Proceedings

ROTORUA LAKES SYMPOSIUM 2015

Lake Weed and Wallabies

Their Role and Control in the Ecology of the Rotorua Lakes

12 – 13 March 2015
Sir Howard Morrison Performing Arts Centre
(Rotorua Convention Centre)
1170 Fenton Street, Rotorua, 3010

Hosted by

LakesWATER QUALITYSociety

EDITOR'S NOTE

Material for the Symposium Proceedings has been received 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 numbering relates to the slides used not the original PowerPoint presentation. The papers were sent to the original presenter to ensure they were satisfied with the transcription.

Panel discussions have 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, Sue la Roche, a LWQS member, 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, Ian McLean who always has good advice and excellent editing skills, 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

Disclaimer: These Proceedings report the formal presentations and open forum sessions of the Symposium, which was designed to encourage open discussion amongst those managing, studying or with an interest in the Rotorua Lakes region. The information is **not** intended to substitute for official policy statements from parent organisations.

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LakesWATER QUALITYSociety

- their role and control in the ecology of the Rotorua Lakes

Sir Howard Morrison Performing Arts Centre (Rotorua Convention Centre)
1170 Fenton Street, Rotorua, New Zealand

	Thursday 12 March		Friday 13 March
8.00	*Registration*	8.00	*Registration*
	Session 1: Scene Setting ***Chair: John Green, LWQS***		***Session 5 : Ecological Health of the Catchments*** ***Chair, Mayor Steve Chadwick, RLC***
8.15	Karakia and Opening	8.30	The Importance of Restoring the Rotorua Lakes Mayor Steve Chadwick, Rotorua Lakes Council
8.20	Te Arawa - Kaitiaki of Te Arawa Lakes Dr Sir Toby Curtis, Chair, Te Arawa Lakes Trust	8.40	New Zealand's Indigenous Forests - Their Status and Drivers of Change Dr Rob Allen, Landcare Research, Lincoln
8.30	Current State of the Rotorua Lakes Prof David Hamilton, Waikato University	9.10	Ecological Perspectives Willie Shaw, Wildland Consultants Ltd
9.00	Weed Management - Lessons from the USA Dr John Madsen, Agricultural Research Service US Department of Agriculture and UCDavis	9.35	Okataina Phosphorus Study Theodore Kpodonu, Waikato University
		9.40	The Link Between Erosion, Phosphorus and Water Quaility Dr Max Gibbs, NIWA
9.50	10 min Discussion	9.50	10 min Discussion
10.00	*Morning Break*	10.00	*Morning Break*
	Session 2 : The Issues ***Chair, Cr Lyall Thurston, BOPRC***		***Session 6 : Control of Animal Pests*** ***Chair, Dr Ken Hughey, Chief Science Advisor, DOC***
10.30	Weeds and the Rotorua Lakes Dr John Clayton, NIWA	10.30	Control of Pests in Lake Catchments Dr Alastair Fairweather, Department of Conservation
10.55	Crown Perspective Hon Dr Nick Smith, Minister for the Environment	11.00	BoPRC Experiences with Animal Pests Dale Williams
11.15	Busting Myths on Water Weeds Mary de Winton, NIWA	11.20	Perspective of a Consultant and Contractor Cam Speedy, Wildlife Management Associates
11.35	Speaker Panel & Discussion	11.50	20 min Discussion
12.00	*Luncheon Break*	12.00	*Luncheon Break*
	Session 3 : The Toolbox ***Chair, Clive Howard-Williams, Freshwater and Estuaries, NIWA***		***Session 7 : Responsibilities and Funding*** ***Chair, Willie Emery, Te Arawa Lakes Trust***
1.00	Purpose of Weed Harvesting Dr Fleur Matheson, NIWA	1.00	Watching for Invasive Species - Public Engagement Tracey Burton, Freshwater Ecologist NIWA
1.20	Rotoehu Weed Harvest Programme Richard Mallinson, BOPRC	1.20	Statutory Responsibilities and Barriers to Action Guy Salmon, Ecologic Foundation
1.40	Bio-control of Aquatic Weeds Dr Quentin Paynter, Landcare Research	1.40	Weed Management Agency role David Mole, LINZ
2.00	Spraying as a Solution Dr Deborah Hofstra, NIWA	2.00	Consenting Road-blocks Angus McKenzie, Latitude Planning Services
2.20	10 min Discussion	2.20	Speaker Panel & Discussion
2.30	*Afternoon Break*		
	Session 4 : Lake Weeds - The Way Forward ***Chair, Prof Chad Hewitt, Head, School of Science, Waikato University***	2.50	Closing Comments John Green, LWQS
3.00	Potential Lake Rotorua Scenarios Dr Max Gibbs, NIWA	3.00	*Symposium Concludes*
3.20	Okawa Bay - Case Study Paul Scholes, BoPRC		
3.40	Case Studies Rohan Wells, NIWA		
4.05	Biosecurity Management Overview Paul Champion, NIWA		
4.25	10 min Discussion		
4.35	Wrap up summary of day Dr John Madsen		
5.00	*Free-time*		
6.00	***Pre-Dinner Drinks 7.00pm Symposium Dinner***		

For previous Symposia Proceedings, Newsletters and Water Quality Information please refer to the Lakeswater Quality website

http://www.lakeswaterquality.co.nz

Bay of Plenty REGIONAL COUNCIL

Destination ROTORUA

NIWA Taihoro Nukurangi

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FOREWORD - ROTORUA LAKES SYMPOSIUM 2015

LAKE WEED AND WALLABIES

John Green
Chair, LakesWater Quality Society Inc.

The Rotorua Lakes Symposium 2015 is the 9th event of its kind hosted by the LWQS. It was held in Rotorua at the Sir Howard Morrison Performing Arts Centre on 12-13 March 2015. The theme of the symposium was lake weed and wallabies and their role and control in the ecology of the Rotorua Lakes.

With the success of the Rotorua Te Arawa Strategy Group's Action Programmes in restoring the 12 Rotorua lakes, greater water clarity has resulted in higher levels of photosynthesis with more growth of lake weed, especially introduced species. Our Society was interested in the management and control techniques which would successfully contain, control or eradicate invasive weeds.

On the first day lake weed was addressed with the help of many experts with wide ranging skills and experience. Our guest speaker from the United States, Dr John Madsen of the Agricultural Research Service, US Department of Agriculture, set the scene and showcased lessons from the United States. The Hon Dr Nick Smith, the Minister for the Environment, gave us an enlightening and informative overview of Government's policy on freshwater management

The speakers gave us a rich insight into the challenges of introduced pest and lake weed species. Our special thanks go to John Clayton and his team at NIWA who demonstrated their world class knowledge of the different ways to deal with the management of invasive species. We also thank the NIWA team for assistance in planning the Symposium.

The second day focused on the ecological health of our lakes catchments, particularly Lake Okataina, and the role of wallabies and other browsing animals. The speakers gave a strong insight into the practical aspects of pest eradication and containment and left us with much food for thought. They showed that the problem of the increasing phosphorus in Lake Okataina is complex and that there is more work to be done. We sincerely thank all speakers for their presentations and participation.

I would like to thank the Session Chairs for their excellent conduct of the programme – Cr Lyall Thurston, BOPRC; Dr Clive Howard-Williams, NIWA; Prof Chad Hewitt, University of Waikato; Mayor Steve Chadwick, Rotorua Lakes Council; Dr Ken Hughey, DOC: and Ian McLean, LWQS.

Finally I would like to thank our sponsors. Without their support our Society would not be able to bring these important scientific symposia to life – Bay of Plenty Regional Council, Rotorua Lakes Council and the Rotorua Energy Charitable Trust.

I know you will enjoy reading these Proceedings and hope that they add to your understanding of this interesting aspect the restoration and management of our Rotorua Lakes.

John Green
CHAIRMAN

Session 1 : Scene Setting

SESSION CHAIR – John Green, LakesWater Quality Society

TE ARAWA – KAITAKI OF TE ARAWA LAKES

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

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

He also chaired the North Harbour Secondary Schools Union, and the National Maori Sports Association. He is currently Chair of Te Arawa Lakes Trust, Chair of Rotorua Te Arawa Lakes Strategy Group, Deputy Chair of Te Wananga o Aotearoa Council and a member of both the Iwi Leaders Forum and the Police Commissioner's Forum.

TRANSCRIPT

Kia hiwa rā! Kia hiwa rā!	Stay watchful, stay watchful
Kia hiwa rā i tēnei tuku,	at this lookout
Kia hiwa rā ki tērā tuku.	At that look out
Whano, whano! Haramai te toki!	Behold, behold, our defender has come
Haumi ē! Tāiki ē!	Peace and tranquillity will prevail

Cultural Framework

The Te Arawa Lakes Trust has embarked on a project to develop a Te Arawa Cultural Values Framework, in regard to the 14 lakes located in our tribal region. There are a host of positives that we believe can accrue as an outcome of this exercise. Already the calibre of people acknowledged for their cultural expertise have added a lot by their attendance. Their presence and contribution injected a level of enthusiasm and confidence in the compilation of the final draft. It is hoped that distribution among the wider community will elicit constructive feedback.

Rights and Interests in Freshwater

Negotiations on iwi rights and interests have been ongoing for a number of years now, between the Crown and the Iwi Leaders Group. The word 'ownership' was deemed unhelpful in the process. It tended to highlight the exclusive element. Hence 'rights and interests' were seen as a neutral term and therefore more preferable. At this stage the Land and Water Forum, together with Local Government NZ, are keen for Iwi and the Crown to come to an agreed understanding re 'rights and interests', by yesterday if possible!

Hon Minister, I could not forfeit this wonderful opportunity to emphasise the sooner timeline, rather than later. On behalf of the Iwi Leaders' Forum, thank you for resourcing the Land and Water Forum, to enable them to continue their sterling work.

Again, I join our Chair John Green and his team to welcome you all to this conference.

A, kāti. Ngā manuhiri tūārangi, ngā mātāwaka, ngā mana hurihuri noa tō tātau whare - tēnā koutou, tēna tātau katoa.

E kore te aroha e maroke i te rā.

CURRENT STATE OF THE ROTORUA LAKES

Professor David Hamilton, BSc PhD
Biological Sciences
The University of Waikato
Hamilton
davidh@waikato.ac.nz

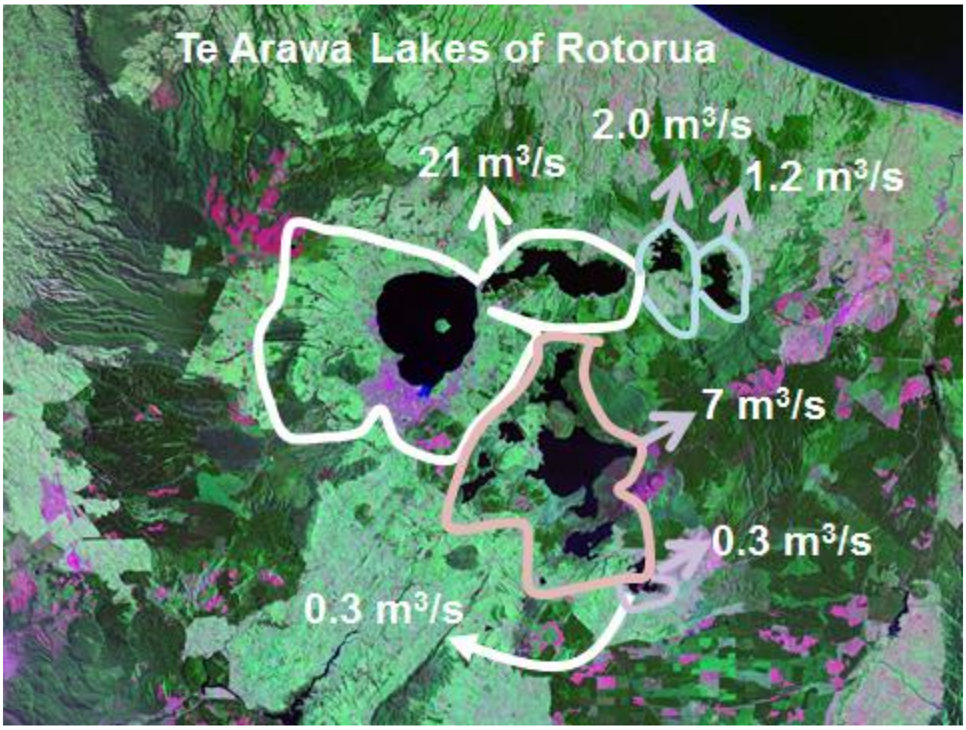
David Hamilton is a professor in Biological Sciences at the University of Waikato and is the inaugural holder of the Bay of Plenty Regional Council Chair in Lake Restoration. In this role he provides support for the Rotorua Te Arawa Lakes Programme including as a long-standing member of the Water Quality Technical Advisory Group for the programme. Hamilton is immediate past president of the New Zealand Freshwater Sciences Society (2010-2014), was a founding member of the Global Lake Ecological Observatory Network (GLEON; 2004) and helped establish the International Society for Limnology journal Inland Waters (2010). He holds an adjunct professorial position at the Nanjing Institute of Geography and Limnology in China. During his Ph.D. study at the University of Otago, Hamilton examined water quality of 10 lakes on the east coast of the South Island. He then held post-doctoral and faculty positions at the University of Western Australia where, as a member of the Centre for Water Research, he developed computer models that are widely used for lake modelling across the world today.

ABSTRACT
The Rotorua Te Arawa Lakes' programme of restoration has arguably been the most ambitious and effective of any for a group of lakes around the world. It has been characterised by willingness to 'try things', to be guided closely by scientific input, and to now have excellent structures for monitoring and implementation of actions. Still, major challenges remain. One of these is the potential for a sense of complacency, particularly when some lakes have responded extremely positively to in-lake treatments (e.g. Rotorua) or major one-off actions (e.g. Rotoiti). It is essential that these improvements in lake water quality, some of which may not be able to be maintained indefinitely in their current mode, not delay further catchment management actions.

Another challenge is exotic oxygen weeds, particularly where it is difficult to harvest large accumulations. The final challenge relates to climate. Recent years have been characterised by droughts and intense rainfall events that challenge land management practices. Further, surface water temperatures in the lakes in 2015 have been greater than at any time in the past. If these changes are symptomatic of a future climate, then there will need to be greater effort put into building resilience in the lakes and their catchments.

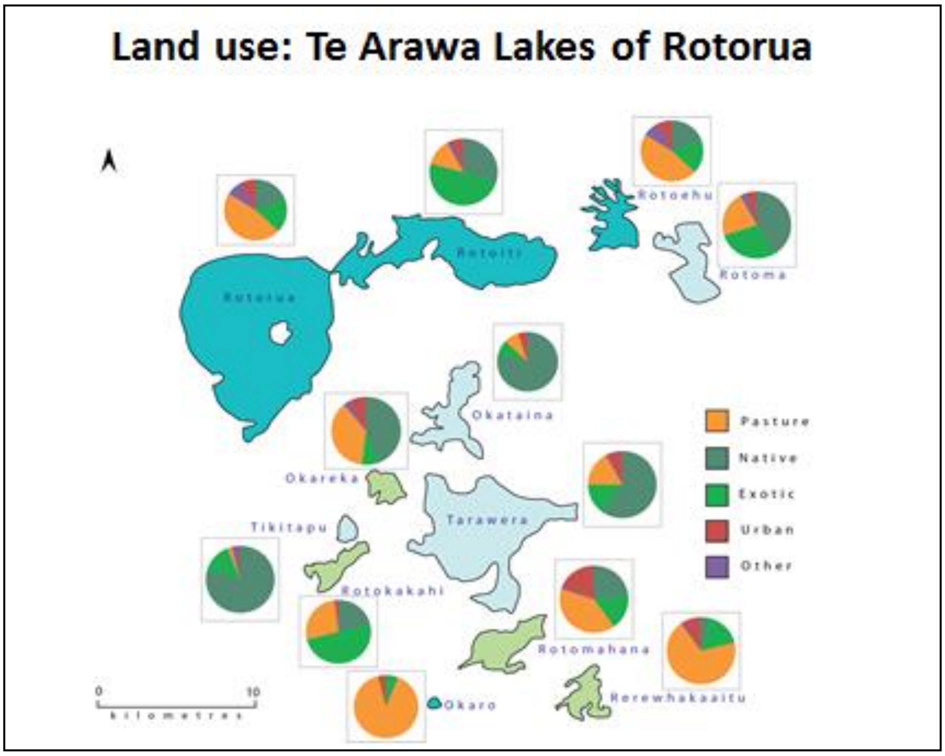
TRANSCRIPT
One of the most interesting things that I have been involved in recently has been considerations of wastewater treatment for many of the lake communities. The amount of wastewater that is produced is tiny by comparison with the amount that falls on the landscape and runs off, but it is a significant nutrient source and also one of the most expensive to treat. In terms of treatment costs, for example, we talk of more than $1,000 a kilo to remove phosphorus so that it does not have an impact on the lakes. Obviously one of the considerations is how we evaluate these relative sources of water and wastewater nutrients to the lakes.

Slide 1



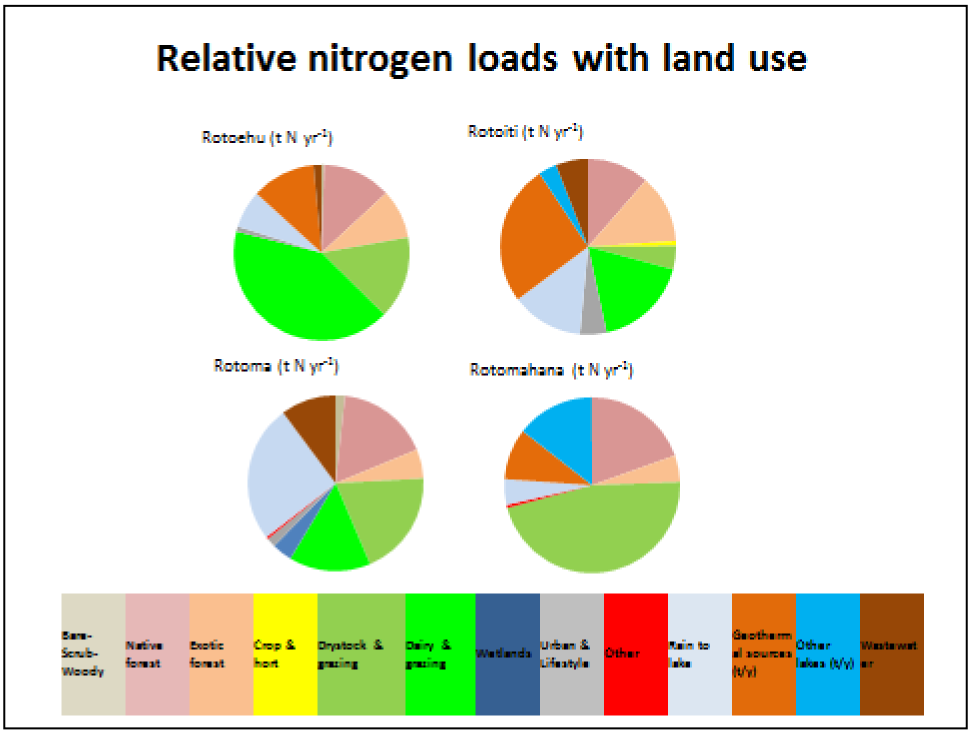
We do not often look at the bigger picture of what is happening with the amount of water being transported around these lakes. **Slide 1** shows that 21 cubic metres a second goes down the Kaituna River and out into the ocean through the Kaituna-Maketu system. There are small and largely unknown outflows for Rotoehu and Rotoma and 7 cubic metres a second exits through the Tarawera outflow. Lake Rerewhakaaitu to the south is interesting. The best we know is that roughly one third goes down the Waikato River, one third goes to the Rangitaiki and one third into the Tarawera catchment. It is a relatively small flow but for someone in Hamilton, they would have been drinking a few molecules of water from their tap that originally had fallen in the Rerewhakaaitu catchment.

Slide 2



Slide 2 (above) shows the land use of the 12 lakes that are included in the programmes of management and restoration by the Rotorua Te Arawa Lakes Strategy Group. Considering 14 lakes (including some of the southern Te Arawa lakes), there is a variety of different land uses. We would like to think that lakes with totally native catchments are pristine, but I am sure we are going to hear plenty on that today (with regard to weed invasions). On the other hand Lake Okaro, furthest south, is almost totally dominated by pasture.

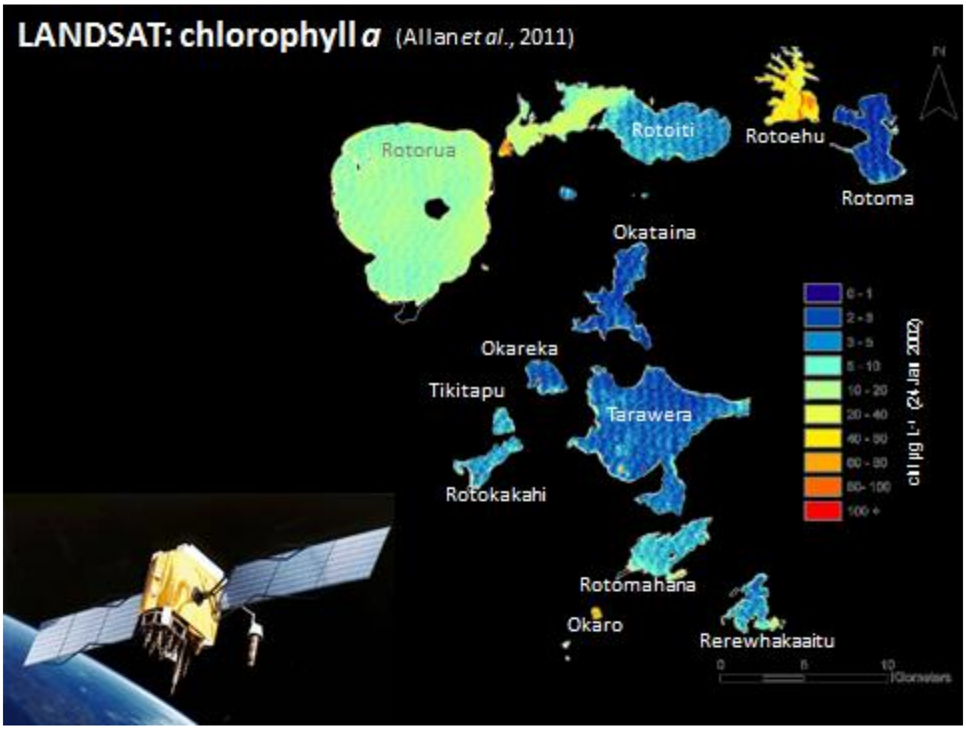
Slide 3



With this information we can look at different land use types and make a conversion assuming specific rates of nutrient export for each of those land uses. **Slide 3** shows the export of total nitrogen for four of these lakes. The scale at the bottom corresponds to different land uses. Of course for a lake like Rotomahana there is a large component of pastoral land use which impacts on the lake water quality. Lake Rotoiti itself has a relatively small pastoral component and hence part of the success of the Ohau Channel diversion wall was to take away the inputs from the Rotorua catchment, which is about 50% pastoral by area. In one hit, by constructing the diversion wall, we were able to remove a very substantial percentage of the nutrient inputs from Lake Rotoiti.

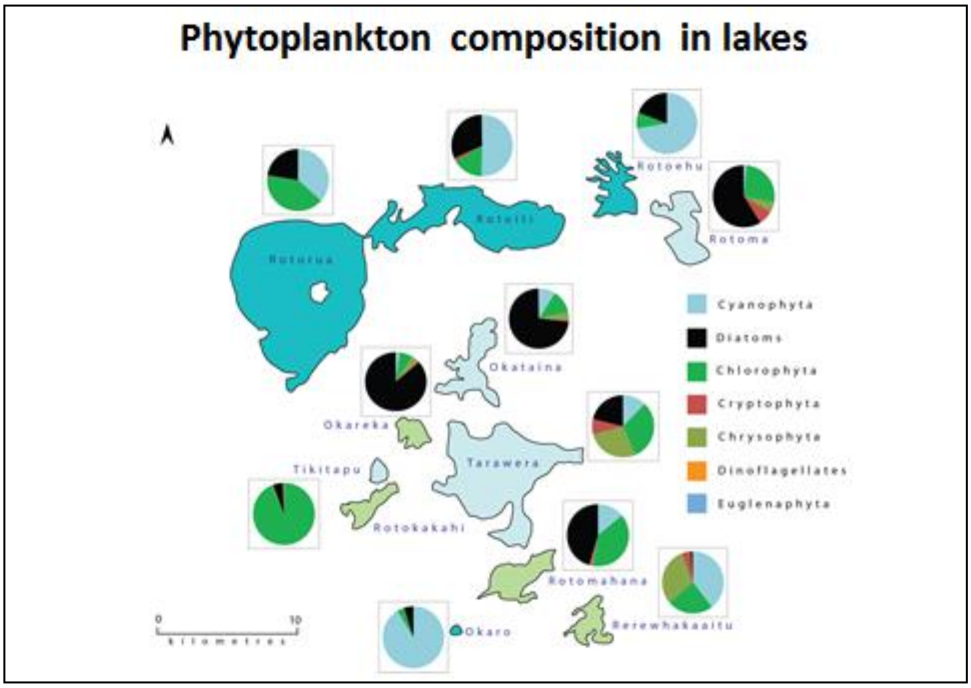
There are a couple of other factors that influence the water quality of these lakes. Shallow lakes tend to be more productive than deep lakes. With more light relative to the lake volume there are higher levels of chlorophyll *a*. **Slide 4** (over) is a LANDSAT chlorophyll *a* image taken pre diversion wall. For Lake Rotoiti, for example, there is a big chlorophyll gradient from west to east, which was largely due to the input of nutrients from Rotorua. As a result there was a lot of algal growth in the shallower part of the western basin compared with the eastern basin. Some of the other shallow lakes like Rotoehu and Okaro are dominated largely by pasture, and much more productive in terms of the amount of chlorophyll *a,* or algal concentrations

Slide 4

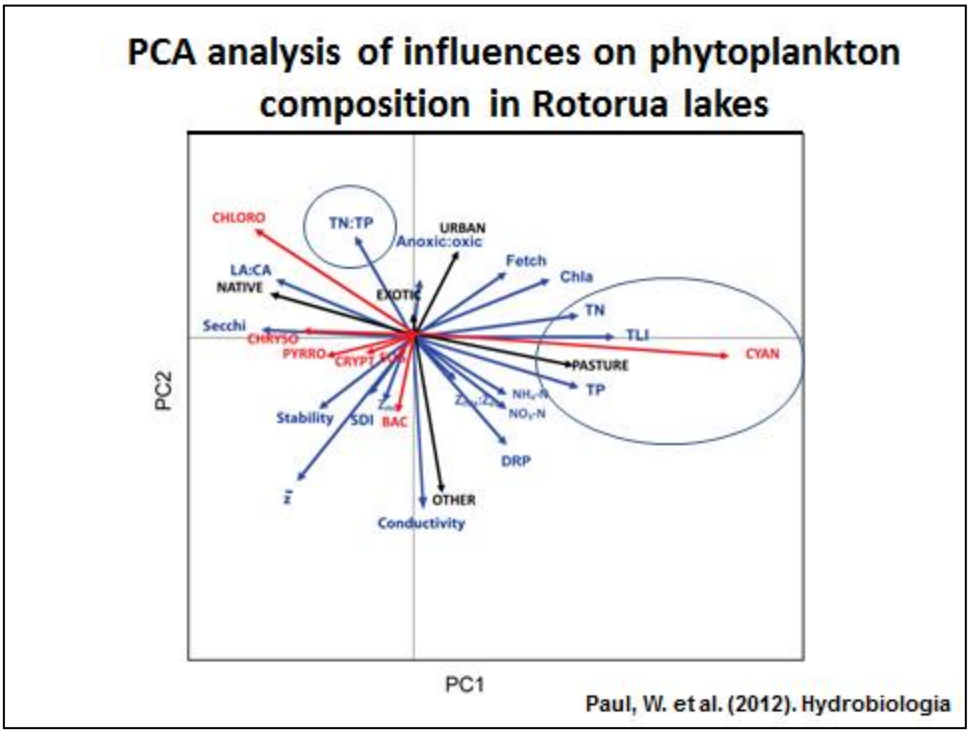


Water quality means different things to different people. One of the important influences on water quality is the phytoplankton composition (**Slide 5**); the different types of algae that grow in these lakes. A lake such as Tikitapu is predominantly one group, chlorophyta. Lake Okaro has another group, cyanophyta, or blue-green algae which dominate. Changing the composition with more and more nutrients changes the types of algae that grow in these lakes. Okaro for example is very nutrient enriched and has mostly blue-green algae. By contrast lakes such as Tikitapu have very low nutrient concentrations and as a consequence do not have high levels of blue green algae. These blue-green algae are the ones that tend to float and accumulate in bays and can cause health problems.

Slide 5

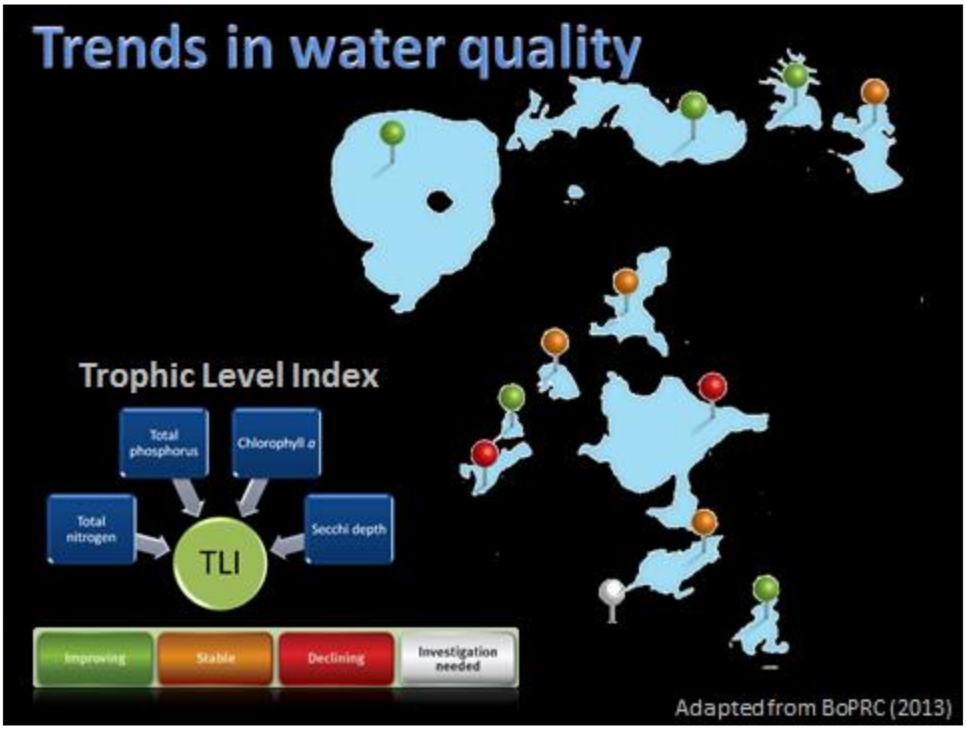


Slide 6



Slide 6 is a Principal Components Analysis of the influences on phytoplankton composition in the Rotorua Lakes but it is useful to point out the key features. The blue-green align statistically with some key drivers; total nitrogen, the Trophic Level Index (TLI) used to indicate the trophic state of these lakes, the amount of pasture in the catchment and total phosphorus concentrations. It is logical increases in nutrients lead to more blue-green algae (cyanobacteria). By contrast the 'good guys' of the phytoplankton communities, the chrysophytes, the chlorophytes and the diatoms, group out the other way aligning with lakes which have lower nutrient concentration in the lakes.

Slide 7

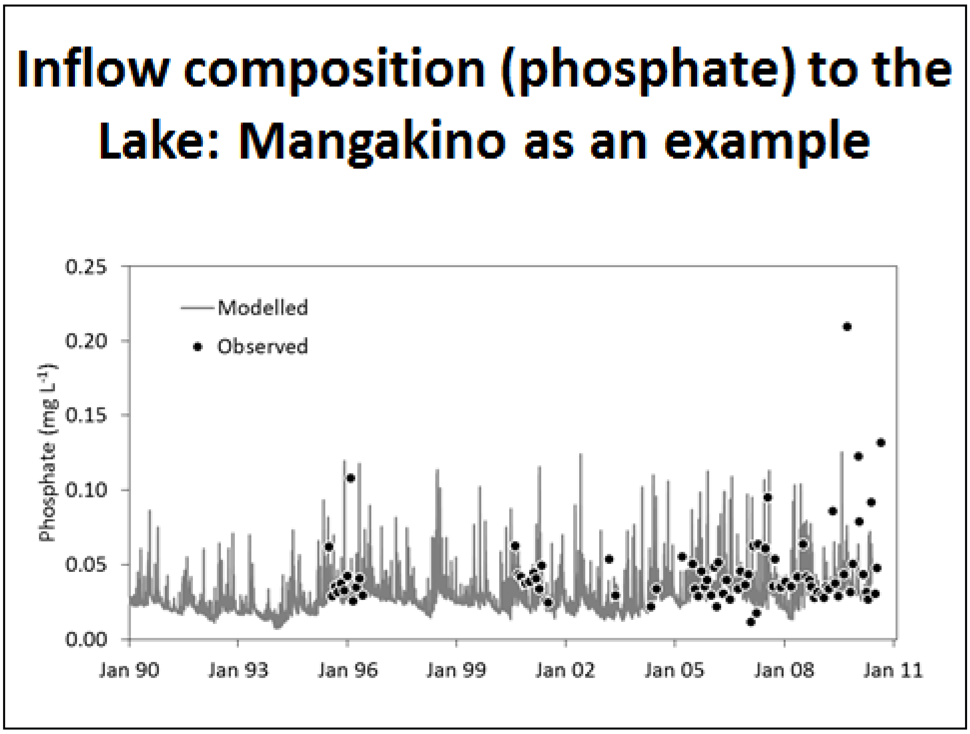


Nutrient ratios did not appear to have any bearing on the types of algae in the lakes. These ratios have been hugely contentious recently. There is pressure to limit just one nutrient (e.g., phosphorus), or alternately nitrogen, but in this particular case it is both nutrients that limit phytoplankton in the Rotorua lakes.

What about the trends? **Slide 7** (above) shows some of the lakes are improving and it is no coincidence that these lakes have had major engineering interventions to address their poor water quality. Alum dosing has been used in Rotorua and in Rotoehu and also in Okaro, and of course the diversion wall has been constructed in Lake Rotoiti. By contrast other lakes are stable. Some such as Tarawera are showing signs of decline.

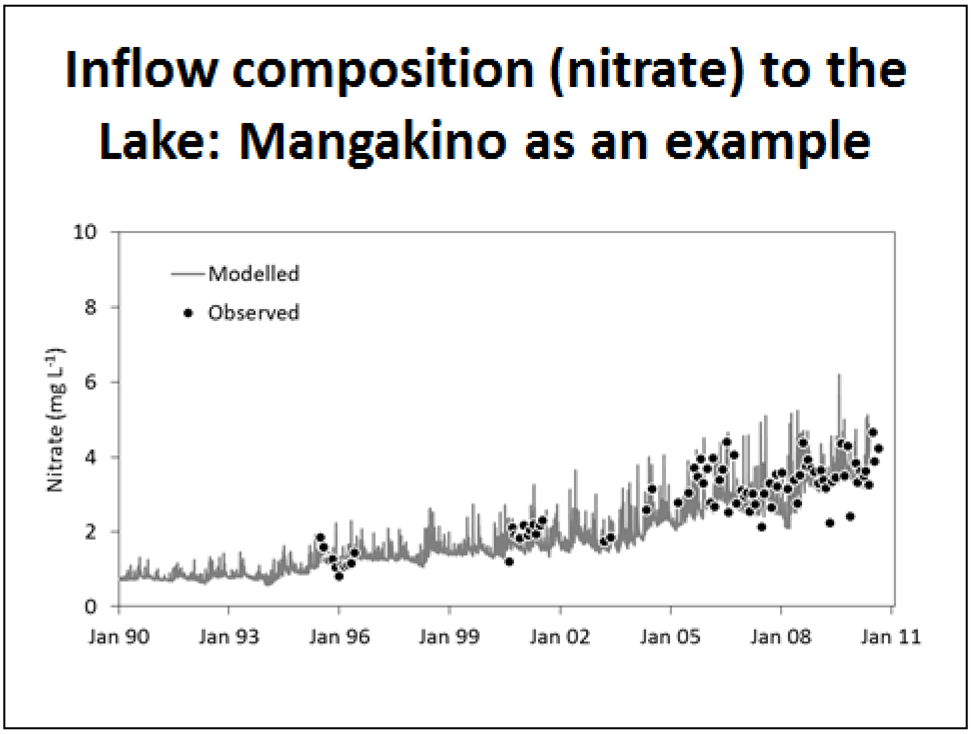
Rerewhakaaitu is a fascinating case study. Its catchment area is dominated by pastoral land use, particularly dairy. However, the catchment is comparatively tiny compared with the lake area which is one of its distinguishing features. Many of the lakes such as Rotorua have a very large catchment area relative to the lake area. We need to be cognisant of what the lake area is when making land use change within a catchment. Although Rerewhakaaitu is a small catchment the lake is still in pretty good shape - mesotrophic - in the middle range of trophic state.

Slide 8

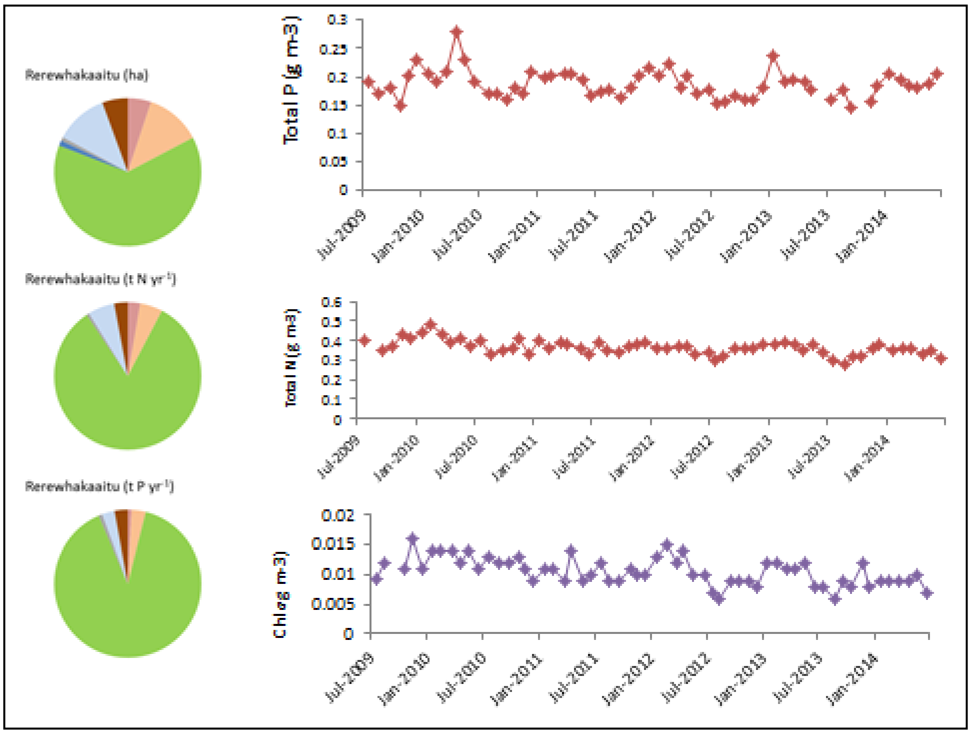


Slide 8 shows the Mangakino Stream inflow to Rerewhakaaitu. It shows no particular trend through time in phosphorus concentrations. If anything there may be a slight hint of decline. However, there may be some very high concentrations recently and these may be linked to extreme climate events rather than land use practices per se. In **Slide 9** (over) there is a very significant trend in nitrate shown in the Mangakino Stream which reflects gradual accumulation of nitrate from the impacts of land use change in the aquifer that ultimately supplies the Mangakino Stream and goes into the lake.

