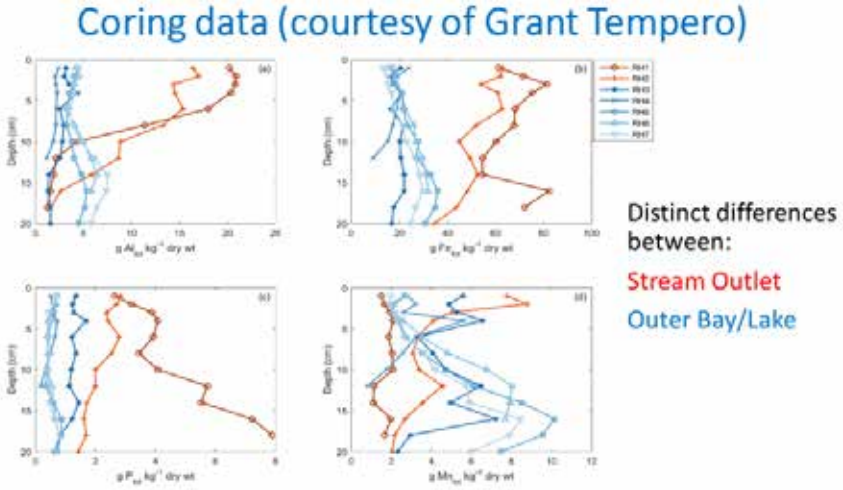
Iron behaves very similarly but has a couple of other factors which affect it, such as it gets cycled with oxygen dependant on how much oxygen is in the water and it is also cycled biologically so is used by algae to take up nutrients, among other factors that can affect it. This unfortunately is a very important point as both the Waitangi Springs and Lake Rotoehu have a large amount of Iron within the sediments.



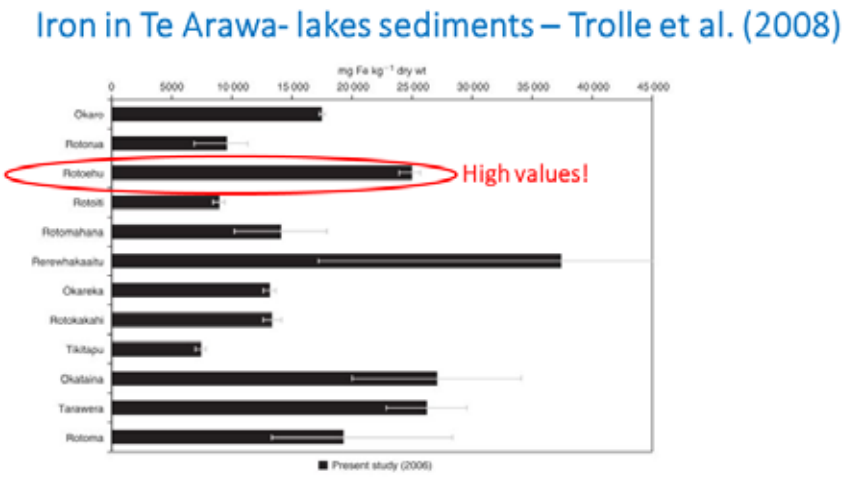
Below I am also presenting some data from the fractions of phosphorus bearing minerals, labile phosphorus, and residual phosphorus in the sediment from the Waitangi Springs. These sediment extractions were taken in the Waitangi Stream by Adam Hartland and Ben Shirley at the University of Waikato. The bars run from 0m being the lake upstream into the Waitangi Spring. The primary phosphorus binding elements are calcium or the apatite mineral, aluminium hydroxides, and iron hydroxides components within the sediment. They clearly delineate that iron is preferentially binding the phosphorus in the sediment in that stream. This gives us the justification that although we add alum and it is effective, it is not binding the greatest portion of phosphorus within the stream water as the accumulation of flock is part of the sediments. You can see in the blue that the alum is effective, but it is because there are increased iron concentrations in the stream, iron is already binding a large amount of phosphorus, before the alum dosing. This means that the phosphorus bound to iron is releasable under anoxic conditions if they exist.



Grant Tempero took this coring data which shows elemental distributions of Al, Fe, P and Mn with respect to depth. In the outlet sites RH1, RH2, and RH3 (Waitangi Spring inlet), sediment aluminium and iron are much higher in than in the central portion of the lake. The red lines are RH1 and RH2 (at Waitangi Spring inlet) and blue lines are further out in the lake (see sampling locations below). In Figure C the sediment phosphorus is showing that there is a negative trend and being released back to the water column. That is probably iron bound phosphorus which is becoming anoxic and then allowing that phosphorus to be released back into the water column. This is a theme in Rotoehu and potentially why we have such a large amount of phosphorus and algal growth in the lake.



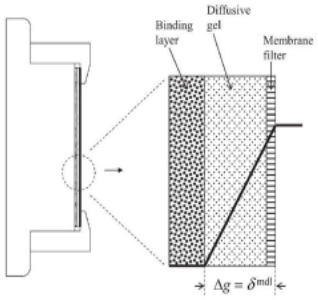
These are sediment Iron distributions from cores taken throughout many of the Rotorua lakes which was work published by Dennis Trolle when he was at the University of Waikato. It is not uncommon in the Rotorua Te Arawa Lakes to find high iron values. As we can see, Lake Rotoehu in comparison to these other lakes has a lot of iron in its sediments. Lakes Rerewhakaaitu and Tarawera also have a large amount of iron. It is likely that the variation in local volcanic geology is contributing to these differences in sediment composition, and therefore certain lakes are likely more affected by iron bound phosphorus. Of course, other physical and biogeochemical factors can also influence these processes.



In my thesis I used these passive samplers called DGT's which allowed me to look at the temporal dissolved component of aluminium and iron and in the water. It is an important value to measure so we know how much is dissolved or 'labile' Al and Fe is there. I also took discrete water samples of dissolved and total nutrients, alkalinity, dissolved cations and anions in order to undertake a chemical water balance. Finally, real time plume tracking, stream discharge and some chemical speciation modelling, was also carried out much of which is too detailed for this talk.

Methods

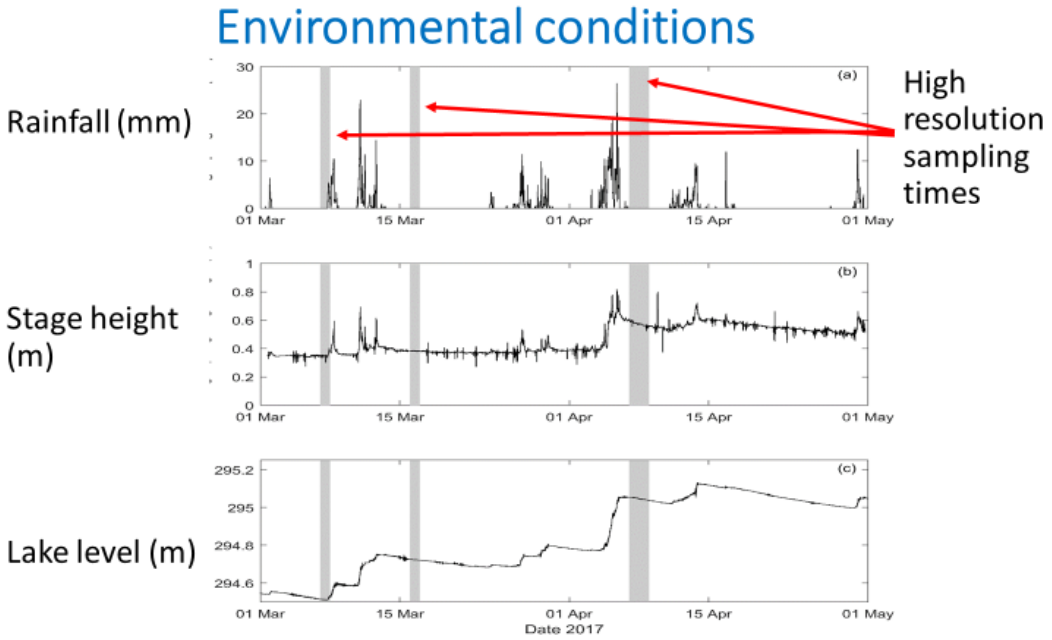
- DGTs- Chelex– Metals (Fe, Al) ICPMS , temperature moorings



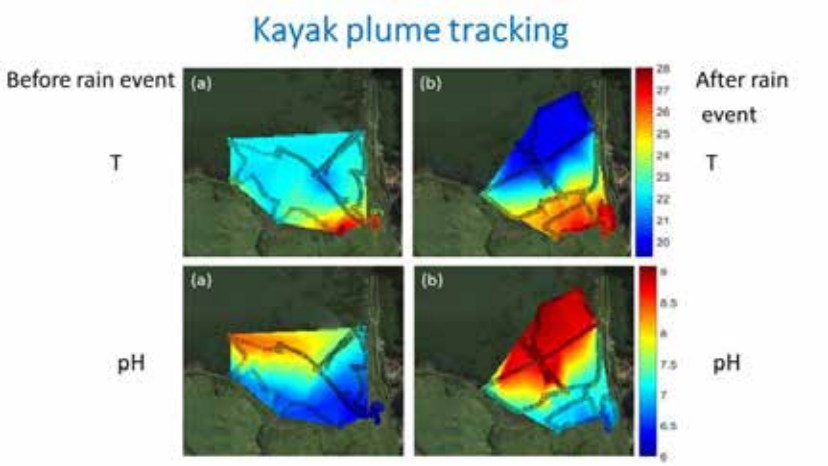
- Dissolved water samples- ICPMS- IC- Alkalinity- Nutrients (DIN, DRP)
- Real Time Plume tracking – Kayak mounted Sonde and RBR Concerto Temp, pH, Cond, DO, Turbidity
- Stream Discharge – Deployed ADCP in outlet channel.
- PHREEQC Chemical Speciation Modelling.

This was my kayak and I attached a YSI Sonde which allowed me to measure physico-chemical properties (Temp, Dissolved Oxygen, Conductivity, and pH) and I GPS tracked

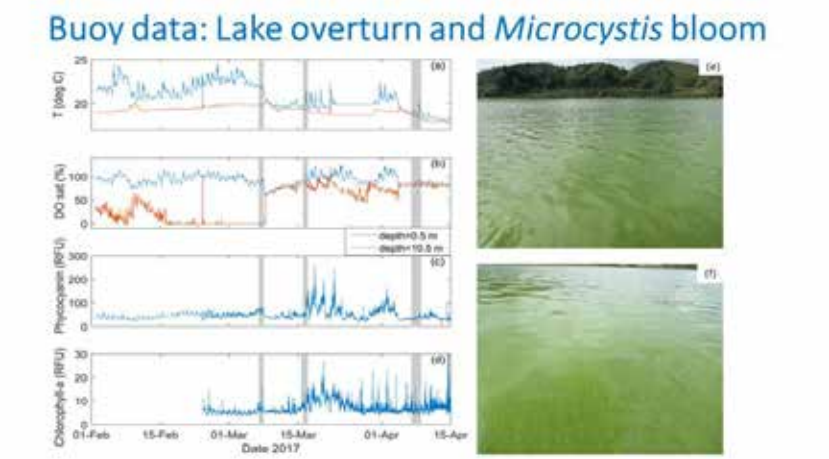
this in order to spatially characterize the bay. I did multiple transects throughout the bay and measured the physical properties in the water. I also managed to examine the before-after effects of a large rain event and its impacts on the geochemistry of the system. This was during the 2017 Edgecumbe floods, thus the lake level increased by about a metre over that time. It gave me the perspective of what it is like at both low flows and with the higher lake level and the dynamic processes that occurred during this change.



These are before and after spatially interpolated plots of temperature and pH from the plume tracking. As you can see the temperature of the geothermal stream is almost 30 degrees when it enters the lake and quickly dissipates out in the lake water where it is around 20 degrees. After the first large rain event you can see on the top right that the temperature gradient extended further out into the lake, likely owing to the increased stream discharge. In the top left plot there is a big blue patch in the temperature in the centre of the plot, which is a large bed of *Ceratophyllum.* It is evident how the *Ceratophyllum* has an impact on the mixing processes. This is also reducing the transport of alum and iron particles to the lake which we have already seen from the sediment cores. Therefore, the macrophytes are effectively acting as a filtering net to the inflow.



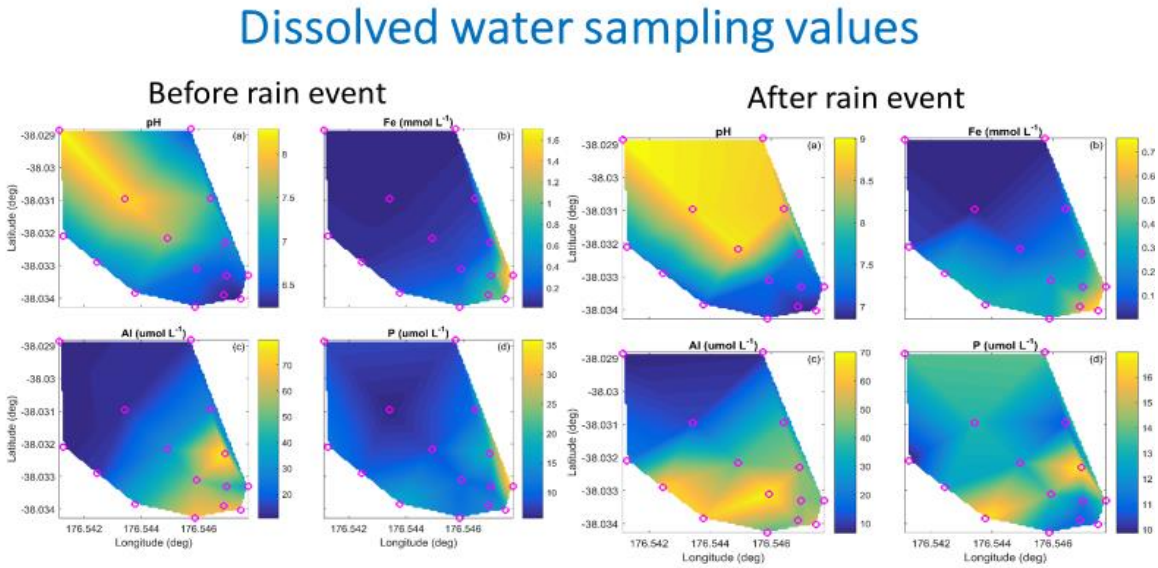
On the bottom plot is the pH value, so you see this big pH gradient which mirrors the temperature signature. The pH ranges from 6 right up to 8 on the left, that was before the rain event, and then after the rain event the surface lake pH increased markedly, extending up to pH9.



The pH increase seen in the outer portion of Te Wairoa bay also coincided with an algal bloom likely owning to lake destratification during the rain/wind storm. In the top left figures (a and b) you will see that initially surface temperature and oxygen values (blue lines 0.5 m depth) and the bottom temperatures and oxygen values (orange lines 10.5 m depth) are distinctly different. Then around March 6th (1st grey line) we see homogenisation of temperature and oxygen values which coincide with a large rain/wind event and the lake de-stratifying. Essentially what this equates to is the mixing of two distinct water masses in the lake (bottom and surface waters). The bottom water (10.5m) which is likely high in dissolved nutrients (phosphorus and ammonium) and low oxygen and the surface water which is high oxygen and lower nutrients (0.5m). Furthermore, around March 16th you can see that the surface chlorophyll and phycocyanin sensors that are on the buoy that Chris maintains pick up the lake wide *Microcystis* cyanobacterial algal bloom. This is something that has occurred more frequently in the lake in the last few summers which have been very warm and the lake has stratified more frequently and the lake level has increased in depth.

The dissolved water sampling values (next page) showed a large increase in phosphorus after the rain wind event. On the left, in the bottom right quadrant there are lower values and then on the right there is a marked increase especially in the lake. The dissolved

aluminium values also often seemed to coincide with the *Ceratophyllum* patches and that is probably due to the ability of dense macrophytes to alter the surface pH upwards through intense photosynthesis leading to solubilising the aluminium and release of phosphorus.



Summary

The pH, oxygen and dissolved phosphorus values increased with distance from the Waitangi Spring. I should note that the phosphorus load was reduced by 50% from the alum dosing point out to the lake. But it is inconclusive whether or not that phosphorus is being retained within the sediments, so there are other processes at play that could be allowing it to be released internally back into the lake. The temperature major ion concentrations and conductivity all decreased with distance into the bay. The *Ceratophyllum* patches play a large role in altering the nearshore water column properties and preventing any excess alum from making its way to the lake. Although the alum dosing is effective in removing dissolved phosphorus from the stream water, colloidal and particulate iron is likely to be a major sink for the phosphorus in the lake itself. Further work understanding the spatio-temporal chemistry of lake water and sediments would provide improved understanding in how to better manage the lake moving forward.

- pH, O_2 and DRP values increased with distance from the Waitangi Springs outlet
    - Some patchiness was observed.
    - Temperature, major ion concentrations and conductivity all decreased with distance into the bay
- Dense vegetation within the stream and the stream-lake interface promotes the deposition of sediments and particulate matter
    - Sediment cores indicated that Al and Fe deposition was highest at the stream outlet
- Dense *C. demersum* beds played a critical role in altering water column properties and mixing
    - During daylight, high rates of photosynthesis, led to high pH and O_2 levels
    - These locally influenced the concentrations and speciation of Al, Fe and DRP

    - These processes control the availability of limiting nutrients within Lake Rotoehu
- Although dosing is effective, high colloidal and particulate Fe is likely to be a major sink for DRP within the system.

Further work can be found in my thesis around diel cycling and effects of macrophytes available through the university of Waikato research commons

https://researchcommons.waikato.ac.nz/handle/10289/11692

My thanks go to:

- Bay of Plenty Regional Council
- Andy Bruere, Niroy Sumeran (BOPRC)
- Adam Hartland, Grant Tempero, David Hamilton, Troy Baisden (UOW)
- All those who helped with fieldwork
    - Andy Pearson
    - Julia Mullarney
    - Dean Sandwell
    - Warrick Powrie
    - Lee Layborie
    - Nicola Lovett

QUESTIONS

Rowland Burdon, LWQS: You mentioned algal blooms, were they all strictly algal blooms or did they include cyanobacterial blooms and if they did include cyanobacterial blooms were any of them Nitrogen fixing?

Chris Eager: I am not an algal expert, but I did check up on what, the Council provided those photos to me just after the bloom occurred, and that was Microcystis bloom. I am not 100% sure whether it was Nitrogen fixing or not. Those sorts of studies require specialisation in the field, but perhaps somebody else could answer that.

John Green, LWQS: I am an accountant not a chemist, but you have a lake which is not too dissimilar to Rotorua in depth, Rotorua is about 11 metres, and this is 8. But you are getting hot water coming in, and putting in Alum and then you are losing it as it cools down, is that right?

Chris Eager: It is generally pH dependant, though not necessarily, but primarily pH is driving whether or not Aluminium is soluble, whether it is amorphous or whether it is soluble again at high pH.

John Green: What stage does the pH start coming in, because it is not there when it is coming in from the springs?

Chris Eager: Yes, it is in the Waitangi Spring itself at pH 6, which is optimal for flock formation, and that is why most of it is already bound to iron. There are minute differences in how iron and aluminium behave with respect to pH, but we see ferrihydrate formation which is that red coating that you see out at Rotoehu. The fact that we cannot control that formation of iron oxide means that we could either limit its distribution into the lake, but the lake has been fed iron for millennia, or we could limit it by detention but there are not many other ways. The *Ceratophyllum* itself is blocking it, but it is still not keeping all the iron from making its way to the lake.

LAKE BEHAVIOUR AND COMPLEMENTARY NITROGEN-PHOSPHORUS WEED MECHANISMS

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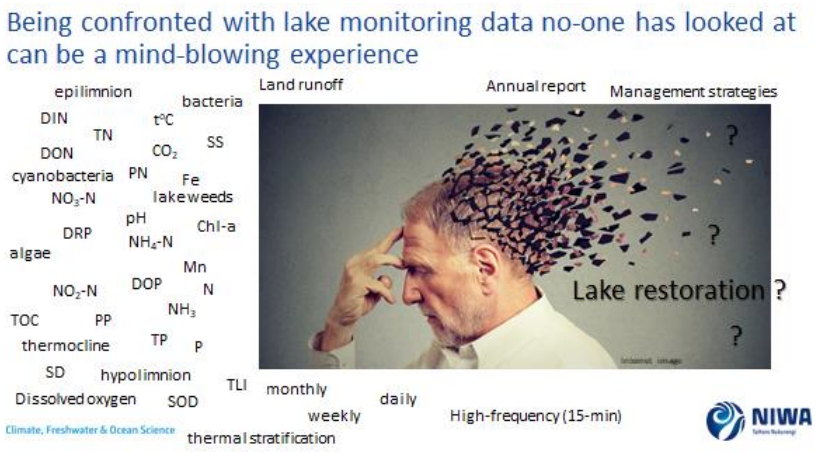
Dr Max Gibbs is a water quality scientist who has worked for NIWA for 54 years and has worked on lakes and lake restoration since 1973. He was awarded an Honorary Doctorate of the University of Waikato in 2010 for his work on lake restoration and mentoring of students . In 2015 Max was recipient of the University of Waikato KUDOS Lifetime Achievement award. Max started working on the Rotorua lakes in 1981 and discovered the role of the Ohau channel inflow to Lake Rotoiti, which lead to the installation of the diversion wall . Over the subsequent 38 years , he has developed a profound understanding of how lakes work . Today he is talking about 'Lake behaviour and complementary Nitrogen-Phosphorus-Weed mechanisms', focusing on understanding monitoring data being collected, and how to interpret it.