Slide 9



Slide 10

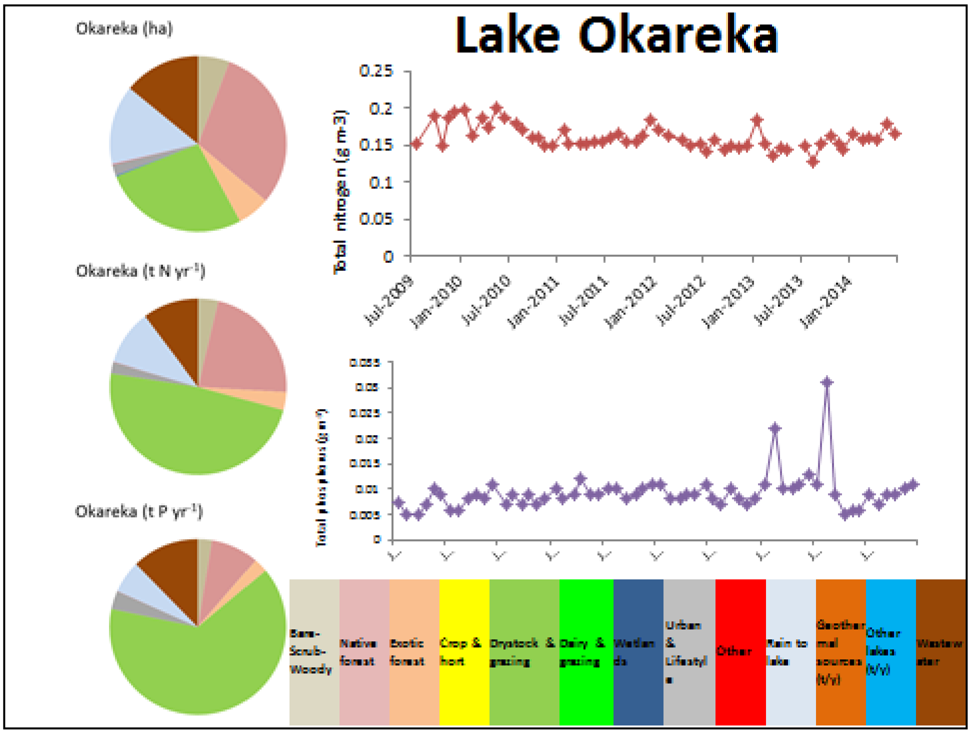


This trend in the stream inflow may appear as a potential driver of deterioration in the lake but in fact the time trend in **Slide 10** shows total phosphorus as relatively stable and perhaps even slightly declining; total nitrogen not changing; and chlorophyll *a* concentrations as probably declining slightly. A distinguishing feature of this catchment is that over the 10 or 20 years there have been improvements in the management of land, particularly in terms of phosphorus. As it happens phosphorus is the critical limiting nutrient in this lake. The soils in the catchment have a particular capacity to absorb phosphorus and as a consequence the changes that occurred in nitrogen are not reflected in changes in chlorophyll *a* as an indicator of the algal concentrations.

Slide 10 also shows that pastoral land use contribute a disproportionate amount of the nitrogen and phosphorus loads to Rerewhakaaitu, but this lake is being saved by two redeeming features:

1) The catchment area is so small relative to the lake area
2) The soils are very absorptive of the phosphorus that may get into the lake

Slide 11

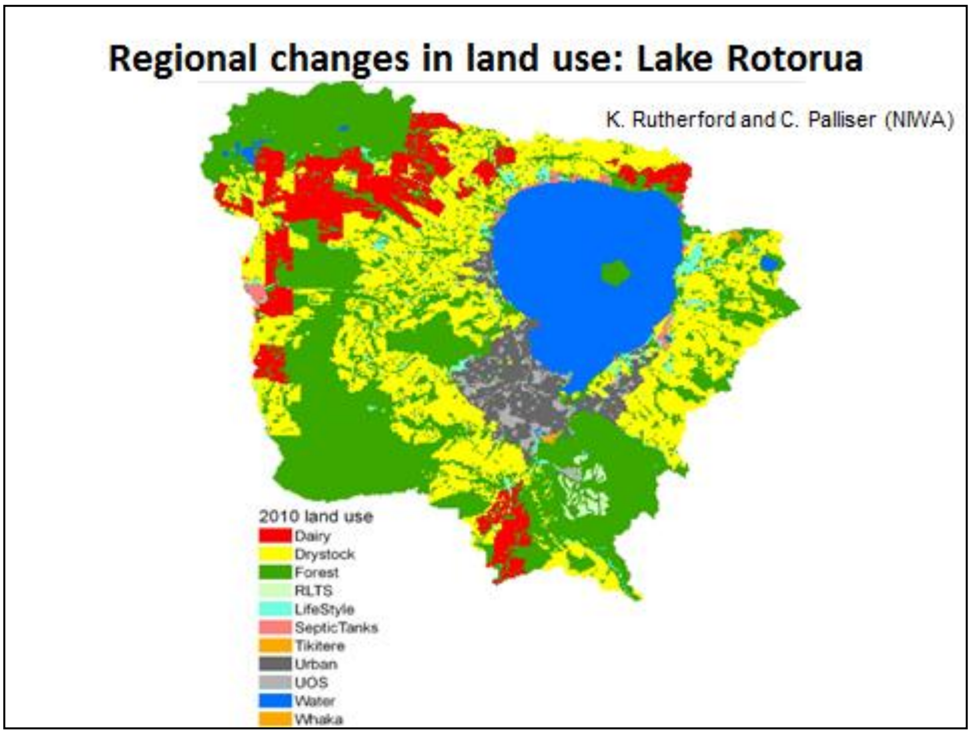


Lake Okareka **(Slide 11)** shows that the total phosphorus is trending up slightly. I have not looked at this trend statistically. The extreme high values are probably associated with some of the extreme rainfall events that we have had recently. There is not a lot of change in total nitrogen, maybe even a small decline that may possibly be related to the reticulation of wastewater in that catchment. Generally, despite the fact that that catchment underwent wastewater reticulation about 4 or 5 years ago, there has been very little change in the nutrient concentrations in the lake. In terms of chlorophyll *a* there has been a slight increase. So the changes that could have been brought about with either changes in land use practises or land use itself, have not taken place and as a consequence there is a small increasing trend, at least for phosphorus.

Rotorua has a 425 square kilometre catchment, 80 square kilometres of lake and is relatively shallow. One of the remarkable things that has occurred, which is often overlooked, is the fantastic work by Kit Rutherford examining changes in land use through time, from the 1940s to the current day **(Slide 12)**. The gradual change over a number of years ultimately led to changes in the catchment; from forest and scrub to pastoral and dairy farming.

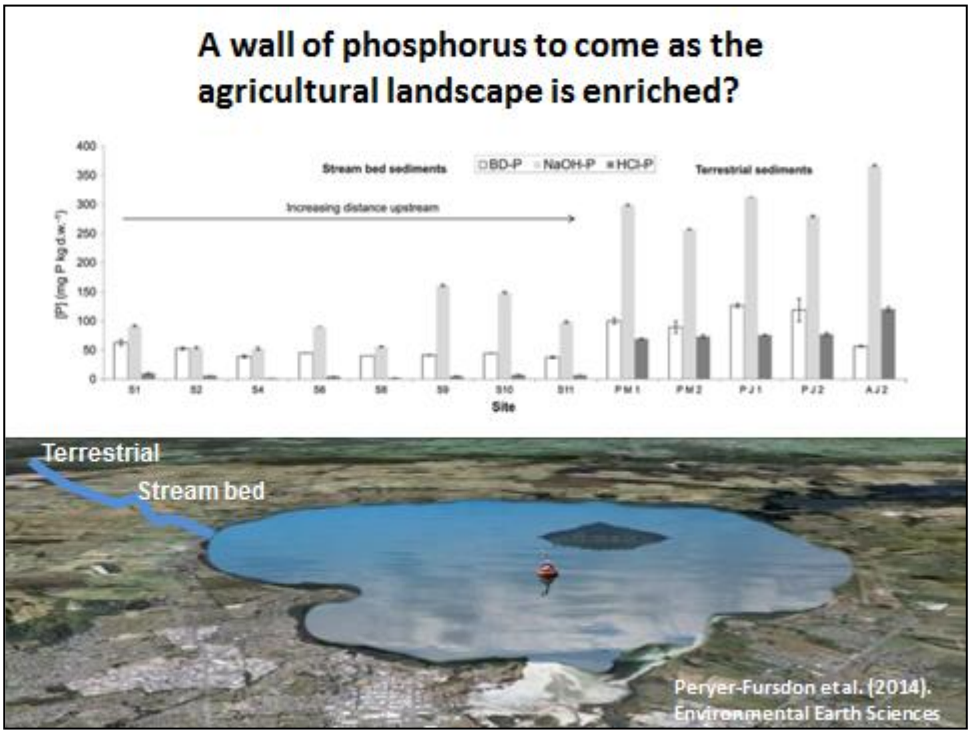
Part of the response to that changed the deterioration in lake water quality has been alum dosing, which has been designed to lock up some of the phosphorus arising from the Utuhina and Puarenga Streams

Slide 12



GNS has done a lot of examining transport of nitrogen from the catchment of Lake Rotorua to the catchment. We know that the groundwater aquifers in the Rotorua catchment are gradually enriching in nitrate, but we have not thought so much about phosphorus in terms of a potential load to come to the lake. **Slide 13** shows a longitudinal profile from a stream bed up into the terrestrial catchment. The size of the bars at difference locations represents the phosphorus concentrations of the sediment at that location. The agricultural sediments are enriched as we would expect but the stream beds have a much lower concentration of phosphorus. So it is at this point that we start to ask – what happens if these sediments get into the stream beds? They are obviously going to

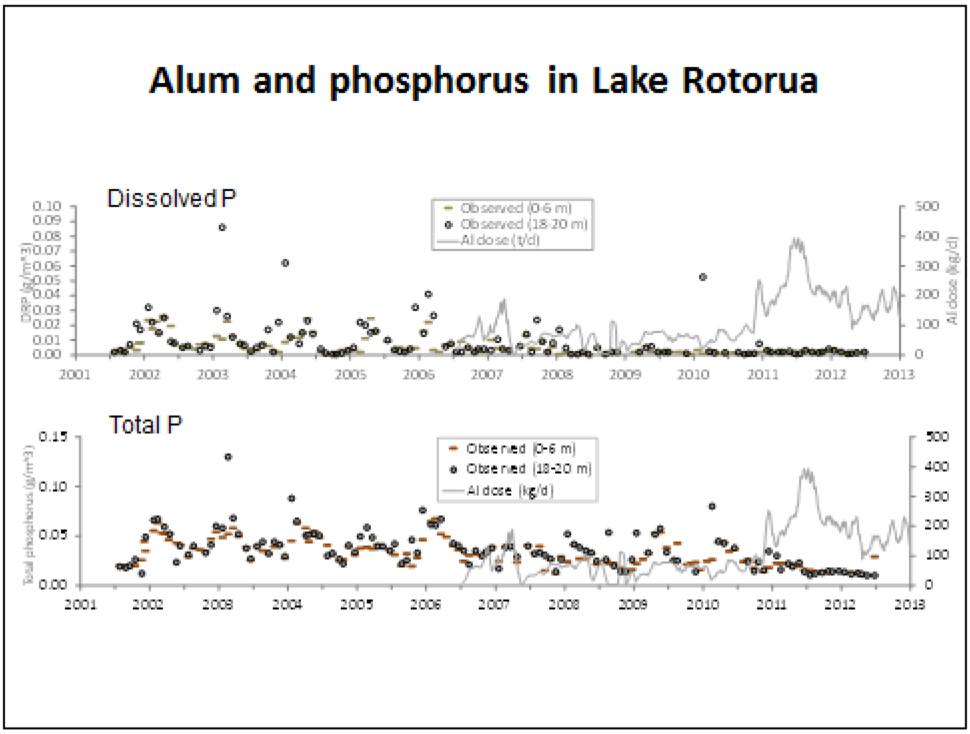
Slide 13



be more enriched in phosphorus and potentially contribute to phosphorus loads to Rotorua and as a result, will increase algal growth in Rotorua.

At the same time any increase in phosphorus loads are being offset by the alum dosing. **Slide 14** looks at dissolved phosphorus and total phosphorus concentrations in Lake Rotorua. There is a peak of alum dosing of nearly 400 kilos per day in 2011.The consequence of this was to sediment out the phosphorus, and concentrations decreased to about 15 milligrams per cubic metre. The average concentrations through the early 200's were about 40 milligrams per cubic metre and so they have more than halved over the period of alum dosing.

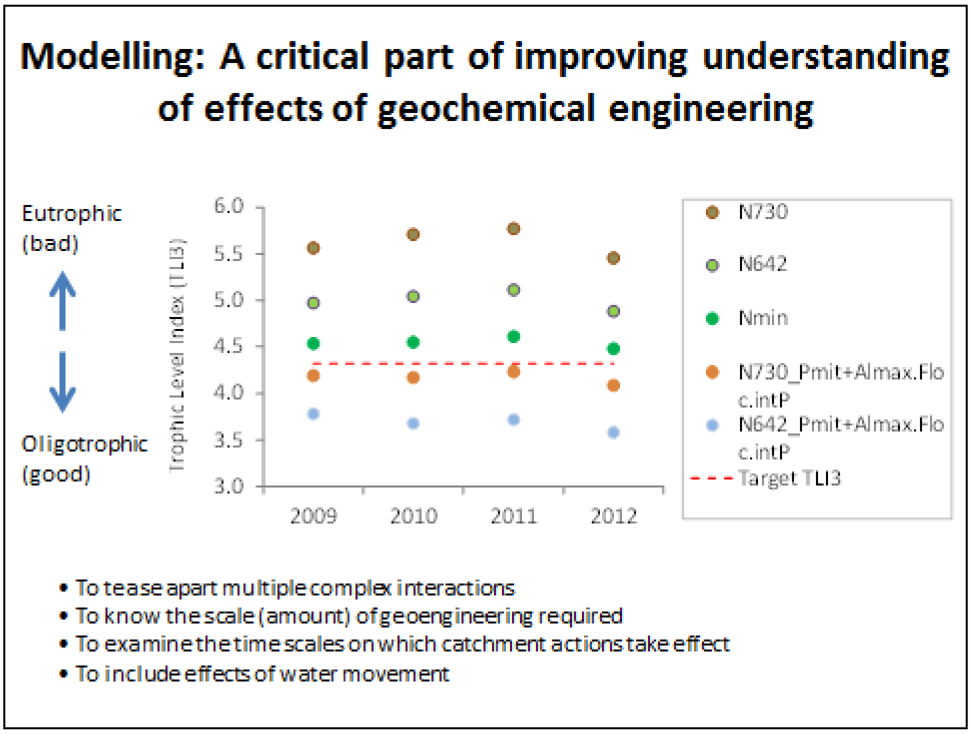
Slide 14



At the same time we looked very closely at the inflows to Lake Rotorua to ask if the inflows were the driver of the improvements in water quality. Not at all; in fact one of the challenges has been that with the climate of recent years the amount of phosphorus coming into the lake has, if anything, increased at the same time as the concentrations within the lake have decreased very substantially. We are obviously seeing the impact of the alum dosing.

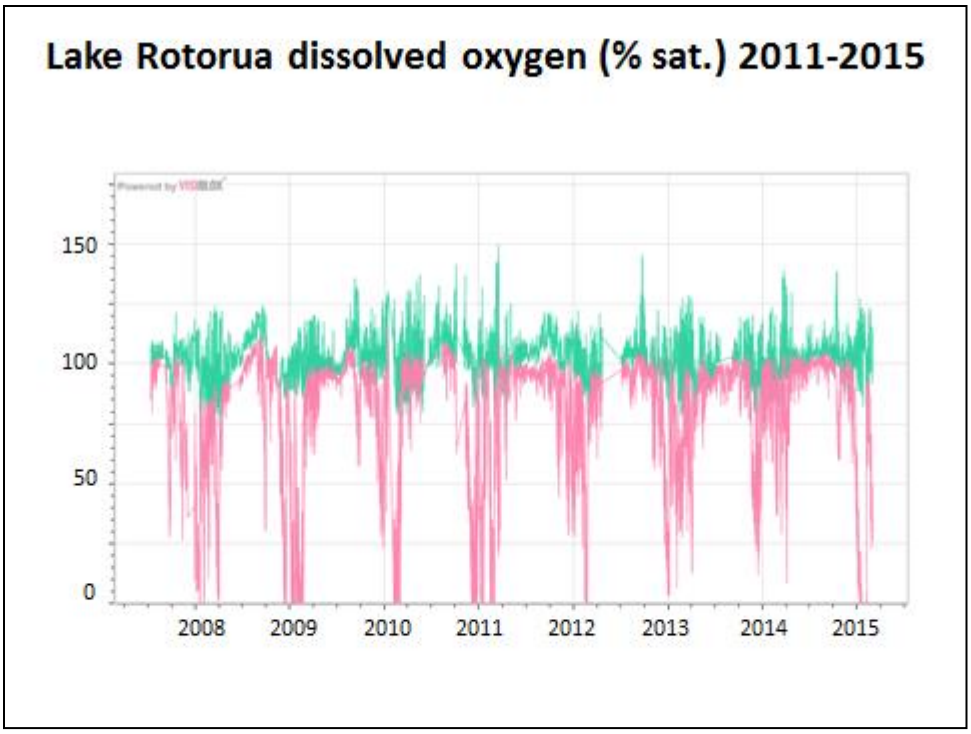
We supplement this information with some modelling to improve the understanding of the effects of geochemical engineering – in other words the alum dosing **(Slide 15)** (over). One of the goals is to say, 'What would have happened if we didn't alum dose? What would have happened if we applied some catchment management procedures?' We have gauged the modelling outcomes for these scenarios in terms of Trophic Level Index (TLI). The goal for Rotorua is 4.2 but because we use a slightly modified TLI level in the model, it is 4.3 in this particular slide. The consequence of not alum dosing would have been a TLI of around about 5, somewhere between the light green and the darker grey green khaki at the top. By contrast Rotorua has met its target, sitting around or just below the line over that period. So clearly the alum dosing has had a huge impact in improving water quality.

Slide 15



I have touched on the challenges of climate; the past summer of 2014-5 has been particularly interesting. **Slide 16** shows dissolved oxygen levels in percentage of saturation, where 100% is essentially a healthy system. There are two lines showing surface-water bottom-water concentrations of dissolved oxygen in Lake Rotorua. Typically the lake water dissolved oxygen is around 100% of saturation. When the lake stratified over the past (2014-5) summer, oxygen concentrations in bottom waters went down over a period of two or three weeks, stayed near zero for about three weeks and then shot back up. In the past we have had brief periods when there has been no oxygen present in bottom waters, usually interspersed with mixing that restores the oxygen, but because we

Slide 16



had such a hot summer, mixing was reduced and dissolved oxygen was depleted for a long period of time.

Briefly examining other lakes, Okaro is an example where alum has not been so successful but we have learnt quite a lot along the way. In this case the poor water quality in the lake has rendered the alum dosing largely ineffective, and this is related to the high pH value. High values of pH are often associated with algal blooms. Applying alum in this situation is not going to be effective. By contrast Rotorua has moderate variations in pH and alum has been highly effective.

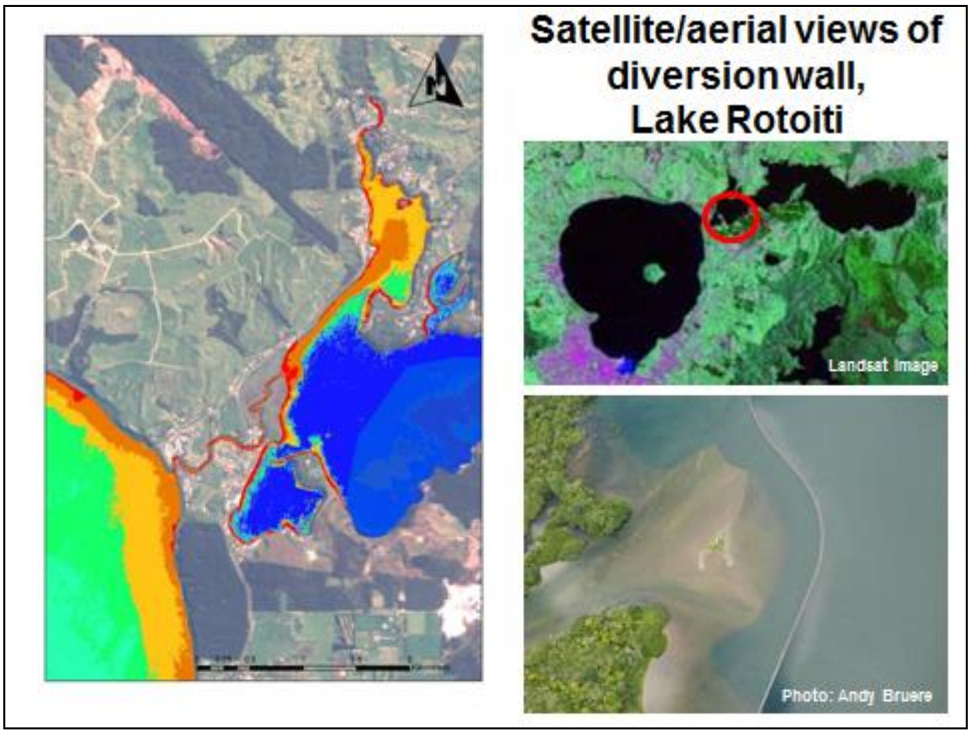
Slide 17

I cannot do justice to covering scientific aspects of the 12 (or 14) lakes in this region. **Slide 17** shows Rotoiti in the summer of 2003/4. We know that the Ohau Channel diversion wall was highly effective. **Slide 18** is the situation once the wall is in place. Water from the Ohau Channel is diverted by the wall down into the Kaituna System. One can see very clearly in **Slide 19** the sediment levels. Rotorua has moderate levels of suspended sediment that are reflected in the satellite image and they are transported

Slide 18

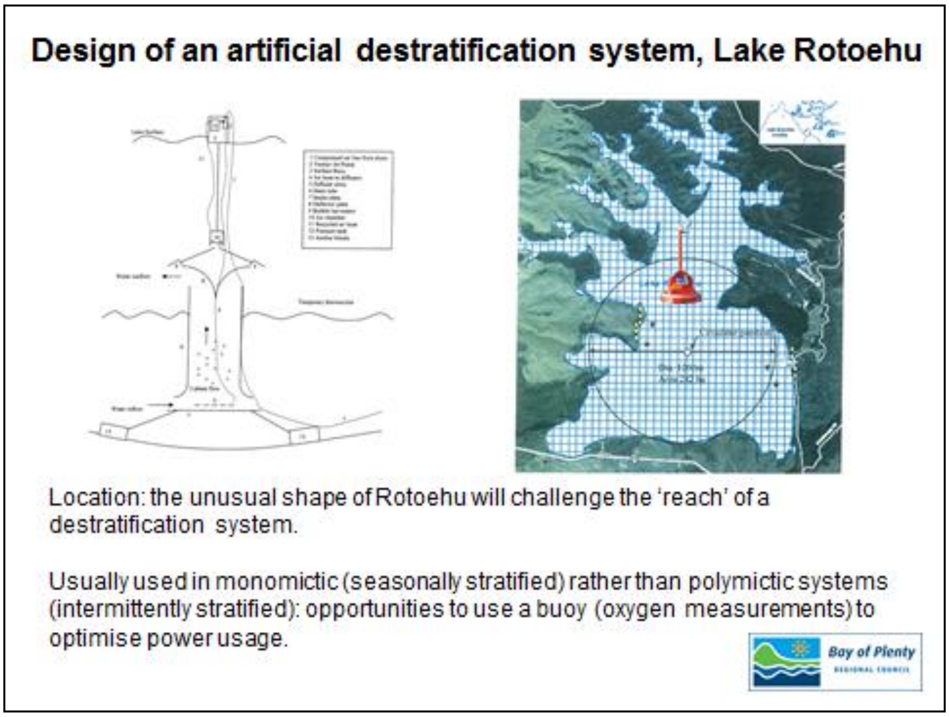
down the Kaituna Maketu system. The diversion is highly effective in taking that water away, and with it about 60% of the nutrient load from Lake Rotorua. The result has been quite a remarkable recovery of Lake Rotoiti. The final stage is to have oxygen persist in the bottom waters over the entire summer period.

Slide 19



Lake Rotoehu is a lake where different things have been tried to improve water quality and it makes a fascinating case study. **Slide 20** shows the effects of the artificial destratification system being used to aerate and destratify the water column, and prevent mixing events in Lake Rotoehu. It is a big lake and the original model predictions always indicated it would be a struggle to generate enough aeration to fully mix Rotoehu.

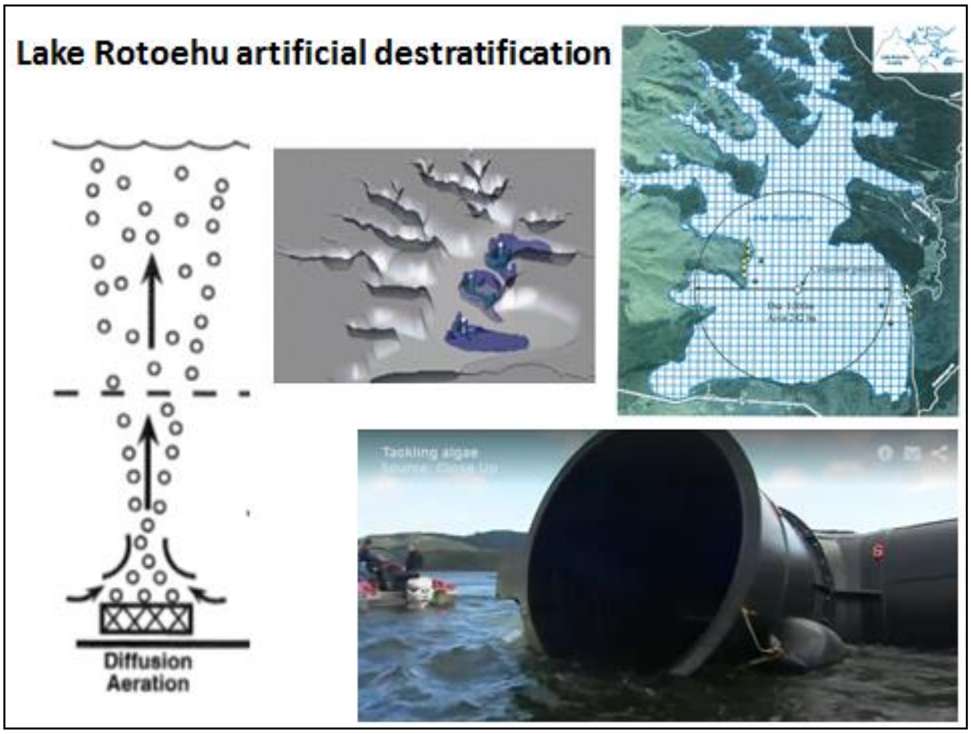
Slide 20



Slides 21, 22 and 23 show the large aeration device and the complimentary management programmes on the lake such as alum dosing and weed harvesting **(Slide 24)**.

Slide 21

Slide 22

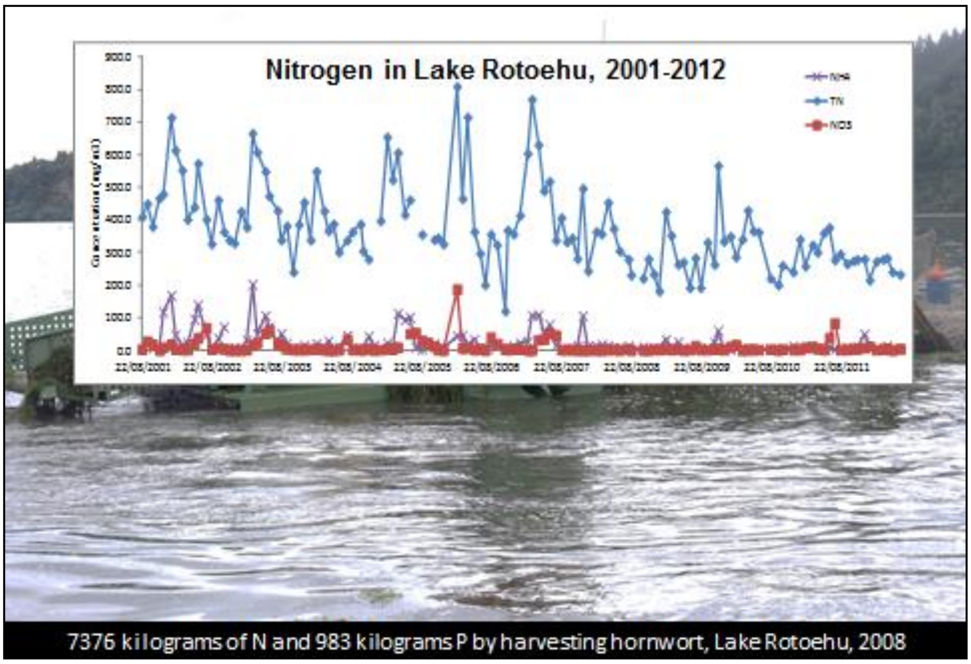


Slide 23

Slide 24

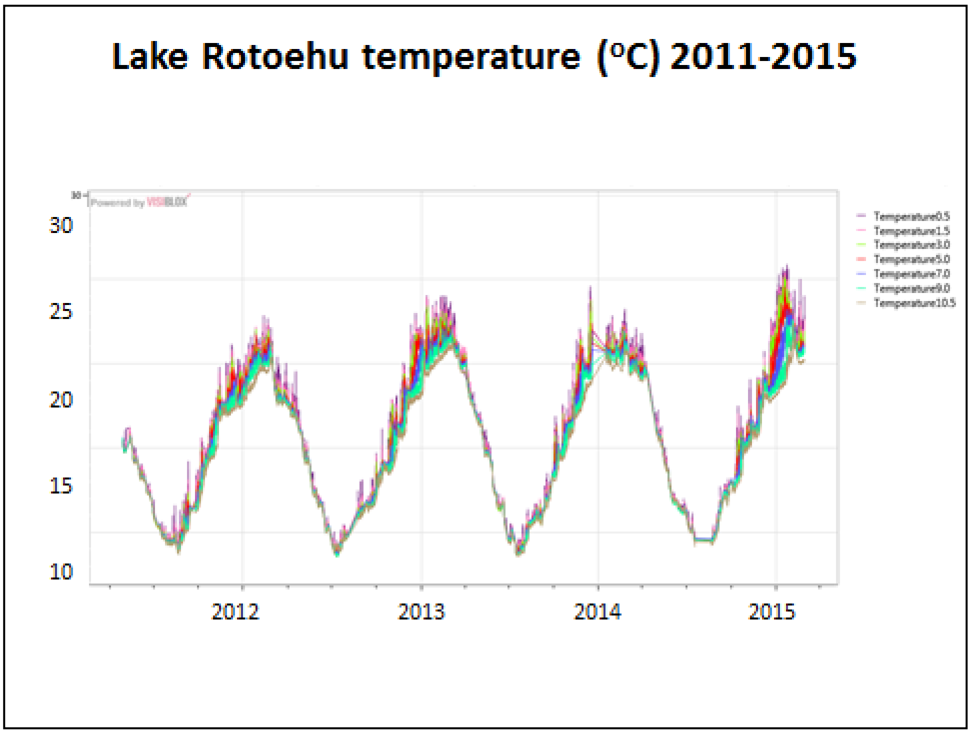
The weed harvesting has been used partly to meet the goals for nutrient reduction in Lake Rotoehu **(Slide 25)**. The graph shows that total nitrogen has progressively declined and the improvements have occurred over a number of years.

Slide 25



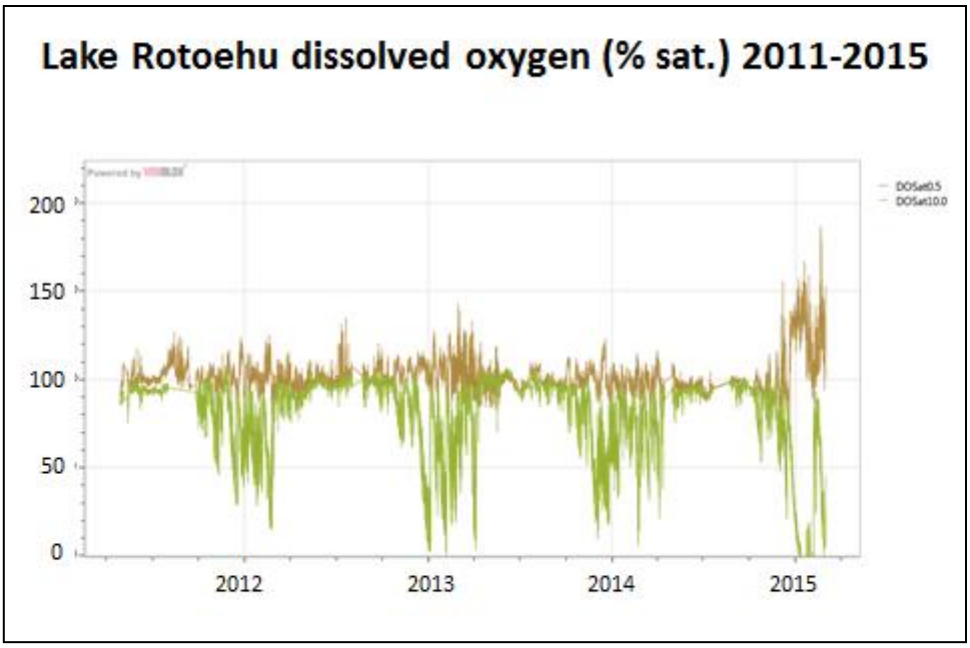
The climate over this summer of 2015 has been a challenge for lake management and this is illustrated in **Slide 26** by the variations in temperature. Typically there are small variations in temperature between the top and the bottom associated with the waters not mixing. This particular summer was exceptional and temperatures got over 27 degrees Celsius in Lake Rotoehu and there was prolonged stratification.

Slide 26



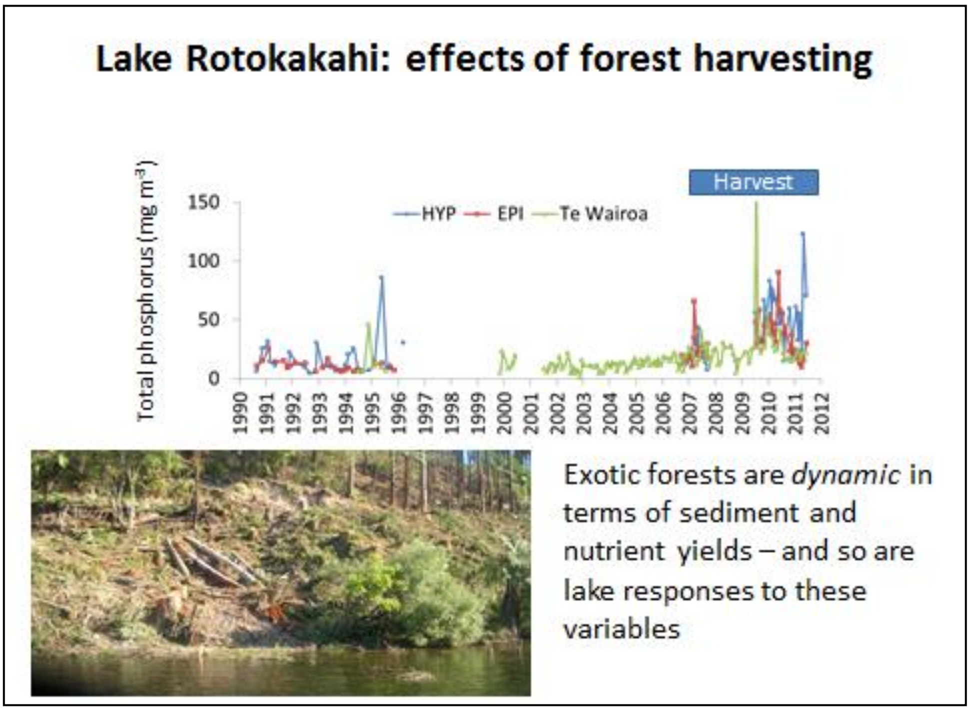
Slide 27 shows dissolved oxygen as a percent of saturation in Lake Rotoehu. There was no oxygen in the bottom waters of the lake for about 5 or 6 weeks. That loss of oxygen brings about a release of nutrients into the bottom waters and stimulates further algal growth. Instead there was limited response of algae to lack of mixing, likely as a consequence of alum dosing in both Lakes Rotoehu and Rotorua.

Slide 27



Slide 28 is a snapshot of Rotokakihi and points to the effects of harvesting right up to the edge of the lake. The impact has been most evident in increases in total phosphorus concentrations.

Slide 28



In summary I want to emphasise the importance of the Rotorua Lakes Water Quality Technical Advisory Group **(Slide 29)** which has endeavoured to throw away any preconceived ideas and get together quarterly for a day a year to look at what can be done to address issues in the lakes and make recommendations to others who ultimately make decisions on what needs to be done. It would be an interesting case study to look in particular at how closely science has aligned with implementation and policy as outcomes from the Water Quality Technical Advisory Group. I am not aware of too many other cases around the world where the science, the policy and the management actions have actually aligned together.

Slide 29

I would like to acknowledge particularly the Bay of Plenty Regional Council in the Chair that I hold, but also to the people that help put this work together, particularly Chris McBride and his work with the high frequency boys that are out on the lakes.

WEED MANAGEMENT – LESSONS FROM THE USA

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John is a Research Biologist with the US Department of Agriculture, Agricultural Research Service, Exotic and Invasive Weed Research Unit in Davis, California. He has been involved in research on the ecology and management of invasive aquatic plants around the country for over 25 years. John has a Bachelor of Science degree from Wheaton College, Wheaton, Illinois, and Master of Science and Doctor of Philosophy degrees in Botany from the University of Wisconsin-Madison. Before joining ARS in California in April 2014, he was an Associate Professor of Research and Extension in the Geosystems Research Institute and the Department of Plant and Soil Sciences, Mississippi State University. Prior to that, he was an Assistant Professor of Biology at Minnesota State University-Mankato from 2000-2003, and a Research Biologist with the US Army Engineer Research and Development Centre from 1991 to 2000.

He has served as an Associate Editor of the Journal of Aquatic Plant Management (1996-1997, 2011-current), Editor of the Journal of Aquatic Plant Management and Board Member (1997-2002), and a Director and Board Member (2010-2013). He has also served as the Chair of the Student Affairs Committee (1996-1997), the Legislative Affairs Committee (2010-2013), and the Membership Committee (2010-2013). He is currently the Vice President of the Aquatic Plant Management Society, a chapter of the Weed Science Society of America. He has been a Member of the Board of Directors for both the Texas Aquatic Plant Management Society (1993-1994) and the Mid-South Aquatic Plant Management Society (MSAPMS, 2005-2007). He has served as Chair of the Scholarship Committee for both TAPMS (1993-1996) and MSAPMS (2005-2014). He was also President-Elect (2007-2008), President (2008-2009), and Immediate Past President (2009-2010) of the MSAPMS.

He has also served as an Associate Editor for the journals Invasive Plant Science and Management, and Wetlands. He was Secretary of the Weed Science Society (2012-2014), Board of Director Member of the Council for Agricultural Science and Technology (CAST, 2011-2014), APMS Representative to CAST (2008-2011), and a Board of Director's Member for the Texas River and Reservoir Management Society (1994-1996).

ABSTRACT

Aquatic weed management has a more than 100 year history in the United States, with the first efforts by the US Army Corps of Engineers to remove water hyacinth from south-eastern United States waters in 1899. Through these efforts, several important lessons have been learned. First, plant management requires a plan of action that considers the level of infestation, makes site-specific management recommendations, and considers all potential techniques for use both spatially and temporally.

A good plan also includes public involvement and education. Integrated Plant Management has become the model for aquatic plant management. It includes developing an understanding of factors that exacerbate plant growth, and methods to mitigate plant

growth and enhance management success, including an understanding of target plant biology and phenology. In addition, most natural water bodies will require selective management, targeting the weed and minimizing the impact on desirable native plant species.

Steady funding to invest in plant management is a necessity. Disruptions to funding will result in larger problems in the future. An important part of the investment is a consistent investment in applied research, with the target of improved plant control. In the United States, an attempt is made to consider biological, chemical, mechanical, and physical techniques for management of aquatic weeds. The use of these techniques is restricted by economic, environmental, and regulatory thresholds.

While biological control may appear to be the preferred approach, many weeds do not have an effective biological control agent. Even effective biological control agents do not provide uniform control across the ecological range of a weed. Chemical control is still the most widely used technique in the United States. Chemical control is effective and relatively inexpensive, but increased regulatory restriction has impacted the use of herbicides in some areas.

Mechanical techniques use machines to remove plant growth. In particular, harvesting is widely used as an immediate control to plant growth. However, harvesting is relatively slow and expensive, and may have a significant fish and aquatic animal bycatch. Physical control involves altering the environment to reduce plant growth. In the United States, this includes the use of benthic barriers, shading materials, and drawdown. Each of these techniques can be considered tools in our plant management toolbox, and all have their place and utility.

TRANSCRIPT

My talk today gives an overview of aquatic plant management and aquatic weed problems in the United States. I will talk about developing integrated management plans and what that means. I want to emphasise the importance of research as a part of ongoing aquatic plant management programmes and look at some of the commonly used management techniques, both their positive and negative aspects.

I must make a few caveats to begin with. The first is to point out that the United States government and my parents spent a small fortune to teach me to speak and write English, so I would appreciate your tolerance of that. I have heard many people helpfully try and correct my poor use of English but it is hopeless; so, I will forewarn you.

Please do not construe anything I say as a specific recommendation of what you should do; that would be very arrogant of me to fly in and tell you what you need to do. Rather, I will tell you what I have found in the United States, and not everybody there might agree with what I say either. Any comments I make are my own observations and opinions and not the official policy of the United States government. No one has ever called from the higher echelons to ask me what I think and I doubt that is going to change in the near future. Lastly, any mention of a product name is certainly not an endorsement by the United States government or the United States Department of Agriculture.