TRANSCRIPT

Thank you for the previous presenters, Troy, Chris McBride, Simon Park, Cyrus and of course Chris Eager, you have broken the ground for a lot of what I want to talk about. I was out on Lake Rotoehu in June with Andy and crew, and the discussion got around to how the algal bloom is formed and what were the processes behind it. Several of the processes have been discussed already. I have looked at many lakes and accumulated a lot of information and talked to various regional councillors.

I talked to one regional council person who had 35 years of data that nobody had looked at, and it was a mind-blowing experience for him. All of those numbers, what do they mean, how do you put them into a report or a management strategy? So this talk is about understanding the monitoring data collected and how it relates to the future water quality of the lake being monitored.

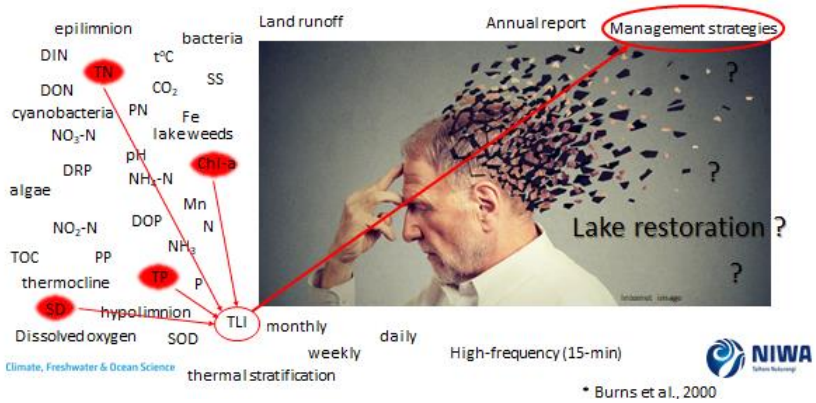


There are two types of data; you have the data which controls and the data about the species being controlled:

Controlling:	temperature	$t^{o}C$	**Controlled:**	algal biomass	Chl-*a*
	dissolved oxygen	DO		algal species	
	pH	pH		clarity	SD
	Phosphorus	P			
	Nitrogen	N			
	Carbon	C			

These ones are controlling the algal biomass, algal species and the water clarity. When we look at a lake the first thing we notice is its appearance, is it clean or is it dirty? The lack of clarity is caused by suspended particles, often algae. We measure clarity as Secchi depth (SD) and measure algae as chlorophyll (Chl-a). The chlorophyll is composed of carbon, nitrogen and phosphorus. We measure nitrogen as total nitrogen (TN) and phosphorus as total phosphorus (TP) and we forget about carbon because there is plenty in the atmosphere as CO_2.

Four data are used to produce the Trophic Level Index; total nitrogen, chlorophyll, total phosphorus and Secchi depth. Managers can interpret these data for management strategies and you have seen that with the work of Troy and Chris McBride who gave a good explanation of it.



The TLI is designed to compare lakes and classifications. This shows the classifications, a linear TLI index and a logarithmic parameter that we put into our monitoring data. We

cannot do much with chlorophyll and Secchi depth but total phosphorus and total nitrogen are the reactive elements. If we have a eutrophic lake and want to take it to mesotrophic, managers will shift that phosphorus level down below 20 and shift the nitrogen below 337 to achieve a mesotrophic lake.

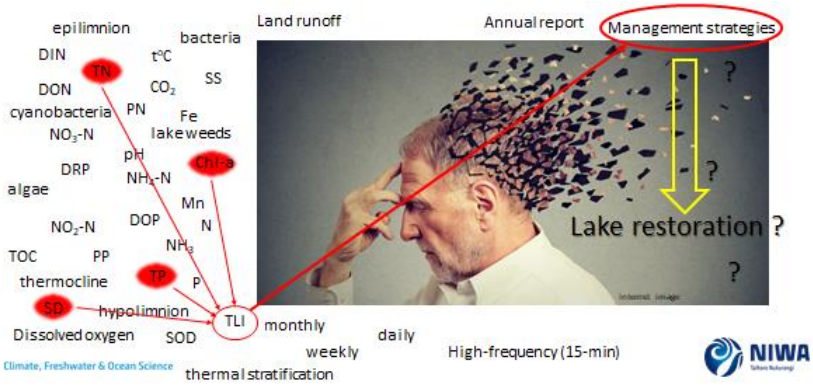
TLI allows lakes to be classified and compared

Lake Classification	Trophic Level	Concentration (mg m^{-3}) Chl *a*	TP	TN	Secchi depth (m)
Ultra-microtrophic	0.0 – 1.0	0.13 – 0.33	0.84 – 1.8	16 – 34	24 – 31
Microtrophic	1.0 – 2.0	0.33 – 0.82	1.8 – 4.1	34 – 73	15 – 24
Oligotrophic	2.0 – 3.0	0.82 – 2.0	4.1 – 9.0	73 – 157	7.8 – 15
Mesotrophic	3.0 – 4.0	2.0 – 5.0	9.0 – 20	157 – 337	3.6 – 7.8
Eutrophic	4.0 – 5.0	5.0 – 12.0	20 – 43	337 – 725	1.6 – 3.6
Supertrophic	5.0 – 6.0	12.0 – 31.0	43 – 96	725 – 1558	0.7 – 1.6
Hypertrophic	6.0 – 7.0	>31	>96	>1558	<0.7

Nitrogen TLn = -3.61 + 3.01log10 (TN)
Phosphorus TLp = 0.218 + 2.92log10 (TP)
Chlorophyll a TLc = 2.22 + 2.54log10 (Chla).
Secchi depth TLs = 5.10 + 2.27log10 (1/ZSD – 1/40)

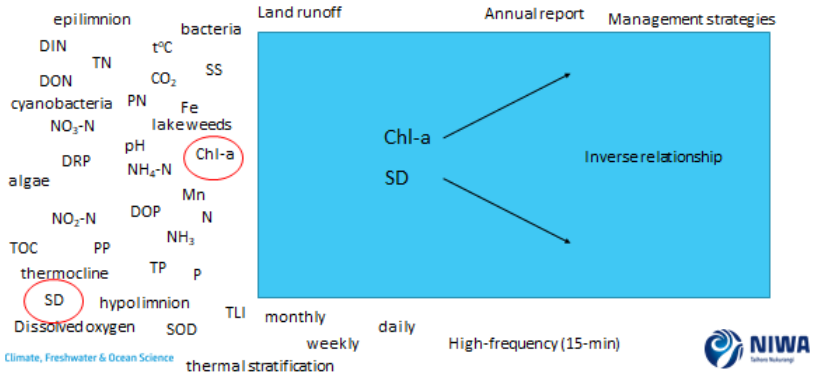
NIWA

The TLI is a record of the past and all the other data are the paths to the future.



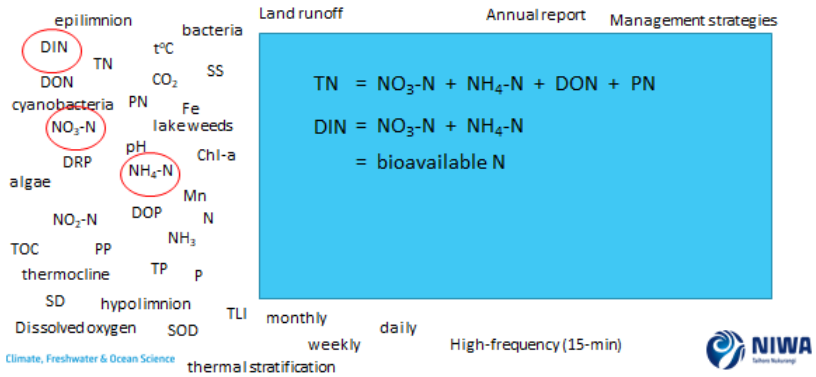
The mechanisms and interactions look at chlorophyll and Secchi depth. We cannot do anything about chlorophyll and Secchi depth is a measure of chlorophyll turbidity, so there is an inverse relationship, as chlorophyll increases Secchi depth goes down, and vice versa, so we cannot manage those.

Mechanisms and interactions: Chl-a, SD

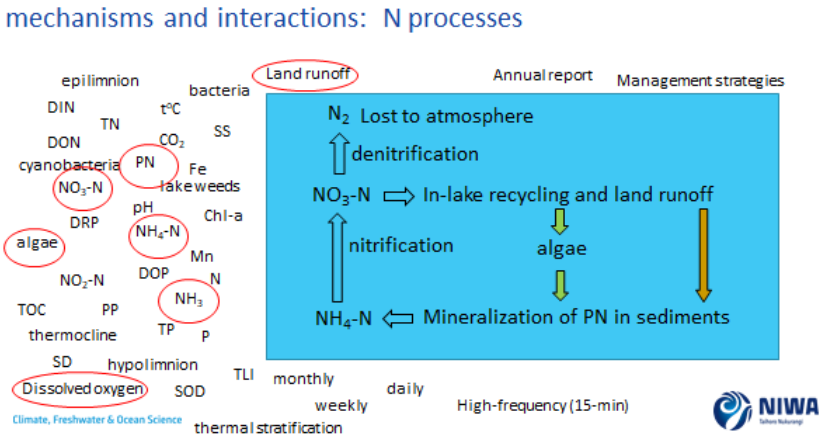


But what we can do is manage the TN or the TP that goes into the chlorophyll. Total nitrogen is a composition of nitrate ammonium and dissolved organic nitrogen and particulate nitrogen. It is only the nitrate and the ammonium which are bio available. Our measurements are always focussing on totals, whereas the controlling factors are in fact dissolved components. For instance, nitrate comes from in-lake recycling and the land run off of nitrate itself. In the lake the algae use the nitrate and the runoff goes into the sediments as particulate nitrogen, mineralised to ammonia, released from the sediments, and is nitrified to nitrate.

We now have a situation that if the nitrate comes in contact with a sediment de-nitrification occurs and the nitrate is converted to nitrogen gas which is lost from the system. Total phosphorus has a similar sort of cycle except that DRP is the bio available P and DRP can be sequested by iron in aerobic water, and it can be released from the sediments in anoxic water.

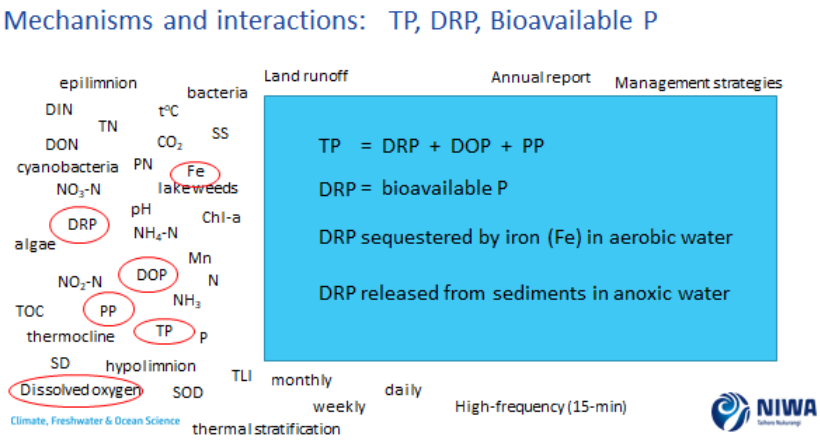


The source of DRP is in-lake cycling and in the Rotorua district it is also from the springs. The DRP in the lake becomes algae, sediments as particulate phosphorus, and is mineralised in the sediment under anoxic conditions, and it will stay there unless the overlying water becomes anoxic. The particulate phosphorus comes off the land and land management plans hopefully will reduce that component. phosphorus is bound to the fine sediments and that contributes to the sediment load in the lake.

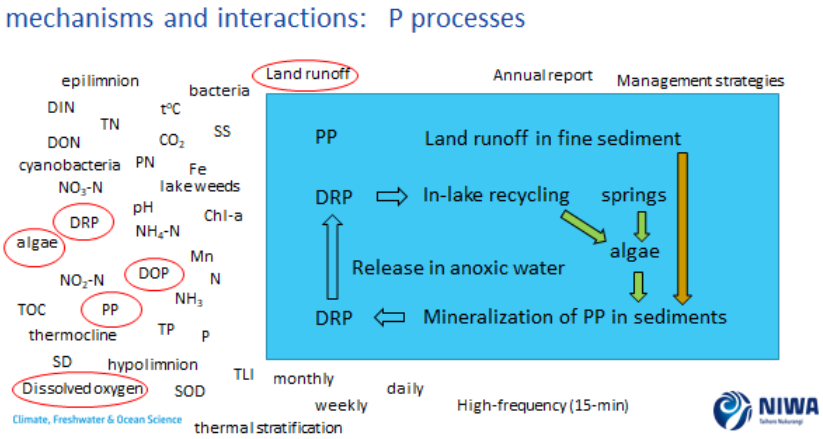


We talk about release under anoxic conditions, so how do you get anoxic conditions in a lake? You get thermal stratification which isolates the hypolimnion from the oxygen supply in the epilimnion. In other words, you cannot get the oxygen from the top water layer into the bottom water layer. If the sediment oxygen demand, that is the organic matter decomposing in the bottom of the lake, is sufficient to use all of the dissolved oxygen in

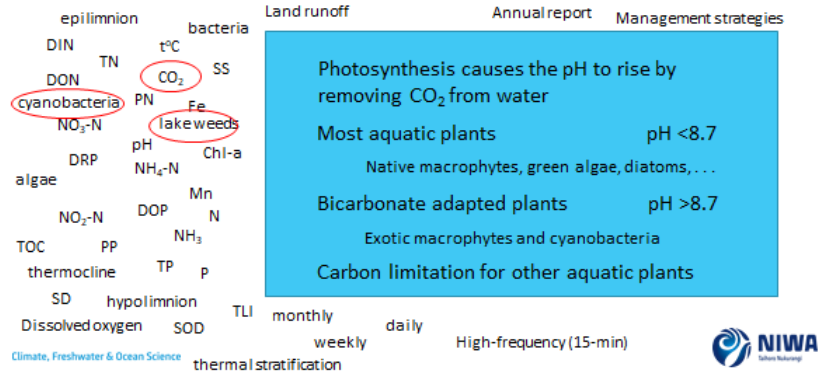
the hypolimnion before the lake next mixes, the hypolimnion becomes anoxic. Iron binding dissolves and DRP is released.



Algal growth is controlled by the bio available nutrients, so you have DRP. Nitrate and ammonia will stimulate algal growth. If you have a high ratio of nitrogen to phosphorus this favours the growth of green algae and diatoms. Conversely if you have a low N to P ratio this favours cyanobacteria, so a management might be simply to reduce the DRP. This is universally done around the world, such as alum dosing or other measures, to control the Phosphorus coming into the lake.

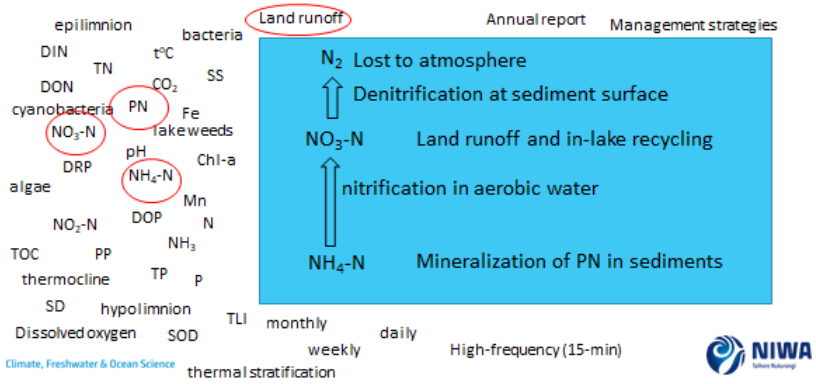


Chris Eager mentioned the pH effect which is caused by photosynthesis; this removes the carbon dioxide out of the water. If you shake a bottle of water up with a soda stream you get carbonic acid. As the algae remove the CO_2 the pH rises. Most aquatic plants native to New Zealand can raise the pH to around about 8.7 but they cannot continue

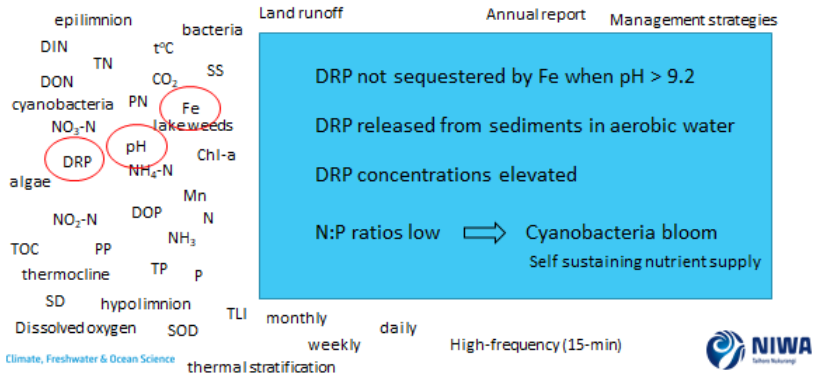


photosynthesizing above that pH. Their photosynthetic system does not cope with that. Conversely bicarbonate adapted plants such as exotic macrophytes, and C*eratophyllum* happens to be a bicarbonate adapted plant, and cyanobacteria can shift the pH much higher than 8.7. The Soda Springs in Lake Rotoehu are bicarbonate rich and maybe that is something to look at in the ability for *Ceratophyllum* to grow in there. But essentially the exotic macrophytes and the cyanobacteria convert the lake to be carbon limited. This is a factor we have not looked at before. Carbon limitation is killing the native species in favour of the exotics.

If we look at the pH effect on the nitrogen processes, our original system, with a high pH, you lose the de-nitrification because that stops. Nitrification stops because the bacteria cannot cope with the high pH. In-lake recycling stops and the ammonium NH_4 is transformed in ammonia (NH_3) which is toxic. Since cyanobacteria are one of the major suppliers of high pH in the edge water it is very likely that ammonia toxicity is the cause of fish kills when you have a near shore cyanobacteria bloom, rather than cyanobacteria toxins.

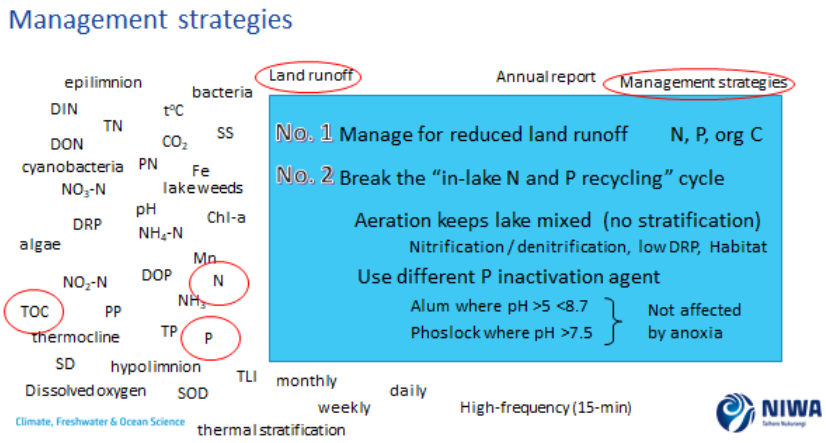


DRP under high pH is not sequested by iron and it is released from sediments in the aerobic water and the DRP concentrations become elevated in the water. So, you end up with a low N to P ratio and a cyanobacteria bloom. Now cyanobacteria require nitrogen and phosphorus, well they have already knocked out all the other competitors for nitrogen by converting ammonium into ammonia, now they have a source of DRP, which they manage, so they are mining the sediments there and become self-sustaining.