There are two publications that are readily available that I would highly recommend:

> *Benefits of Controlling Nuisance Aquatic Plants and Algae in the United States. 2014*. Council for Agricultural Science and Technology. www.cast-science.org

Biology and Control of Aquatic Plants: A Best Management Practices Handbook. Aquatic Ecosystem Restoration Foundation. www.aquatics.org

The first is an article written by the Council for Agricultural Science and Technology. I was the liaison between the Council for Agricultural Science and Technology and the authors on the production of this publication. It is about the benefits of controlling nuisance aquatic plants and algae in the United States, showing that we do, in fact, derive many benefits, both economic and ecological, from managing invasive and nuisance species.

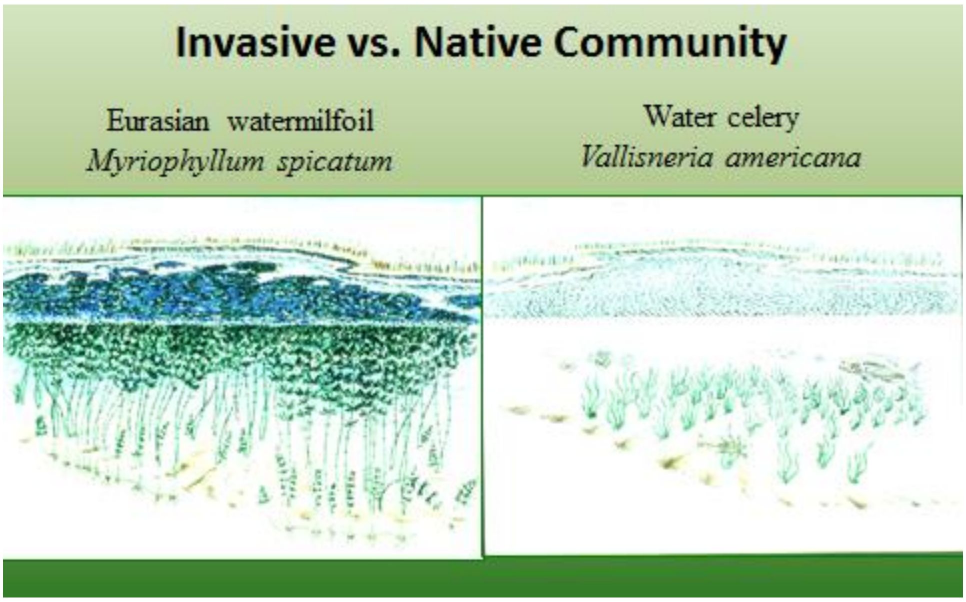
The second is a Best Management Practices handbook and is a multi-author publication on different species as well as different management techniques. It is written by experts in the field: the biological control section is written by entomologists, the herbicide section is written by weed scientists, and so on.

Benefits of Aquatic plants

- Stabilize lakes sediments, reducing re-suspension, keep the nutrient content in the water lower
- Increase sedimentation, reducing turbidity, thus improving transparency
- Provide habitat for insects, forage fish, fish spawning and YOY fish
- Provide food for waterfowl and other animals

We are talking about controlling invasive aquatic plants, but I want to point out that there are many benefits of aquatic plants. Our goal is not to kill all the vascular plants in the lake, but rather to preserve the native plant community that typically is well behaved. They are a great place for aquatic organisms to hang out. We want to preserve the native plant community, and we are not seeking to overdo the management of plants in general, but rather are targeting the invasive aquatic plants, plants that are from somewhere else.

Slide 1



For instance, in the United States **(Slide 1)** Eurasian watermilfoil will form a very dense surface canopy in contrast to our native water celery. Water celery is a very desirable plant in the United States both for fish habitat as well as for waterfowl food and very rarely causes a nuisance. It is important to stress that invasive aquatic plants are not a direct result of nitrification. Nuisance problems are a direct result of an invasion of a novel species. In the United States we find invasive species in very oligotrophic lakes as well as very eutrophic lakes, across the entire span of water quality. The assumption is often made that the plants are there because there are too many nutrients in the water. Most of these species derive their nutrients from the sediment rather than the water so they are not a result of increased nutrients in the water.

Economic Impacts of Invasive Plants

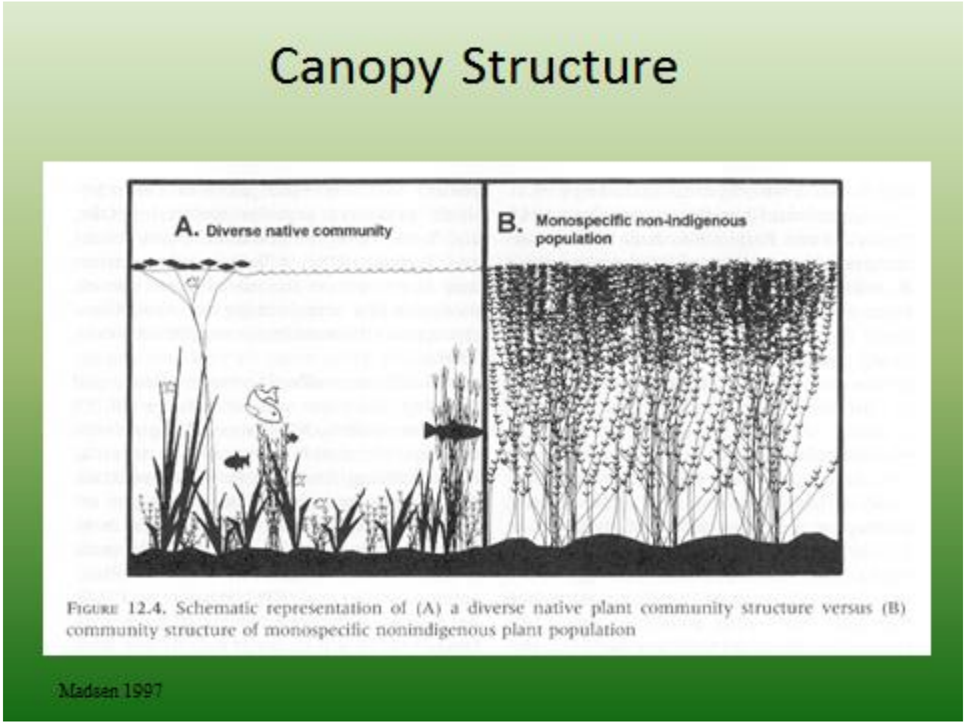
- Obstructing commercial and recreational navigation
- Interfering with hydropower generation
- Disrupting the flow of irrigation
- Disrupting the flow and quality of drinking water
- Exasperating the problems of controlling floods
- Encouraging the spread of insect-borne diseases
- Impairing recreational use
- Decreasing property value
- Affecting human health

Ecological Effects of Invasive Plants

- Degrades water quality
- Reduces species diversity of plant and animal
- Suppresses native plant species
- Potentially impacts endangered species
- Alters animal communities
- Alters ecosystem services

Both the economic and ecological effects stem from the growth form of the invasive species. **(Slide 2)** The invasive species, which is captioned under B, forms a very dense surface canopy and tends to exclude other species, as opposed to the diverse native community under A which has a variety of open and vegetated spaces that provide a more optimal habitat for organisms. So both the nuisance and ecological problems are derived from the formation of these dense mono specific surface canopies.

Slide 2

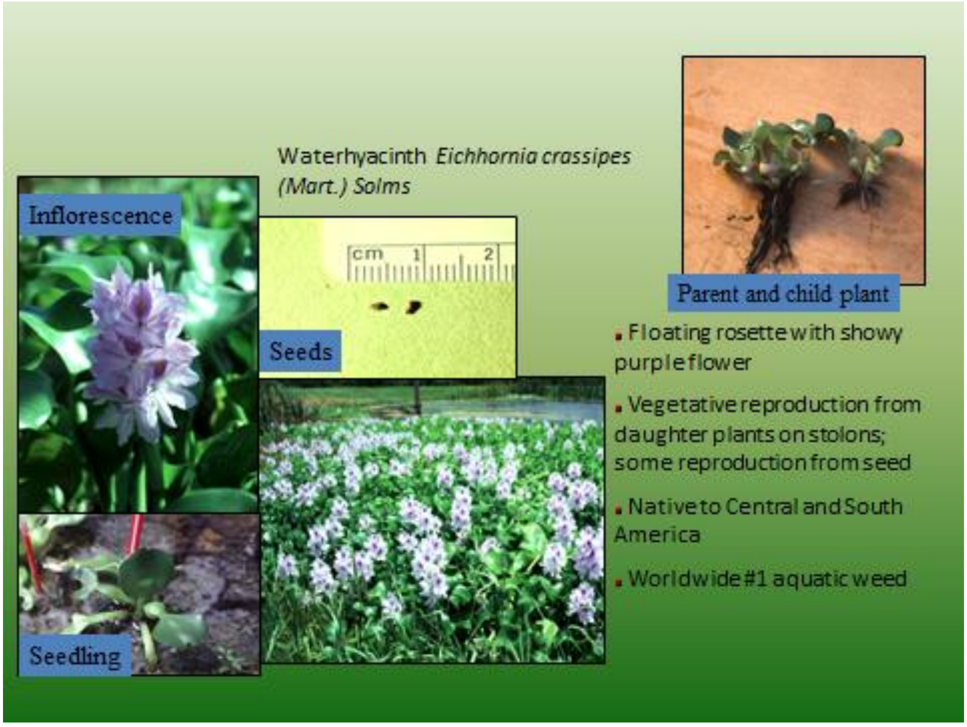


In the United States we have what I call the Big 3. **(Slide 3)** The total acreage of nuisance problems is largely dominated by these 3 species, although there are certainly many others. The big three are hydrilla, water hyacinth and Eurasian watermilfoil. Water hyacinth is the number one aquatic weed worldwide, particularly in tropical and sub-tropical regions. The doubling time, that is the length of time it takes to get twice as much biomass, or twice the number of hectares covered, is 7 to 8 days. You may come and look at the problem and then come back the next week and there will be twice as much of the same problem.

Slide 3

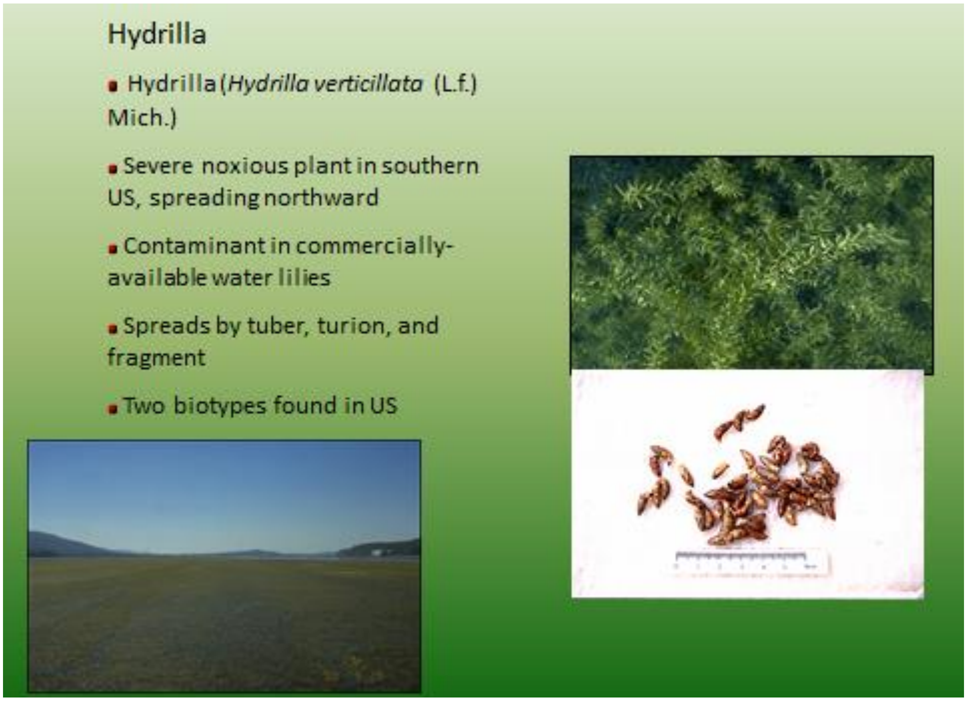
Slide 4 explains in part why water hyacinth is such a tremendous weed. The reproduction is almost entirely vegetative. It was originally from the Amazonian basin in South America.

Slide 4



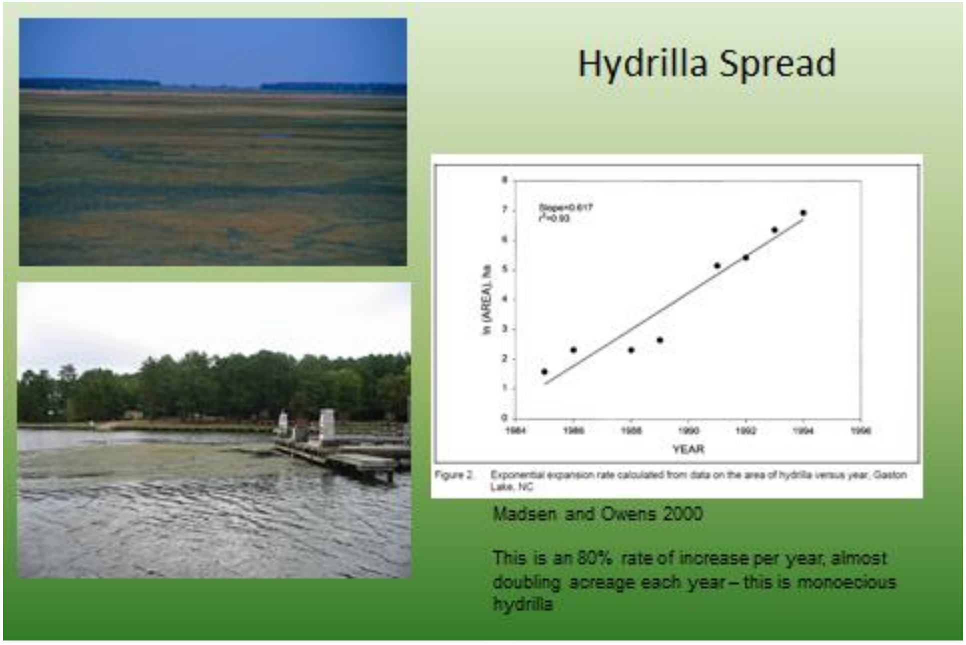
Hydrilla **(Slide 5)** is a submersed plant found in the United States and has two biotypes, monoecious and dioecious, two different varieties, and each a severe nuisance. It was thought for many years that hydrilla was a weed of the southern United States but it is now expanding well into the northern states.

Slide 5



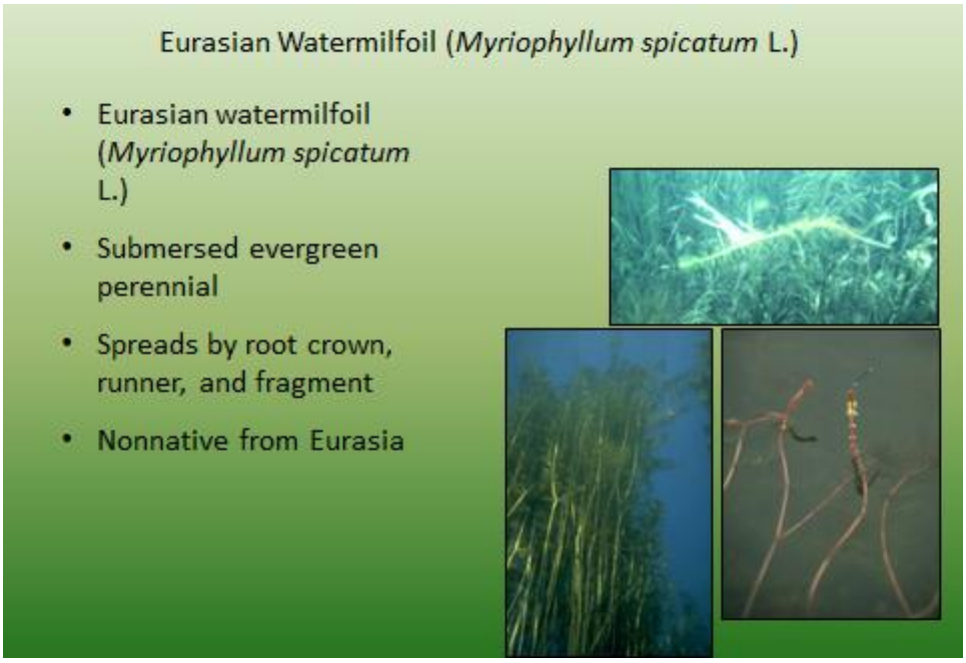
The picture on the upper left hand side of **Slide 6** is a lake in Florida. The Florida lakes tend to be fairly shallow averaging 3 metres in depth, and there will be a surface canopy of hydrilla for much of the year across 80% of the lake. Likewise at the bottom, the monoecious hydrilla forms dense surface canopies though typically not quite as extensive. It can spread very vigorously as well.

Slide 6



The third is Eurasian watermilfoil. Those of you who know my background will understand why I have a slight affection for this plant even though it is a vigorous weed. I have been studying this plant now for 25 years and while some people might call it a weed I call it my bread and butter. **(Slide 7)** It is a submerged evergreen perennial, spreading by vegetative means. It forms stem fragments by creating an abscission zone, much like the process by which leaves fall off trees in the fall. These are purposeful propagules and the canopy will shatter into thousands of fragments that drift off and form new colonies.

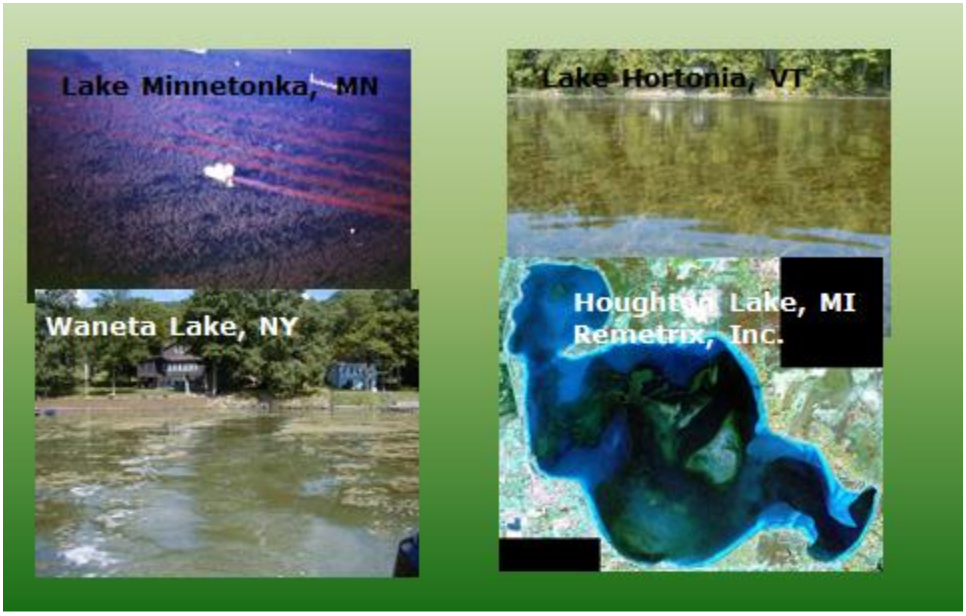
Slide 7



Slide 8

What impresses me about Eurasian watermilfoil is the vast diversity of habitats into which it will thrive. (**Slide 8)** From cold water oligotrophic rivers like the Fall River in California to some of the river reservoirs like the Pend Oreille River in Washington, shallow pot hole lakes in the prairies of Illinois to brackish water estuaries like Mobile Bay in Alabama.

Slide 9



Slide 9 at the top left shows the very large kettle lakes of Lake Minnetonka in Minnesota and the ongoing treatment using a fluorescent dye to help track where the herbicide goes. It is in front of the home of a professional football player and a very high value property.

Below that is Waneta Lake, one of the Finger Lakes in New York which are very deep with steep sides. In Vermont those lakes are on a granite rock layer with very poor nutrients. The last one is Houghton Lake in Michigan which is about 8,000 hectares and the 4,000 hectares of Eurasian watermilfoil can be seen in the satellite image of that lake.

We have dozens of other invasive aquatic plants including emergent, riparian, floating, free-floating and submerged plants that span the range from aquatic algae through flowering plants to the planktonic algae **(Slide 10).**

Slide 10

The paradigm in the United States for developing pest management plans is integrated pest management. This is a definition I took off the US Department of Agriculture web page and the more I read it the more confused I become. Basically the idea is to use multiple tactics to optimise the control between the different pests that are on a crop plant in an ecologically and environmentally sound manner.

Integrated Pest Management (IPM)

'A decision-based process involving coordinated use of multiple tactics for optimizing the control of all classes of pests (insects, pathogens, weeds, vertebrates) in an ecologically and economically sound manner.'

US Department of Agriculture

IPM was designed for cropping and agro ecosystems and for wildland weeds or aquatic weeds. The question is what is relevant in aquatic plant management from this paradigm? The two things of most relevance are to understand the invasion process of these invasive plants, and secondly, to understand how we can use the life history of these plants to improve management.

Main Points of Integrated Pest Management

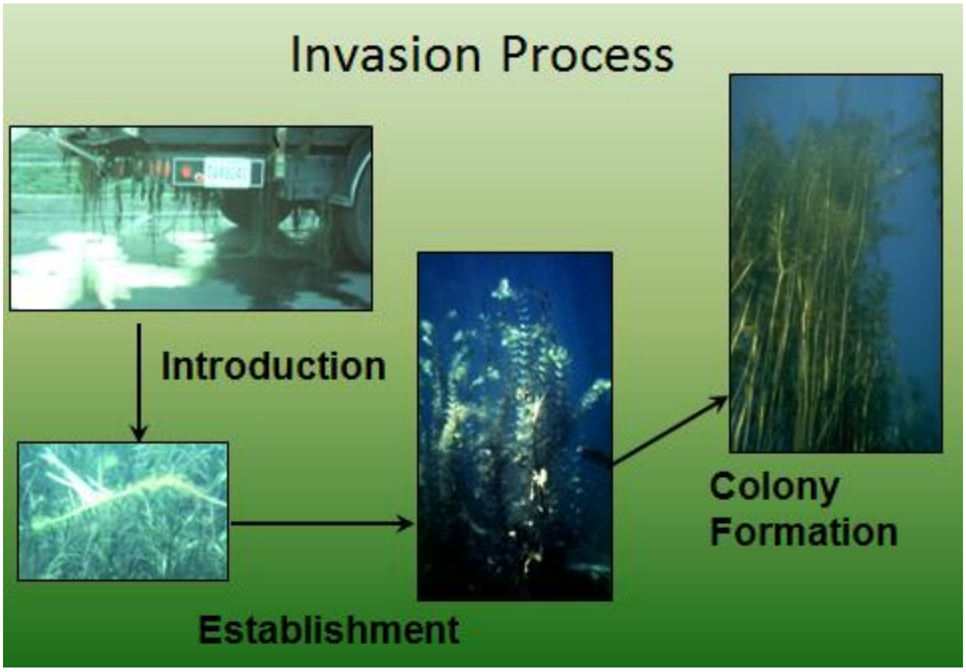
- Simultaneous management of multiple pests
- Regular monitoring of pests, and their natural enemies and antagonists as well
- Use of economic, ecological, or treatment thresholds when applying pesticides
- Integrated use of multiple, suppressive tactics to control pests

IPM for Aquatic Plants

- IPM is largely designed for cropping systems and agroecosystems
- What does this mean for aquatic plant management?
  - Ecological understanding of invasion process
  - Ecological life history and management

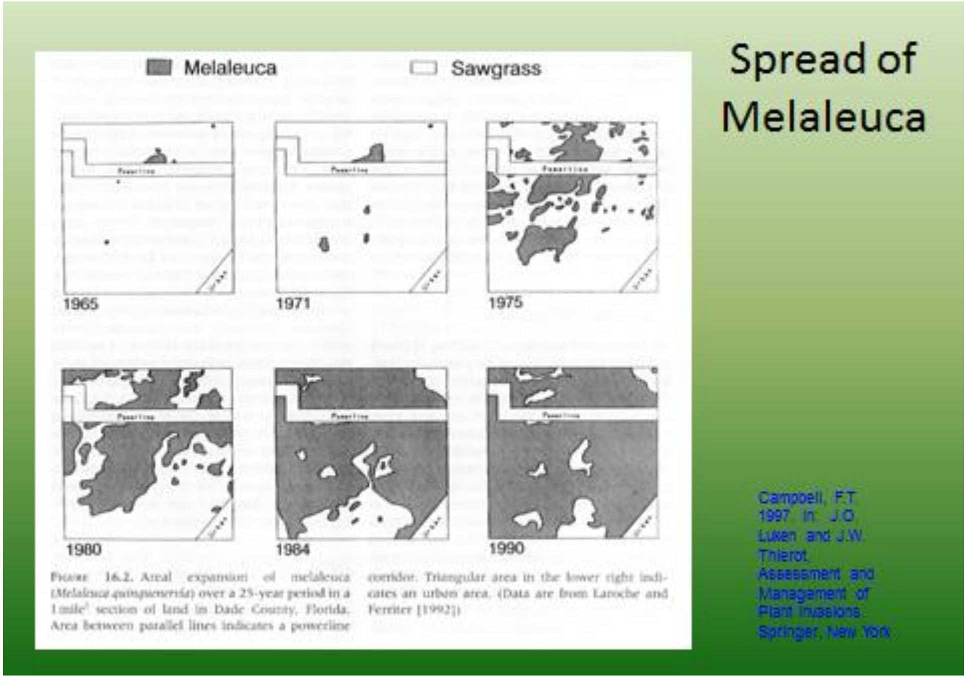
Slide 11 shows the invasion process where a plant is introduced to a lake and that plant propagule establishes and grows into larger and larger colonies. The predominant way of moving plants around is on boats and boat trailers. The licence plate on that trailer says, 'US Government'. In the words of the great philosopher Pogo, 'We have met the enemy and he is us'.

Slide 11



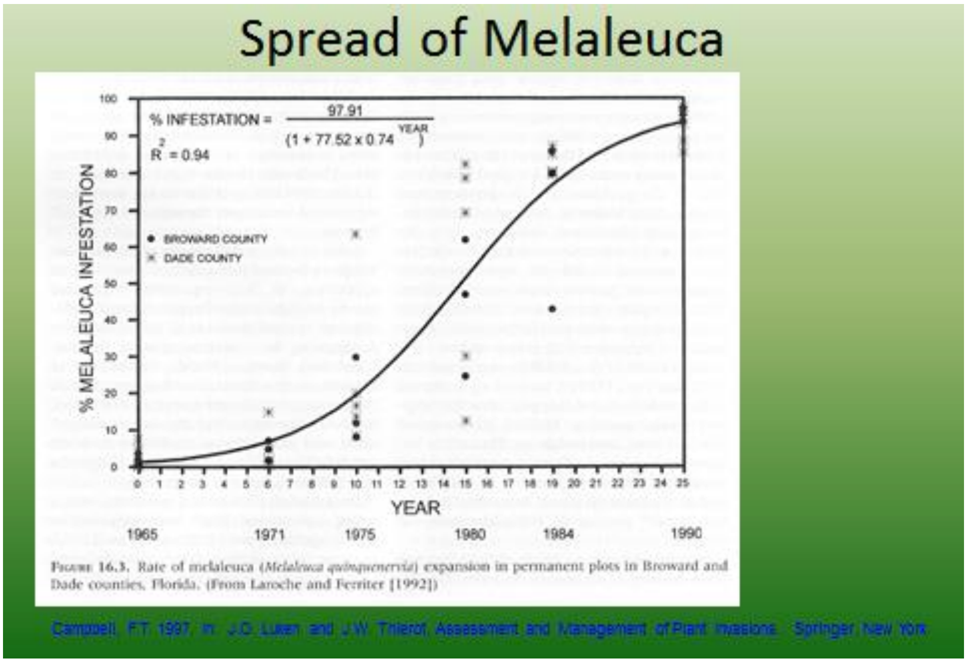
Slide 12 is about the spread of melaleuca. It can grow as a wetland tree and in this case in the Everglades of Florida. The authors of this paper studied the appearance of colonies in a large section of the Everglades and how an individual colony will spread and new colonies form and coalesce over time until eventually the entire area is dominated by this plant.

Slide 12



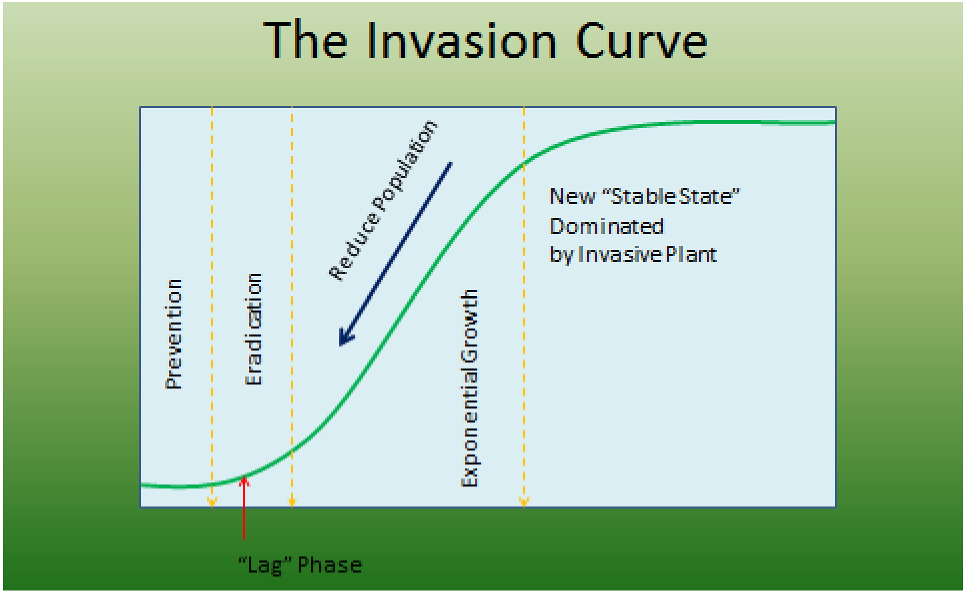
This process may look similar to what you might experience with invasive plants in your lakes. **Slide 13** details how much of the area is covered and put it on a timeline. Those who have taken biology will say, 'I've seen that before'. It is the Sigmoid growth curve where plants start out in a lag phase not spreading particularly rapidly. Then they grow at an exponential rate, faster and faster until they cover the entire available habitat and can no longer spread.

Slide 13



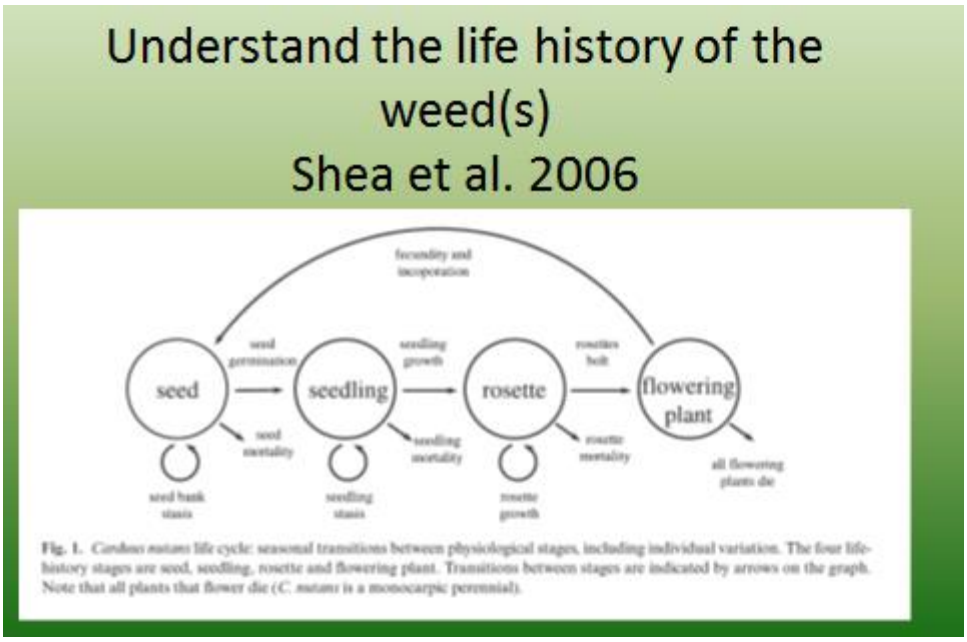
Slide 14 is a restatement of this invasion curve which show a few features of interest. The first is that the best time to control a plant is before we have it, namely, prevention. Second, when a species first appears in the lake is the next best time to manage that plant. Do not wait to see whether or not that plant is going to be a nuisance, it needs to be managed right away. As the exponential growth continues the management should try to reduce the population down to a level that can be sustainably managed. Ultimately if nothing is done a new stable state is reached, one dominated by the invasive plant. The larger the infestation gets the more expensive and difficult it is to manage that population: either eradicate or maintain at a lower level.

Slide 14



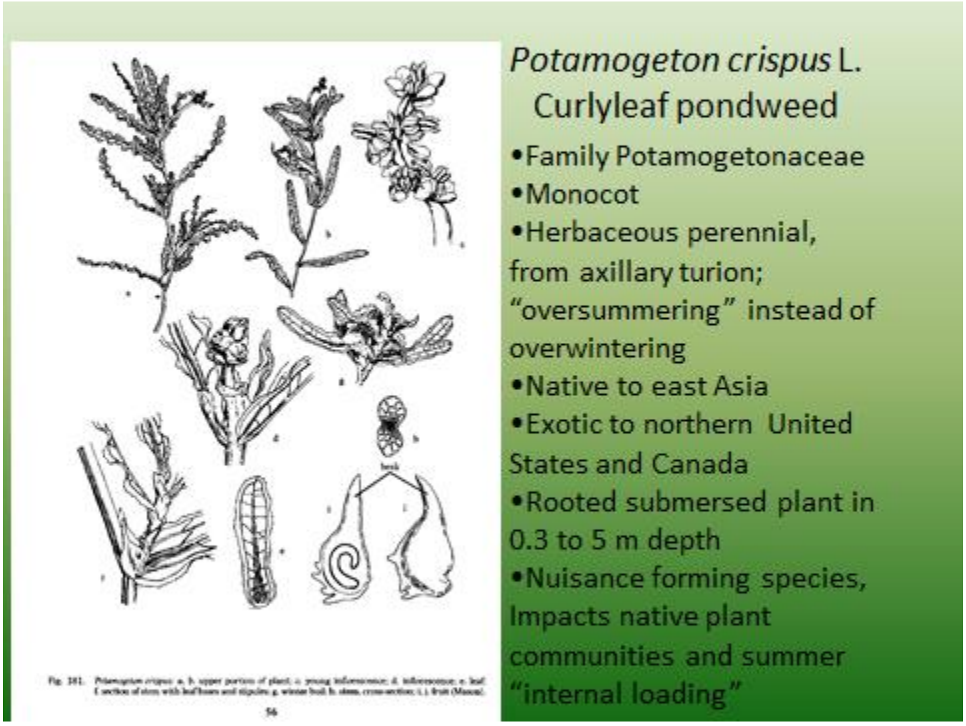
The second thing from IPM that we can incorporate into aquatic plant management is to develop an understanding of the life history of the pest **(Slide 15)** and target stages where it is more susceptible to manage and affect long term management to reduce the population. This is difficult particularly for plants like lagarosiphon and egeria which do not have a vegetative propagule. It is hard to know how we could apply this and more research is needed.

Slide 15

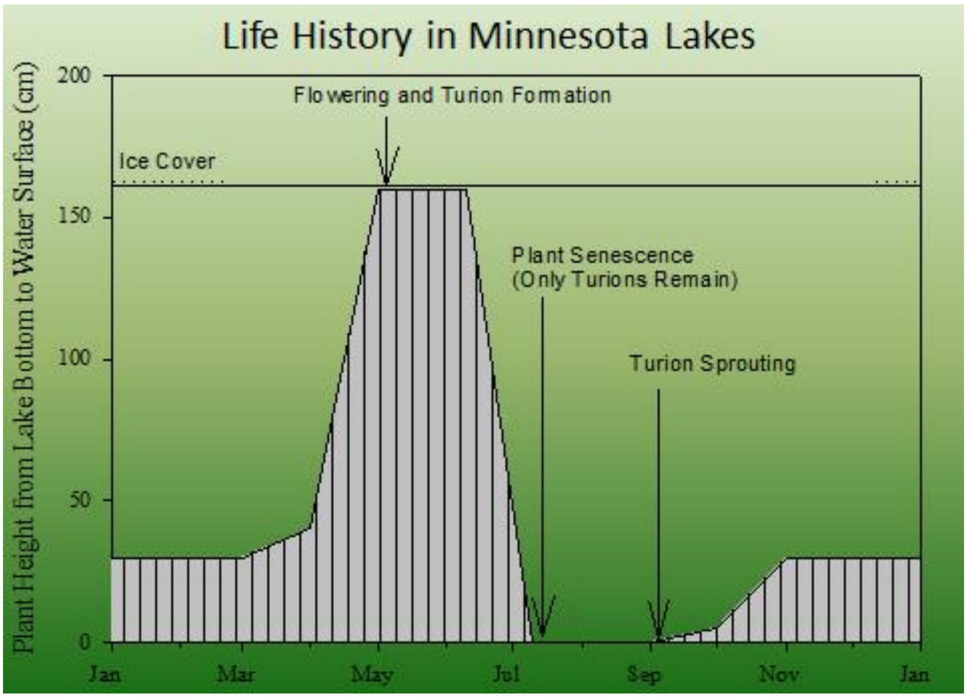


There are many instances in which we can identify the critical propagule, the critical life stage. **Slide 16** is an example from the Minnesota Lakes in the United States managing curlyleaf pondweed. This is an herbaceous perennial, which rather than over-wintering, it over-summers as a dormant turion. In its life history the turion sprout in the fall growing slowly to a low level over winter. Then they grow rapidly to the surface in early spring, flower, form the turion and then die back.

Slide 16

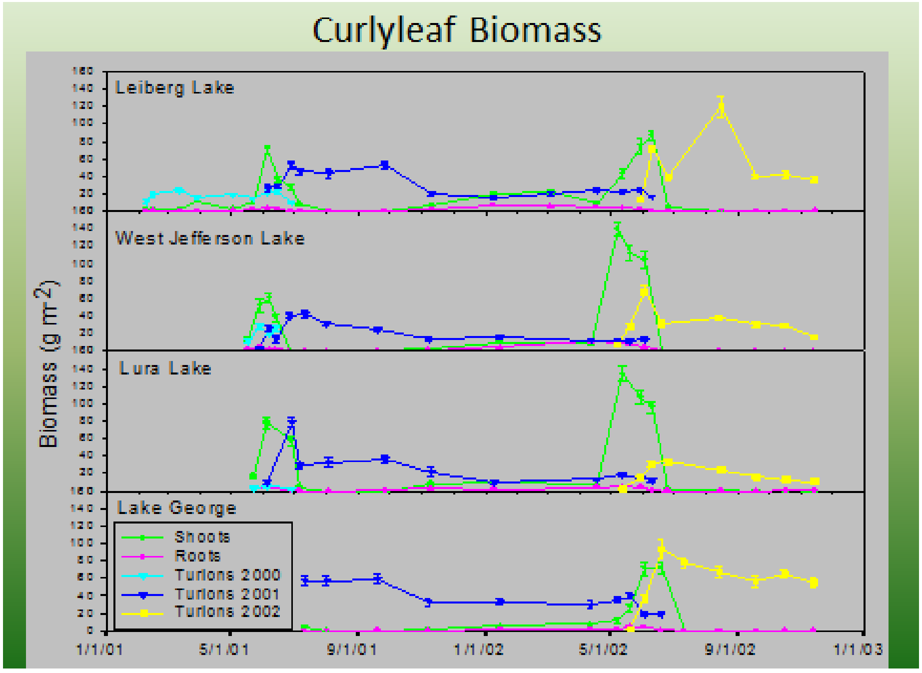


Slide 17



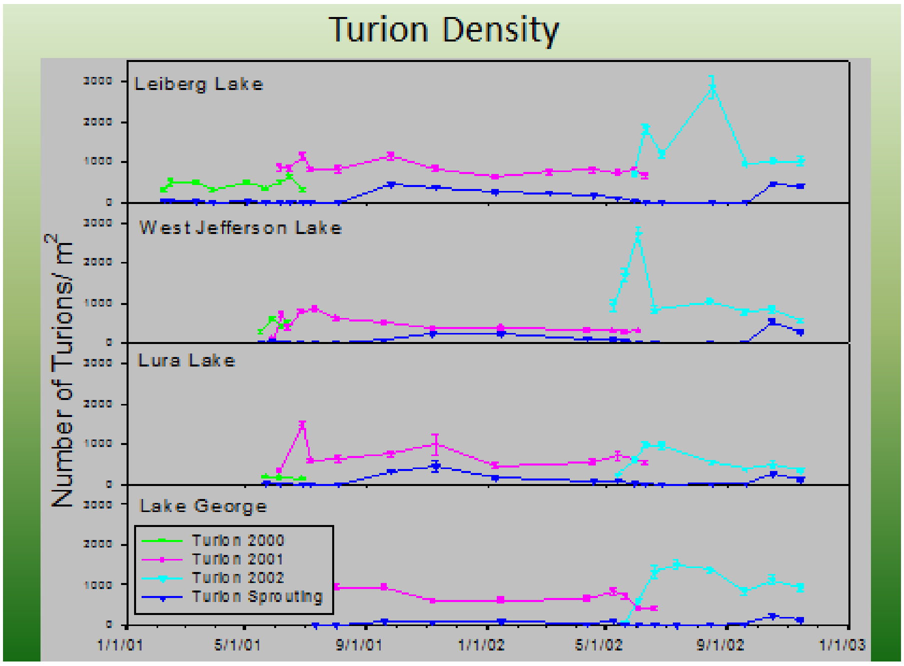
Traditionally in Minnesota and elsewhere in the northern states folks appear at their lake cabins around the end of May and see a mass of curlyleaf pondweed. They pick up the phone, call the company that manages aquatic plants and say, 'Hey I've got a nuisance problem'. The authorities come by mid-June and apply the herbicide and the plants die. Another great job done! Well I have news for them; the plants were going to die anyway. They could have sprayed water and achieved the same effect. I was with the US Army Corps of Engineers at the time and we suggested a change in the way to manage this weed to effect long term control of curlyleaf pondweed **(Slide 17)**.