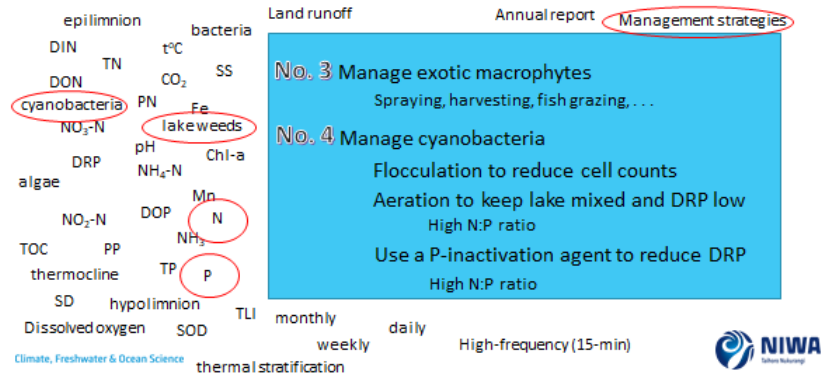
The management strategies for lake restoration need to intervene at critical points to break the key parts of the nutrient cycle. Number 1 would be manage the land catchment for reduced run off of nitrogen, phosphorus and carbon. Simon Park demonstrated the farm environmental plans which are a great way of implementing that basic strategy for

restoring lakes. The second strategy is to break the in-lake nitrogen, phosphorus recycling cycle. Aeration keeps the lake mixed, there is no stratification and you cannot get anoxic water at the bottom of the lake, therefore nitrification and denitrification can continue. You have low DRP, therefore cyanobacteria are unlikely to be dominant and there is increased habitat for the aquatic biota in the lake.



If you cannot keep the DRP low with aeration then you need a different P inactivation agent other than iron. Chris was talking about alum which is good in that it works in the pH range from 5 to 8.7 and is not affected by anoxia. If your pH is going to be 8.5 to 10 then Phoslock is an option to consider. It has not been used in New Zealand yet, but is used widely in Europe and northern hemisphere lakes.

Strategy 3 would be to manage exotic macrophytes using spraying, harvesting, fish grazing etc, and then direct management of cyanobacteria by flocculation to reduce cell counts in specific areas of the lake, aeration to keep the lake mixed, and use of P inactivation agents to drop the DRP concentration in the water. You have these strategies but you need to monitor them to determine the efficacy of the strategies that you have implemented.



We come back to our friend management strategies, how often do you monitor? Monthly, weekly, daily, or can you use high frequency data to give you information? How do you interpret the data?

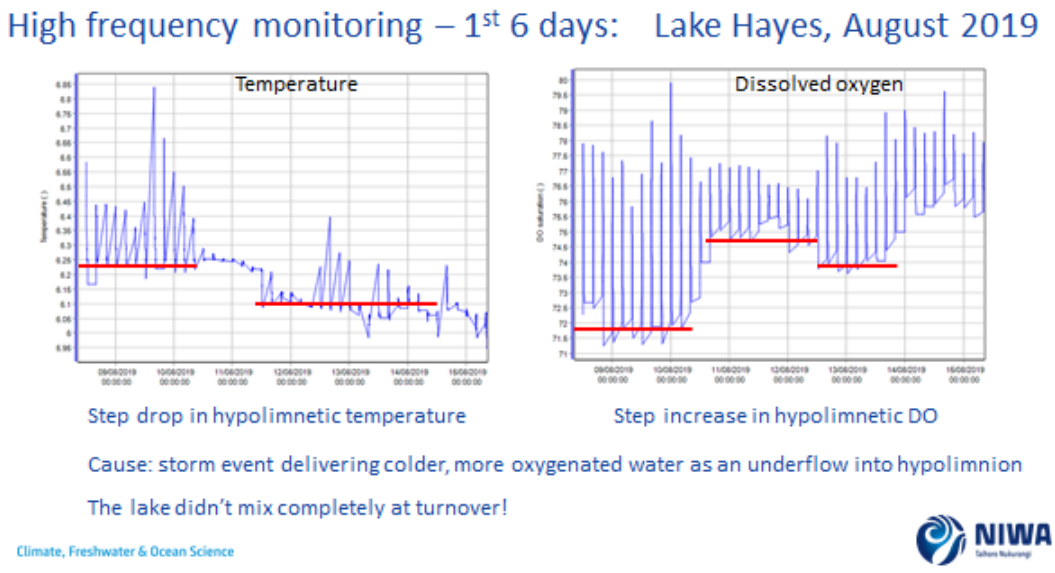
The TLI change indicates the efficacy of the management strategies. The monitoring data shows the process responses to the implemented management strategies and the monitoring data enables adaptive management. You can tweak this or tweak that to give

an improvement in whichever way you move with your TLI index. It may also indicate where and when an intervention might be most effective, get the biggest bang for the buck.

Is the monitoring and data biased? Very likely. Most of us monitor from a central lake station, one station for the whole lake. It is ok for the TLI but you are missing the action in the edge waters and it is those waters where find the fish are dying.

Manual monitoring is done during day light at the same time of day during calm conditions because we do not like getting wet and sea sick; that is biased. When designing and monitoring a programme, we should consider using a high frequency monitoring buoy, 15-minute interval data looking at temperature in the epilimnion, cyanobacteria, pH and chlorophyll in the epilimnion. Then we have dissolved oxygen in the hypolimnion as well as the temperature. This will give a lot of information about what is going on in the lake and maybe even new information.

Recently I looked at the data from Lake Hayes, the first 6 days of a new monitoring programme using a monitoring buoy, put in by Chris McBride. The graph gives a profile that starts on the bed of the lake and periodically rises to the surface, basically the temperature of the hypolimnion, which is 6.25 approximately and should not change. But we had a sudden drop in the bottom water temperature and an increase in oxygen. What causes that? A storm event went through the system and caused excessive run off, resulting in a high volume of water flooding into the lake. It was colder than the lake surface and under flowed into the bottom of the lake. But it was water that was fully oxygenated and it raised the oxygen content of the bottom of the lake.



What do we gain form this piece of data? In those 6 days we learnt that the lake does not mix completely at turn over. A management strategy might be to implement a mixing regime to get oxygen at full concentration after turn over.

I will leave it at that point. Thank you.

QUESTIONS

Ian McLean, LWQS: Thank you, what should be done next please?

Max Gibbs: The simple answer would be to say 'it all', but we need to look at the data already collected with a critical eye, to make sure that it is appropriate and that we have not got corrupted data. We need to understand what processes are going on, not just the TLI, but the components that are driving the TLI. We can adjust those so that the value of the TLI can be shifted in the right direction.

Professor David Hamilton: Max as you are aware there are a lot of other options, some coming out of Europe for what has and has not been used in controlling algal blooms. A couple of things that were not mentioned, hydrogen peroxide has become very popular in some of the Dutch lakes with various caveats around whether or not it is useful and safe, but it is one that has certainly been popularised. Two or three other things that we could discuss later.

The critical point is - are you controlling the actual bloom or are you controlling the factors that lead to the bloom? One of them is a sustainable long-term approach; the other deals with the acute effects of the bloom that impact on recreation. What do you want to do in terms of the lake?

This is partly a comment for you but partly the fact that there are lots of new things coming on the market for controlling cyanobacteria blooms. The big difficulty that I see with new things such as nanobubbles is that people marketing them are not willing to invest in evidence-based science to underpin their product. A good example is Phoslock which is now widely accepted, but has taken 20 years to get to that point. We need to turn things around and say to these people who push their product to the managers, who are being inundated, that without good evidence based science to underpin these techniques, they need to go away.

Max Gibbs: Thank you David, the spontaneous treatment of a bloom by flocculation or peroxide or any of these other algal knockdown methods, even nanobubbles, does not treat the symptom as you rightly point out. The symptom is an ecosystem being driven by excess DRP available . Not total phosphorus , but DRP , so the DRP factors need to be looked at, reducing the amount that comes off farm land. Changing the system to reduce the anoxia is the longer-term remedial action . But as David said there are a lot of other mechanisms.

My talk was to bore you to tears with the chemistry, hopefully I have done that and shown you what we have that has not been looked at yet. In other words, the data bases which are incredibly valuable, thank you.

LAKE ROTOEHU RESTORATION: FUTURE ACTIONS

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TRANSCRIPT

There have been some good presentations ahead of me, I knew that they were going to be good and I thought I would do something a little different to keep your attention. Max has put together a really good description of the in-lake processes which people would appreciate, but I am a lot simpler than you Max. I am going to get a piece of equipment. I could not figure out whether I should play you the harmonica or the guitar so I will play them both. The song came to mind yesterday when Don Atkinson said something about Lake Rotoehu, and Stuart (Session Chair) said there is no time for a long presentation so I will not sing all the verses.

Andy sang 'Father and Son' by Cat Stevens

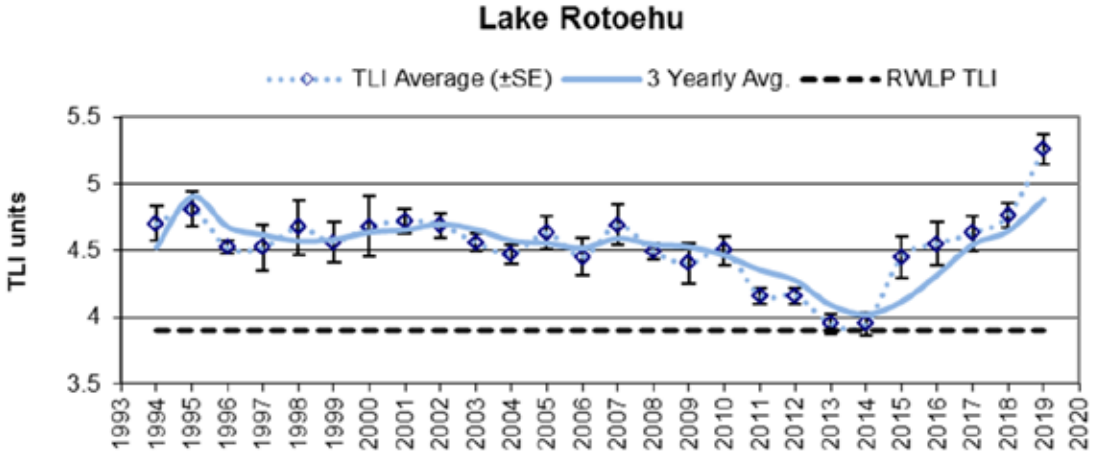
Don called Lake Rotoehu the problem child, and that song is a bit of advice to the problem child. The opening words link to what Lars Anderson said in his keynote speech yesterday about restoration programmes around the world often being a two or three year project doing a lot of work and then running out of funding. This presentation of mine is about, 'It's not time to change', it is time to continue going forward. We have heard today lots of science from the people that have gone before me, especially Chris Eager and Max Gibbs, and then the leadership from Troy Baisden and David Hamilton. Those people, in their roles, can help us figure out the way forward.