Slide 18



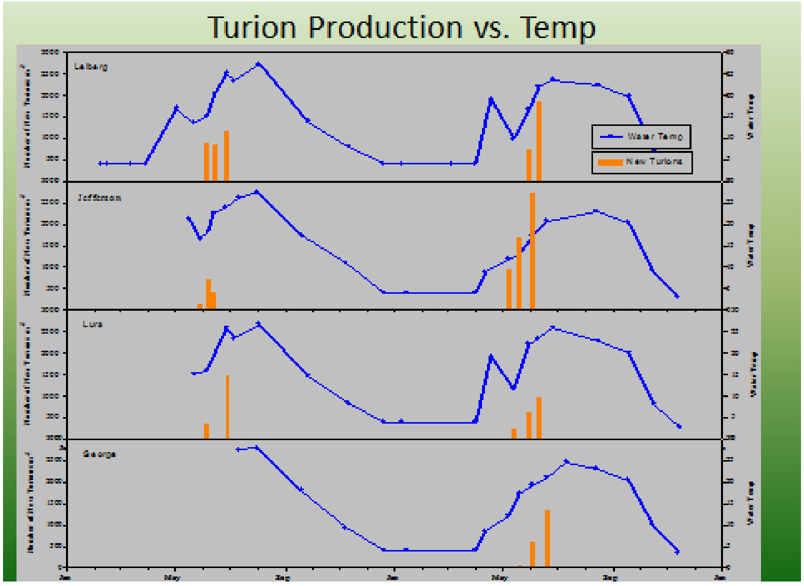
Slide 18 is a study I did when at Minnesota State University. The bright green line is the biomass of the shoots which have very short periods of time growing up into the water column. The other long lines are the very high biomass of turion, the vegetative propagule. There will be thousands per square metre of the turion from this plant. **(Slide 19)**

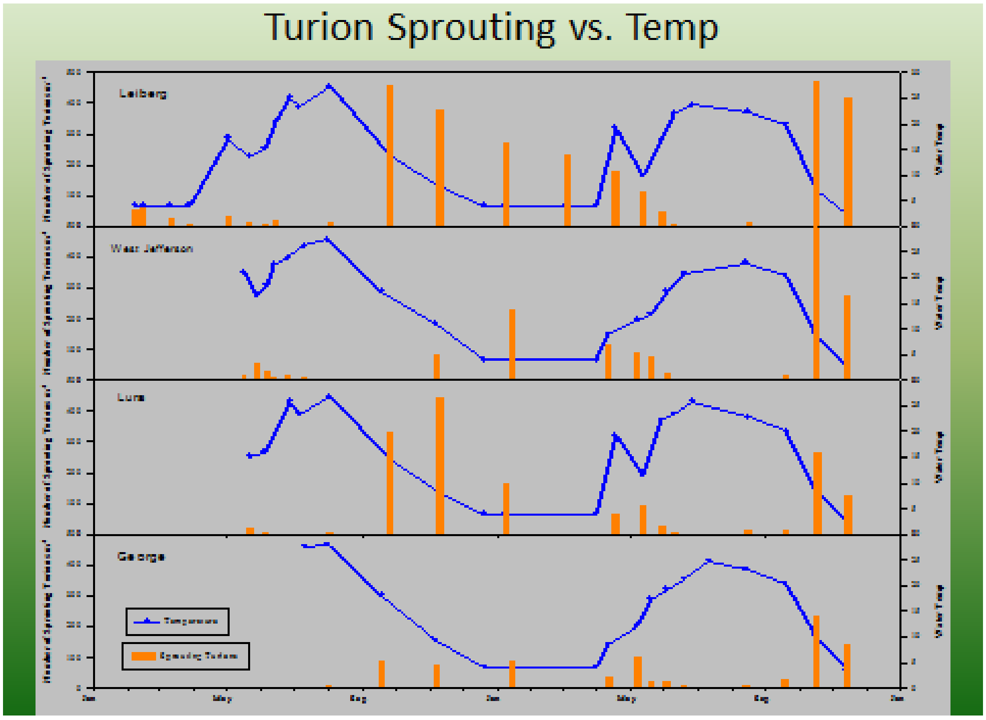
Slide 19



Slide 20

Turions are very sensitive to increasing water temperature in the spring and form in a very synchronised time, over about a 4 to 6 week period. **(Slide 20)** If we use some management strategy before that time we can prevent turion production and affect long term management



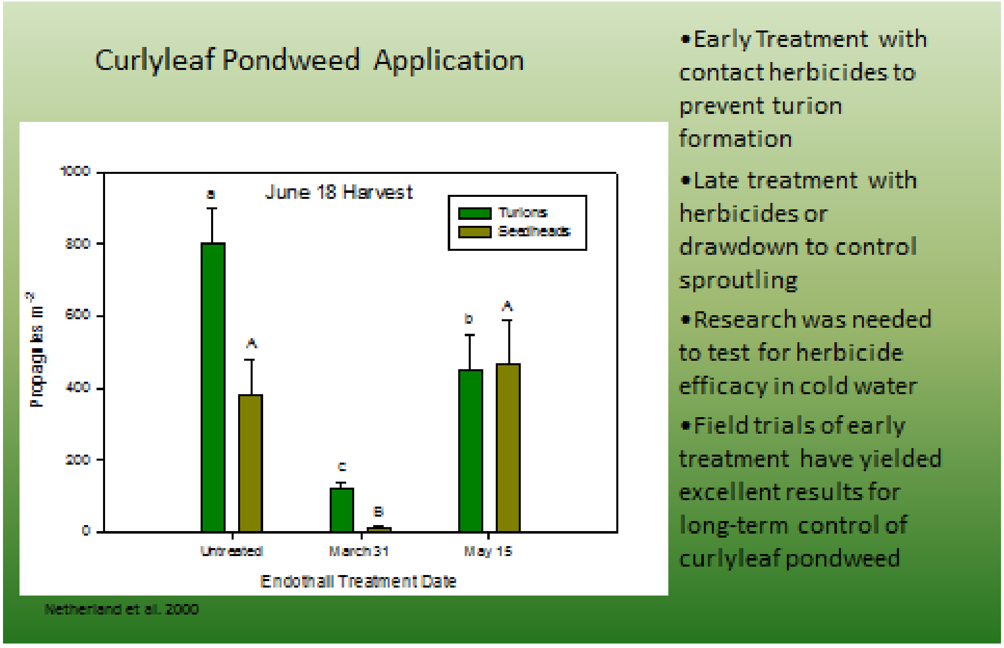


Slide 21

The next best time is when the turions sprout, which is the rational time, for instance, for weed prevention in lawns. We apply a herbicide that kills the seedlings as they sprout. With curlyleaf pondweed this would not be effective because the sprouting occurs over a very long period of time. **(Slide 21)**

The herbicide labels for both diquat and endothall say not to apply if water temperatures are less than 65 degrees Fahrenheit (18 degrees Celsius). We did some research to show that the herbicide would be effective at much lower temperatures, even at 10 degrees Fahrenheit. The company went back and revised their labels so that we could use this tool to control curlyleaf pondweed in long term effective management.

Slide 22



We then did trials to prevent turion formation, applying endothall and diquat. **(Slide 22)** This was the policy for a number of states in the cold northern temperate states where they recommended treatment of curlyleaf pondweed before turion formation. The State of Minnesota then contracted the University of Minnesota to monitor 6 of the lakes receiving whole-lake treatments with endothall and compare them to 3 lakes not treated. They found that in every single treated lake the formation of turions was prevented and this reduced the population of curlyleaf pondweed over the long term. **(Slide 23)** It was a very effective application of research combined with companies that provided the tools used to manage the aquatic plants and with states that developed the regulations to change the way that aquatic plants are managed.

Production of turions in treated and untreated lakes (Johnson 2010)

Table 2. Production of new curlyleaf pondweed turions (N produced/m²) in June within the littoral area (≤4.6 m depth) of herbicide-treated lakes and untreated reference lakes 2006 to 2008; presented as littoral mean ($\bar{x}$) with standard errors (*SE*) in parentheses.

		HERBICIDE-TREATED LAKES						UNTREATED REFERENCE		
		Crookneck	Fish *	Julia	L. Mission	Rush	Weaver *	Coal	Rebecca	Vails
2006	$\bar{x}$	<1	3	0	0	0	0	96	1871	360
	(*SE*)	(<1)	(2)	-	-	-	-	(47)	(589)	(144)
2007		<1	<1	0	<1	0	0	312	778	509
		(<1)	(<1)	-	(<1)	-	-	(93)	(210)	(124)
2008		2	<1	0	0	0	0	87	313	379
		(2)	(<1)	-	-	-	-	(46)	(93)	(124)

* Fish and Weaver were treated for four consecutive years (2005 to 2008)

Slide 23

Research is important to develop new management patterns (whether herbicidal, biological or mechanical) by identifying key points in these weeds' life cycles and understanding more about both our target weeds and our native plants so we can selectively manage the target weed.

In the last few years the changes in our herbicide regulations have required that everyone develop an integrated pest management plan for their lakes when treating larger areas. We have had to retrain people to develop these plans and incorporate integrated pest management into their programmes. Management plan elements include prevention, assessing the problem, tracking the resources to manage the weeds, ongoing monitoring, doing education and outreach, setting very specific goals, doing site-specific management and then evaluating management activity.

We need to educate everyone using the water bodies so that we do not spread invasive weeds from one lake to another. In the United States a number of states have enacted very tough legislation and regulations which they enforce. In the State of Minnesota if one is seen driving down the road with weeds on their trailer a highway patrolman will ticket that person and that has been very effective. In many of the western states it is necessary when towing a boat to pull over at inspection stations to have the boat inspected for plants.

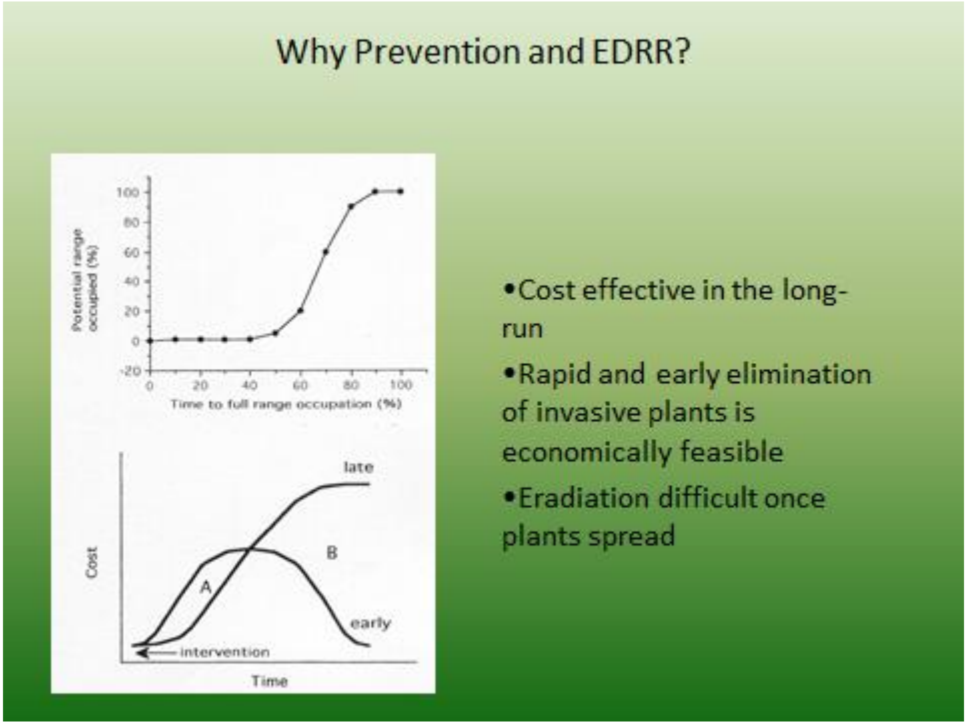
Boats are the No. 1 mode of invasive species spread in North America. The most important focus for prevention is at boat launches and on the transportation of weeds on boats.

The next most important thing is early detection. It is important to search a lake regularly to find invasive species and look for new species. In many of the states in the United States they utilise volunteers, to either search for plants or monitor boats and trailers at boat launches. In this case there needs to be one contact person in an area or a state to receive the reported sightings and verify the identification of that species. In my experience many volunteers, while enthusiastic, are not terribly knowledgeable and it is important to follow up on those sightings.

Having a rapid response plan is the essential follow-up to verified sightings. I was working with the State of Montana for a number of years when they found Eurasian watermilfoil in a new reservoir. The State required an environmental assessment before they could do any management. It took two years. Do you think the Eurasian watermilfoil was polite and waited for the State to finish their plan before starting to grow up again? It certainly did not. We need to be ready to jump on problem plants with both feet which will be cheaper in the long run. **(Slide 24)**

Control plants early rather than wait and see.

Slide 24



Education and outreach should be a very important programme. In the United States we have a built-in system called Cooperative Extension where a specialist will compile information and send it to the county-level agents that deal with people on a day to day basis. It is also important to reach the various people who may have a concern about the water body in question. Giving information and addressing concerns from the onset can help answer an objection that could otherwise stop a programme. Lastly it is important to be transparent. Prepare information and let people know what you are doing and why.

Complying with permits may require monitoring and assessments of the success of the management activities.

There are also a number of things that volunteers can do, or what we call in the States, Citizen Scientists. Train volunteers to identify plants and reporting the occurrence of invasive plant species via the web.

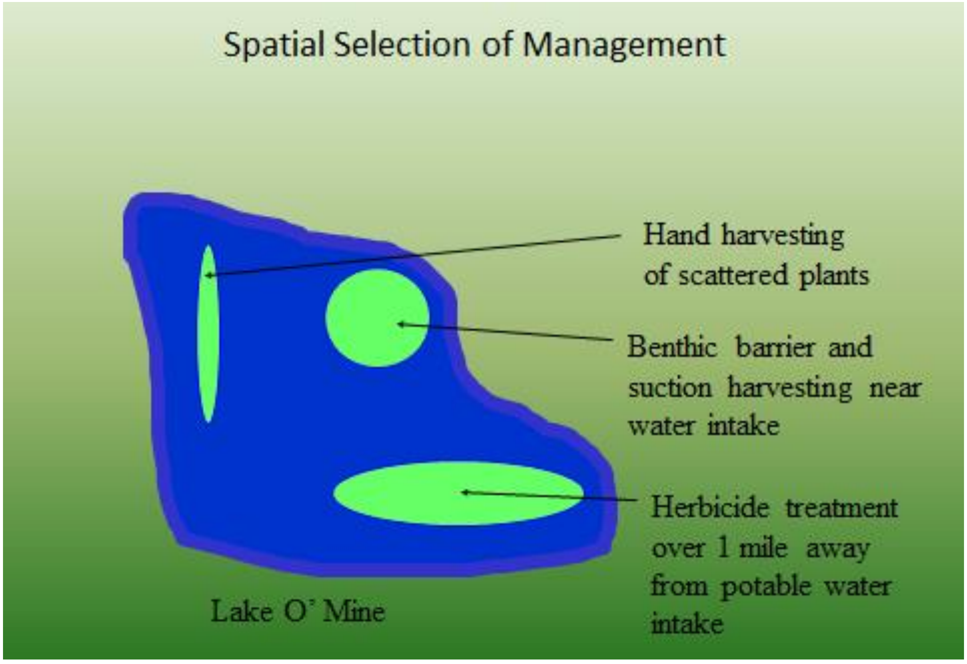
Develop very specific management goals based on a statement of the problem. In a hypothetical example we may find that 90% of the potential habitat of our weed is topped out with the weed which we do not want and our goal is to reduce that to 15%. That is a concrete goal and can be assessed using an objective monitoring technique. This eliminates unnecessary discussion on whether the outcome was successful. Have a goal, either meet it or not, and then it can be revised and move on.

It is essential to implement goals in ways that are acceptable to environmental and economic standards, to the stakeholders and to regulatory agencies. It will take a long time to pursue treatment plans that are outside of the law. People are very reluctant to agree to those!

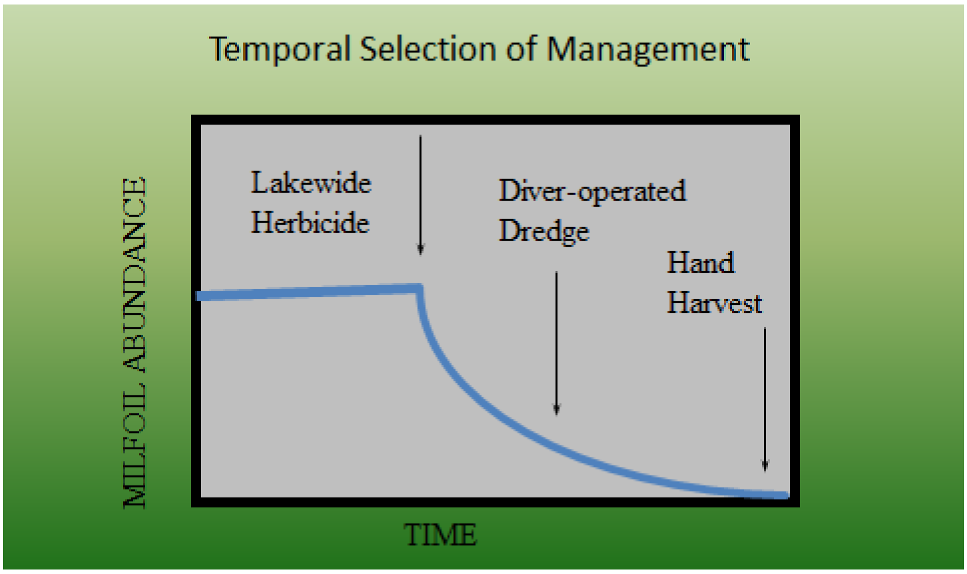
Vary techniques both spatially and temporally. What do I mean by that? Look at each weed site and develop a site specific management strategy, whether the site is a lake or a discreet portion of the lake. Consider all the available techniques and evaluate them

based on their merit, not just how you feel but how effective are they really. Techniques will vary both spatially and temporally. For instance there may be areas conducive to hand pulling in a particular lake if there are only scattered plants. It would be just as easy to remove them by hand as it would be to do any other technique. There may be a particularly sensitive spot environmentally, for instance, near a drinking water intake suitable for a benthic barrier treatment or diver-operated suction harvesting. But an area with very dense plants remote from that sensitive zone it would be suitable to use a herbicide to bring the population down more quickly. **(Slide 25)**

Slide 25



Over time techniques will change and **Slide 26** is based on a lake where 70% of the littoral zone (the area that can be colonized by rooted plants) was dominated by Eurasian watermilfoil. The first approach was a whole lake treatment with fluridone which achieved 98% control. Then there was a combination of diver-operated dredging and benthic barriers to control the remaining 2%. In subsequent years there were fragments of Eurasian watermilfoil which were removed by hand. Monitoring has continued for the past 20 years and it has been a very successful programme for this lake.

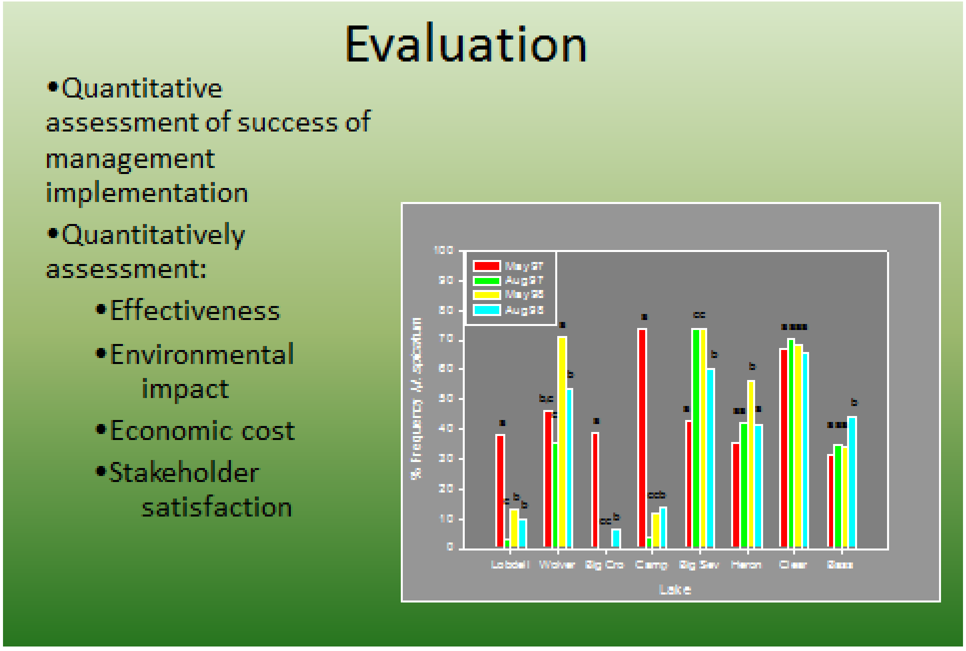


Slide 26

There are several aquatic plant management techniques we use in the United States:

- biological control
- chemical control
- mechanical control
- physical control
- institutional control

Slide 27



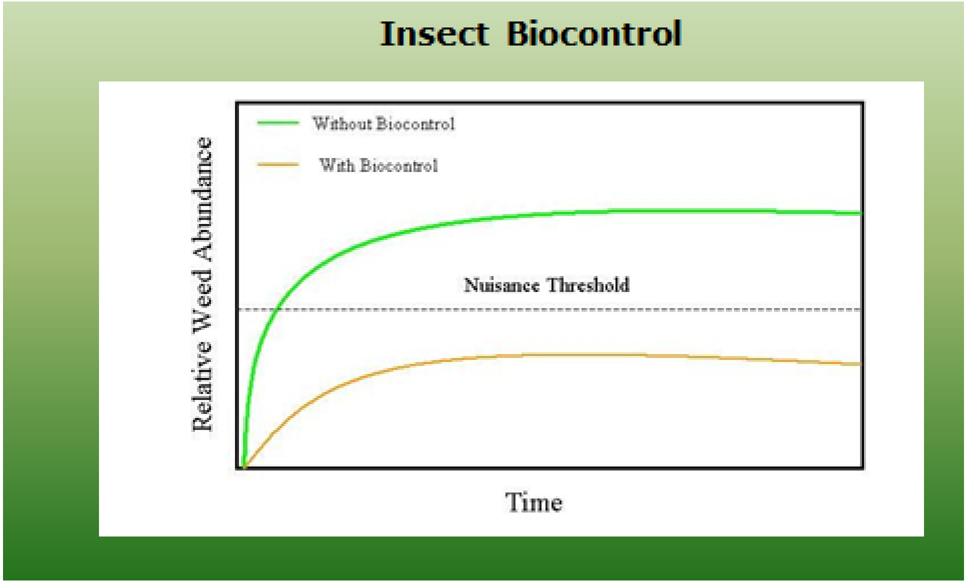
Find the ones that are most suitable for a particular lake and evaluate those techniques. Has this been successful or not? Based on that objective evaluation using quantitative data, decide on some improvements or continue with the current practice. Because management of aquatic plants is an iterative process, learn from your mistakes, learn from your partial successes and then move on. **(Slide 27)**

The two most common biological control techniques are the classical insect approach using insects that feed on the target weed or grass carp. There are also pathogens (classical or naturalized).

There have been four significant bio-control agents released on aquatic plants in the United States targeting alligator weed, water hyacinth, hydrilla and giant salvinia. Alligator weed was the first programme and it was hugely successful. Within 2 years of releasing the insects, plants growing in the water were gone. Along the Gulf Coast in the southernmost states water insects respond very quickly to alligator weed growing in the water. However they do not attack alligator weed growing in moist soil. The level of success in the United States with other species has been substantially less. But the whole purpose with insect biological control is to reduce the biomass of the plant below the nuisance threshold not eliminate it. **(Slide 28)**

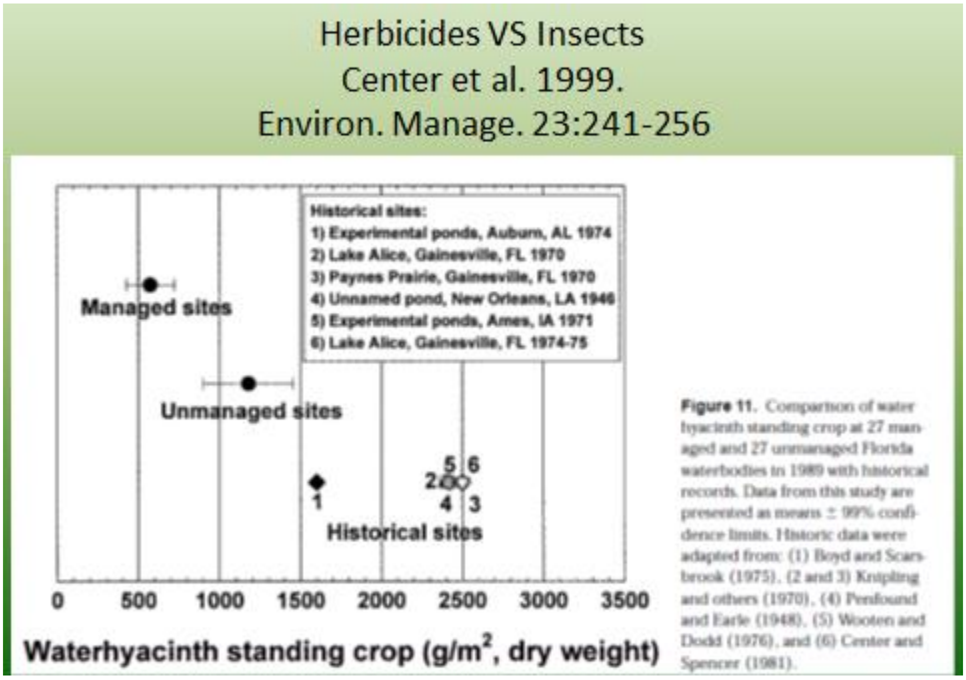
The biological control researchers will set the threshold to have a self-sustaining population of insects. A successful biological control programme is when insects are established and can survive on their own. Sometimes no nuisance threshold has been set. Comments like mine are sometimes interpreted as saying biological control does not work but it is not what I am saying. **Slide 29** is research in Florida by Ted Center, an

Slide 28



eminent bio-control researcher. If we look at the historical data, the growth of the water hyacinth was 2,500 grams per square metre. Looking at the sites that are not managed with herbicides but have a sustaining population of insects, the biomass is 1,200 grams per square metre. The biomass is cut in half. In some ways it is a success, but if 1,200 grams per square metre of biomass is completely covering a waterway that is not a success in terms of suppressing the nuisance of the plant.

Slide 29



The typical biomass of sites being actively managed with herbicides was about 500 grams per square metre. At these sites the waterways stayed open to navigation. If there is no common goal clearly stated, there is no nuisance threshold stated, some people will say that the programme is a success, others will say it is a failure. That is why it is important to have clearly stated goals in a management programme.

Environmental Effects of Grass Carp

Abstract.—We investigated effects of triploid grass carp *Ctenopharyngodon idella* on aquatic macrophyte communities, water quality, and public satisfaction for 98 lakes and ponds in Washington State stocked with grass carp between 1990 and 1995.

Grass carp had few noticeable effects on macrophyte communities until 19 months following stocking. After 19 months, submersed macrophytes were either completely eradicated (39% of the lakes) or not controlled (42% of the lakes) in most lakes.

Intermediate control of submersed macrophytes occurred in 18% of lakes at a median stocking rate of 24 fish per vegetated surface acre. Most of the landowners interviewed (83%) were satisfied with the results of introducing grass carp.

For sites where all submersed macrophytes were eradicated, average turbidity was higher (11 nephelometric turbidity units, NTU) than at sites where macrophytes were controlled to intermediate levels (4 NTU) or unaffected by grass carp grazing (5 NTU).

Bonar, S.A., B. Boldin, and M. Divens. 2002. *Effects of triploid grass carp on aquatic plants, water quality, and public satisfaction in Washington State.* N. Am. J. Fish. Manage. 22:96-105.

The grass carp can be effective on some species. They have a natural feeding preference and there tends to be an ‘all or nothing’ effect. A paper by Bonar, Boldin and Divens in Washington State clearly defines both the benefits and the drawbacks of using grass carp. The first thing to note is that no successful management was observed until at least 19 months after stocking. The effects are seen a year and a half later which is pretty typical. About 39% of the lakes had complete elimination of all submerged aquatic plants. If the goal is to completely remove all plants grass carp is perfect, there just has to be enough stock. But in another 42% of the lakes no control of any plant species was observed, so that might be termed a failure. In all the cases with complete elimination of aquatic plants the turbidity more than doubled which is another drawback of grass carp.

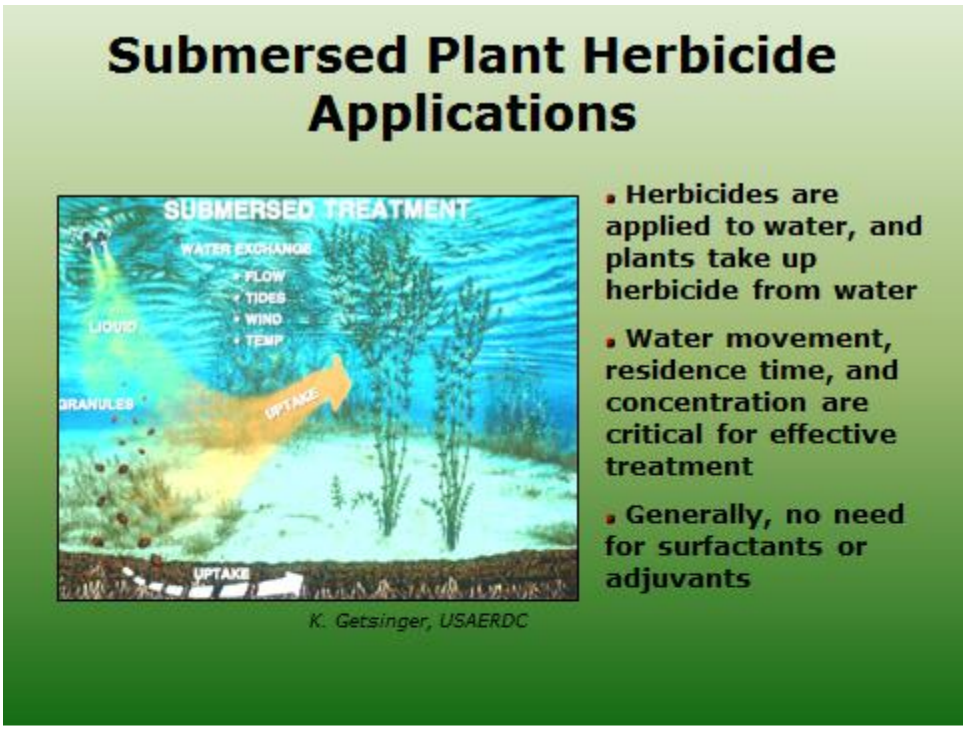
In the US we currently have 14 active ingredients that are labelled for use in aquatic sites. Most of these have been labelled since 2000. One of the drivers was the populations of hydrilla that were resistant to the active ingredient in Floridone. Hydrilla is a $A30 million per year market in Florida alone, so there was a lot of interest in a suitable product. We clearly have a lot more tools than New Zealand in terms of herbicides, but there are some things that we would still like to see labelled for aquatic use. For an emergent or floating leaf plant we put the product into a tank and add surfactants to help penetrate the waxy cuticle. The products above do not come with a surfactant, in part because many states require additional registration. These are applied directly to the foliage and absorbed by the plant through that mode very much like a terrestrial plant application. Instead of a tractor a boat is used.

EPA-Approved Aquatic Herbicides (see www.aquatics.org)

- 2,4-D (AquaKleen, DMA-IV, Navigate, others)
- Bispyribac sodium (Tradewind)
- Carfentrazone (Stingray)
- Complexed and chelated copper (A veritable host)
- Diquat (Reward, Weedtrine)
- Endothall (Aquathol K, Aquathol Super K, Hydrothol 191)
- Flumioxazin (Clipper)
- Fluridone (Sonar)
- Glyphosate (Aquapro, Rodeo, others)
- Imazamox (Clearcast)
- Imazapyr (Habitat, others)
- Penoxsulam (Galleon SC)
- Peroxidases (Greenclean, Pac-27)
- Topramezone (Oasis)
- Triclopyr (Renovate 3, others)

For submerged plants, herbicides are applied to the water either through hoses that are trailing in the water or through injecting a liquid or dropping a granular herbicide into the water. (**Slide 30**) It is very important to understand both the residence time in the water - how quickly the product will dissipate, and the concentration of the product in the water which will determine whether the herbicide is effective in controlling the plant. Adjusting the concentration and exposure time will determine selective control. Selectivity is controlling the target plant with minimal or no damage to the native plant which is the goal of most management programmes in the United States. There is a common misconception that when a herbicide is applied to the water it kills all the plants, but that is

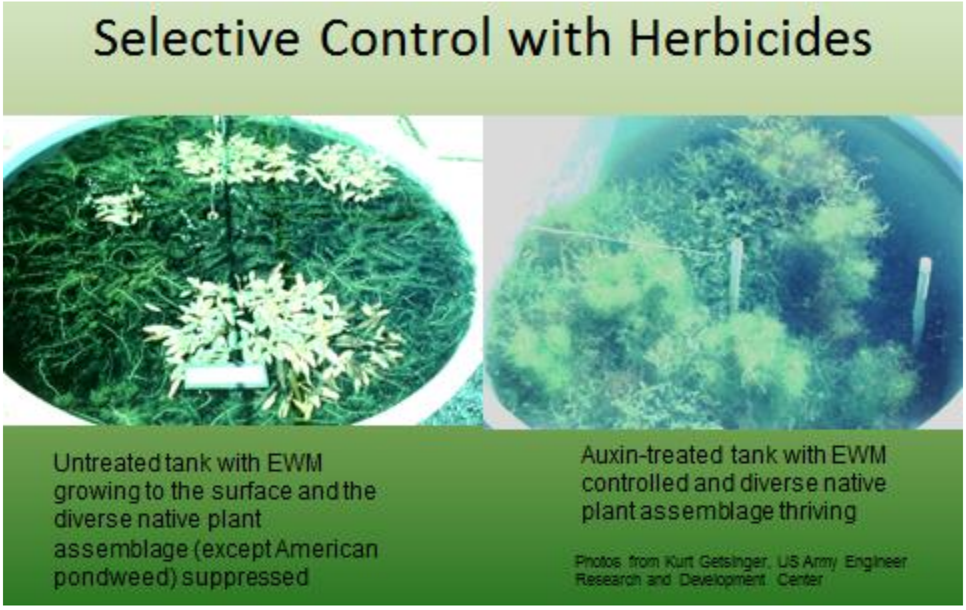
Slide 30



simply not true.

Slide 31 shows an untreated tank with Eurasian watermilfoil planted with a half dozen other native species in comparison with a tank planted in the same way and treated with triclopyr and auxin herbicide showing that the Eurasian watermilfoil was completely controlled, leaving a diverse assemblage of native plants.

Slide 31



Quite often we harm the native plant species but typically there are some species that are tolerant to the herbicide. In fact we select the active ingredient, the concentration and the anticipated exposure time to ensure that we have some level of selectivity. Different products have different levels of effectiveness on different target species as well as on the native plants. **(Slide 32)**

Slide 32

Herbicide Selection

Table. Efficacy of U.S. EPA-Approved herbicides on common invasive aquatic weeds. E, excellent; G, good; F, fair; P, poor; NA, not applicable.

Chemical	Alligatorweed	Eurasian watermilfoil	Giant salvinia	Hydrilla	Waterhyacinth
2,4-D	E	E	P	P	E
Copper	P	P	P	E	P
Diquat	G	G	G	G	G
Endothall	NA	G	NA	G	NA
Glyphosate	E	NA	G	NA	E
Imazapyr	E	NA	P	NA	E
Fluridone	NA	E	NA	E	NA
Triclopyr	E	E	P	P	E

A mechanical control technique is one that involves either using manual labour or a tool to remove plant growth. A physical control technique changes the environment to prevent or reduce the growth of aquatic plants. Some of the mechanical control techniques include hand pulling, cutting, harvesting, diver-operated suction harvesting and rotovating. Hand harvesting is the most widely used control technique in the world. In many areas of the

world labour is inexpensive and hand pulling the weeds or using a simple tool to pull them from the water is still a very viable technique. But it should be targeted at species that are scattered, where more time is spent looking for the plant than doing a control technique. This technique is most effective if labour is inexpensive or there are volunteers who know the right plant.

We once had a dive club volunteer to help control Eurasian watermilfoil on Lake George. We left for a while and later returned to find a big pile of native plants in the bin. When we asked, 'What's going on here?' The answer was, 'It was too turbid to hand pull the milfoil here so we decided to hand pull it over there where the visibility was better.'

It can be a useful technique, particularly in areas sensitive to other control techniques. Hand harvesting is also best used in smaller areas or in areas where there are scattered plants.

Cutting is where an implement severs the stem from the root but there is no effort to remove the plant matter. There are a number of places that use cutting, though in most lakes people find the floating mats of plants somewhat obnoxious.

Harvesting, in contrast, is where the cutting machine also removes the biomass from the water and disposes of it onshore. There has been a lot of discussion in the United States about using harvesting as a nutrient reduction technique. This is a paper from 1974 by Spencer Peterson researching a very eutrophic lake. He determined that harvesting was inefficient for nutrient removal because of the very high loading rates of nitrogen and phosphorus to that lake. If there is a very discreet and reasonable nutrient reduction goal, then harvesting may make some sense. Trying to change the trophic state of the lake based on harvesting alone is unlikely to work.

Harvesting as Nutrient Reduction

Peterson et al. 1974. J. Wat. Pollut Control Fed. 46:697-707

Perhaps the most significant conclusion to be derived from this study is that continuous harvest of aquatic plants from Lake Sallie during the growing season could not offset the high loading of phosphorus and nitrogen.

The wet-weight harvest of 944,000 lb (428,576 kg) of plants was successful in removing only 1.37 percent of the total phosphorus input to the lake, or 1.03 percent of the phosphorus contained in the water volume of the lake during the fall circulation period.

Harvesting is also the only aquatic plant management control technique which, when used according to the manufacturer's specifications, kills fish. It is ironic that when I talk to groups and mention herbicides everybody assumes that I will kill fish. The herbicides that are labelled for aquatic use in the United States, when used according to the label, will not kill fish, but harvesting will. There is nothing to prevent it killing fish; it is a giant mechanical predator.

In **Slide 33** Mikoil found that by harvesting the entire littoral zone of the lake he removed about 5% of the standing crop of fish. Now most of the fish are young of the year fish that

are seeking to escape predation in the dense weed mats. Fish produce many more young in a year than are likely to survive and harvesting is not likely to cause the collapse of a year class of fish. Nevertheless, if killing fish is not an option, then harvesting should not be an option.

Slide 33

Total Fish Impact: Largemouth Bass

Mikol, G.F. 1985. Journal of Aquatic Plant Management 23:59-63.

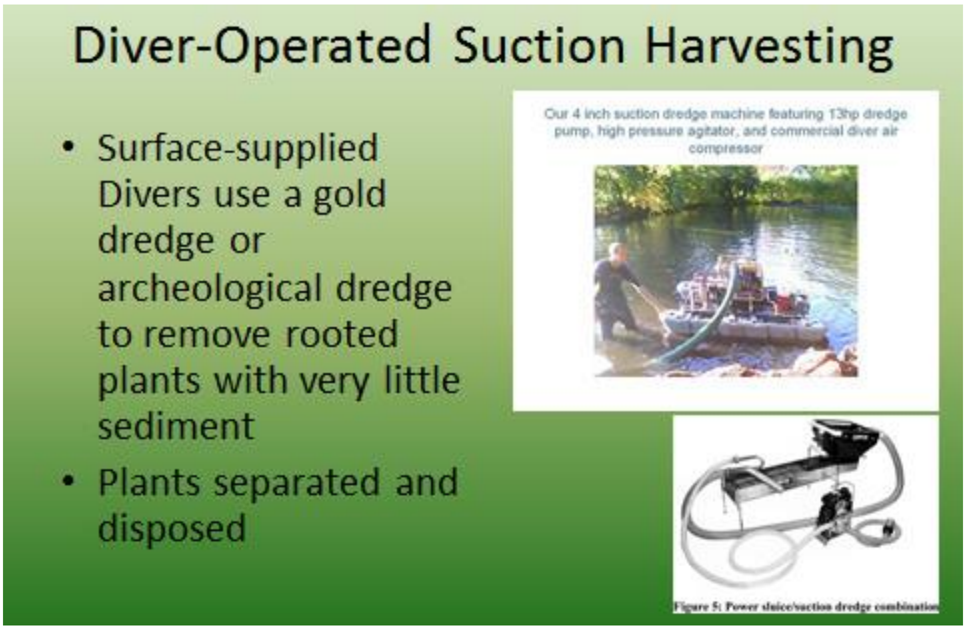
TABLE 4. SUMMARY OF DIRET EFFECTS OF 1982 MECHANICAL HARVESTING ON JUVENILE LARGEMOUTH BASS (*Micropterus salmoides*).

	COLLECTION DATE 8/13/82[1]		
	Site #1	Site #2	Combined
Total # fish removed	11	7	18
# fish removed/ha	220	56	103
Fish standing crop estimate (#/ha)	1,894	1,894	1,894
% standing crop removed	11.6	3.0	5.4

[1]Site #1 was previously harvested in June 1982. Site #2 was previously unharvested.

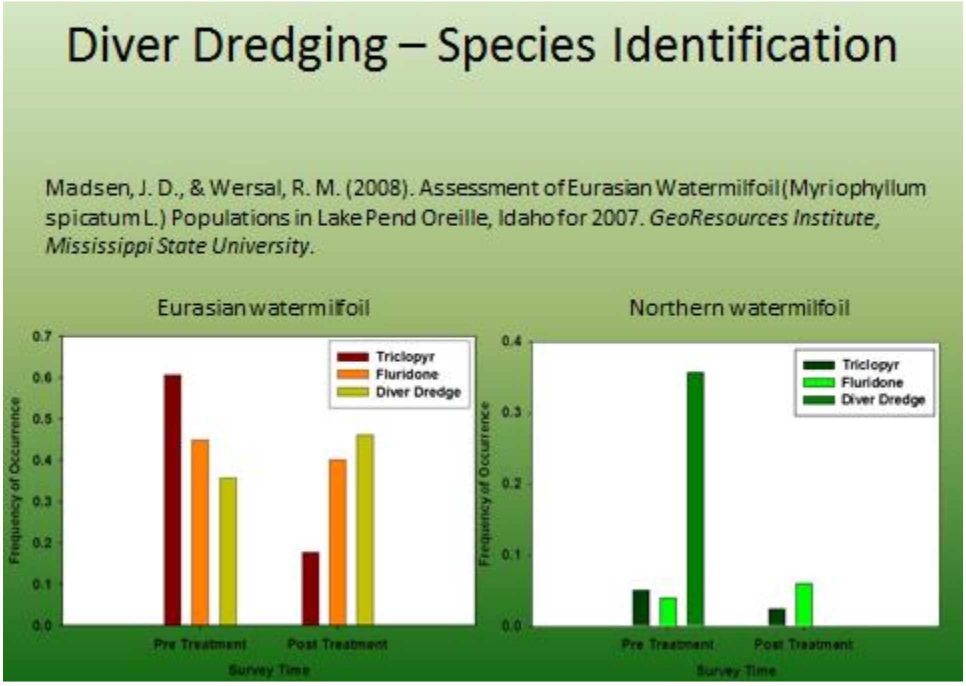
Diver-operated suction harvesting is a technique gaining interest in the United States. One or two divers are attached by surplus air supply to a machine that uses a venturi pump to create suction to remove material. These are widely used for gold dredging and underwater archaeology. In **Slide 34** they suck up the plants, (either like a vacuum or the diver hand pulls a plant to feed into the machine) and deposit them on shore. It makes hand removal more systematic and efficient. It is used where there are small infestations that are not dense.

Slide 34



Most importantly the operators must identify their target plant. That sounds common sense but we did a study in Idaho on the effectiveness of triclopyr, fluridone and a diver dredge at a number of sites. **(Slide 35)** We found that the Eurasian watermilfoil was increasing in the diver dredge areas. We analysed all our data and found that Northern watermilfoil was eradicated at the diver dredge sites. Instead of controlling Eurasian watermilfoil the desirable native plant was being controlled. It is important to train the operators in the identification of the target plant species.

Slide 35



QUESTIONS:

Don Atkinson, LWQS: Excellent, John, thank you very much for giving that United States perspective, I really enjoyed it. The tool box that you have is significantly larger than ours. I am unaware of us having an eradication programme for any weeds in New Zealand. We are trying to manage them and not even doing a good job of that. Have you got a controlling authority that sets the standards and requires the eradication, or is it more an adlib process?

Dr John Madsen: In the United States, except for a very few species, there is no federal authority to enforce the eradication of species. Our agency that oversees the prevention of species coming into the country is USDA APHIS, the Animal Plant Health Inspection Service. There are very few species that they undertake to manage or attempt to eradicate. They usually are a direct threat to agriculture and the species that they target are eradicated by themselves or their co-operators, the states' Department of Agriculture.

The bulk of our plant enforcement activity is done at the state level. The 50 states are as different from each other as you could possibly imagine. The western states have been very aggressive about rangeland weeds to the point where each county has a weed supervisor paid for by the county because livelihoods are dependent on timber, rangelands or cattle. They are very active in finding weeds and, if on private property, they give notice that you have x number of days to control that weed, or they will come and control it and then send a tax bill.

There are about 13 states with that level of authority and those counties get matching money from the Federal Government to control weeds on both state and federal lands. They are very active in both management and in some cases eradication. Then there are other states that have no regulation and the best they do is monitor nurseries for prescribed plants. If there are some specific state regulations or legislation of interest I can direct you to examples.

Don Atkinson, LWQS: Does that include the control in respect of lake weeds?

Dr John Madsen: Yes in the western states in particular, some species of lake weeds are included under their noxious weed law. For instance in the State of Idaho I work with the State Department of Agriculture on three specific weeds that are noxious weeds under their law and they are mandated to manage those weeds in one way or another.

Kathy White, Waikato Regional Councillor: I have two questions. Do you have an opinion about whether herbicide application is acceptable or effective when it is applied by helicopter as opposed to applied by boat? What is your opinion of the method that we call shredding or mulching, you talked about cutting, and when the weed is cut but not removed.

Dr John Madsen: Many states do use herbicide applications by helicopter for both emergent and submersed weeds and get excellent results. The State of Florida treats most of their hydrilla lakes using helicopter applications of granular formulations. But it is important with helicopter applications to do it at a very low level and in such a way that there is no drift. The right product is also important when applied from that altitude as some can be corrosive to infrastructure because of the chemical properties of the herbicide. It is a very specialized form of aviation and it is not for people who are untrained. There are a lot of helicopter applications but usually not near human habitation.

I mean usually not in front of somebody's docks because nobody likes to be woken at 5 o'clock in the morning to the sound of a helicopter applying herbicide on their lake.

The other one is shredding. If your goal is to control weeds or manage the amount then shredding is certainly an acceptable technique. You still kill fish but remove the problem of transport and disposal of plants, which can be a real nuisance and very costly. Obviously when shredding there is no nutrient removal as part of the harvesting activity, but you can be more efficient and effective in terms of controlling that plant but not necessarily long term control, depending on the species and how the cutting is applied. But I mulch every week at home on my lawn which is quite effective at keeping the biomass down.

Kathy White: Regarding the helicopter application are there any other risks apart from possible damage to infrastructure if spraying too near human habitat?

Dr John Madsen: It is not so much that there is a danger to people with the helicopter application, but there will be a lot of phone calls okay. We find this influences our selection of herbicide in some areas of the country. There are very few calls if applying triclopyr, but if applying 2,4-D which is cheaper, there will be a lot of phone calls. Personally, considering that these are not nice personable phone calls, there might be a reason to select the more expensive product over the less expensive product. In the same way, you will get many phone calls when doing helicopter applications and you tend only to get a few phone calls when doing a boat application. So what was the other question?

Kathy White: The other question regarding shredding, some people have said to me that there are risks connected with that, in localised areas there can be doubling of nutrient levels and also the possibility of spreading weed when you shred or mulch it, that you spread it downstream and may increase the level of weed over the long term.

Dr John Madsen: I will try and address both of those. With shredding the plant matter goes through the grinder coming out as a mush that is unlikely to grow. The plants come out in very small bits. Not everything goes through the grinder; a lot is pulled up by the cutting blades and bars and can drift off and make fragments. In general I do not recommend harvesting or shredding for a new infestation because it tends to spread the plant as opposed to some other technique. But if there is a very large infestation already and the purpose is to gain boat lanes for access, or something similar, then shredding as opposed to harvesting does make sense.

Can you nutrient release? Yes it is a possibility and sometimes using a grinder might stimulate an algal bloom. This depends on the environmental conditions and how much nutrients run in that plant material. But quite often you get algal blooms when the plants start to senesce in the fall. However, in general, harvesting or shredding should be before the plants are so dense that you have a very large amount of biomass to control.

Max Gibbs, NIWA: Coming back to your curlyleaf pondweed situation. If you were to use mulching and grinding before the turions formed do you think that would be an effective control or management mechanism?

Dr John Madsen: Yes, you do not have to use a herbicide pursuing that strategy. You could mulch and grind as long as harvesting is below the level at which the turions are formed. There are harvesters in the United States that are made with the cutting bars on a vertical arm that can be raised and lowered for an even cut near the bottom, and then collect the material. Harvesting is slower and more difficult to remove all the plants that

are forming turions in a fairly short period of time. But it could be done, just as you could use other techniques.

Session Two : The Issues

SESSION CHAIR – Cr Lyall Thurston, Bay of Plenty Regional Council

WEEDS AND THE ROTORUA LAKES

Dr John Clayton
Principal Scientist - Freshwater Ecology, NIWA, Hamilton
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John is a Principal Scientist and Programme Leader with NIWA Hamilton and has carried out research on New Zealand freshwaters for over 44 years and did his PhD thesis on Lake Rotoma. His first paid job was as an environmental consultant; then as an Engineering Scientist for the NZ Electricity Department working on hydro lakes around New Zealand; then as a research scientist at MAF Ruakura Research Station, before joining NIWA in 1992. His speciality is applied research and technical consultancy on aquatic plants, including their management and control. His work encompasses weed risk assessment and biosecurity; aquatic weed management; biotic and environmental impacts, and lake health assessment using macrophyte indicators. He has been a key adviser on preventative weed management for the world rowing events at Lake Karapiro in 2010 and towards the eradication of alien aquatic weeds from New Zealand. John has also applied his knowledge and experience gained from over 1000 SCUBA dives in New Zealand freshwaters to develop rapid vegetation survey methods, including a recent management tool (LakeSPI) to assess lake ecological condition. Research in lakes has also involved a wide range of environmental impact assessments, including the effect of turbidity and boron from mining discharges, arsenic accumulation in macrophytes and water level fluctuations on hydrolakes. His aim is to supply robust and pragmatic solutions and tools for water body managers seeking to manage aquatic vegetation resources and issues.

ABSTRACT
The Rotorua Lakes are of volcanic origin and they form an integral feature of the regions landscape. No other region in New Zealand has such an interesting combination of lakes in close proximity, each of which offers unique cultural values and a diversity of recreational activities.

Rotorua lake weeds rose to public and political prominence in the 1960s and the first seminar addressing this issue was held in 1964. A second meeting followed in 1966 with a 'Seminar on Water Weeds'. These seminars involved outside experts and many will remember Prof Val Chapman, University of Auckland, who had a prominent role supervising research on these weed problems with his students. I was his last PhD student before he retired in c. 1975.

This talk will provide an outline of key changes in the Rotorua Lakes over time by focusing on the aquatic plants. The aquatic plants in a lake provide a window into understanding the health and condition of each lake and this talk explains how native and invasive plants can be used to assess or describe lake condition, enabling lakes to be ranked, monitored and compared. The native condition of each lake has been compromised by two key impacts; invasive plant species and declining water clarity. Other potential impacts are also discussed. Key invasive weed species will be illustrated and discussed, including

their spread and ecological impacts. Some of the history of management response will be discussed along with some thoughts about the future.

TRANSCRIPT
I am going to talk about weeds in the Rotorua Te Arawa lakes. I must first thank Dr John Madsen for his excellent talk and the opportunity that this seminar has provided to compare our countries' respective approaches around the politics of weed management and the science behind control. We are indeed relieved and pleased to see that a lot of his work in the USA endorses the approach that we have adopted in New Zealand.

Slide 1 looks at the distribution of the main Rotorua Lakes. The Rotorua Te Arawa Lakes face a number of challenges, including water quality and invasive species. Nutrients and sediments are two of the biggest drivers of water quality. However, an important point to note is that nuisance weed growths are not dependent upon water quality, so you can still have a weed problem with either good or bad water quality.

Slide 1

An increase in algae (including blue green algae) is often associated with an increase in nutrients; while the decline in kakahi (mussels) and koura (crayfish) is often associated with declining sediment density and increasing organic content. Although this symposium is about 'Weeds and Wallabies', there needs to be recognition of the major threat and impact that pest fish would have on these lakes if they were allowed to establish, which includes the decline of desirable aquatic vegetation and native koura.

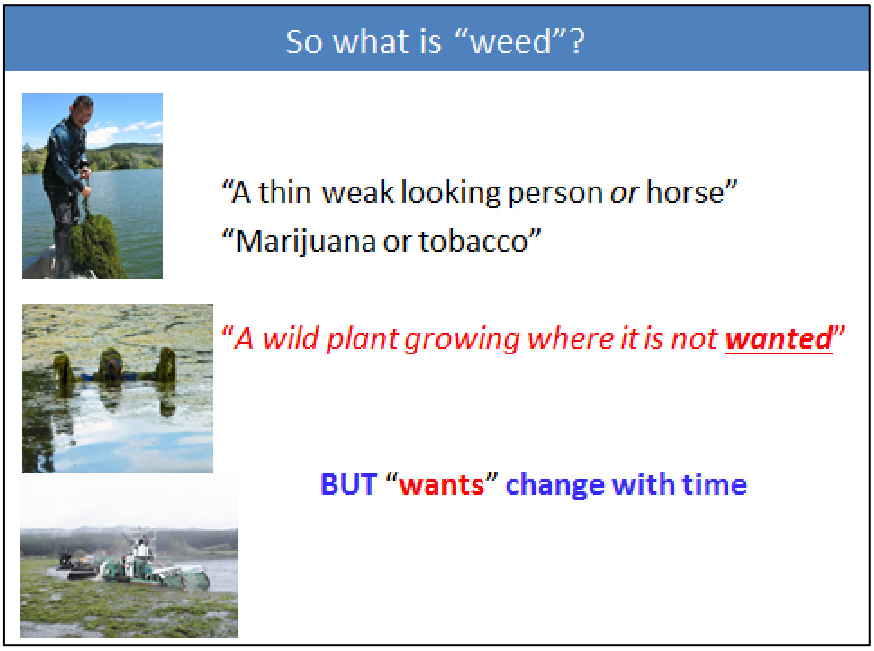
The decline of submerged plants can also be caused by reducing water quality, especially clarity. However despite changing water quality over the years, a major issue for the Rotorua Te Arawa Lakes has been the challenge from invasive plant or weed species. In 1961 residents of Lake Rotoiti met to decide on how to rid their lake of invasive weeds. The Lake Weed Society was formed, with a focus particularly on lagarosiphon and its control. Professors Chapman and John Brown (Auckland University) were key contributors in those days. Many of you here will remember those characters. (Professor

Val. Chapman was my PhD supervisor and Professor John Brown continued as my supervisor once Prof Chapman retired).

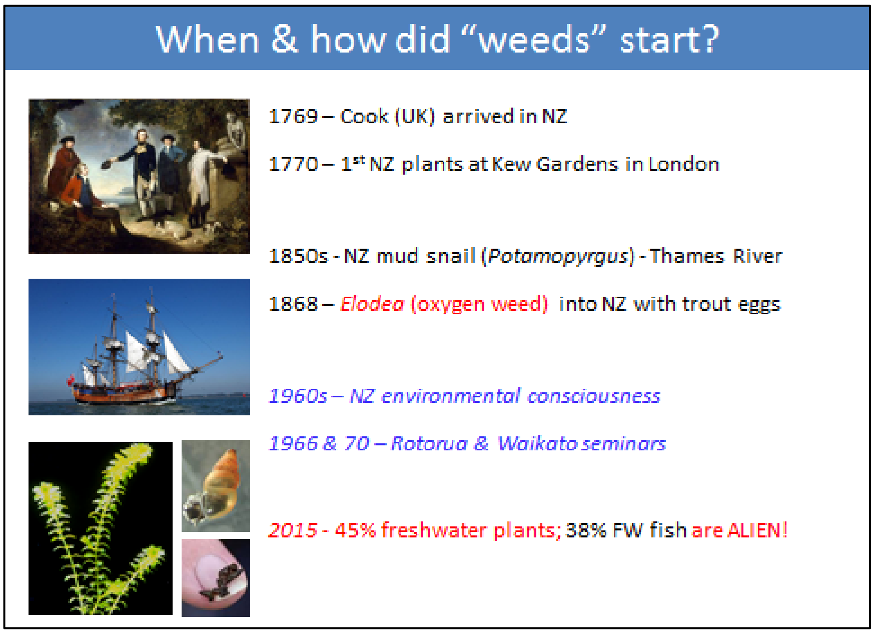
In 1966 and 1970 there were two interesting booklets published on weed control in the Rotorua and Waikato Lakes, produced by Prof. V. J. Chapman. I recommend you read these if you get a chance. In the late 1990s the focus of the Lake Weed Society expanded to include water quality and the name of the society changed to the LakesWater Quality Society.

Aquatic plants can be desirable and beneficial; however certain species are renowned for their weediness. Of course what is a weed in one country may not be in another. So, what is a weed? **Slide 2** attempts some definitions, the most relevant one being ‘a wild plant growing where it is not wanted’. But ‘want’ is the operative word and ‘wants’ change with time.

Slide 2



Slide 3



When and how did weeds start? **Slide 3** goes back to 1769 when Captain Cook sailed the first ship to New Zealand from the United Kingdom. By 1770 the first of our New Zealand plants were growing in Kew Gardens in London. Over subsequent years, multiple voyages from the UK bought many European fauna and flora from the UK. Even the tiny New Zealand mud snail, *Potamopyrgus antipodarum*, first appeared in the Thames River around the 1850s because sailors filled up their water barrels from our rivers as a potable water supply before sailing back to the old country. On their return to London they emptied any remaining dregs into the river. Our pond snail has subsequently spread from the United Kingdom through Europe and more recently to America, which is causing them some upset at the moment. These examples demonstrate just how easily biota can spread between countries.

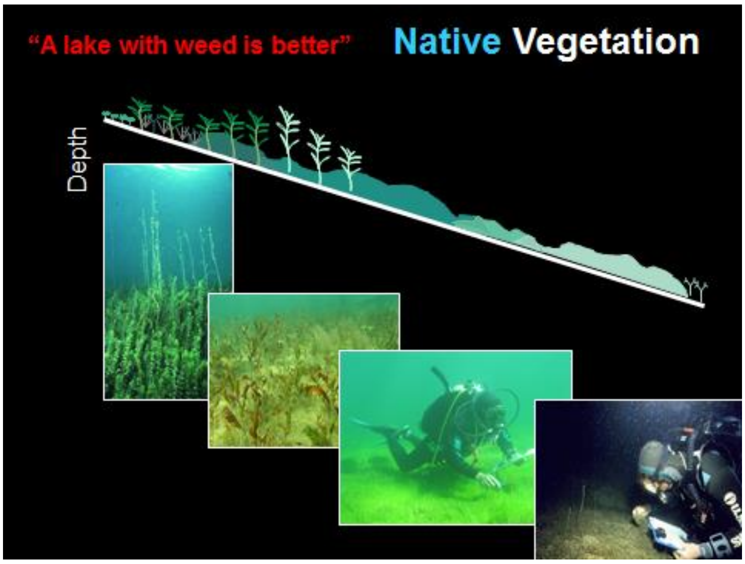
With respect to pest aquatic weed species, *Elodea Canadensis* (elodea or oxygen weed) was introduced to New Zealand with trout eggs in 1868. Public perception during these early years generally failed to appreciate or respect the inherent value of indigenous fauna and flora, so for many decades the introduction and acclimatisation of foreign species was considered acceptable and even desirable. Many mammal species were introduced as food for farming and for sport. It was another 100 years, to the 1960s, before environmental consciousness really took hold. Roll the clock forward to now (2015) and it is interesting to note that 45% of freshwater plants and 38% of the fish species that we have in New Zealand are alien.

However it is not all bad news. There has been significant progress made with weed control in New Zealand over the last 40-50 years. For example, several serious weed species have been eradicated from the country and because they are not seen any more it is a classic case of 'out of sight and out of mind'.

Several great successes in the Rotorua Lakes area are worth noting. **(Slide 4)** Water hyacinth was first identified in New Zealand in 1913, but its potential impact on waterbodies was recognised, so it was banned from import in 1927 and declared a noxious weed in 1950. At this time water hyacinth was already spreading and forming floating rafts on Lake Rotorua, but fortunately early control works enabled eradication.

Slide 4

Yellow Water Poppy (*Hydrocleys nymphoides*) was discovered in a pond at the margin of Lake Rotoehu and was eradicated in 1976; while marshwort (*Nymphoides geminate*) was found growing along the margins of Lake Okareka in 1981, where it had spread from an original 1976 planting in an ornamental pond on an adjacent property. The entire weed population was covered with polythene and was ultimately eradicated. Many of you will remember the water net saga. Apart from some initial progress controlling submerged weed bed habitat that supported surface floating rafts of water net, this weed largely disappeared on its own accord without explanation.



Slide 4

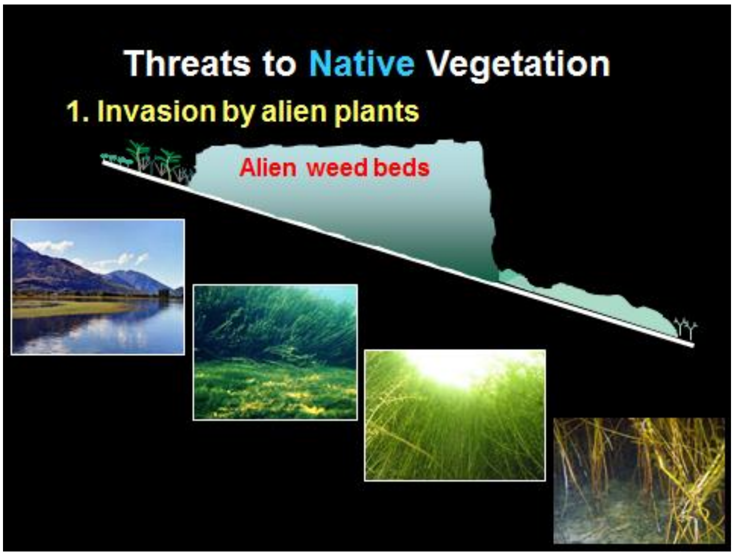
A lake without weed is often a relatively sterile unproductive environment. Ideally it would be preferable to have entirely native plants, but foreign plant species may still be better than no aquatic vegetation at all. It is well recognised that invasive species pose most of the problems. **Slide 4** is an example of a native vegetation profile through a lake that has good water clarity. As the water becomes more turbid submerged aquatic plants will not grow as deeply. Most of the Rotorua Lakes can support a moderate to good depth of vegetation, and the clearest lakes have plants growing down to around 15 metres and sometimes deeper.

Slides 5, 6 and 7

In shallower water, native milfoils and pondweeds **(Slides 4-6)** are common. In deeper waters **(Slide 7)** charophytes (comprised of several *Chara* and *Nitella* species) can form undulating carpets down to 15 metres; and in some clear South Island

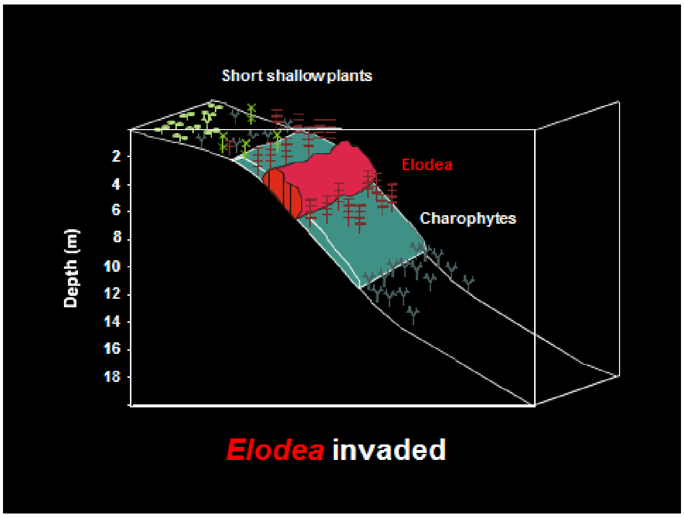
lakes they can reach 30-40 metres. There are many different species of *Chara* and *Nitella*.

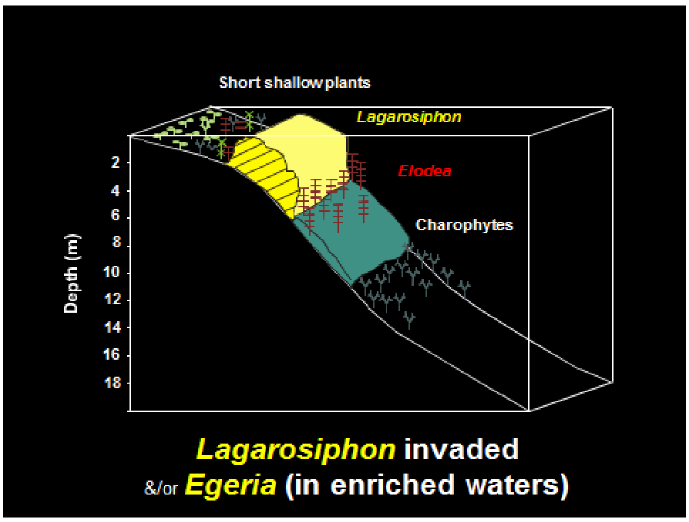
Alien plants are a major threat to native vegetation. **Slide 8** shows what can happen when alien plants invade and displace the native plants. Generally native plants may survive in shallow water where wave action or fluctuating water levels create a disturbance zone. Likewise, if the water is clear, native plants can still occupy the deep water zone.



Slide 8

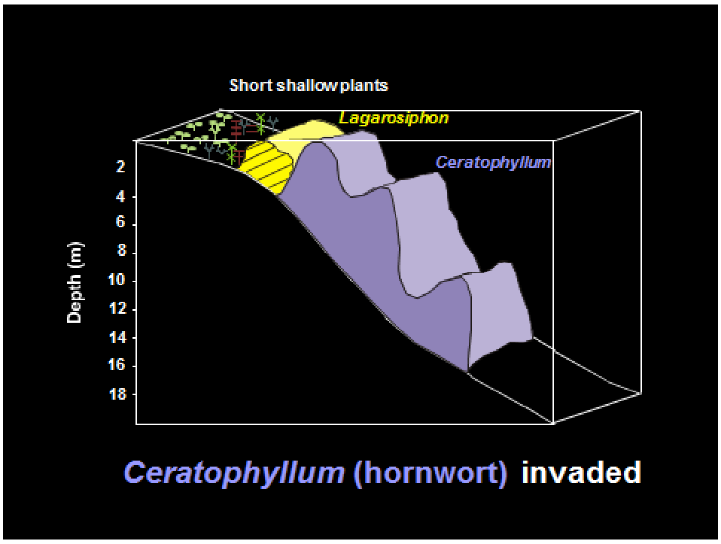
Slides 9-11 show the increasing impact caused by three key invasive species (*Elodea*, *Lagarosiphon* and *Ceratophyllum*). *Elodea* and *lagarosiphon* are now widespread around New Zealand, while *Ceratophyllum* (commonly called 'hornwort') has so far been restricted to the North Island. Each of these species respectively has an increasingly large impact on the displacement of native plant communities and on lake usage (e.g., recreational and power generation). The worst of these weeds is undoubtedly hornwort, which has unfortunately spread around most of the Rotorua Lakes and much of the North Island.





Slides 9 and 10

Slide 11



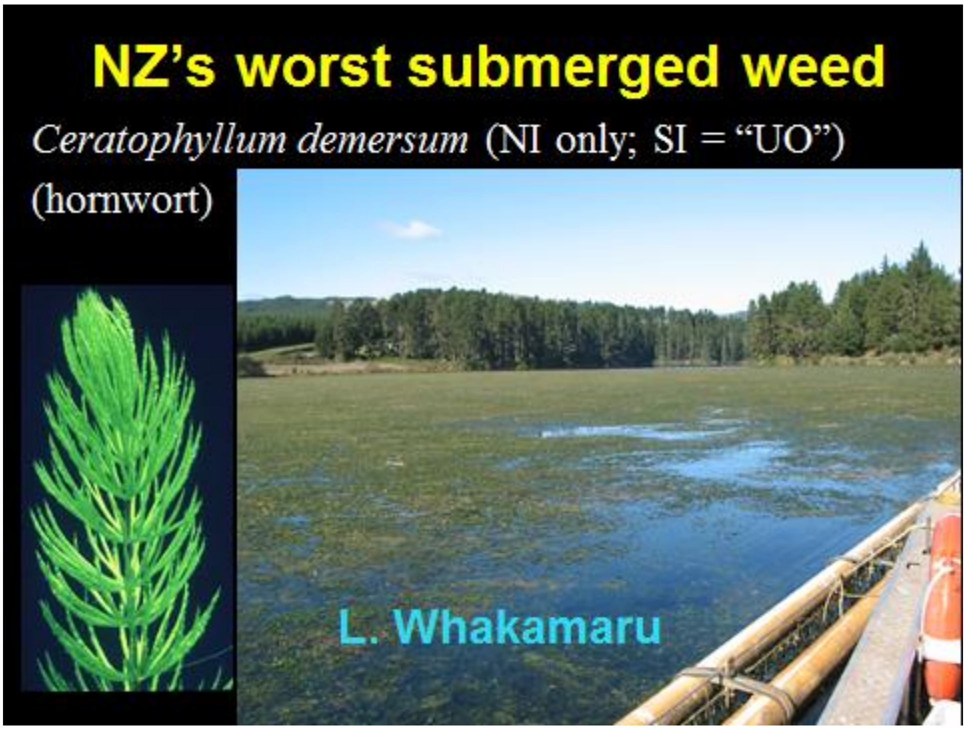
Slide 12 - Lake Rotoma shows tall lagarosiphon beds invading into and displacing low-growing native charophyte meadows in deeper water. If you dive inside a weed bed you find it is usually a dark inhospitable environment with a lot of organic matter and low oxygen levels. A world biomass record for lagarosiphon was collected from a $1m^2$ quadrant taken in Lake Rotoma.

Slide 12

Slide 13 also shows lagarosiphon weed beds in Lake Aratiatia, the first hydro lake below Lake Taupo.

Slide 13

Slide 14



Slide 14 shows floating rafts of *Ceratophyllum* (hornwort) at Lake Whakamaru, a hydro lake half way down the Waikato River. This weed is widespread in the North Island; but it is an 'unwanted' organism (UO) in the South Island; a Biosecurity NZ classification that means it is targeted for eradication whenever found.

Slide 15

Slide 15 (above) shows dense floating rafts of seasonal weed drift accumulating on a boom above the power station. If this weed drift gets passed the boom and down to the hydro power station, the cost of clearance and potential risk of station shut down is significant.

Slide 16

Slide 16 shows the extent of hornwort drift around the Lake Rotoehu shoreline; while the photo at bottom left (Hamish Lass from Bay of Plenty Regional Council) shows how easily hornwort can be spread by a boat anchor. Clearly, it is very difficult not to spread weed. Although 'Check, Clean and Dry' messages are widely displayed, it is obvious how easy it is for this weed to be spread.

There are key problems caused by invasive weeds. Firstly, invasive weed species grow vegetatively and after a few years of invasive weed growth, the native seed bank becomes so deeply buried it has no chance of regenerating.

Another problem is the reduction in animal biodiversity. Dense weed beds are often associated with low oxygen levels and pH can fluctuate wildly from photosynthesis. Furthermore, organic accumulation often leads to low density sediments beneath invasive weeds that can impede or prevent kakahi and koura survival. As sediment becomes more organic, kakahi sink below the sediment surface and drown in the soft silt.

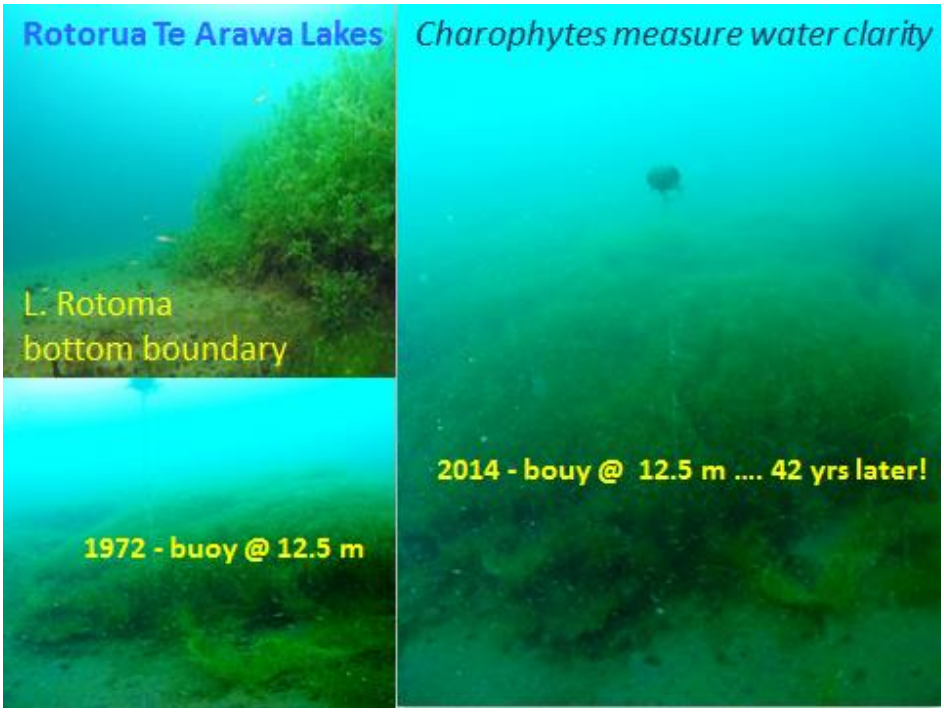
Slide 17 is a picture taken in Lake Rotokakihi where organic matter has built up. Some mussels are visible at the surface, but many are partially 'buried', struggling to keep their

siphons open as they slowly sink into sediment. Crayfish mostly avoid weed beds growing on soft organic sediment. If catfish become established in these lakes; it will be the cat fish mouths that any remaining koura will end up (Slide 20 – bottom left).

Slide 18

As nutrients increase there tends to be more algae suspended in the water and detritus also accumulates on plant surfaces thereby reducing plant health. Declining water clarity also decreases the depth that submerged plants can grow. **(Slide 18)**

Slide 19



Lake Rotoma is a good example of a clear lake. It has some well-formed deep charophyte boundaries **(Slide 19)**. Charophyte bottom depth boundaries represent an annually

integrated light limiting compensation point for sustainable plant growth. These boundaries can be used to measure changes in water clarity or lake level. In 1972, I placed a submersed float on a nylon line attached to a brick. Periodic inspections up to 2014 have demonstrated that over a 42 year period that bottom boundary has been stable, which therefore supports a relatively consistent water clarity. Lake Rotoma has had periods of lake level fluctuation and during these times the bottom plant boundary has responded proportionally, but with a notable lag phase.

Lake Okataina is the best example of a lake with no outlet. As a consequence the lake level rises and falls in direct proportion to rainfall. During an earthquake the lake level has also been known to drop. **Slide 20** shows a 5 metre water level fluctuation over a 3 year period. The lake level reached up to the store windowsills in 1972, dropping 5 metres over the next 3 years.

Slide 20

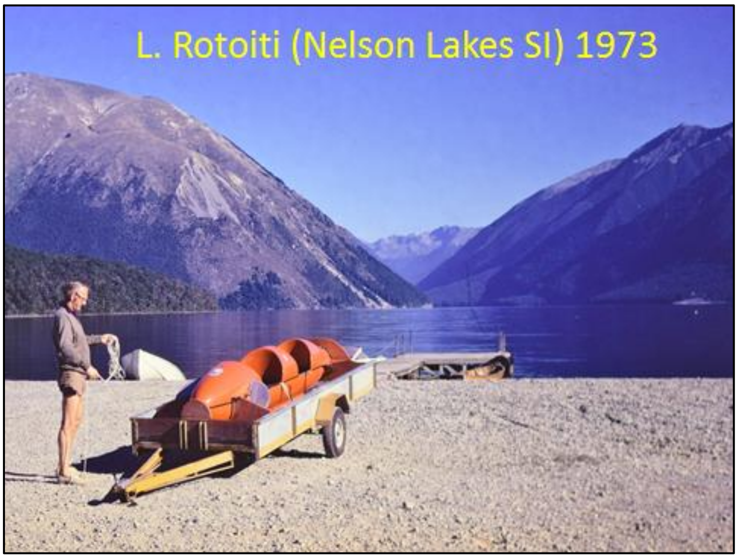
Slide 21

Charophytes integrate long term water clarity conditions

Charophyte Mean max depth (m)		1980/90s	2013/14	Years
Stable	Rotoma	14.5	14.5	30
	Okareka	9	8.5	30
	Okataina	15	13.5	30
Declining	Rotomahana	18	9.5	25
	Tarawera	16	7	25
Improving	Rotorua	0	7.1	last 10 yrs
	Okaro	0	1	last 4 yrs

Slide 21 compares charophyte depth limits from several lakes as a measure of water clarity. As previously noted, Rotoma has been stable for 42 years, while Okareka and Okataina have also remained relatively stable over the last 30 years. Tarawera and Rotomahana are two lakes where charophyte depth limits have declined substantially over the last 25 years. On the other hand, Lakes Rotorua and Okaro are showing recent improvements based on plant bottom depth boundaries.

Slide 22 shows the use of a two man underwater submarine, which the Auckland University bought in 1973. We surveyed the underwater vegetation in Lakes Rotoiti & Rotoroa in the Nelson Lakes National Park and several of the Rotorua Te Arawa Lakes.



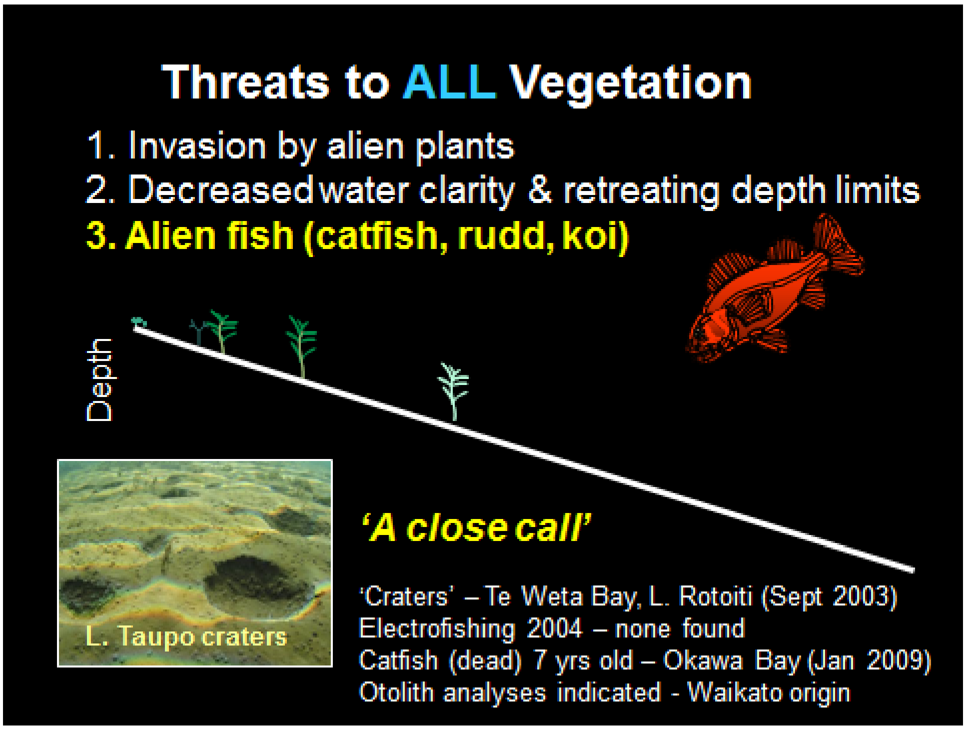
Slide 22

Slide 23 provides some excerpts from my Dive Log 43 years ago. In Lake Okataina we found the crayfish appeared rather aggressive as they reared up and confronted us with their claws raised. In other lakes they scurried into the charophytes meadows and hid. In Lake Rerewhakaaitu my professor went for one of his rare dives in extremely poor visibility at the time and I noted in my dive notes that he was, 'surprisingly agile but somewhat nervous'. I retrospectively worked out that he was 63, which is younger than I am now and still diving in these lakes!