You have already seen some of these pictures of Lake Rotoehu and the question was asked before, 'Is that an algal bloom or a cyanobacterial bloom? I understand that that it is a cyanobacterial bloom and they are awful. They were so thick in some arms of the lake

that it was like a nice cottage cheese which, when it does go off, goes white and is horrific, and the community does not like it.

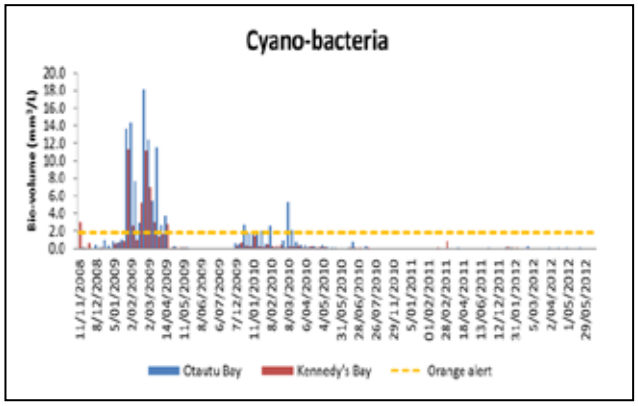
It is not the first time that it has been like that. This photograph below, taken from a helicopter was in the early 2000's and there is a bloom going right across the centre of Lake Rotoehu. This is by Kennedy Bay and the area where the *Hornwort*, or *Ceratophyllum* tends to congregate due to the westerly wind conditions in that lake when it grows. This is what the lake looked like in those times. So it has been there before and it has been bad.

We thought we had it under control because this is a graph of the TLI. You have been warned not to just rely on the TLI from Max but it is a helpful measure, or a number telling us what is going on with the lakes as we manage it. Several speakers have given an explanation of the TLI so I will just say that in the early 1990's through to the 2000's we were all upset with the quality of water there, including the community, and we started doing things and the water quality looked better, ticking along down to the dotted line. We were ready to pat ourselves on the back and do some high fives and then up it went again.



'But that doesn't matter', 'Something happened with the weather', 'It's only one year', 'It will pop back down next year'. We held our breath; we did not do any high fives that year. It kept getting worse and you can see there is a problem. We knew there was a problem a little earlier than this. Maybe we did not think hard enough about it then.

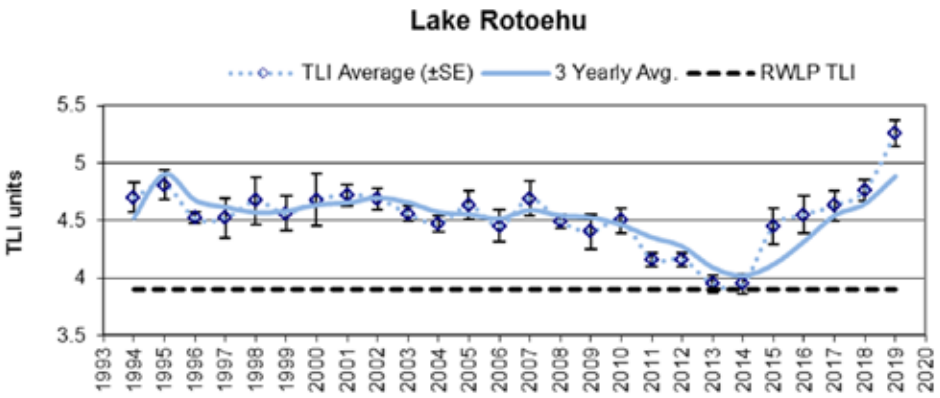
We have done quite a number of things in managing that lake over the years. In 2006 we started our weed harvesting and somebody came up with the idea that if we took the *Ceratophyllum*, this massive body of weed, out of the lake and transported it away it would remove the nitrogen and phosphorus that had been taken up during the growing season. A great idea and prior to that period, we had had cyanobacterial blooms.



This is a graph of our cyanobacterial bloom monitoring, showing the sort of numbers that we were getting. The orange line is where the Medical Officer of Health tells everybody it is a really bad idea to swim there, even if you have not figured it out for yourself because of the colour of the water. Then in 2010 we started alum dosing in the lake and soon after that the lake had very clear water quality and the community was really really happy about that.

We had been working with Ian Kusabs and Jo Butterworth to monitor koura in the lake and give us an idea as to what was going on there. One of their observations was that koura were moving into deeper parts of the lake as there was more oxygen and the lake was in a healthy state. Everybody can relate to that statement, I**f there is more oxygen, it is healthier**. We are usually a lot healthier when there is more oxygen around us and most organisms, except for anaerobic ones, like oxygen too.

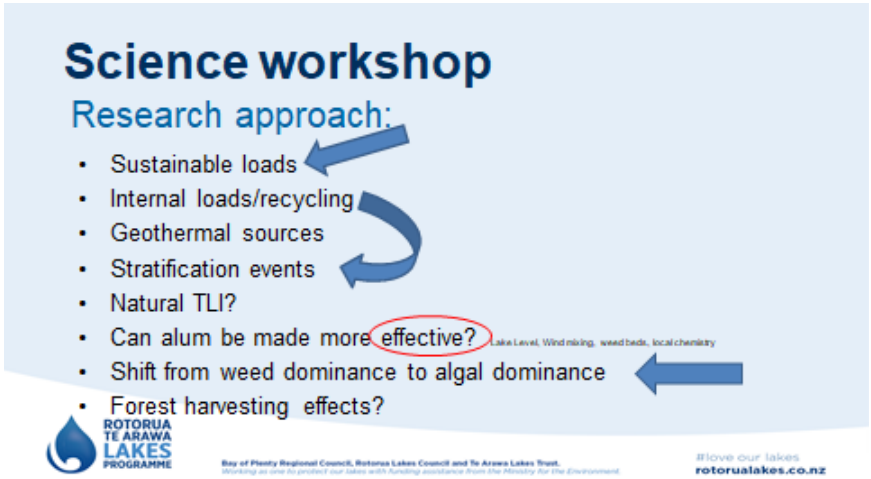
Then in 2019 we turned the alum off and you will go, 'Whoa, what did you do that for, that was pretty stupid.' Well the reason was that we knew that is was not working. Chris Eager had told us that there were some problems with the chemistry and we thought we were wasting our time. We flicked it off, which was pretty easy to do.



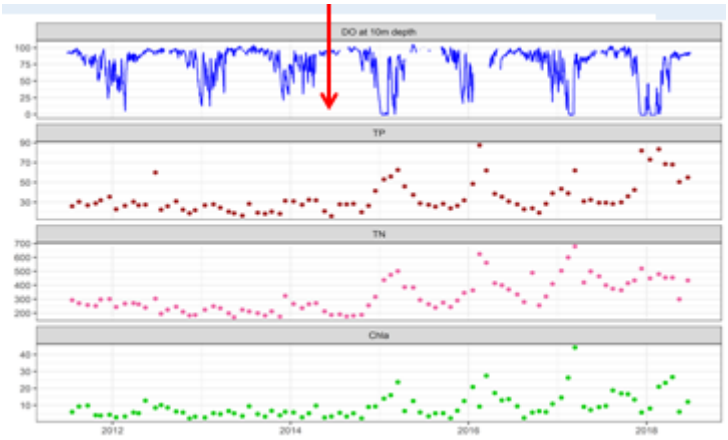
If you look again at the TLI graph, alum dosing bean in 2010 and things got better but from 2014 it began to get worse. In my mind that aligns with what Chris said that the alum was doing something, but it was not doing everything and it was not doing enough. That is what the lake looked like over the summer and right through into autumn when we had some really warm temperatures. This thing just kept on as a blooming mess.

The lake had moved from having *Hornwort*, which congregated over in Kennedy Bay and we were able to run a harvester. In fact we were so excited about harvesting weed that we bought our own harvester and for the last 2 or 3 years we have had it sitting in the shed doing nothing.

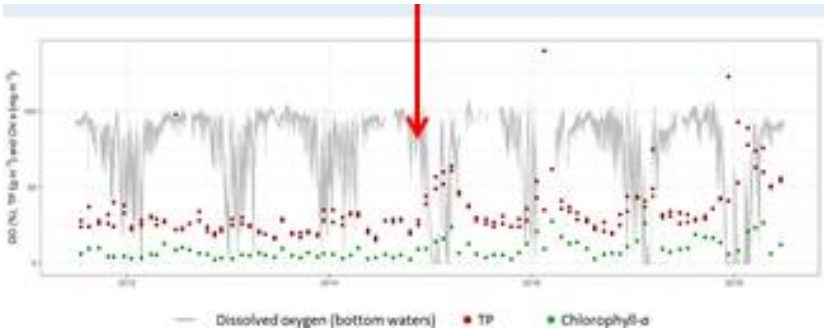
What do we do about this! We needed to go back to our science team and find out what the problem was. In October 2018 we pulled all our scientists together and had a workshop and went through all of these things. Have we got the sustainable load right? Do we know what the target should be? Was Lake Rotoehu really at a TLI of 3.9 before it started to go eutrophic? Can we make alum more effective?



We wanted to make sure we were right with the sustainable loads and at this stage (red arrow on the graph) we were about where we needed to be. That is how much nitrogen and phosphorus we need to get out of the system and we are not too far wrong.



In terms of internal recycling, I do not know whether the scientists will agree with me totally, but when a lake turns eutrophic and starts to have regular algal blooms, and it is over that TLI of 4, then this internal recycling becomes very important and drives in as much nutrient to the lake as anything going on in the catchment. We found from the work that Chris McBride is doing with his monitoring buoy that we were getting more stratification events which have then turned around to provide more nutrients from internal loading.



What I was really interested in was can we make alum more effective? One of my staff was really on to my case after this workshop. She said it was all very well to have science monitoring but what happens in 2020, then 2021, when the community says we still have an algal bloom, are we just doing a bit more science? Is there some research that we can do in parallel to see what is required to fix that lake?