Slide 23

Slide 24 (over**)** returns to the threat of alien fish. There has already been one close call in Lake Rotoiti when in 2003 I found several 'craters' scalloped into Te Weta Bay sediments (see Slide 24 – 'L Taupo craters', caused by catfish). The University of Waikato was notified and they attempted electrofishing, but unfortunately this was not successful. However, 7 years later there was a dead catfish washed up in Okawa Bay. Luckily that

Slide 24

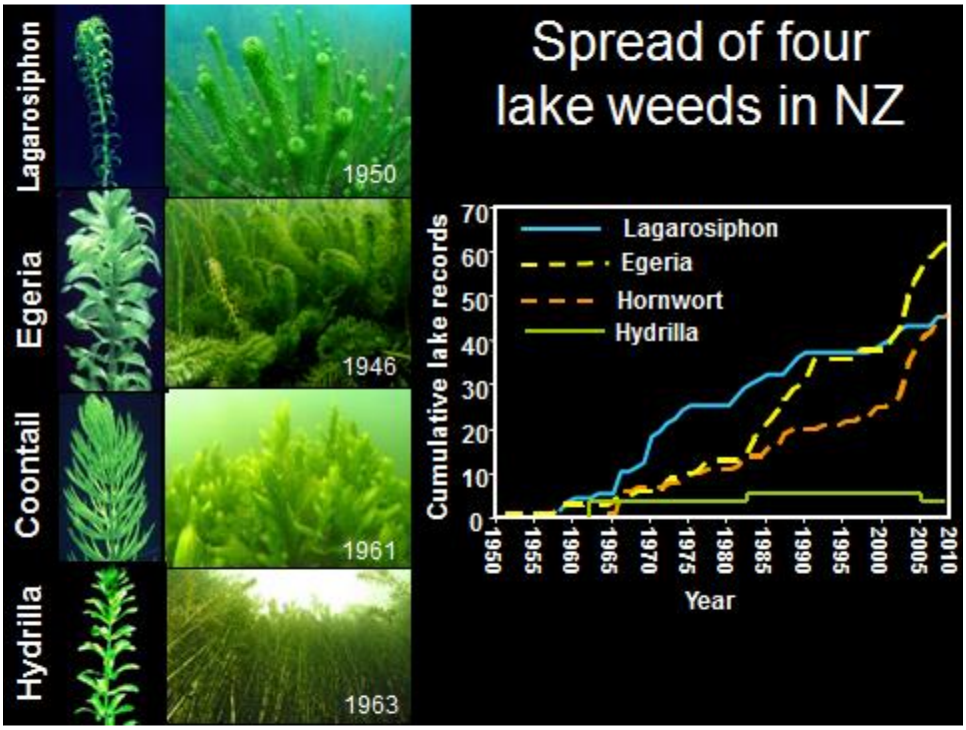


catfish was a male. It may well have been a very different outcome if this had been a fertile female! It is almost inevitable that sooner or later catfish will establish in the Rotorua Lakes, but we must do everything possible to prevent them establishing and this applies to other alien biota too.

Slide 25

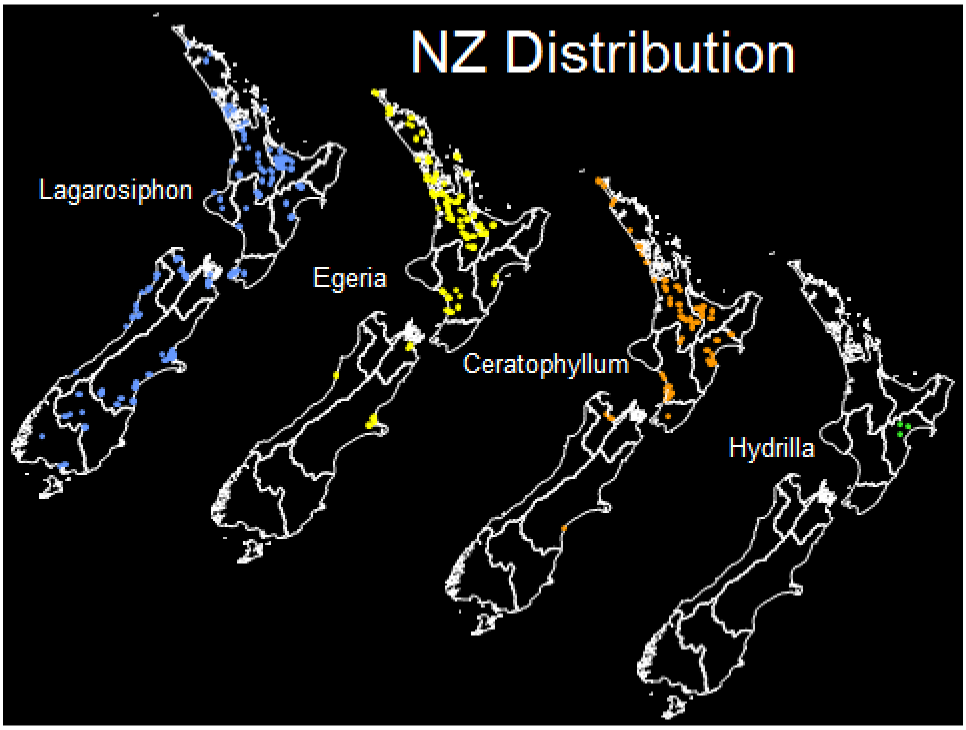
Slide 25 illustrates some of New Zealand's worst aquatic weeds. **Slide 26** shows the rate of spread since 1950; with all species steadily expanding their range, with the exception of hydrilla which has been contained and controlled. **Slide 27** shows the distribution of lagarosiphon right across the country; egeria mostly in the North Island with a little in the

Slide 26



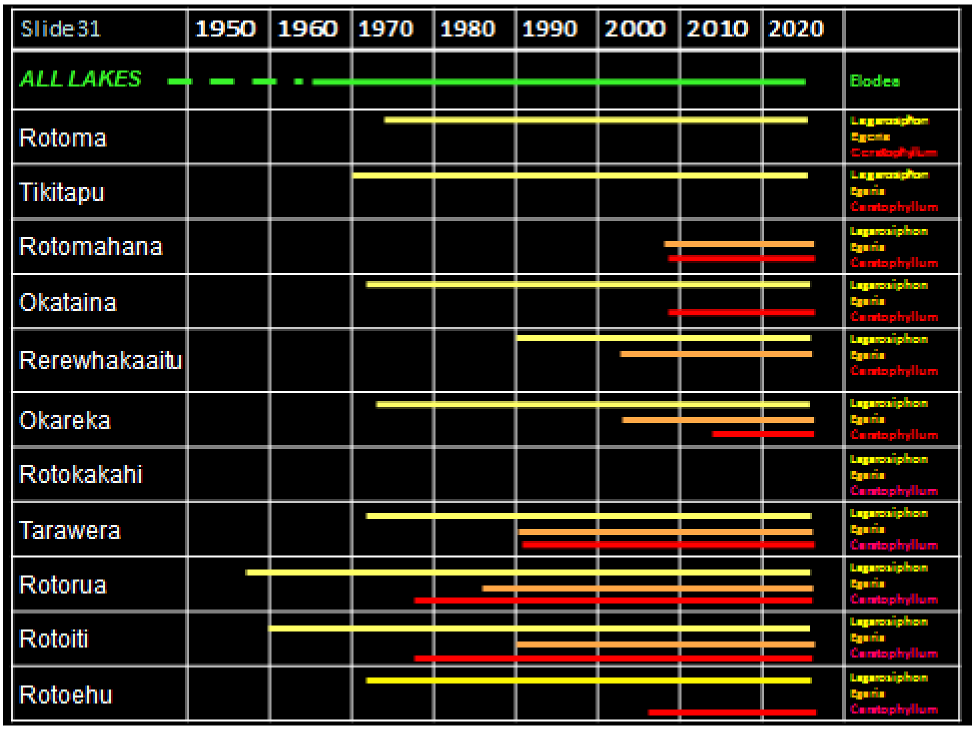
South Island. Ceratophyllum, is an 'unwanted' organism in the South Island (Ministry of Primary Industries classification), and is therefore targeted for eradication from all South Island sites. Hydrilla is only recorded in the Hawkes Bay and the introduction of grass carp into these lakes has effectively eliminated any risk of further spread. Previously hydrilla was one of the biggest weed threats to New Zealand waterbodies.

Slide 27



Slide 28 shows the approximate arrival date of the major aquatic weed species into the Rotorua Te Arawa Lakes. Elodea was the first of the oxygen weeds, introduced during the 1950's, most probably as an escapee from a trout hatchery in the Lake Rotorua catchment. Elodea has one of lowest impacts on these lakes out of all the main aquatic weed species. Its use in hatcheries, along with deliberate spread, preceded the awareness of undesirable impacts that exotic species can have on native aquatic vegetation. Lagarosiphon was the second submerged weed to have a prominent impact on these lakes, establishing in the late 1950s in Lakes Rotorua and Rotoiti, and subsequently through many of the remaining lakes in the 1960s. Lakes Rotokakihi and Rotomahana are the only two large lakes still free of lagarosiphon. Egeria first established in Lakes Rotorua, Rotoiti and Tarawera in the late 1980s, followed by three more lakes after the year 2000. Finally ceratophyllum (hornwort), which is undoubtedly the worst of all these weed species, has now established in seven of the lakes, with only Lakes Rotoma, Tikitapu and Rotokakahi still clear.

Slide 28



In the year 2000 a survey of plant traders showed that there were 27% new species which we did not know were present in New Zealand at that time. There are now over 50 naturalised alien aquatic plants in New Zealand, 75% of which have been introduced as ornamental plants. However, there are many more aquatic threats, both plants and fauna, outside New Zealand borders that could still enter the country. Common low impact species are often spread naturally by birds and wind; but the high impact species are spread mostly by humans, particularly through use of water craft and ornamental ponds.

The key trends and drivers that are or have the potential to impact on New Zealand freshwaters are:

- a continuing spread of existing pest species - fish and plants
- increasing human pressure from tourism, infrastructure and road access to lakes
- new weeds coming through the New Zealand border
- weed escalation due to climate change
- changing water use patterns:

- water storage and reticulation systems developing for agricultural development which impacts on water quality through the nutrients and water clarity from the sediments
- water level change compromises the habitat quality

The implications for the future include:

- increasing loss (often irreversible) of aquatic vegetation from lakes
- a decline of ecological function and benefits in terms of water quality and habitat
- loss of habitat including wetlands for dependent biota
- extinction of indigenous species
- the decline of water quality and the value of freshwater resources

We can conclude that the spread of existing weeds will continue largely due to human behaviour, and new invasive species will arrive through commerce, travel and the internet (e.g., TradeMe). But New Zealand has got unique opportunities based on its history, isolation and legislation, to face these problems but the challenges are vast. There are multiple managers, costs and priorities. At the end of the day we are all human; we need food, we need shelter, and we need safety. We also want the comforts of life; one example being the need for electricity which requires dams.

It is the environment that is often compromised as a consequence of our anthropocentric priorities. However we can make a difference. We need to appreciate our natural heritage, and educate ourselves and others; since awareness is critical in terms of being able to change behaviour. Research is also needed for better tools to help prevent pests entering New Zealand; including more effective lake interceptions. We have many examples of successful containment and restoration, including the eradication of five aquatic weed species from the country. We have the opportunity to manage many of our lakes as if they were islands; so just like the restoration of native wildlife on off-shore islands, we can achieve similar restoration goals for targeted fresh water lakes.

I would like to acknowledge the Bay of Plenty Regional Council; Te Arawa Lakes Trust and Land Information New Zealand for their proactive management, public engagement and research support; the responsible tour operators that follow the ‘Check. Clean & Dry’ initiatives; the many Rotorua Lakes residents that watch out and care for these lakes; and finally my awesome Freshwater Biosecurity team who have worked together with me on these and many other New Zealand lakes and waterbodies for most of their careers.

CROWN PERSPECTIVE

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

Hon Dr Nick Smith was born and educated in North Canterbury in a bridge construction family. He subsequently completed an Honours (First Class) degree in civil engineering and a PhD in landslides at the University of Canterbury. Nick was politically active from a young age and influenced by a year as an AFS scholar to Delaware, in the United States. He became a district councillor while studying and has held many offices in Young Nationals and in the National Party prior to being selected as the National candidate for Tasman in 1989.He won the Tasman seat in 1990 and 1993, and following the introduction of MMP, Nelson in 1996, 1999, 2002, 2005, 2008, 2011 and 2014 despite both having a long previous history as Labour areas. In 2014, he secured exactly 20,000 votes - increasing his majority to 7,605 while National secured its highest ever party vote in Nelson with 16,904 votes. Nick has held 12 Ministerial portfolios in the Bolger, Shipley and Key Cabinets, from Conservation, Building and Construction, Housing, Education, Immigration, Corrections, Social Welfare, Treaty Negotiations, Environment, ACC, Climate Change and Local Government.

His greatest passion has been improving New Zealand's management of the environment and natural resources. In 1998, he founded the Bluegreens as a group within National with the objective of advancing policies that support economic prosperity and a clean, green New Zealand. National achievements in which Nick has played a significant role include the creation of the Kahurangi and Rakiura National Parks, 17 marine reserves, the introduction of the Emissions Trading Scheme to reduce greenhouse gas emissions, the establishment of the Energy Efficiency and Conservation Authority, and the Environment Protection Authority.

Nick's recreational interests include kayaking, tramping, tennis, golf, and he plays the left wing in the Parliamentary rugby team. He completed the Coast to Coast and kayaked the Cook Strait with his friend and colleague Hon Bill English MP.

TRANSCRIPT

Kia ora huihui tatou katoa. Can I acknowledge Te Arawa and particularly Sir Toby Curtis and thank him for his welcome. It is not just his leadership in this region but more generally his leadership with the Iwi leaders in which there is very deep engagement with Government about many issues. Can I also acknowledge Jane Nees from the Bay of Plenty Regional Council and Rotorua Mayor Steve Chadwick. Part of the success story of the Rotorua Lakes has been the working of District, Regional and Central Government together on progressing better fresh water management.

I too want to acknowledge Professor David Hamilton of the University of Waikato who has been an invaluable advisor to the society and to me both in opposition and in Government. It is critical that our policy position associated with your lakes, and more nationally around fresh water, is underpinned with the very smartest of brains that we can tap into. I also want to acknowledge the international guest that we have from California, Dr John Madsen.

Water issues are some of the most complex public policy issues I have dealt with and to have good scientists, both nationally and internationally, who can help us communicate is invaluable.

My final formal acknowledgement is to John Green and the LakesWater Quality Society. Your organisation, founded back 54 years ago, has been a real pioneer in community advocacy for important environmental issues such as water quality and can take a huge amount of credit for the changes that have been made in Rotorua. In my view it is a real model for many other parts of New Zealand in overcoming the tragedy of the commons. There is a theoretical notion that we all keep a good eye on our own little bit of paradise, but we can be pretty negligent of those areas that are public domain. I recently attended a big public meeting in my area where we have established a group for the Maitai River and the LakesWater Quality Society was noted as being an organisation that had played such a constructive role. Others around New Zealand are emulating the work of the society. I commend you, not just for what you have done here, but for the way in which others are looking to what has been done here as they work out their solutions.

This is the fifth LakesWater Symposium that I have attended and I have been inspired by the vision, by the cross sector engagement and by the long term drive of this organisation as we have challenged ourselves as a country about how we manage fresh water. It is over a decade ago, when I was thinner and fitter, and got out into a kayak with TV cameras to make the point at a time when Lake Rotoiti was in very poor shape with acute algae blooms. I wrote to the Parliamentary Commissioner for the Environment. Having been recycled several times as Minister of Conversation and now Environment, it is great today to come back and read the technical reports of just how much progress has been made with some of these lakes.

My primary role this morning is to give an overview of Government policy direction around freshwater management; to reflect on where we are after our 7 years in government, and to give a bit of a steer on my new challenges in the Environment role since the October election.

The first is to note the huge gain in New Zealanders debating how we fix our challenges around fresh water quality, rather than the debate from Kaitaia to Bluff as to whether we even had a problem. There was an uncomfortable level of complacency a decade ago as to whether New Zealand really had issues with fresh water quality. A lot of political energy was in the process of denial rather than dealing with it. I am much encouraged that across New Zealand focus has now shifted and people are actively involved in these very challenging issues.

There are 5 key dimensions of the Government's policy direction around improving fresh water quality. The first is that the Government needs to take a stronger leadership position. Take all the work that went into the policy development and passing of the Resource Management Act back in 1991 when we set up a very devolved framework for managing fresh water and little else occurred. That is why when we came to Government in late 2008 we said this system will not work without a stronger level of clear direction from central government.

It began with the RMA making provision for both national policy and national environmental standards. It is somewhat extraordinary after 17 years of the Act that neither of those tools have been used at all in respect of fresh water management. In 2009 we did the National Environmental Standard on Fresh Water Takes having to be metered. Only about 25% of fresh water taken across New Zealand was metered.

Currently we are up to 81% and will be over 96% when those regulations have fully rolled out.

The second big step was in 2012 when the National Policy Statement on Fresh Water was approved and it was further extended in 2014 when the National Objectives Framework gave that National Policy Statement more substance and set those national bottom lines for water quality. It is the Government's view that we have to do more in that space on an ongoing basis, and I will talk on some of the next steps in a moment.

The second key driver has been to try and get a more collaborative approach to dealing with the challenges around fresh water. There was a very polarised argument in New Zealand around fresh water. At its worst we had the Federated Farmers referring back 10 years ago to those that were advocating for fresh water as economic terrorists and on the other hand you had the confrontational dirty dairying campaigns; people in other rooms, people not engaging.

I was inspired through an Environment Defence Society Conference to establish the Land and Water Forum in 2009. I want to compliment all those that have been part of that Land and Water Forum process. At the time of putting it together officials said, 'This is impossible, you will never get these warring parties in a room together, let alone agreeing on anything other than blaming each other.' They proved the opposite, they proved that by actively engaging with each other they agreed on a huge package of recommended changes on the direction of fresh water policy and had been at the forefront of some of the biggest changes. The real challenge is driving forward with the goodwill that has been built up nationally through the Land and Water Forum to deal with these issues, catchment by catchment, lake by lake, with that same level of collaboration and goodwill. Certainly in this community you have been a leader in that regard. I compliment Todd McClay, the local Member of Parliament, who has been an enthusiast for that, but even more so the parties to that collaboration that have enabled additional steps to be taken. That needs to occur across so many water bodies in New Zealand.

I have to acknowledge, both in the Land and Water Forum and in the collaborative processes that are occurring across catchments, the hugely constructive role that Iwi are playing in helping us drive solutions. Our Maori communities have a more holistic view of the environment; they have both economic and environmental interests. These collaborative processes have been powerful glue in keeping the process on track. Collaboration is a key part of the Government's direction.

The third is the importance of strong science underpinning our improvements in fresh water. One of the things that makes the political debate around fresh water so challenging is how to explain an issue as complex as fresh water management, whether it be nutrients, sediments or faecal coliform counts, and communicate where we are making progress and where we are not across the whole of New Zealand. We need to make the investment in science so that we are able to enjoy the economic benefits of New Zealand's plentiful water resources, but at the same time improving water quality. It requires the very best of science brains and is behind the $42 million that our Government has invested in the fresh water research science strategy.

The fourth direction is around this question of balance. Our fresh water resources are incredibly important to New Zealand's ongoing economic development. New Zealand has no shortage of fresh water. We are blessed as one of the richest nations in the world in fresh water resources. The real challenge is how we grow the economic opportunities from that fresh water resource and at the same time better manage its quality and

opportunities for recreation. The fourth dimension of the Government's work is to get that balance and ensure the pragmatism in our work and understand that for New Zealand to succeed we need to be both clean, green and prosperous; the blue green vision as I like to speak of it.

The fifth dimension is the issue of who pays for the adjustments to lift our game. I am intensely lobbied from all sides of the equation around who should meet the cost of unsustainable activity when it impacts on the quality of our fresh water. A complete purist from a property rights' perspective would say that people have developed their farms completely within the law, or other such businesses that depend on water, and should not meet any costs of adjustment. It should be the good old tax and rate payer writing out the cheques.

There are people at the other end of the spectrum who say if a water resource has been over allocated, or there is too much intensification of land in a catchment, it is the responsibility of those that have done the intensification. All the cost of adjustment should be met by those responsible. I plead guilty after 25 years of being a pragmatic politician to believing that the pain has to be shared. If we are to make real progress in our clean-up programmes we need to find the balance. The rate payer, the tax payer and those land users are all going to have to share in the costs of the adjustments to ensure that our fresh water bodies are better managed.

That is very much the model that we have advanced here with the Rotorua Lakes. We have seen the Government put forward $72 million and a commitment through the next 17 years in conjunction with the regional and district councils to make a total expenditure of over $200 million going into the adjustment that is required. The Government is committed to spending another $100 million on a further buffer fund to help in this adjustment. The Government support for communities, including Rotorua, is going to be on the basis of the rate payers and the land owners also sharing the pain of that adjustment.

The last comment I want to make is in respect of the forward agenda. A massive piece of work that I am up to my eyeballs in at the moment involves substantive reform of the Resource Management Act. One of the most important perspectives in respect of water is taking the collaborative model so successfully being used in areas such as Rotorua, and in the broader sense with the national approach by the Land and Water Forum, and provide the statutory framework for collaborative processes in that Act. The Land and Water Forum recommended a new approach to developing plans and rules, an approach that does not involve long years of arduous debate and expense through the Environment Court and incentivises parties to come together to find solutions. A key part of the RMA Reform Bill that I will be introducing to Parliament this year is to formally mandate those processes and provide the incentives to find collaborative solutions.

Another important piece of work is the passing of the new Environmental Reporting Act through Parliament. We might proclaim to the world that our nation is clean and green but we are the only country out of 32 in the OECD that does not have a formal statutory process for environmental reporting. The analogy I would give you is that this country spends about a billion dollars a year on people we love called accountants and auditors who minutely manage and ensure quite rightly that this country is properly and responsibly managing its financial resources. We spend less than $1/50^{th}$ of that on the monitoring and reporting of New Zealand's natural capital balance sheet.

Our ambition through that Environment Reporting Act is to set up an independent national wide system of environmental reporting that enables us as Kiwis to get honest information

about just how clean and green we really are; which lakes and rivers in New Zealand are of good quality and which are poor, which are improving and which are deteriorating? Good quality independent information jointly put together by statistics from my own Ministry and audited by the Parliamentary Commissioner for the Environment. In my view this is an important step if we are to give integrity to the clean green brand that we all take pride in as New Zealanders.

I am hoping that the extra advantage from that system is that communities like your own view those reports and see where they match up. There will be a fair amount of angst in communities when people find out their lakes are, for instance, the most polluted in New Zealand. In my view it will motivate communities to get cracking to improve them. Equally so I want communities that have been responsible custodians of their pubic water bodies to be able to celebrate how they come through that sort of reporting with integrity.

A third issue on my plate is putting formally in law on a nationwide basis the very simple requirement for dairy cows to be out of streams and rivers. I was aghast at some of the implications of the processes of the Resource Management Act. If under the current law I set out a national environment standard requiring something as simple as every dairy farmer in New Zealand fencing their stock out of their streams, not only would there be a public consultation and appeal process around the development of that national environment standard, then every one of our regional councils would implement that national environment standard through their regional process. Even then the standard would not come into effect until up to 30 years when each individual farmer's resource consent came up for renewal. That is bureaucratic nonsense for a pretty simple basic standard that we should apply to a sector that is so important to New Zealand and one that Fonterra themselves are aiming to have in place. We have got important work to do with the sector around the changes to the Resource Management Act and the implementation of that new standard that we intend to have in place with an instant fine regime by 1 July 2017.

We have the Land and Water Forum reinvigorated and back on task with the work on improving New Zealand's fresh water. A concern for me as a Minister back in his straps after 3 or 4 months is that there are over 15 different funds from Government and NGOs supporting programmes for restoration of fresh water bodies. At the same time there are a lot of collaborative groups around New Zealand. It is a huge step forward that much more is being done throughout New Zealand in clean-ups and improving fresh water management but it is not very well coordinated. I am working with a number of groups to get these funding streams and the coordination of clean-up programmes to work better.

I want to conclude where I started and that is this Rotorua community and those involved in the LakesWater Society and the partnership that has taken place here should be hugely proud of the successes that have been made. I would encourage you to share your experiences with other communities that have equally challenging water quality issues.

My very last point is that nature's clock ticks far slower than ours; this is a long haul game. Improving water quality in the lakes of this district, as for many other water bodies around New Zealand, requires not just a one off quick fix but a really long term ongoing sensible commitment to improvement. It is fantastic to see the improvements in your own water bodies, but please do not take your foot off the accelerator if our children and grandchildren are going to be able to enjoy what is not just special about the lakes in this part of New Zealand but throughout the whole country.

QUESTIONS

Clive Howard-William, NIWA: Thanks very much Minister for that really interesting talk about the Government's direction. I was puzzled over your comments about the 15 different funds to support restoration. I had no idea there was that kind of complexity and your move to consolidate them. Are these funds Government and how do you intend to consolidate the 15 different funds?

Hon Dr Nick Smith: Yes and it will not necessarily be a consolidation but we will try and get a better coordination in the incentives that operate them. If I take my own ministry, there is the Fresh Start for Fresh Water Fund, the specific funding that has been provided for Taupo and Lake Rotorua which was a one off. Then there is the new fund that we committed to at the election which is a $100 million buffer fund. There is the Community Environment Fund administered by the Ministry for the Environment, the Community Partnership Fund administered by my old portfolio the Department of Conservation and the Sustainability Farming Fund that is run by MAF. These are the Government pots.

There is one of the most amazing acts of philanthropy and generosity in New Zealand from the Next Foundation which is $100million for supporting 'high impact' environmental and education projects. Then a net based crowd-sourcing funding initiative around fresh water has been launched. There is lottery funding which is like a quasi-Government agency. There are a large number of regional councils that are quite rightly investing their funds and there is another pot through the process of Treaty Settlements where the Government often creates partnership funds between an iwi and Government for clean ups in areas.

There is a worry coming back into the portfolio about the nationwide scrap over who meets the cost of restoring things that were wrong in the past.

There are quite different approaches from each of those funds and if we are going to get the best bangs for our buck and community consensus we are all going to have to put our hands in our own pots. In my view there is an important piece of work to get those funds working in a more coordinated way.

Ken Hughey, DOC: I am wearing my Lincoln University hat for this question. In terms of your third initiative regarding strong science underpinning our improvements in fresh water, the question that comes up on the Water Zone Committee that I am on in North Canterbury, is what to do with the over-wintering cows on the hill country? How do we keep them out of the streams? That is also a question for Fonterra as well, thank you.

Hon Dr Nick Smith: You are absolutely right and it is a reminder of how challenging this all is. When it comes to saying, 'All dairy cows out of rivers and streams', what about when the dairy cows are on other blocks as they often are. What about beef cattle, because their poos are not that much different to the dairy cows! What about sheep? This is where it needs a good dose of kiwi pragmatism and ingenuity. Go down the road and say, 'We're not going to have any stock in the streams'. Insisting that a farmer is not able to have stock accessing streams in the back blocks of the McKenzie country where there are very low stocking levels is totally impractical. If you ask the question, 'Is it too hard? Is it so hard that we do nothing?' My answer is that we need to progressively work our way through this.

The policy commitment by 1 July 2013 is specifically for dairy cows and streams and rivers as the first regulatory bite with an instant fine regime. A lot of people out there are

not happy and there are a lot of different enforcement regimes. I get quite frustrated when somebody has offended and ends up spending $80,000 on a court process. I am a fan of instant fines and a nationally consistent approach.

Step one is to do the dairy cows and through encouragement and education start working on the progressive steps that we need from there. You are absolutely right to expose that, it is a bit pragmatic and anomalous, but it has to be a simple clean first step that we need to take down this road.

Mary Stanton, LWQS: Minister, I am local hapu and Iwi Te Arawa and also LakesWater Quality Society. We need money to protect our lakes; our lakes are never going to disappear, they are with us forever. People take advantage of our lakes economically, environmentally, socially and culturally, but my question is, 'Who owns the water? Do you own the water?' If this is the case then I believe that you should be responsible for looking after our lakes. I believe that this is a political issue. I know we all want to look after the lakes, Maori, Pakeha, all nationalities. I believe the only way to protect the lakes is to come through you; tell us you own the water, kia ora.

Hon Dr Nick Smith: Kia ora, tough question! The honest answer. This has been the subject of significant dialogue and engagement between the Crown and Iwi leaders. The Government's position is that no one owns the water. I worry that there is almost an overstated Westminster British culture that someone has to physically own everything and that is so with water. The reason I say that is that simple ownership of water is impractical because the very water that might be in your lake this week and that I might drink while I am in your lovely part of the world, might next month be in Russia or some other part of the world.

So the simplistic notion that water is owned by anybody is not where the Crown is at. That has been our formal point of view in both the Waitangi Tribunal Hearings and in my dialogue with the Iwi leaders. That does not mean that people might not own interests in water such as I have a water right that enables me to irrigate, or I have a right of accessing water for my domestic use, or for that matter for your marae and for human needs. Simply because people do not own it does not mean that people do not have interest in it. The nature of the discussion the Crown is having with Te Arawa and other Iwi is to get a greater degree of clarity and agreement about those interests that not just Maori but others also have in water.

In terms of who pays the bill, I will just reiterate the message that I gave during my speech and that is that we share the gains, we share the pain. In respect of the Rotorua Lakes the Government has committed $72 million. We have spent $36 million of that and we will make some changes on 1 July as a consequence of agreements we have reached. We are now putting some of that money into buying up nutrients as part of sharing that pain process and both the Bay of Plenty and the District Council are putting their hands in their pockets and there are many private citizens that are also contributing too. If there are to be restoration programmes it is my view that everybody is going to have to put their hands in their pockets, the Government included.

Finally to give you the numbers, if you take the amount of money that our Government has spent on fresh water clean ups in our 6 years in Government it is more than 5 times as much as was spent in the previous 6 years, a 5 fold increase over 2 terms in the amount spent. I think you would accept that the last couple of terms of government have been financially a lot harder than what they were in the preceding two. So this stuff is hard.

I will finish with one last message and that is I travel all over New Zealand and meet with local government and societies that are concerned with lake water quality in these areas. They all say to me, you are putting $72 million into the Rotorua Lakes, we want the same. If you look at it honestly across New Zealand around fresh water quality we have been far more generous with tax payers' money in this community than many others. But can I also say, 'Take a salute'. Why is that? It is because you have had your act together, because you have had good relationships, because there has been collaboration, because you have had science involved and you are proving that you can get results. My message to those other communities is have a look at what has been achieved in Rotorua because the Government is prepared to back those who have the sort of formula for making progress on improving their fresh water quality.

I apologise for leaving, I know I would get far more sense out of this room for the next few hours than I am likely to get back in Parliament, but I must meet those Parliamentary duties. I wish all of those involved in the Rotorua LakesWater Quality Society congratulations for what you have achieved and best wishes as you work through this really important challenge.

Thanks very much.

BUSTING MYTHS ON WATER WEEDS

Mary de Winton
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Mary is a Freshwater Ecologist at NIWA, Hamilton, with over 25 years' research experience on submerged vegetation management. During this time Mary has worked on (and within) over 155 New Zealand lakes. Research interests include the biosecurity management of invasive water weeds, the enhancement and restoration of native submerged plants, resource survey, management of vegetation data and its application to research questions, and the taxonomy of New Zealand native charophytes.

ASTRACT
Troublesome aquatic weeds have been an issue for the Rotorua Te Arawa Lakes for decades, but what do we really know about what drives water weed problems? Some common held beliefs about water weeds are 'one weed is as bad as another', 'waterfowl move water weeds around' and 'nutrient enrichment drives weed invasion'. However, these assumptions are incorrect or represent an oversimplified view of the problem. Exploring these popular misconceptions on water weeds will help us get a better understanding of weed problems, the role of humans and what we can do about it. This talk will draw evidence from New Zealand and international research findings and information specific to the Rotorua Te Arawa Lakes.

Weed issues for the Rotorua Te Arawa Lakes involve just a few species of alien plant species that share characteristics including a high 'standing crop' (bulk biomass present at any one time), dense canopy at, or close to the water surface and generation of numerous fragments that can accumulate onshore. Nevertheless, these few species can be further distinguished and ranked in terms of 'weediness' and impact. Recognition that some weeds are worse than others allows for more effective and proactive management of weed threats.

Water fowl are often implicated in spreading the most problematic water weeds that we have in New Zealand and yet there little real evidence that this is the case. Instead there is ample evidence that human activities are primarily responsible for the spread of water weeds between lake catchments. This means that it should be possible to intercept the routes and mechanisms (pathways and vectors) by which these water weeds can enter lakes.

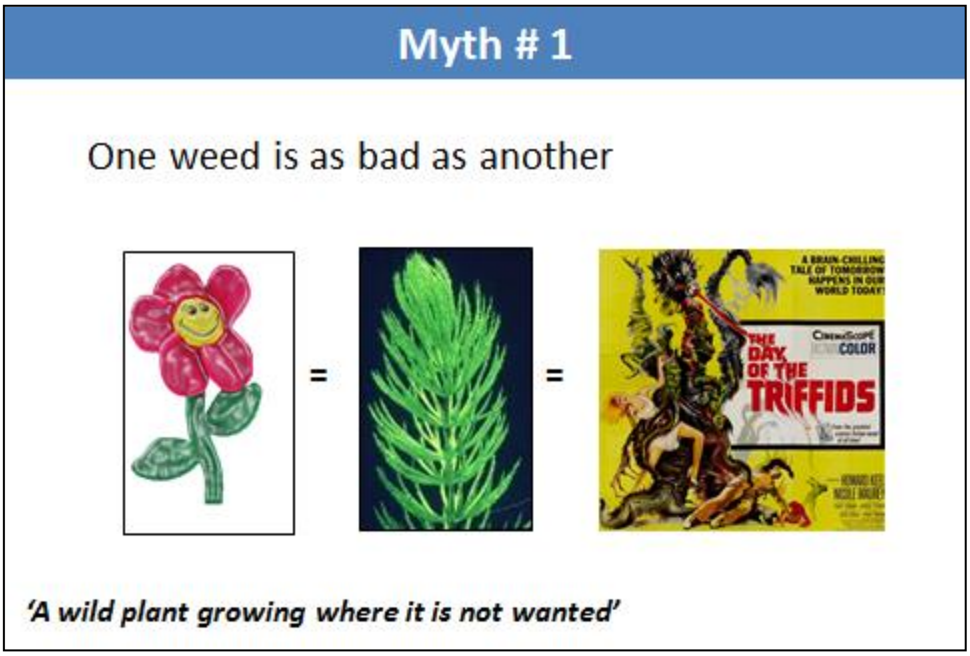
Weed invasions in freshwater systems are suggested to be linked with nutrient enrichment. However, the presence of our worst water weeds and the development of weed-related problems are not limited to eutrophied lakes, but can be equally problematic in oligotrophic New Zealand lakes. Indeed, the most enriched lake systems have very limited submerged vegetation development. Therefore improving water quality does not necessarily flow on to the anticipated improvements in weed problems and there may even be increased weed development as lakes become less enriched.

TRANSCRIPT
In this talk I want to explore some popular misconceptions about water weeds, particularly those myths relevant to the management of submerged weeds in the Rotorua Te Arawa Lakes. I want to look at evidence drawn from international and New Zealand research and, where possible to information specific to the Rotorua Te Arawa Lakes. The talk will

focus on submerged weed problems in lakes, the issues, and the role of some weed species, how these problem species invade lakes, and what conditions lead to weed problems.

Myth # 1 One weed is as bad as another
It is the common perception that any plant that grows in the water is a ‘water weed’. Certainly the common definition of a weed – ‘a plant growing where it is not wanted’ would suggest that weed issues are situational and any plant has the potential to be a weed.

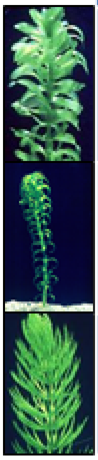
Slide 1



Slide 2

Evidence

- Weed issues in Rotorua Te Arawa lakes
- Three culprits



Species	Status	Reproduction	Max depth
Egeria	Alien	Vegetative	10 m
Lagarosiphon	Alien	Vegetative	6.5 m
Ceratophyllum (hornwort)	Alien	Vegetative	10-15 m

However when we look at the Rotorua Arawa Lakes in **Slide 2** we can see it is a small number of submerged plant species that are the usual culprits, these are the tongue twister species; egeria, lagarosiphon and ceratophyllum, better known as hornwort. These are alien plants, none produce seed in this country so all are reliant on vegetative fragments of shoots to spread and establish new populations. They can grow to considerable depths in lakes.

But these species share additional, sinister characteristics. They are all phenomenal space invaders, able to grow into 5 to 10 m tall weed beds that can occupy the entire water column. It is hard to believe it but these plants comprise over 90% water, these water-filled tissues can create a very large bulk biomass or 'standing crop' – the fresh biomass present in the water at any one time. For instance on the left hand of **Slide 3** you can see a snorkel diver beside a massive bed of ceratophyllum.

Slide 3

Our American colleagues have a great term, 'topping out', to describe weed beds that reach the water surface. The photo in the centre of the slide shows a topped out lagarosiphon weed bed in Lake Wanaka. These can strike fear into the recreational boater because they are so difficult to navigate through.

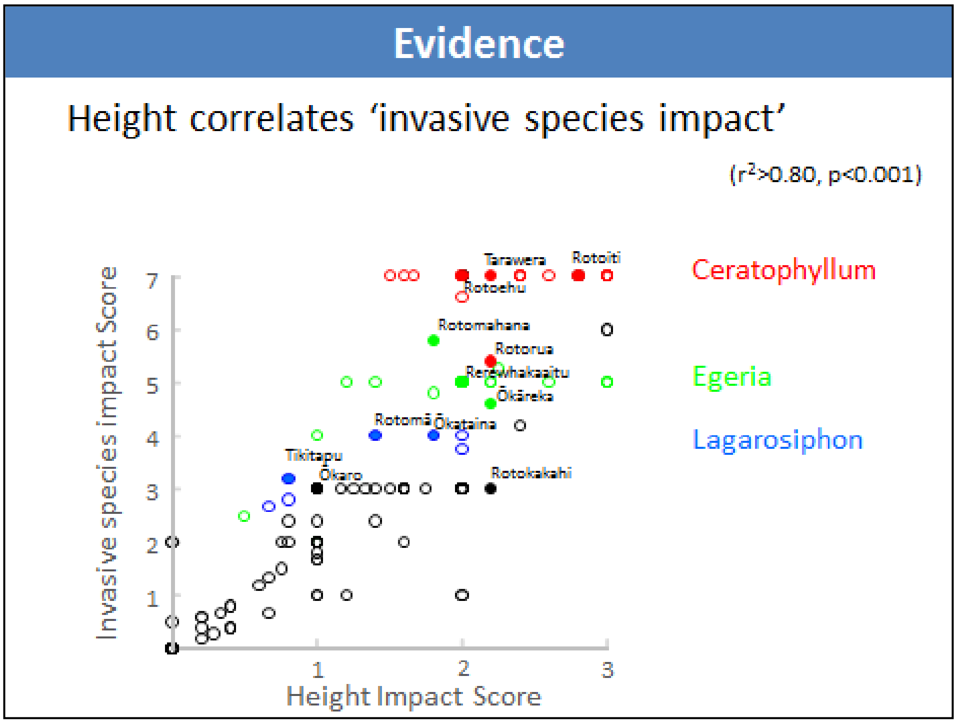
Flow on impacts include the deposition of their debris on beaches. These problem weed species are built to disperse by fragmentation, they are brittle and prone to dislodgement by waves and strong currents. Dense accumulations on beaches, decay and release odours that may necessitate their removal by mechanical means at some cost.

The influence of our worst weeds can be seen in New Zealand wide measurements of the weed impacts in lakes. LakeSPI is a monitoring method using submerged plants as indicators (SPI). Measurements made include weed height, as well as canopy cover, proportion of vegetation occupied and their depth impact.

Slide 4 shows the average height impact scores for 194 NZ lakes, but the other measures had a similar pattern. A score for weed height is along the horizontal axis, greater score means taller beds. You can see that ceratophyllum in red, egeria in green and lagarosiphon in blue tend to have greater impact in terms of height than other weeds, shown in black. This tendency for weediness is recognised by a higher ranking for a potential invasive impact score for these species in LakeSPI, shown on the vertical graph axis.

Where do the Rotorua lakes fall on this graph? Rotoiti, Tarawera and Rotoehu already experience large weed beds of ceratophyllum. Although ceratophyllum has also recently invaded Okataina and Okareka, ongoing management is currently preventing major impacts. Lakes with lower weed impacts, Rotoma, Tikitapu, Rotokakahi and Okaro would benefit from protection against the introduction of worse weed species.

Slide 4



So there are species that are strongly associated with water weed problems in lakes, and even within this group, some weeds prove worse than others. Agencies like BOP Regional Council can use this information to recognise the worst threats to the Rotorua lakes, and to prioritise protection and proactive responses to threats.

Myth # 2 water fowl move water weeds around

Just last year the CEO of an NGO stated that international research 'finds that weed [egeria in this context] is most likely spread by geese and swans, and suggested that hunting ought to be viewed as part of the risk management.[1]

Slide 5

I want to look at this concept more closely. Firstly, how would birds transport weeds that can only reproduce vegetatively and which lack barbs or burs to attach to feathers. Could weed get entwined around legs or necks? More plausible perhaps is nest building by birds. This crested grebe has built a nest out of locally available materials, in this case using lagarosiphon. **(Slide 5)** But it is still a stretch to think this a major means by which our worst weeds are spread lake to lake.

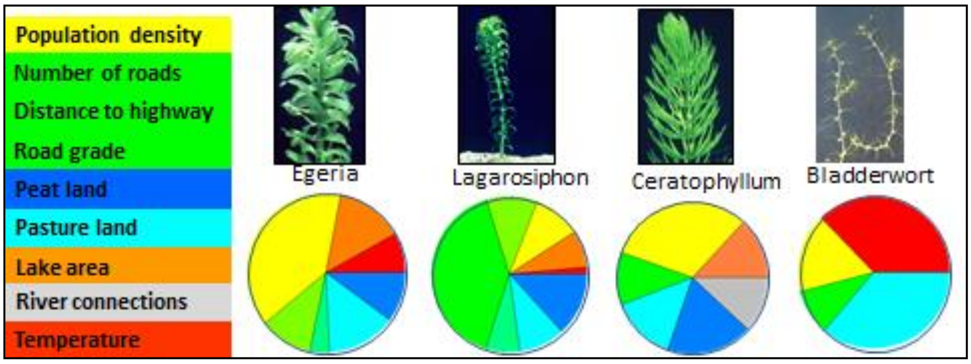
[1] https://au.news.yahoo.com/a/24818204/duck-hunting-ban-breaches-treaty-settlement/ https://nz.news.yahoo.com/a/-/top-stories/24818204/duck-hunting-ban-breaches-treaty-settlement/

There is definitely plenty of evidence that waterfowl carry seed of water plants internally and over long distances[2], many seeds passing through their digestive systems unharmed. At least 10 published papers confirm this ability. But I was unable to find any published accounts of vegetative propagules being moved long distance by birds.

We also note that adjacent lakes in New Zealand often differ in vegetative weed composition. For example, Lake Waikaremoana remained lagarosiphon free for 30 years despite close proximity to invaded Lake Whakamarino.[3] The first weed discovery in lakes is frequently noted at boat ramps which strongly implicates boat traffic as the major vector.[4]

What other evidence do we have? A statistical modelling approach was used to identify lake and catchment characteristics that were most strongly associated with weed invasion by 4 species.[5] We used species presence and absence from surveys of 381 lakes. Over 15 lake and catchment characteristics were screened, and whittled this down to 9 which performed the best. **(Slide 6)**

Slide 6



The clear result was that measures of human access explained the distribution of ceratophyllum, lagarosiphon and egeria. The density of human population in the vicinity, and roading infrastructure measures in yellow and green. This contrasts with the fourth species which produces seed and is spread by waterfowl.

What does busting this myth mean for management of weeds in the Rotorua Te Arawa Lakes. Spread of the worst weeds is preventable. There are a number of proactive actions that can be taken (education campaigns like the check, clean dry message, events like this symposium, signage, weed cordons such as instigated by Bay of Plenty Regional Council or wash down facilities. Boaties enjoying the lakes need to take responsibility for

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[2] Figuerola, J., and A. J. Green. 2002. Dispersal of aquatic organisms by waterbirds: a review of past research and priorities for future studies. *Freshwater Biology,* 47:483–494.

[3] de Winton, M.D.; Champion, P.D.; Clayton, J.S.; Wells, R.D.S. 2009. Spread and status of seven submerged pest plants in New Zealand lakes. *New Zealand Journal of Marine & Freshwater Research*, 43: 547–561.

[4] Johnstone IM, Coffey BT, Howard-Williams C 1985. The role of recreational boat traffic in interlake dispersal of macrophytes: a New Zealand case study. *Journal of Environmental Management* 20: 263–279.

[5] Compton T. J.; de Winton, M.; Leathwick J. R.; Wadhwa, S. 2012. Predicting spread of invasive macrophytes in New Zealand lakes using indirect measures of human accessibility. *Freshwater Biology*, 57: 938–948, doi:10.1111/j.1365-2427.2012.02754.x.

trailer and boat hygiene. Surveillance, such as undertaken by the Regional Council at hotspots such as boat ramps can intercept weeds at an early stage when something can be done. **(Slide 7)**

Slide 7

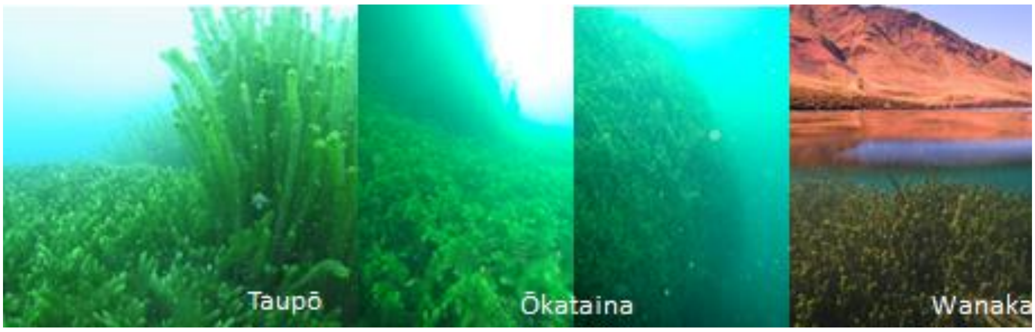
Myth # 3 Nutrient enrichment drives weed invasion

This may surprise, but in my opinion the role of nutrient enrichment of lake waters in driving weed invasion is overstated. It is difficult to reconcile statements like this one linking hornwort (ceratophyllum) invasion to nutrient enrichment of water when large weed beds, up to 8 m tall, can develop in oligotrophic lakes like Taupo and Okataina:-

> *'Parliamentary Commissioner for the Environment says: Invasive exotic weeds like hornwort grow prolifically in response to excess nutrients.'*[6]

Likewise pristine lakes such as Lake Wanaka exhibit weed problems from tall-growing lagarosiphon if it is left unchecked. **(Slide 8)**

Slide 8



This is an important concept. If invasive weeds are simply the passengers of environmental change, we would expect them to dominate only where habitat modification like nutrient enrichment has occurred. We would also expect our weed woes to lessen as eutrophication is managed and reversed.

Look at the evidence for weed issues being driven by the trophic status of lakes. When we look at the published literature about submerged plants and levels of nutrients N and P in the water, we can draw some conclusions:

- Plants *can* uptake nitrogen (N) and phosphorus (P) from water or sediments.[7]

[6] http://www.pce.parliament.nz/publications/all-publications/water-quality-in-new-zealand-land-use-and-nutrient-pollution

- There's good evidence that N & P in water can subsidise the nutrient requirements of establishing weed fragments.[8]
- In general nutrients are preferentially uptaken from where they are most available.[9] This is in the sediments of most lakes, unless waters are extremely enriched.[10]
- Plant growth (here as biomass increment over time) is commonly found to decrease across a nutrient gradient of eutrophic to hyper-eutrophic,[11] even for ceratophyllum, a species commonly assumed to respond to water enrichment.

Looking more closely at the literature on weeds and trophic status of New Zealand lakes, early researchers were surprised to find no relationship between trophic status and standing crop or plant re-growth in the Rotorua Te Arawa Lakes.[12] A world record standing crop of 3kg per m^2 dry weight was recorded in Lake Rotoma,[13] although this was in an atypical area of the lake. When grown on two sediment types within two lakes, lagarosiphon actually grew faster in oligotrophic Lake Taupo than eutrophic Lake Rotorua.[14]

Slide 9 looks at how 7 major water weeds are distributed over lakes of different trophic status as TLI.[15] Certainly microtrophic and ultra-oligotrophic lakes do not support the larger vascular plants. There were more eutrophic lakes with weeds than mesotrophic and oligotrophic lakes, but much fewer weed records in the most highly enriched lakes.

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[7] Feijoó, C., García, M.E., Momo, F., Toja, J. 2002. Nutrient absorption by the submerged macrophyte *Egeria densa* Planch: effect of ammonium and phosphorus availability in the water column on growth and nutrient uptake. *Limnetica,* 21(1-2): 03-104.

[8] Rattray, M.R., Howard-Williams, C., Brown, J.M.A. 1994. Rates of early growth of propagules of *Lagarosiphon major* and *Myriophyllum triphyllum* in lakes of differing trophic status. *New Zealand Journal of Marine and Freshwater Research*, 28(3), 235-241.
Kuntz, K., Heidbuchel, P., Hussner, A. 2014. Effects of water nutrients on regeneration capacity of submerged aquatic plant fragments. *Annales De Limnologie - International Journal of Limnology*, 50(2):155-162.

[9] Carignan R. 1982. An empirical model to estimate the relative importance of roots in phosphorus uptake by aquatic macrophytes. *Canadian Journal of Fisheries and Aquatic Sciences*, 39, 243–247.

[10] Carignan R., Kalff J. 1980. Phosphorus sources for aquatic weeds: water or sediments? *Science*, 207: 987–988.

[11] Lombardo, P., Cooke, G.D. 2003. *Ceratophyllum demersum* - phosphorus interactions in nutrient enriched aquaria. *Hydrobiologia*, 497(1-3), 79-90.

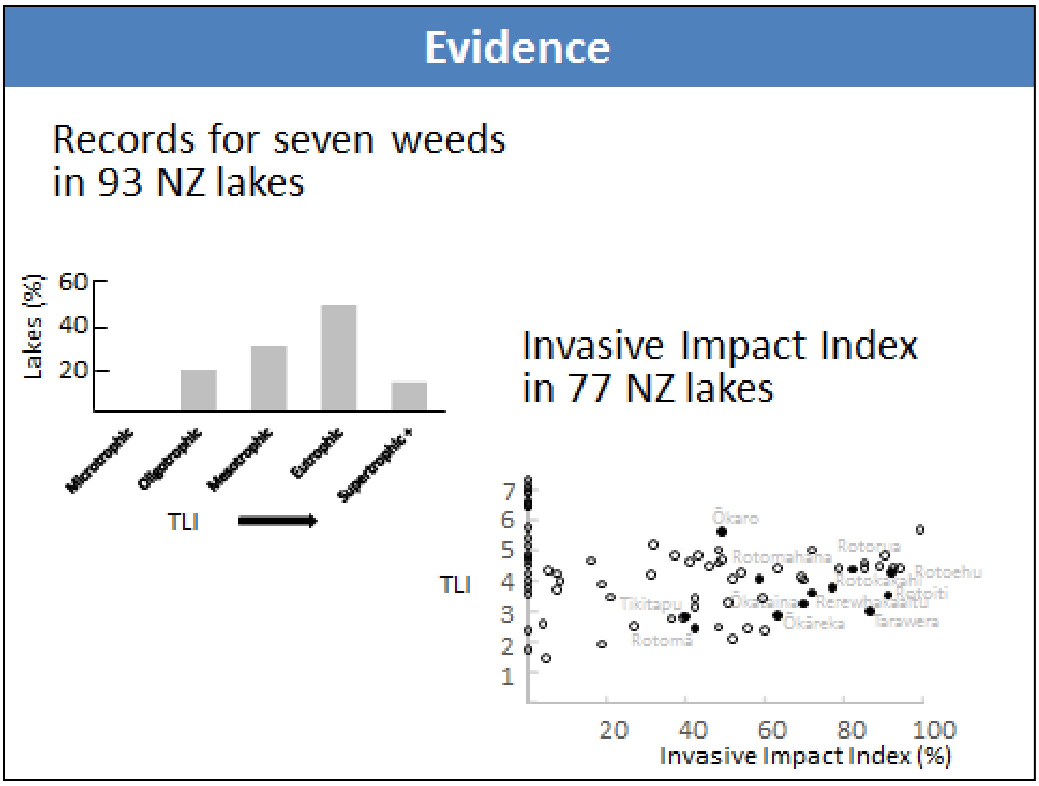
[12] Brown, J.M.A., Dromgoole, F.I. 1977. The ecophysiology of Lagarosiphon in the Rotorua Lakes. *Proceedings of the 30th New Zealand Weed and Pest Control Conference*, 130 – 134.

[13] Clayton, J.S. 1982. Effects of fluctuations in water level and growth of *Lagarosiphon major* on the aquatic vascular plants in Lake Rotoma, 1973-80. *New Zealand Journal of Marine and Freshwater Research*, 16:89-94.

[14] Rattray, M.R., C. Howard-Williams, Brown, J.M.A. 1991. Sediment and water as sources of nitrogen and phosphorus for submerged rooted aquatic macrophytes. *Aquat*. Bot. 40: 225–237.

[15] de Winton, M.D.; Champion, P.D.; Clayton, J.S.; Wells, R.D.S. 2009. Spread and status of seven submerged pest plants in New Zealand lakes. *New Zealand Journal of Marine & Freshwater Research*, 43: 547–561.

Slide 9



Looking at the overall measure of the invasive impact of weeds in 77 New Zealand lakes from LakeSPI data and how that relates to TLI[16], the higher TLI number means more enriched lake water conditions. The index captures proportion of vegetation dominated by weeds, their depth extent, height and canopy cover. The filled circles show the distribution of the Rotorua Te Arawa Lakes across these gradients. Results show little evidence of a role for nutrient enrichment in increasing the impacts by water weeds in lakes.

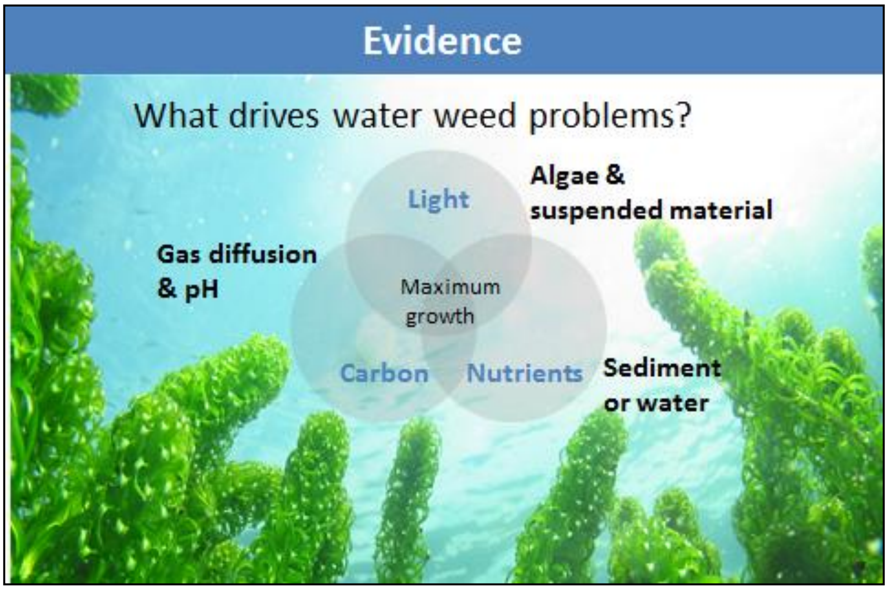
We can also note that none of the eight lakes with a TLI of 6 or more registered an invasive impact index, this is because these extremely enriched systems become dominated by phytoplankton or epiphytes at the expense of plants. Even the worst weed is not competitive against sustained algal blooms.

Why are weed problems seemingly uncoupled from lake trophic status? The answer is that nutrients supplied by sediment and/or water are not the only things driving weed biomass development. **(Slide 10)**

Submerged plant growth also needs adequate levels of light, so high levels of algae and suspended material can limit growth substantially, especially highly nutrient enriched lakes. Submerged plants also need a dissolved inorganic carbon source for photosynthesis, with availability limited by lack of gas diffusion and different forms of carbon influenced by pH. High rates of growth will occur in the ‘sweet spot’ where all these conditions are supplied in sufficient levels for high growth. Add to this self-shading within big weed beds, respiratory losses and physical disturbance of beds. So growth does not determine the final standing crop.

[16] de Winton M.D., Clayton J. S., Edwards, T. 2012. Incorporating invasive weeds into a plant indicator method (LakeSPI) to assess lake ecological condition. *Hydrobiologia*: Volume 691, Issue 1 (2012), Page 47-58 *Hydrobiologia* (DOI) 10.1007/s10750-012-1009-0.

Slide 10



What are the important conclusions from busting this nutrient myth? Firstly, water weeds are not merely passengers of environmental degradation. They do not respond to degradation in the form of nutrient enrichment. Lakes protected from eutrophication are not protected from invasion. Improvements in water quality of eutrophied lakes might actually increase weed problems. Weed problems need to be managed by other means than eutrophication management.

I would like thank the NIWA Freshwater Biosecurity team from whom I have shamelessly stolen images for this talk and a lot of the ideas and also the Bay of Plenty Regional Council's lakes' data. I would also like to make special thanks to the LakesWater Quality Society for putting on this Lake Weed and Wallabies Symposium. As John Green mentioned, there was a bit of an in-house joke as to what the solution might be for both of these. So I will leave you with this.

QUESTIONS

Paul Scholes, BOPRC: (The full question not tapped). …avian effects in small lakes. How do you explain weeds in remote lakes?

Mary de Winton, NIWA: Definitely recreational boating is one of the key vectors of weed spread in smaller lakes without road access. There are other vectors which can be involved such as ditch drain clearage machinery that has been working in a contaminated drain. It can introduce weeds to a new area. Weeds can also spread on eel fishing nets and other fishing equipment which is used from lake to lake. For the larger lakes with boats ramps with good road access it is primarily boating traffic which is the main vector.

Pauline Keen, Federated Farmers: I was wondering about the swans and the bird life on the lake that you said grazed weeds. Do they cause a lot of break up and spread from grazing?

John Clayton, NIWA: Yes that is a good question. Generally when there is enough weed at the surface for a swan to graze there would be enough natural fragmentation from wave action and people with their jet skis to spread it around. If it was eelgrass it would not spread because they need basal stem material but the oxygen weed could spread from fragmentation for sure. The question is whether it is a risk? Put it in the context of how much habitat saturation there is already for that particular weed. Quite often if a weed has got that far developed it has already had opportunity to spread by other means.

Session Three : The Toolbox

CHAIR – Dr Clive Howard-Williams, Freshwater and Estuaries, NIWA

PURPOSE OF WEED HARVESTING

Dr Fleur Matheson
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Fleur is an Aquatic Biogeochemist with over 13 years' experience in aquatic plant research. During this time she has worked in both freshwater and estuarine ecosystems. Research interests include environmental effects assessment of lake weed control methods, lake weed biosecurity management and surveillance, instream plant and nutrient guidelines, effects of wastewater treatment plant discharges on instream aquatic ecology and the ecology and rehabilitation of seagrass.

ABSTRACT
Harvesting is one potential option to control nuisance growths of lake weeds. Mechanical harvester units can typically remove lake weed to 2-3m below the water surface. Yet common weed species in NZ lakes often grow to deeper depths, so typically only the upper canopy of large weed beds can be removed with this technique. Nevertheless, harvesting can be a useful tool to reduce weed abundance in sensitive areas (e.g. boat ramps, beaches), or from areas where it is likely to detach and form drifting rafts that interfere with various recreational or commercial interests. It is not a suitable option for weed control in areas where weed fragments generated by the harvesting activity pose a biosecurity risk. For example, in areas where an infestation of a new weed has been found or the weed has a limited distribution within the lake. Most New Zealand lake weed species can grow vegetatively from fragments broken off the main weed bed. Even small fragments (<1-2cm length) can remain viable for long periods of time if kept wet.

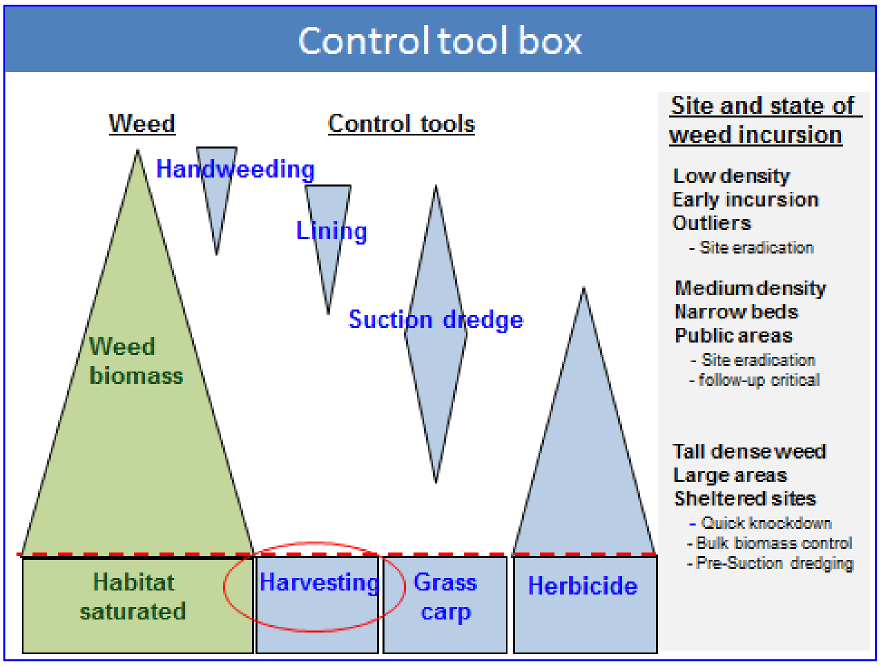
In areas where harvesting units can operate efficiently (e.g. sheltered sites without underwater obstacles), large quantities of weed can conceivably be removed which may benefit lake water quality or offset nutrient inputs from the catchment through removal of nutrients that have been assimilated into the plants as they grow. However, potential downsides of harvesting, particularly where it is done on a large scale, include the kill of fish and other biota trapped in the weed bed at the time of harvest, removal of habitat and flipping of the lake ecosystem to an algal dominated state. Disposal of harvested weed can also be problematic. Lake weeds often bioaccumulate contaminants (e.g. arsenic) that render them unsuitable for use as a compost or stock feed. In lake disposal via pulverizing and/or deep water discharge of negatively buoyant material is a much cheaper option than ferrying harvested weed to shore for transport to an onshore disposal site but is not a suitable option for situations where removal of lake nutrients assimilated into weed is desired. A final consideration is the movement of harvester units between lakes or other waterbodies and any potential biosecurity risks that this raises. A number of New Zealand's worst lake weeds (e.g. hornwort) currently have a limited distribution so ensuring that fragments of such weeds are not inadvertently introduced into a new location by a harvesting unit is paramount. Units must be thoroughly decontaminated before being moved.

This talk will expand upon the general concepts outlined above and provide relevant examples as appropriate for the Rotorua Te Arawa Lakes.

TRANSCRIPT

Harvesting is one of a number of control tools available for the management of lake weeds and selection of an appropriate weed control tool is usually dictated in the first instance by the amount of weed biomass that is present. This paper focuses on harvesting, as circled in the lower part of the diagram, which is, more specifically, large scale mechanical harvesting. (**Slide 1**) This is one of several weed control tools that are appropriate for situations where there is a large and extensive area of weed biomass requiring ongoing management and there is no risk that the weed will be spread further within the lake by the control operation.

Slide 1

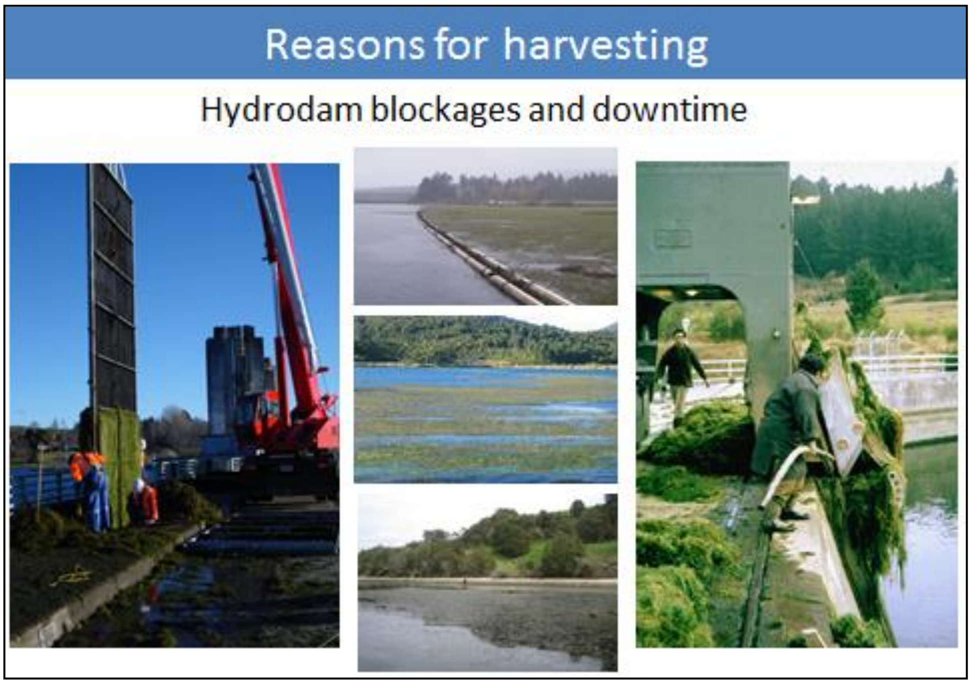


Slide 2

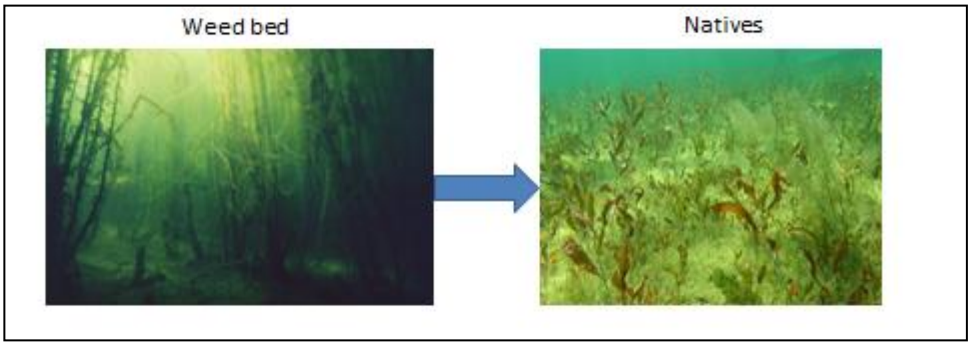
Mechanical harvesting or other large scale weed control operations are typically set up in response to weed having detrimental effects on important lake values, and a key value is lake aesthetics. Weed beds growing close to shore or detached weeds washed up and rotting on shore can have a major impact in areas of high public use. Large weed beds can also be a major nuisance or hazard in areas used for water activities and are particularly hazardous for swimmers. **(Slide 2)**

Slide 3 Weeds are also a major problem in hydro lakes used for power generation. Weed biomass dislodged from growing areas can drift and block dam screens leading to costly station downtime. The weed hornwort is particularly problematic in these lakes as it is more easily dislodged than other species due to having no true roots. In the Waikato hydro lakes mechanical harvesting is one of the number of tools that have been used to manage weed biomass.

Slide 3



Slide 4 Dense weed beds are not only a problem for humans, they also create hazardous conditions for lake biota. Large fluctuations in dissolved oxygen levels occur in dense weed beds, which is a problem for fish. Removing weed biomass can therefore improve this situation and may also allow some native plant recovery, particularly if weed is harvested close to the sediment level. Removal of dense weed can also make these areas more accessible to fish and other wildlife.

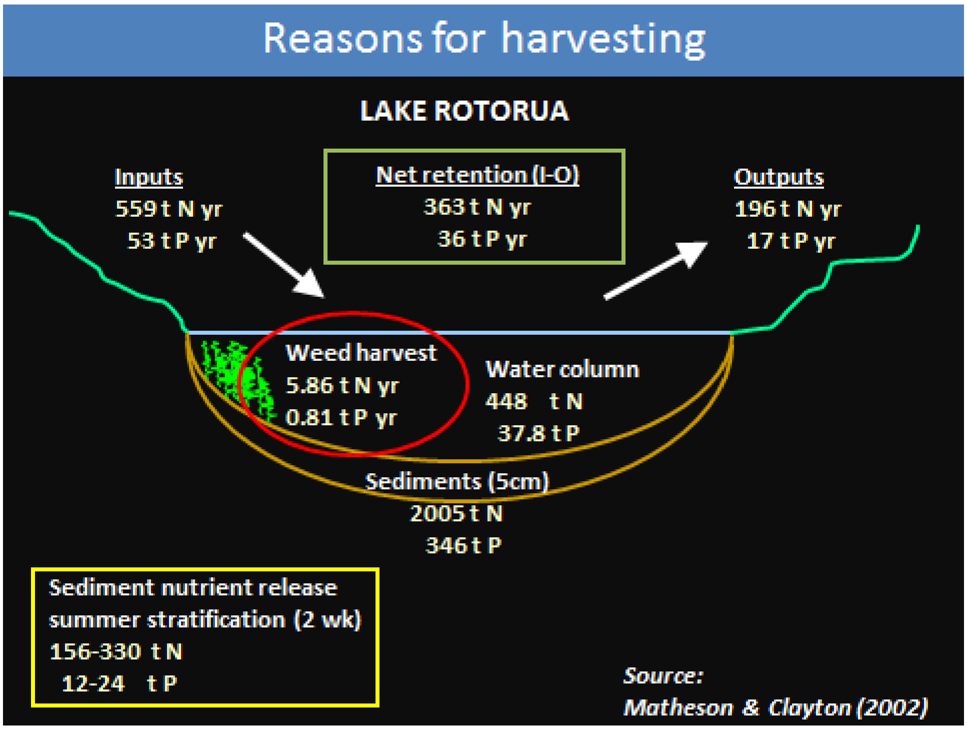


Slide 4

A final reason to harvest which is unique to this particular control tool is nutrient removal. Aquatic plants take out nutrients from lake water and sediments as they grow, so harvesting and removal of these plants from the lake simultaneously removes the nutrient that has been assimilated into the plant tissues. In theory this might improve lake water quality; if the quantity of nutrients that can be removed over time is sufficiently large that the water column and sediment nutrient pools from which the plants assimilate the nutrients start to reduce. The feasibility of this approach needs to be assessed on a case by case basis. But it is usually done by comparing the quantity of nutrients likely to be removed by harvesting within the context of an overall lake nutrient budget. While some studies have shown that an amount of nutrient equivalent to a high proportion of the nutrient inputs to the lake can be removed by harvesting, measureable improvements in water quality have only rarely been documented.

About a decade ago we estimated the amount of nitrogen and phosphorus that could potentially be removed by a harvesting operation in the Rotorua Te Arawa Lakes. This was in relation to lake nutrient budgets using the best information that was available at that time. The key harvesting parameters used in those estimates were a harvesting rate of 0.5 hectare per day, sufficient weed for a year round operation, which was 130 hectares of weed, and the volume of weed removed annually was just over 3,200 tonnes on a wet weight basis.[1]

Slide 5



Slide 5 Thus for all of the lakes where there was potentially sufficient weed for harvest our estimates indicated that the quantity of nutrients that could be removed was very small when viewed as a component of a wider lake nutrient budget. Therefore it was unlikely to affect water column nutrient concentrations and improve lake water quality. The example shown in the slide is Lake Rotorua, where the amount of nitrogen that was estimated to be contained in just the top 5cm of the lake sediments was around 2,000 tonnes, with around

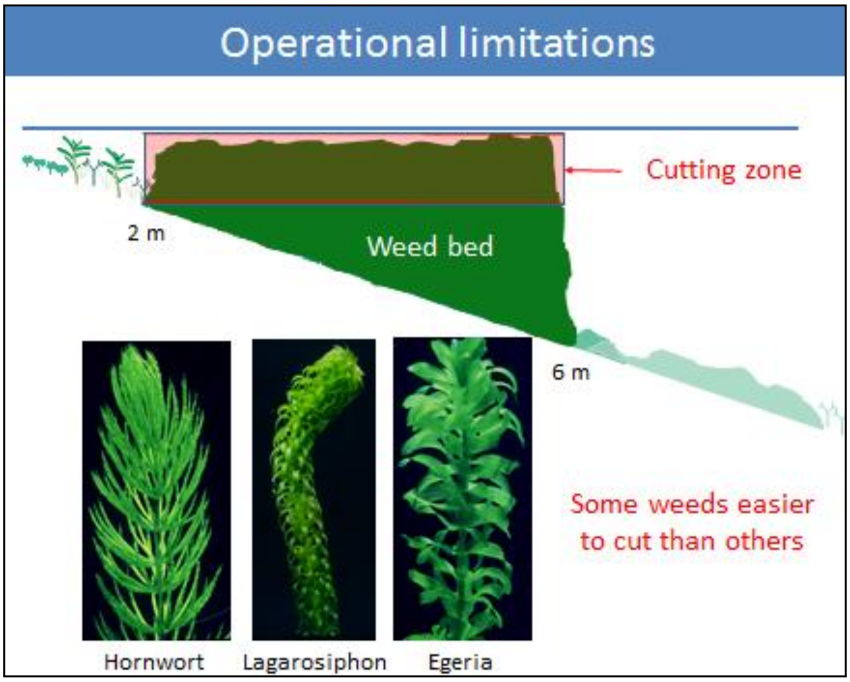
[1] Matheson, F., Clayton, J. (2002). Aquatic plant harvesting in lakes for nutrient renovation. *Report for BOPRC.*

450 tonnes in the water column. Annual net retention (i.e. the difference between inputs and outputs) of around 360 tonnes, and by comparison the amount of nitrogen that might be removed annually by weed harvesting is less than 6 tonnes.

There are a number of reasons for setting up a mechanical harvesting operation, but there are also a number of operational limitations that need to be kept in mind when planning such an operation. **Slide 6** A key limitation is that harvesters can generally only cut weeds to about 2 metres below the water surface, although the development of some very large models used in the USA (such as the Kelpin) have extended this depth range to around 3 metres. Harvesters generally move quite slowly, only slightly more than walking speed and have a relatively limited capacity for storage of harvested weed before unloading is required. On the plus side they are highly manoeuvrable and they can operate in very shallow water.

Slide 6

Slide 7

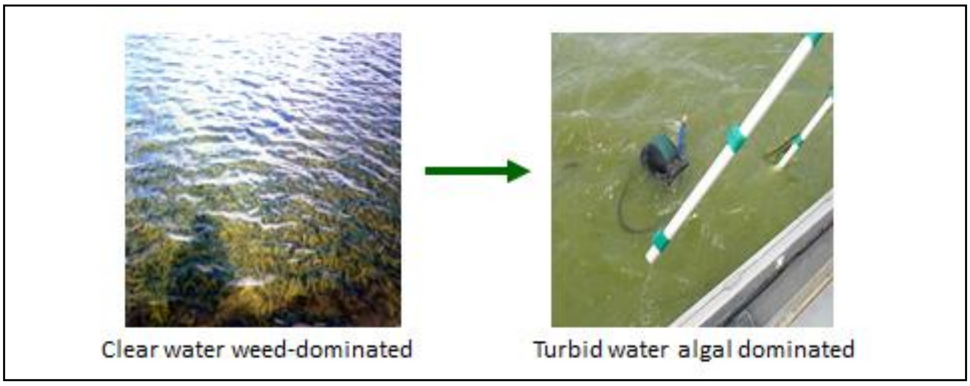


Slide 7 Since the cutting zone of a harvester is usually restricted to the top 2 metres of water column the greatest quantities of weed will usually be removed when the weed is dense and surface reaching. However very dense weeds can sometimes be quite difficult to harvest. In trials in the 1990s, two different harvesters on Lake Rotorua could not cut the dense surface reaching mats of egeria that were present at that time. In contrast, hornwort growths are less dense and appear to be much easier to cut which is demonstrated by the successful harvesting operations in Lake Rotoehu and in the Waikato hydro lakes where this weed is dominant.

There are a number of other operational limitations that also warrant consideration. There must be a suitable access point to launch the harvester and the weed drop off point needs to be close to the work area otherwise much time may be spent travelling to offload the harvested weed unless a transporting barge is also used. Harvesting units can struggle to operate effectively in strong winds and currents. Underwater obstacles and uneven bottom contours can be a problem for operation in shallow water. Weed beds and their growth rates are often variable from year to year so there may be insufficient weed to warrant harvesting in some years but bumper crops that regrow really rapidly in others.

There are also a number of potential ecological impacts that must be weighed up on a case by case basis against the benefits of a harvesting operation. There is usually a bycatch associated with weed harvesting operations. Despite the noise of the machinery some biota are unable to escape and removal of large areas of weed might also result in loss of habitat and cover for some species. Harvesting large areas of weed, particularly in shallow water, can destabilise sediments leading to increased turbidity or nutrient release encouraging a shift away from a macrophyte dominated clear water lake to an algal dominated turbid water state. **(Slide 8)**

Slide 8



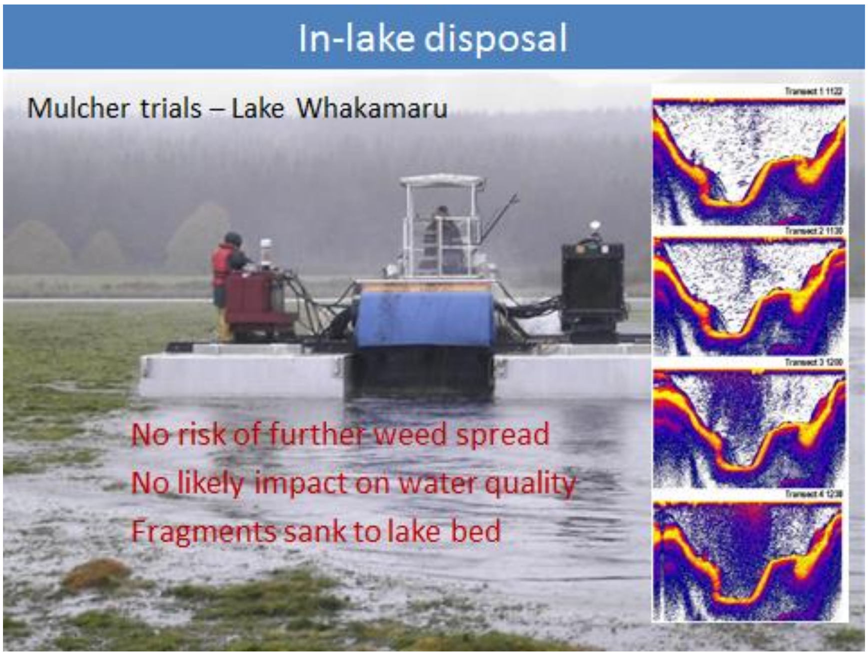
Delving further into the issue of bycatch, overseas research suggests that the amount of bycatch is variable but it some cases it can be large, up to 27,000 fish per acre harvested in one particular study. The amount of bycatch depends on the species that are present in the lake, the location and the timing of the harvest and on the density of weed. A high bycatch is more likely with harvesting close to shore, in dense surface reaching weed and during the spawning season.

Slide 9 Disposal of harvested weed can be problematic and expensive. There are a number of potential options for disposal either in lake or on shore. Transporting weed to shore for disposal can be time consuming and expensive especially if the harvester is operating a long way from the drop off point. So in-lake disposal is therefore an attractive option and suitable in situations where discharge of the processed weed material back into the lake would not have any adverse environmental effects.

Slide 9

An example of in-lake disposal is the mulching of harvested hornwort in the Waikato hydro lakes. In this system hornwort is wide spread, so its habitat is saturated. Theoretical calculations and field tests have shown that the discharge of the harvested weed as mulch fragments back into the water does not have any significant impact on water quality. This is because the quantity of nutrients released from the mulched weed is insignificant compared to the large flux of nutrient that moves through the flowing waters of this system. Concern was expressed about floating weed fragments in the water and fragments being washed up on the shore from the mulching operation. However field trials showed that the mulched fragments were negatively buoyant sinking through the water column and depositing on the lake bed. **Slide 10** shows these sonar profiles run at the time of the trial.