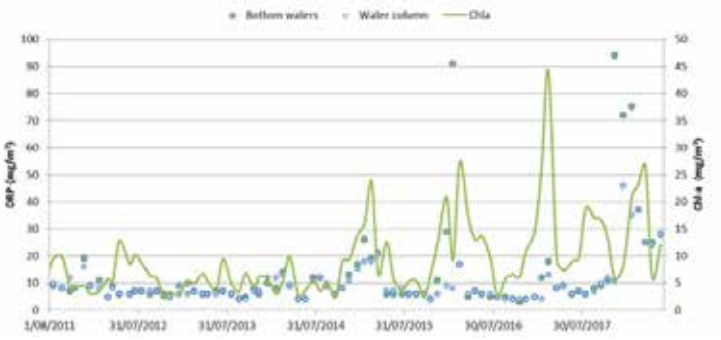
Part of the previous strategy had been weed harvesting and alum dosing and we had thought that weed harvesting had been working well about 2006. But we cannot weed harvest now because there is so much cyanobacteria in that lake. The weed cannot even see the surface of that lake and is not growing.

It might seem negative towards some of the talks yesterday around weed management but we would prefer to have a weed dominant lake, rather than an algal dominant lake in this situation so that we can use that to manage nutrients. How do we optimise the management of weeds and the management of aluminium to get the best solution? At the end of the talk you are probably going to ask questions which Max spoke about, what effect does this weed have on the release of phosphorus from sediments? So we will leave that until then.

We are reasonably confident that the appropriate land use changes have taken place within the catchment. There are two major farms in the catchment. Our staff have

negotiated with those land owners and have agreements in place and we expect that it will take some time before the nutrients, particularly Nitrogen, will clear their way through ground water into the lake and reduce the inputs.

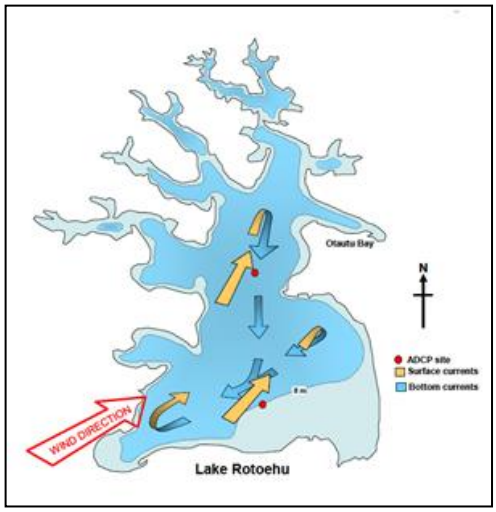
I had a discussion at our TAG some time ago that alum in Rotoehu was never as effective as with Lake Rotorua. There is a very simple metric here, Rotoehu is one tenth the area of Rotorua and not much difference in terms of average depth but we were using about one third of the aluminium in Rotoehu. So far too much aluminium has been used to lock up that DRP. This is a map of Rotorua.



This graph is the work that Chris McBride has been doing with his monitoring buoy and has given us a clue on the stratification. The green line is dissolved oxygen in the bottom waters and prior to about 2014 it was getting close to 0, but after 2014, it got right down to 0 and stayed at 0 for some time. There were long periods of stratification occurring that had not happened prior to that in this record. Associated with that stratification the purple and green, the total Phosphorus levels in the bottom waters and Chlorophyll A in the lake, were spiking up seasonally, and we did not see that in that period 2011 to 2014, so stratification is likely to be having a big impact.

The problem with any science data is that you never have enough from the time you want to look at. There was no data prior to 2011 when the monitoring buoy went into place. Murphy's Law, I think. Internal recycling became much more critical about this period of time.

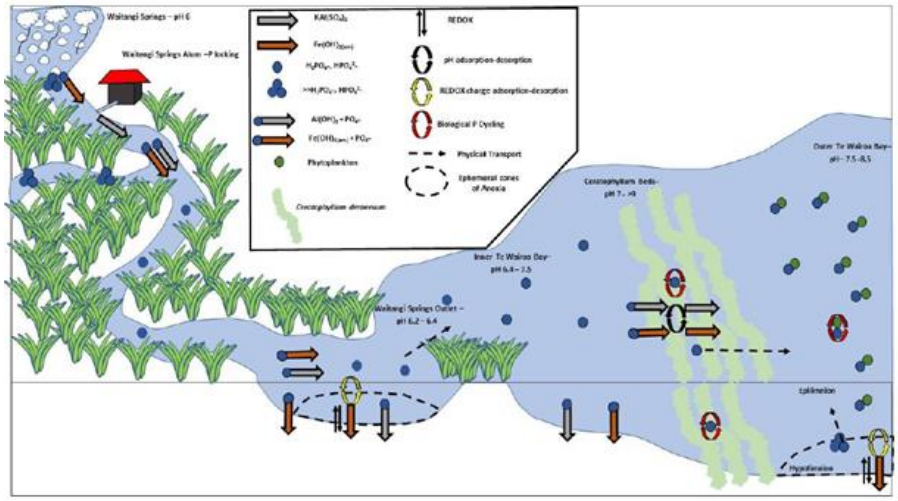
Next step is restoration



Our approach is to address algal blooms with alum dosing in the right location and to allow natural mixing. The scientists told us that alum was not working because we were putting it in the wrong location, and a whole bunch of chemistry causing problems.

I stole this diagram from Max Gibbs who has monitored currents in the lake. He said the red dot in the middle of the lake is about the best place to put the alum if we want to get it mixed within the lake and in contact with the DRP and it will mix with both the north and south currents in a natural way.

We want to address the sediment releases of P, so we believe that by putting it into that part of the lake we have a better opportunity and we are also looking at including it in a resource consent application, and an allowance to dose it in the arms of the lake, as they are quite secluded from the natural water movements of the other parts of the lake. We do not know whether that is necessary at the moment as the science has not been done but if we get the resource consent it gives us the flexibility to manage it.



We want to avoid the local chemistry inhibition that Chris has so capably described in his presentation so I'm not going to go through that diagram other than to put it up there just to remind you what he was talking about. That means we will continue to have permission to put aluminium in the soda spring, in the current location, but we will decide how much we need depending on its efficacy at that point and how much we put in the central part of the lake.

For example, when the lake is very high there is very little flow from the soda spring out into the lake, so common sense would say it is not a good time to put alum into that location at that time. It gives us opportunities now and three different locations to decide the best place to put the aluminium.

Chris also talked about weed filtering or restriction in that area and so if we take it out of there and go into the centre of the lake we avoid that. I'm not sure whether Chris talked about prevailing wind but the prevailing winds there are from the west and blow back into that area, so it is likely that it prevents the mixing back out into the lake. If we can improve water clarity then weed harvesting may become more feasible.

Summary Approach

Sustainable land use is overall what we want to achieve in this catchment but we are doing in-lake interventions to speed things up. Alum to reset the lake phosphorus, shift from algae to weed dominance, reintroduce the weed harvest, adapt alum dose rate and location, with optimising the three places, and review the science. This means reviewing the science at any stage of the process.

I put the last photograph in because Lake Rotoehu is a really beautiful lake, and very few people go there because it has a bad reputation, but it has some beautiful arms or fingers of the lake that are worth going up in a small boat and looking around.

Acknowledgements

I would like to acknowledge these people because I stole diagrams from them which I used in my presentation.

Chris McBride, Waikato University
Chris Eager, Formerly Waikato University
James Dare, BOPRC
Paul Scholes, BOPRC
Max Gibbs, NIWA

Thank you.

QUESTIONS

Ann Green, LWQS: I am interested in the weed, Andy, that you seem so keen to harvest. I could never quite understand why one had to mow the weed, because when you mow the lawn it just gets thicker. So mowing the weed in the lake seems to me to make it thicker. If you do not have weed for a while will it really come back as thick as it is or does it start small and maybe one could think about other measures like spraying it.

Andy Bruere: I am going to be really careful what I say about that because I am certainly not an expert in weed management or weed control. My understanding is that if we improve the water clarity there is enough seed of *Hornwort* for it to grow pretty vigorously and it does not necessarily start off its growth cycle within Kennedy Bay where we harvest it. It can start in other parts of the lake, but the prevailing wind brings it over there. If you said to me do you want weed in the lake as a long term objective, probably the answer would be no. But in the short-term it is an indicator that we have overcome the phosphorus and the water clarity problem and we are only using it because we can. It perhaps reflects on other lakes, we would be horrified if that weed transferred through into Lake Rotoma, only a couple of kilometres to the east. In the long-term it would be good to get rid of it.

I will also add that my strategy is pragmatic around weed management and Max has told me, and supported by what Chris is saying, that the weed might cause some pH issues and phosphorus release. We need to think about that as we go through the process and that is part of the adaptive management we need to apply to this problem and that might involve spraying the weeds sometime in the future, but I cannot answer that right now.

John la Roche: Andy if you move your alum dosing points out into the middle of the lake your pH is going to be wrong isn't it? How do you cope with that?

Andy Bruere: I am going to defer that to Chris if you wouldn't mind?

The original answer to this question was not recorded but Chris has given this reply by email.

Chris Eager: You have raised a good point. Rotoehu at the buoy generally hovers around pH7-8 at the lake surface. What is less certain is the spatial vertical variability in pH with depth seasonally. Chris McBride did have the profiler buoy out for some time during the aeration experiments so perhaps there is data there? Alum floc forms best around pH 5-6. Alum's P binding capacity is better in the pH4-6 range. Rotoehu, has a reasonably high alkalinity so its buffering capacity to resist acidification (from alum dosing) is quite high.

Andy Bruere: Great thanks Chris, I hate to answer a question when I have an expert sitting there.

Nick Miller: This may or may not be relevant to what you have been talking about today, but back in the early 1970's for about a year I was collecting monthly phytoplankton samples for Dr Vivian Cassey Cooper from Lake Rotoehu about 100 meters off the southern shoreline near the beginning of Hongis track. She lives about a kilometre from Waikato University, It might be worth seeing if she has the records of what she counted from those samples.

Andy Bruere: Thank you Nick, I will be in contact with you for the right information on that.

Max Gibbs: The question that was asked before, if you get weed back are we going to have a pH problem? The short answer is yes, the long term is that you have the way of managing it because you have a weed harvester which can take the growing tips off the weed. We will remove the Nitrogen and Phosphorus in the traditional 16 to 1 ratio atomic, the pH is caused because photosynthesis is occurring. If you can maintain the weed levels low, you should be able to have clear water without the pH effect.

Lars Anderson: Just a couple of comments on the weed problem. We had the same conversation at Lake Tahoe and one of the strategies we have there is not to get rid of all the plants for the same reasons you have mentioned. To keep the idea of what this is; if you dry the plants you get about half to 1% P dry weight in the plant, and about 2.5 to 4% nitrogen. You can do the calculations on how many tonnes you pull; you are not going to remove that much nitrogen compared to what is in the sediment for example. But it is true, if you get rid of all the macrophytes you are going to wind up with a clear water situation but not sequestering nutrients in the water column very well. We are proposing at Tahoe to maintain native plants in those Tahoe Keys for example and not get rid of everything for the same reason.

There was a company in California about 20 years ago called Nutripod and they put Hornwort in large cages in ponds to extract nutrients from the pond water to maintain low levels of nitrogen and phosphorus. It kind of worked until they started putting in milfoil by mistake and then we had a problem.

John Green, LWQS: From the Waitangi Spring point of view, have you been monitoring its chemicals and pH for the last 10 years and is that consistent? Or has there been a surprise change that you are not aware of?

Andy Bruere: I am going to see if Chris can help me with that one.

Chris Eager: I am sure GNS monitors the Waitangi Spring outflow for numerous chemical variables on a regular basis, so there is some data there. From anything that I have measured, and the Council has put a pH meter at the inflow in the lake, any measurements have shown no change in the pH. Chris McBride has been monitoring the buoy for many years and the lake pH fluctuates between 7 and 8 from what we have seen, so I would not say it is variable.

Troy Baisden: I was going to interject the numbers from the Action Plan and the Hornwort harvesting. Back at its peak in 2014 and 2015 we were taking almost 3,000 tonnes of harvest per year with an action plan target of 708 kilograms per year of P reduction. According to the accounting we are achieving nearly half a tonne at most of the target via the removals of the Hornwort. It is comparable to achieving that in Taupo or Tarawera or Rotoma which is crazy, but it is quite a different situation in Rotoehu now. Exactly what we do here is quite interesting. So that is as I said a comment, you can decide whether we have all done or not.

ACTIONS AND SYMPOSIUM WRAP-UP

Ian McLean, LWQS
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What great, challenging papers we have heard today. Thank you to all the presenters.

It is splendid to see the progress that has been made in 20 years. I pay tribute to Professor David Hamilton (here today) who revived both lake science in New Zealand and research into the Rotorua Lakes. More than that, he spent many years building relationships with the community here, both Maori and Pakeha. He stayed nights at the fish hatchery. Many times he did the late night drive home to Hamilton through fog and frost. He and his students built up the science and relationships that we have today.

Biosecurity and Lakes

During the Symposium Dr Lars Anderson, (US Department of Agriculture), told us that lake science is harder than rocket science.

He described the numerous pests and weeds that the US authorities face - many of which potentially threatened our lakes. In one sense that does not daunt us. In New Zealand we are used to the threat of foot and mouth disease, fruit fly, or *Mycoplasma bovis*. We live with such threats from abroad.

But what is mind blowing is that aliens are here amongst us. Each lake has its own pests and they differ one from another. These threats are mostly local and from our neighbours in the Waikato.

My view is that for more than 20 years we largely ignored biosecurity for the Rotorua Lakes, and have been playing catch up over the past 5 years.

We were told that ***each lake needs biosecurity borders***. Professor Troy Baisden spoke of changes that need a new approach to science. It requires a huge cultural and disruptive change to think that border security must exist **lake by lake**. This cultural change is about as big as that which led to the Rotorua City Council ceasing to dump garbage on the lake edge about 40 years ago so. In order to bring about such a change of culture a massive public education programme is needed.

Clean Boats

The Symposium was titled 'Float Your Boat, Certify'. The objective was made clear by presenters, and I paraphrase it, 'All Boats Clean'. Robert Win (Environment Southland) put it as: ***Clean boats to be the norm.***

Several presenters showed that bringing about such a change requires several steps; education, communications, monitoring and enforcement. Nicole Cartwright, (Lake Tahoe Resource Conservation District, USA) said that experience at Lake

Tahoe shows that lake biosecurity programmes '***need to have teeth'***. This is because there will be hoons (my word, not hers). Lake-users often meet hoons on the water - people lacking responsibility. The New Zealand surveys reported to the symposium showed that such people are less likely to keep their boats clean.

The LakesWater Quality Society proposal was introduced to the Symposium by Don Atkinson. It involves self-certification of the cleanliness of every boat by its skipper before it is launched in any of the Rotorua Lakes. Certification would be through an app provided, and failure to certify would make a skipper liable for an instant fine. This is ***very light-touch enforcement.*** It would take time to introduce. It was pointed out to us that the earlier steps of education, communications, and monitoring can start right now. Some education and monitoring are already being done by the Bay of Plenty Regional Council, but more could be done as preparation for further action.

It was suggested that stickers be provided for owners to put on their boats. Such stickers could show the home lake of the boat and words on the sticker saying, '***I clean, dry and drain my boat'***. Perhaps the sticker might also show the logos of organisations such as Fish and Game, Te Arawa Lakes Trust, the Councils and LakesWater Quality Society. An expanded education programme with elements such as this could start very quickly and not require any legislation.

Toolbox and technology

I want to congratulate the Regional Council staff, especially Andy Bruere, who are implementing the whole lakes programme, for the great work done over many years.

The weed and pest control toolbox available to the Regional Council was discussed by several presenters. New technology is obviously becoming available all the time. Some of it may work, some may not. NIWA are now evaluating two new chemical herbicides.

My question is this:-

- Who each year refreshes the Regional Council's knowledge of technology available elsewhere in the world?
- Is there an annual snapshot taken and reported to Regional Council?
- Is such information provided to the Regional Council internally, is it done by NIWA, is it done by the University of the Waikato, or is it not done systematically?

If the cleanliness of boats is to be monitored, boats need to be identified - for which there is no legal requirement at present. Lack of registration is not an insuperable barrier to enforcement. While transported on land, boats are on trailers - and every trailer has a registration plate. It would be possible to remotely-sense boats going in and out of the more sensitive lakes and identify them by the trailer plate registration number. What's more, if it is possible to use facial identification on sheep (as has been reported), 'facial recognition' should be possible for boats.

The technology needs to be kept up-to-date: e.g. remote sensing, both under water and from space. This should be reviewed annually and assessed.

Strategy

The Regional Pest Management Plan is primarily a regulatory document, rather than an operational document. There are Lake Management Plans which are operational documents. Hopefully there is also an operational strategic plan which is revised frequently. Such a plan should also be made widely known to the public. Several speakers emphasised the need for continued monitoring as part of the strategy for weed and pest control.

Legislative constraints

It is clear that current legislation constrains weed and pest management.

For example: the symposium was told that EPA (Environment Protection Authority) requires new chemicals to be proven to be safe by New Zealand field trials before being used. However field trials are not permitted unless the chemicals are first proven to be safe. No chicken, hence no egg – and vice versa.

Many people now consider that planning and consenting under the RMA seem to be devices to make lawyers rich. The process of getting a consent is drawn-out. But it is not consultation with the public that takes so much time: the legal processes cause much of the delay. Lodging a formal objection on one of these consents or plans will initiate letters on expensive lawyers' letterhead for the next 2 or 3 years, every one of which probably costs $100 to write.

Both the Biosecurity Act and the RMA (Resource Management Act) are being reviewed. Better legislation can't come soon enough.

Funding

Hon David Parker stressed the intense competition for public funds. He did suggest the Provincial Growth Fund as a possible source for immediate needs of the Rotorua Lakes. Guy Salmon suggested an application to the Provincial Growth Fund to initiate wallaby control in New Zealand - perhaps $20 million or so to cover more than half the costs. Wallabies are now spreading. There have been rumours of them north of Auckland, and that might not be unhelpful to an application for the Provincial Growth Fund.

Iwi

Concern was expressed that Iwi have not participated in this Symposium as much as is desirable. I pay my respects to Ngāti Tarāwhai whose people spoke to us and to my friends the late Joe Malcolm, and Willy Emery whose health is not good. The challenge is for the LakesWater Quality Society to do more to facilitate engagement with iwi. Maybe a small symposium on a suitable marae would help.

Economics of Biosecurity

Carla Muller, an environmental economist, made it quite clear that green, smelly lakes create large economic costs. These costs are real but hard to measure. For example: tourists are not attracted to Rotorua when stinking piles of lake weed crawling with maggots are reported in the media – as they were historically.

We were told of the testing of various rules of thumb to indicate the costs of each of the possible stages of intervention: from *exclusion* through to *control*. One rule of thumb is the belief that ***prevention is much better than cure;*** i.e. keeping weeds and pests out, rather than dealing with or living with new incursions. The data that Carla Muller presented to the symposium was consistent with ***an ounce of prevention being worth a pound of cure***, even though it did not fully prove the proposition.

Other lakes

Perhaps the best way to summarise the presentations on the Tarawera and Rotoehu Lakes is this: we have learnt a lot and there is much more good science available, but very much more is needed. Clearly, Rotoehu and the 8 Tarawera Lakes were shown to be major works in progress.

Rerewhakaaitu

Farm Environment plans in the wider Tarawera catchments were discussed by Simon Park (LandConnect). Chris Sutton spoke about the Farming Collective Plans at Rerewhakaaitu. In my view Chris under-sells himself and the importance of the Rerewhakaaitu plans. These can greatly assist the implementation of the proposed National Policy Statement for Freshwater (it proposes the stimulation of groups around the country to link with the authorities).

At our first Symposium many years ago Chris Sutton accepted responsibility for his farm's discharges of nutrients. He went home and persuaded his fellow farmers to accept responsibility for their farms' discharges, and for the health of Lake Rerewhakaaitu. Despite the best efforts of some bureaucrats, the Rerewhakaaitu farmers managed to keep control of their programme over 18-19 years. Without decrying the good work done in the Rotorua catchment, Rerewhakaaitu is a shining example of what is needed throughout the rest of country. Thank you Chris.

Thanks

Finally, thanks to all the presenters and organisers of the Symposium. Thanks to the Regional Council, Rotorua Lakes Council and Ministry for the Environment for the funding programme for the Rotorua Lakes. Thanks to Te Arawa Lakes Trust for their partnership. May I also congratulate Don Atkinson on his great leadership of LWQS. Thank you all.