Slide 10



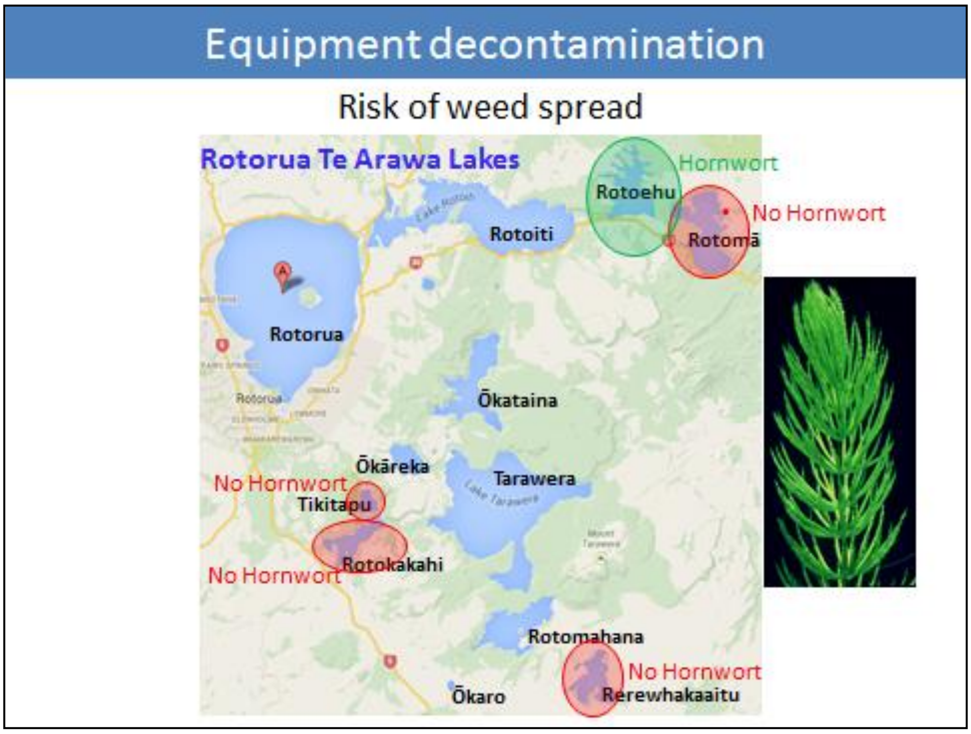
Deep water disposal of weed works on a similar principle in that the material discharged at depth will be negatively buoyant and sink to the lake bed. In the case of unmulched weed that is because the gas spaces within the weed are increasingly compressed by pressure as water depth increases.

For onshore disposal of weed, particularly for use of material as a compost or stock feed, consideration needs to be given to the high water content of the weed and any potential contaminants contained within it. Arsenic, heavy metals and pesticides are of particular concern especially where there are geothermal inputs or industrial, rural or urban discharges. Studies in the Waikato River and Lake Rotoehu have shown that the dominant weeds there contain elevated concentrations of arsenic. However work done by Scion and the Te Arawa Lakes Trust trialling Lake Rotoehu hornwort and vermiculture has shown these concentrations are diluted to acceptable levels if blended with pulp mill solids.

In Lake Horowhenua the suitability of two other lake weed species for use in stock feed compost or vermiculture has also recently been investigated. This work has shown that the unaugmented weed presents some risk if incorporated into stock feed due to elevated arsenic levels in some of the weed. There are also likely to be substantial costs involved in processing the aquatic weed into a pellet form that could be consumed by sheep and cattle. However the concentrations of other contaminants in this weed were generally low therefore indicating that the harvested weed from this lake is probably safe to use in compost or vermiculture.

A final point about all machinery used in these operations is the need for great care to be taken when this machinery is used elsewhere. For example with the current harvesting programme of hornwort on Lake Rotoehu underway; Lake Rotoma, adjacent to it, but also Lakes Tikitapu, Rotokakahi and Rerewhakaaitu do not have hornwort, so any use of the harvester or the associated machinery in those catchments poses a risk to those lakes. **(Slide 11)**

Slide 11



Although it is not the main target of the harvesting operation in Rotoehu, the weed lagarosiphon is also present, but it is not present in Lakes Rotokakahi or Rotomahana. It is unlikely that the harvesting machinery used in Rotoehu would be used in any of these lakes, but it is important that such threats are always recognised and best management practice is that all harvesting equipment is thoroughly decontaminated before being used in any other water body.

In conclusion, mechanical harvesting is a useful tool for ongoing management of extensive areas of lake weed. It is not a quick or complete fix to the problem, it is slow and only the upper parts of the weed beds are typically removed. Measureable improvements in water quality associated with harvesting operations are rare, and bycatch can potentially be significant; this needs to be assessed and managed on a case by case basis. Disposal and use of the harvested weed onshore is a major challenge and the equipment used needs to be thoroughly decontaminated before use elsewhere.

TURNING A NEGATIVE INTO A POSITIVE: AQUATIC WEED HARVESTING, LAKE ROTOEHU

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Richard is a Senior Land Management Officer based in Rotorua with the Bay of Plenty Regional Council and is currently working on the Rotorua Lakes Programme. Richard has a background in biosecurity including terrestrial and aquatic pest plant management, and has been involved in a number of land and lake management projects including biodiversity management plans, sustainable land use management projects and pest management projects.

As part of the Bay of Plenty Regional Council's role in lake water quality Richard has managed Hornwort harvesting for nutrient management from Lake Rotoehu since its inception in 2006.

ABSTRACT
The submerged aquatic weed hornwort (*Ceratophyllum demersum*) has become widespread through Lake Rotoehu since its establishment in the lake around 2000. This exotic pest plant is surface reaching in large parts of this shallow lake making it a perfect candidate for mechanical harvesting.

As part of the Te Arawa - Rotorua Lakes Programme the Lake Rotoehu Action Plan sets out nutrient reduction targets for nitrogen and phosphorus. Realising these targets is integral if lake water quality is to be restored to the trophic level index (TLI) target for Lake Rotoehu. Restoration measures have included land use management efforts to arrest nutrient inputs, phosphorus locking through alum dosing, floating wetlands, and most recently the deployment of two aerators. To date the most successful in-lake nutrient reduction method has been mechanical harvest of hornwort.

Aquatic weed harvesting has resulted in reaching a significant portion of the annual nutrient target for the lake catchment. Attaining this level of nutrient removal has manifested in tangible water quality gains in the past few years. Most noticeable is the reduction in cyanobacterial (blue-green) algal blooms which had been prevalent in the lake in summer months. We discuss the practicalities and problems of submerged lake weed harvesting, disposal options, and impacts of this activity on the lake.

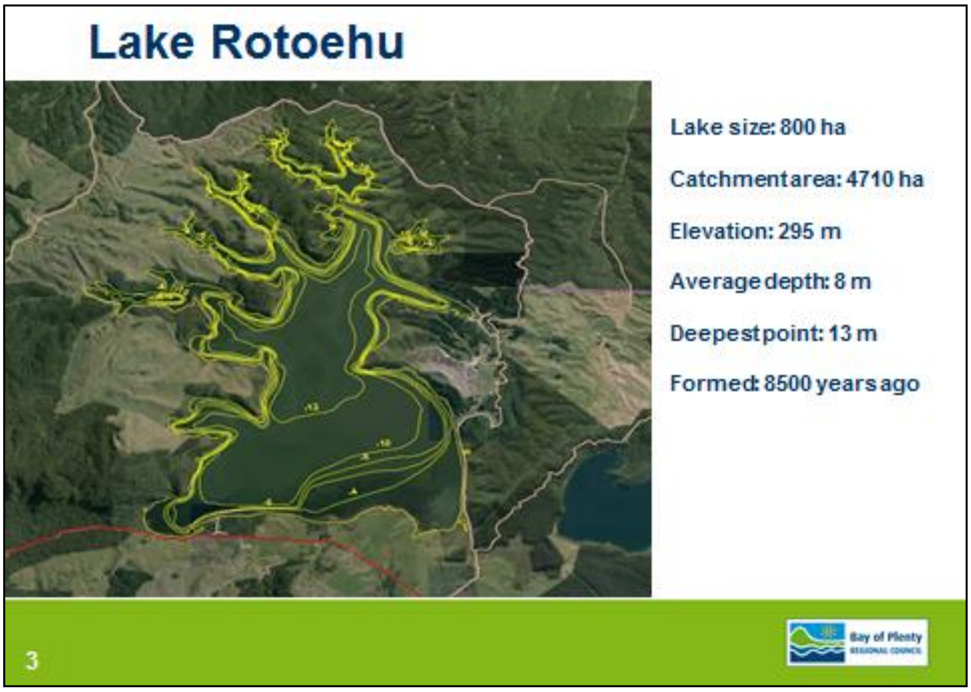
TRANSCRIPT
A major consideration for the Bay of Plenty Regional Council's programme on Lake Rotoehu is the proximity of this lake to Lake Rotoma and the knowledge that hornwort spreads by fragmentation. We are very aware of the risk of it spreading into another lake. They are within a 5 minute drive of each other, and this fact underlies much of the lake's programme in preventing the spread of this weed between lakes. The installed weed cordons and proactive lake weed spraying and harvesting carried out around boat ramps is all to prevent spread.

Lake Rotoehu is one of the original four Ministry of the Environment Deed Funded lakes, along with Rotorua, Rotoiti and Okareka. **(Slide 1)** If you were to design a lake to grow hornwort you could not do much better than Lake Rotoehu. The deepest point of the lake

is about 13 metres and hornwort is quite capable of growing down to that depth given good water clarity. It is a lake which will support 100% hornwort growth under ideal conditions. There are a number of sheltered northern bays where it can grow and a prevailing north westerly wind pushes the weed down into the bottom corner where the harvesting is easily done. This addresses some of the concerns about the travel distance to get to harvested weed; it is right on the doorstep at that point. **(Slide 3)**

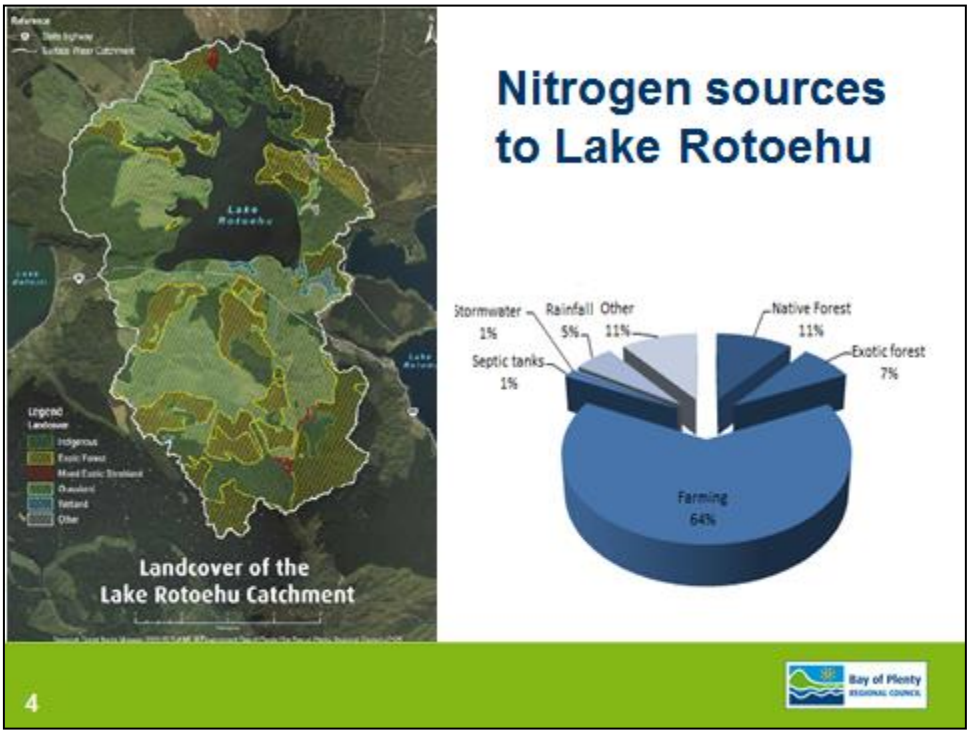
Slide 1

Slide 3



Exact assessment of the nitrogen load into the catchment of Lake Rotoehu is a very important part of the whole process. **Slide 4** is the breakdown of the inputs of nitrogen between farming, exotic forest and native forest and other. The catchment is 4,710 hectares; the total nitrogen load into the lake was estimated to be 53 tonnes of nitrogen. The target was set at 44 tonnes so this is the goal to get down to.

Slide 4



Since the time of compiling this graph, there have been 668 hectares of forestry conversion on the southern side of the lake on Tautara Matawhaura Trust land. An in-lake intervention like harvesting is going to give short term gains, but long term the gains will come from land use change or from some manipulation within the catchment.

The first major algal blooms occurred in Rotoehu in about 1993; a more recent photo on the left was taken in Otautu Bay. The blooms around 2000 were really bad and it was so thick it looked like you could walk on the water and boats left a big green wake behind. Weed growth in the lake was stunted because the light was very limited. The algal blooms certainly needed attention.

Slide 6 taken in March 2009 looks from the south eastern corner of the lake, Te Wairoa Bay towards the Hinehopu end. There were about 60 hectares of surface reaching hornwort which could be harvested. The hornwort growth itself is seasonal, growing through the summer as the water temperature increases and only loosely rooted to the lake bed. Peak growth in late summer has surface reaching or 'Topped Out' weed beds. Then northerly storms easily uproot the infestations and push

them out of the arms and they raft up in the south eastern corner of the lake. They have severe negative impacts on the bio-diversity within the lake, the amenity value to the lake and on the water quality.

Slide 6

In the USA Hornwort is known as coontail, which is quite appropriate looking at **Slide 7**. This NIWA photo shows fresh green shoots of hornwort coming through. Hornwort sampling in Rotoehu gave us 30 kilograms of nitrogen per dry tonne; the wet weight weed is about 4 or 5% dry matter and of that about 3 or 4% is nitrogen. There is a smaller quantity of phosphorus in there as well.

Slide 7

In 2006 we investigated processes for harvesting this weed and the cost efficiencies in taking it out in relation to the amount of nitrogen that can be removed. **(Slide 8)** Using Mighty River Power's harvester called Myrtle, which was used on Whakamaru, we carried out some control work and ascertained the idea that the cost of nitrogen removal this way would be about $40 a kilogram. That information was incorporated into the Action Plan for the lake, released in November 2007 which set targets of 8,880 kg/yr N and 708 kg/yr for P. It addressed the question of whether the target of removing about 8½ tonnes of nitrogen can be achieved by harvesting weed.

Slide 8

Other current initiatives which were put into place in that catchment included the land management change, phosphorus locking, artificial wetlands and aeration, but it was hoped that the end result might be the removal of 2-3 tonnes of nitrogen through harvesting as well. Harvesting operated from 2006 through to 2012 with Mighty River Power's harvester, the photo below taken relatively late in the harvesting season. Much of the weed had started to die back down and most had been removed.

In 2013 about the time the Government sold Mighty River Power the harvester was unavailable. Some alternate methods were trialled, one of them being the use of diggers on pontoons; it was probably the most costly method and it was not particularly efficient. **(Slide 11)** Some elevated levels of arsenic were seen which was likely in relation to the amount of sediment being pulled up

with the weed. The most recent sampling carried out on hornwort in this particular area has shown arsenic within compostable limits, which is around 20 milligrams per kg of nitrogen.

Slide 11

At the end of 2003 Deloittes was commissioned to do a business case study for us looking at four options:

- Continued use of the digger,
- A contractor to purchase and operate a harvester
- BOPRC to purchase a harvester and operate it ourselves
- BOPRC to purchase a harvester and tender out its operation. This option was the most cost effective.

Slide 12 An Aquarius model HM420 is used for harvesting today (March 2015). The hydraulic driven system is powered by an air cooled diesel motor. It has retractable paddle wheels, reciprocating cutter bars onto the cutter arm conveyor belt and the main body conveyors off load from the stern.

Slide 12

We have developed a trailer which acts as an offloading mechanism as well. The Regional Council owns this package which ensures a surety of availability; its operation can be contracted out, which also gives us competitive tendering to operate it. It operated its first full season in 2014 and is currently operating on Rotoehu (March 2015). It gives the flexibility to be used at other sites where amenity weed strandings might be an issue such as

at Okawa Bay on Lake Rotoiti this year.

Weed disposal is an issue and several means of weed disposal have been tried. Truck loads have been transported out of the catchment to a composting operation in Te Puke. **Slide 13** Harvested weed mixed with wood pulp waste in a vermicomposting trial in conjunction with Tautara Matawhaura. Containers of worms were released through this mix so a compost/ vermicast product could be produced. This operation was within the catchment and readings with lysimeters showed leaching back into the catchment. About 60% of the removed nitrogen ended up back in the water table, which was not an ideal state of affairs. For this year's operation weed is to be transported out of the catchment to Kawerau. In order to do that permission from the Ministry of Primary Industries was required. Part of that permission involves quite strict quarantine about water blasting loads down before they leave. We are very aware that we travel through the Rotoma catchment and spreading hornwort into that lake must be prevented.

Slide 13

Slide 14

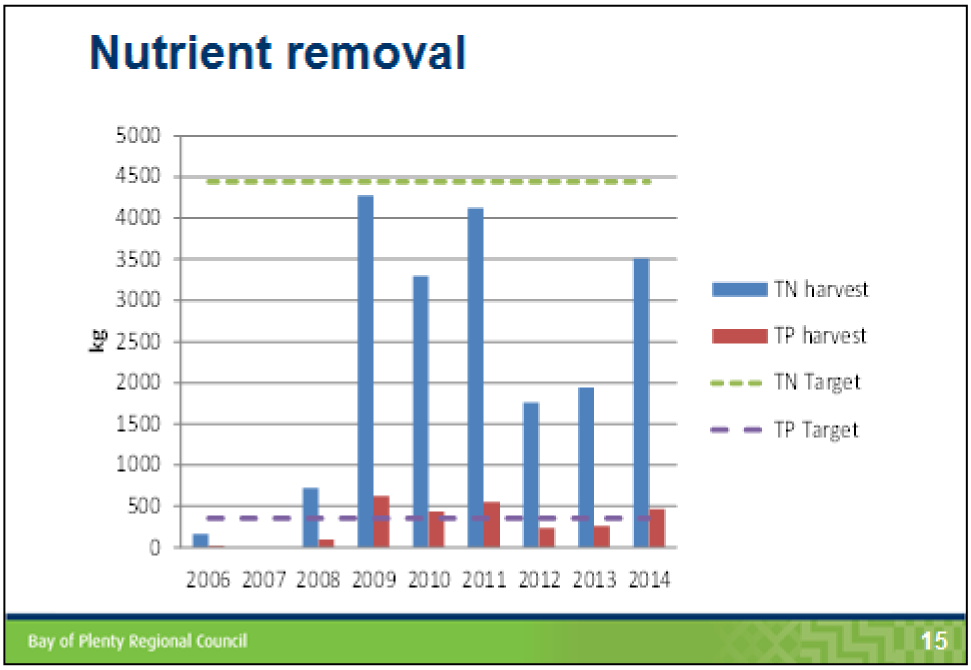
Quantities and Costs per Kg/N 2008-2014

2008	2009	2010	2011	2012	2013	2014
600t	3073t	2744t	3436t	1472t	1622t	2926t
$51.36/Kg	$29.54/kgN	$43.18/kgN	$34.62/kgN	$32.94/kgN	$46.24/kgN	$28.87/KgN

14

Slide 14 indicates the dollar cost per kilogram of nitrogen removed and the quantities that have been removed from 2008. In 2007 there was little weed, so there was no harvesting. In 2008 a small quantity of weed with a long turn around resulted in increased cost per kg. 2011 was a bumper year, 2012 not quite so, 2013 again a bumper year for weed but was the most expensive because the digger was used. 2014 was the first year using the new harvester and the lower price reflects the efficiencies gained from that. 2015 is looking like it is going to be a bumper year; plenty of weed will come out with the harvester.

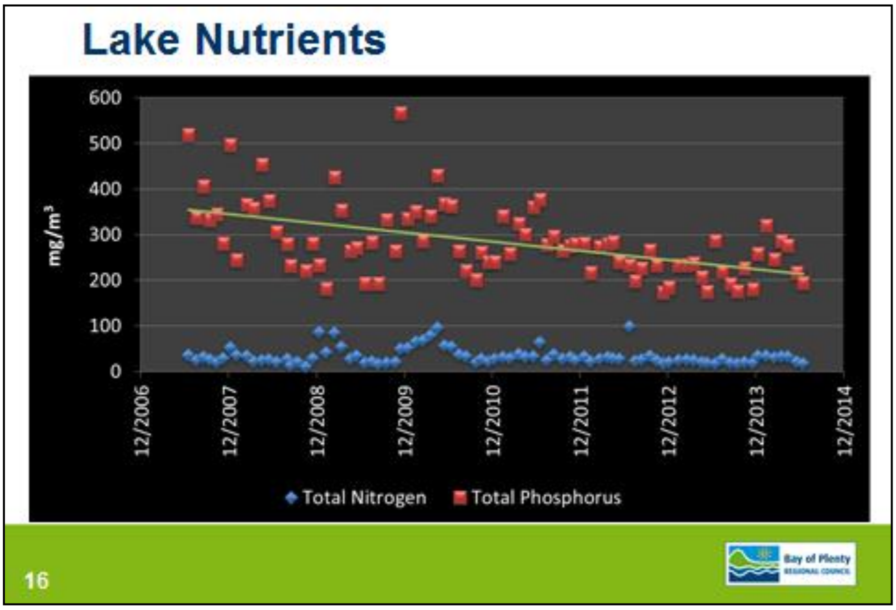
Slide 15



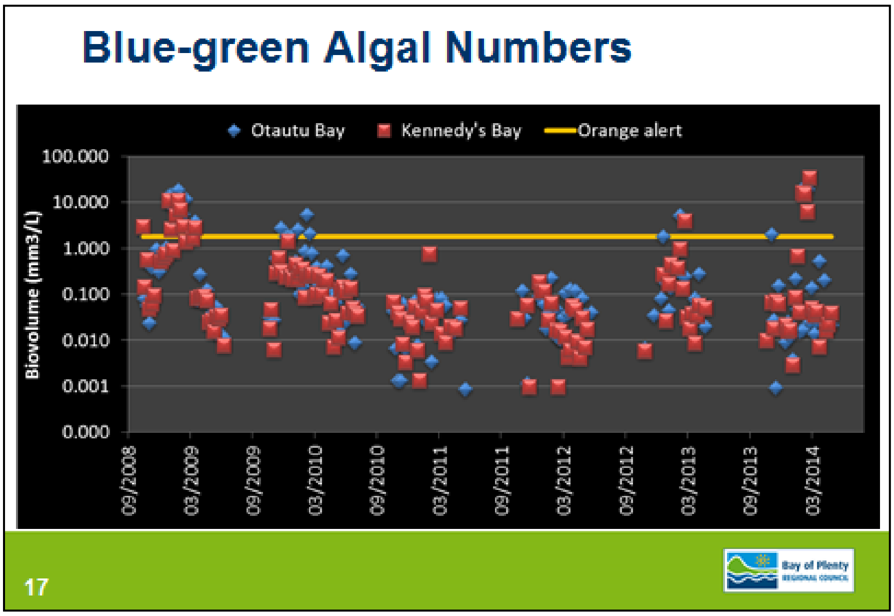
Slide 15 is the total nutrient removal by harvest for years 2006 to 2014. It is variable, there are seasonal variances in how much weed grows and the ability to harvest, but generally speaking it has been quite a successful operation in taking weed out.

Paul Scholes outlined the outcomes of removing some nutrients from Lake Rotoehu. Bay of Plenty Regional Council monitors a range of parameters monthly in the deepest part of the lake. Focussing on the trophic level parameters, nitrogen and phosphorus, there is quite a strong trend in improvement of nitrogen, but not so much in phosphorus since the start of harvesting back in 2006. This translates to far fewer algal blooms than have been seen for many years. **(Slide 16)**

Slide 16



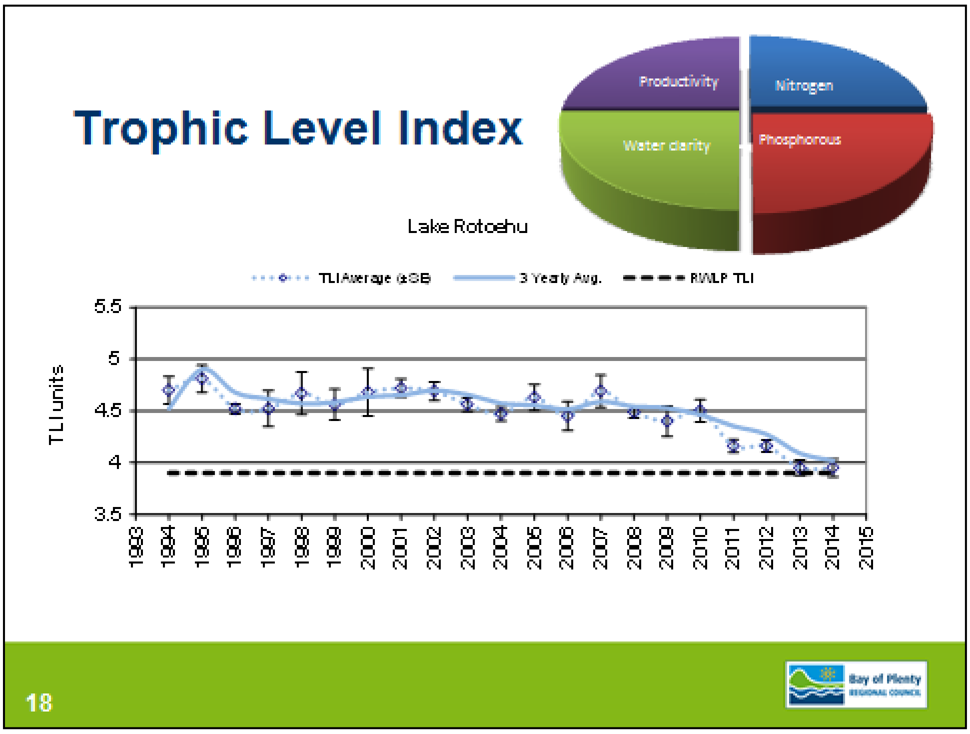
Slide 17



Lake Rotoehu was severely affected by algal blooms up until 2009; the orange line in **Slide 17** of blue-green algae in Rotoehu represents the recreational guideline standard for algal bio-volume. Since the harvesting programme started that algal biomass has dropped below the recreational guideline standard for algal bio-volume, resulting in only one lake health warning in the last 6 years, previous to this season.

This is a positive trend for the Regional Water and Land Plans Trophic Level Index objective for Rotoehu, which is our target for reaching that water quality, based on the four parameters of nitrogen, phosphorus, chlorophyll A, (measure of productivity) and water clarity. It means that things are looking pretty good for Rotoehu at the moment with all those interventions. **(Slide 18)** Although the dominant intervention has been nutrient removal from the harvest, there are now other interventions of aeration, P locking, and a floating wetland.

Slide 18



BIOCONTROL OF AQUATIC WEEDS

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Quentin is an entomologist who is expert in ecology, biological invasions and the biological control of weeds. He was awarded a doctorate in 1991 from Imperial College London (UK) for his work on the host-location behaviour of tsetse flies. He then obtained a Royal Society Fellowship to continue tsetse fly work at ICIPE in Kenya before moving to Montpellier, France in 1993 where he worked for CABI investigating the potential for biological control of Scotch broom. In 1998 Quentin moved to Darwin, Australia where he battled the heat and crocodiles working for CSIRO on the integrated control of a wetland weed Mimosa pigra. In 2003, Quentin took up a position at Landcare Research, based at the Tamaki Campus in Auckland where his research interests have focused on improving the environmental safety and success rate of weed biocontrol. Quentin has extensive experience providing applied biocontrol solutions and he currently leads projects targeting Japanese honeysuckle, wild ginger, privet and alligator weed in New Zealand and a major project targeting a suite of invasive weeds in the Cook Islands.

ABSTRACT
Current control methods for aquatic weeds in New Zealand include mechanical control, herbicides and inundative biological control using sterile grass carp as well as habitat manipulation and integrated control. These options have been used to successfully eradicate weeds (both on a local scale and nationally) and are often highly cost-effective. However, a relatively small number of aquatic weed species have become so widespread that the cost of using these techniques against them can be prohibitive. For example, the annual control costs for hornwort in New Zealand are approximately $3.3 million/yr. A new control method with the potential to reduce these management costs is desirable. In this talk I shall discuss the potential for using classical biological control to tackle some of the worst submerged aquatic weeds in New Zealand.

TRANSCRIPT
We have learnt already that most serious weeds in New Zealand are not native; they were introduced from other countries. Classical biological control is defined as ‘the intentional introduction of an exotic, usually a co-evolved biological control agent, for permanent establishment and long term pest control’. Putting that in simple terms, it is reuniting an introduced weed with its natural enemies that attack it in its home range. The idea is go to the native range of the weed, see what species are chomping it there and bring them back to New Zealand after some stringent safety testing.

There are a number of advantages to biological control, the main one being that it is highly selective. Once the host range testing is done, it can be assured that the biological control agent will attack only the target weed and nothing valuable, otherwise it will not get a permit for release. Biocontrol agents can also disperse naturally to inaccessible infestations and once the initial investment in a biocontrol control programme is achieved and the agents are released, then they persist at no further cost making successful programs very cost effective.

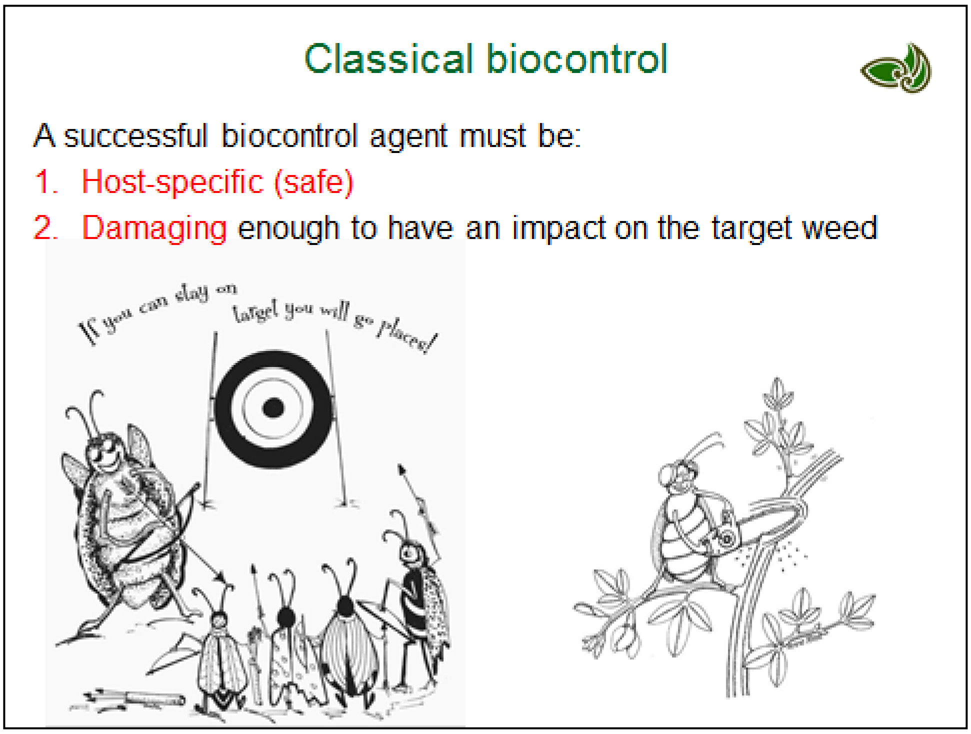
A disadvantage is that the initial investment is costly, especially for a novel weed biocontrol target; it is often in the region of $1.5 to $3 million dollars. Many biocontrol programmes take advantage of programmes that have been done elsewhere. For

example, for woolly nightshade in New Zealand recently, we have used a biocontrol insect that was first introduced into South Africa. It is much cheaper because most or all the host range testing, etc. has already been done. If we do a repeat programme it is cheap.

A big issue with biocontrol is that we can never guarantee it is all going to succeed, especially for novel programmes. A repeat programme gives a good idea of the potential impacts but for a brand new programme we step into virgin territory unsure of what may happen. Another issue is that biocontrol can be quite slow. Surveys in the native range, selection of candidate biocontrol agents and host range testing to make sure they are safe must be done prior to introduction and then time for numbers to build to damaging levels can take years. It would be unusual to get an impact quicker than say 10 years from the commencement of a new programme. Compare this with herbicide spraying which produces an instant result.

All biological control agent introductions in New Zealand are regulated by the Environmental Protection Authority who assess the risks, costs and benefits of proposed biocontrol agent introductions and decide whether agents should be released. If there are objections to a biocontrol being released, there is often a public hearing, where everyone gives their evidence. The EPA then deliberate on whether the biocontrol agent should be released or not.

Slide 1



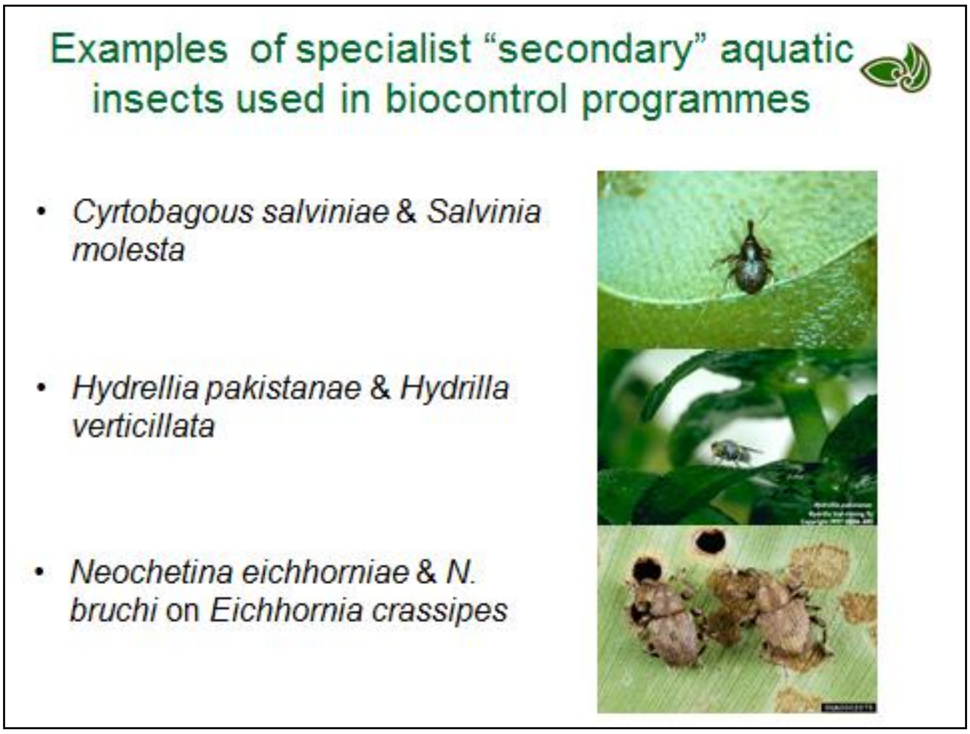
Slide 1 indicates that to be successful there are two key factors in a biocontrol agent. The crucial one is safety, it must be host specific. Permission to release a biocontrol agent will not be given if there is risk of it attacking a native or an economically important plant. The other issue is that it must be damaging enough to have an impact on the weed. In the past it was believed that there was a lack of host specificity in herbivores attacking aquatic plants.

It is true that many so-called primary aquatic insect herbivores are generalists or periphyton feeders. But many macrophytes, for example, the Hydrocharitaceae, evolved

as land plants; and that is where chemical defences co-evolved with insect specialist herbivores. These plants became adapted to an aquatic lifestyle and some specialist insects 'followed their host-plants into the water'.[1]

These are called secondary aquatic insects and in **Slide 2** are a few examples used in biocontrol programmes. The weevil (*Cyrtobagous salviniae)* attacks Salvinia. *Hydrellia* leaf-miner flies have been introduced to control hydrilla in the USA and there are beetles introduced to attack water hyacinth in many places. There has been a reappraisal recently and now it is considered that 'most herbivory on macrophytes is usually by specialized, oligophagus herbivores'.[2] (Oligophagous herbivores eat only a few specific kinds of food).

Slide 2



Recent findings are that some primary aquatic insects can be specialists as well. For example, it has been discovered that a little Chironomid midge *(Polypedium sp.)* has larvae that tunnel into the stem tips of lagarosiphon in South Africa where lagarosiphon is native. **(Slide 3)** Preliminary host range testing conducted in Ireland suggests that this midge is highly host specific. In fact there is now quite a list of bugs being studied which appear to be sufficiently specific to be used as biocontrol agents around the world.

Slide 4 indicates that we can "tick off" the specificity side of things, the next issue is impact. To date most biocontrol programmes against aquatic weeds are focussed on floating aquatics and emergent plants which include some of the most successful programmes ever. **Slide 5** shows Salvinia before and after biocontrol. Not all floating weeds were tackled quite this successfully but this shows what is possible.

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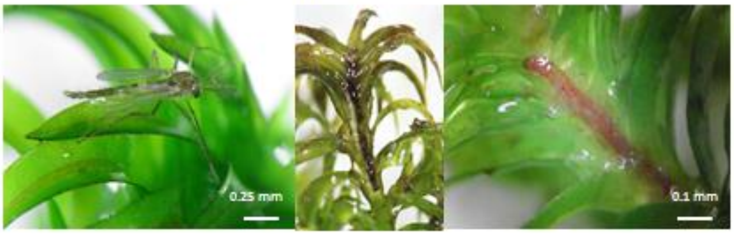
[1] Wilson F 1964: The biological control of weeds. *Annual Review of Entomology,* **9**, 225-244
Cummins KW 1973: Trophic relations of aquatic insects. *Annual Review of Entomology,* **18**, 183-206, Newman RM 1991. *J. N. Am. Benthol. Soc.,* **10**, 89-114

[2] Newman RM 1991. *J. N. Am. Benthol. Soc.,* **10**, 89-114

Slide 3

"Primary" aquatic insects can also be specialist herbivores

Chironomid midge *Polypedilum* sp. is a specialist stem-mining herbivore of *Lagarosiphon major* in South Africa[1]



[1]Earle, W., Mangan, R., O'Brien, M., Baars, J.-R., 2013. Biocontrol Science & Technology 23, 1267-1283

Slide 4

Insects that feed on submerged aquatics currently being investigated globally that are considered sufficiently host-specific for use as biocontrol agents

Target weed	Country where control is desired	Insect species	Guild
Cabomba caroliana	Australia	*Hydrotimetes natans*	Stem-miner
Egeria densa	USA	*Hydrellia* sp. 1	Leaf-miner
Hydrilla verticillata	USA & S. Africa	*Hydrellia pakistanae; H. balciunasi*	Leaf-miners
		Bagous hydrillae	Stem-miner
		Bagous affinis	Tuber-borer
Lagarosiphon major	Ireland	*Hydrellia lagarosiphon*	Leaf-miner
	Ireland	*Polypedilum* sp.	Stem-miner
Myriophyllum spicatum	S. Africa	*Euhrychiopsis lecontei*	Stem-miner

Slide 5

Impact of aquatic herbivores

- Nearly 100% reduction of *Salvinia molesta* in Australia, South Africa & USA

Lake Moondarra, Mt Isa, Queensland (Left = before; Right = after release of the weevil *Cyrtobagous salviniae*) [Photos: CSIRO]

Room, P. M., *et al.* 1981: Successful biological control of the floating weed salvinia. *Nature*, **294**, 78-80.

What about submerged aquatics? To date there has been only one classical biocontrol programme against a submerged aquatic where an agent has been released; *Hydrellia* against hydrilla in the USA. Interestingly many small and large scale tank and pond studies indicated that these flies, (left) mainly *Hydrellia pakistanae*, could greatly reduce hydrilla biomass and everything looked very positive. When released in the field there were similar impacts reported from some localities.[3] But generally the impact has been minimal and the question is why did they not quite reach their potential?[4]

Trichopria columbiana

There are a number of potential reasons. Lethally high summer temperatures cooked the larvae. Aerial spraying against mosquitos is conducted in many areas which also affects the biocontrol agents. There are indications that plant nutritional quality might be important although this is a bit contradictory. If plants are fertilised, biocontrol agents do better but so do the plants!

The major reason seems to be parasitism and this little wasp *Trichopria columbiana* (right) is a parasitoid that can swim under water and attack the biocontrol agents. As an entomologist it is really quite neat, but as a biocontrol practitioner it seems to be incredibly unfair. This parasitism was predictable because there are native *Hydrellia* flies that occur in the USA which are very closely related to the introduced *Hydrellia* biological control agents. The native *Hydrellia* flies attack native Hydrocharitaceae and also occasionally feed on hydrilla, but not to any great extent. This does mean that there was a native parasitoid already attacking native *Hydrellia* flies on hydrilla plants in the USA before the imported *Hydrellia* biocontrol agents were released.[5] Under such circumstances it is not surprising that the parasitoid attacked the biocontrol agent. The good news is that there are no *Hydrellia* flies known to attack submerged macrophytes in New Zealand. If there are no flies then we have to assume there are no parasitoids and the impact of biocontrol could potentially be a lot greater here.

The lesson from the programme in the USA is that, although not a great success, it demonstrated that specific biocontrol agents can have a major impact on submerged aquatics. The limited success should not unduly discourage us regarding the prospects of

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[3] Grodowitz, M. J., et al. 2009. US Army Engineer Research and Development Centre. ERDC/TN APCRP-BC-15.
Grodowitz, M. J., et al. 2004. Proc. XI Int. Symp. Biol. Contr. Weeds. 529-538.
Coon, B. et al.. 2014. *Biocontrol Science & Technology* 24:1243-1264.
[4] Cuda, J., R. Charudattan, M. Grodowitz, R. Newman, J. Shearer, M. Tamayo, and B. Villegas. 2008. Recent advances in biological control of submersed aquatic weeds. *Journal of Aquatic Plant Management* 46:15.
[5] Balciunas JK, Minno MC. 1985. J. *Aquatic Plant Management* 23: 77-83
Paynter Q et al. 2010. J. *Appl. Ecol*. 47, 575-582

biocontrol here, because the factors which impeded biocontrol there might not be a problem here.

In New Zealand there are six submerged aquatic weed species that are potential targets for biocontrol.[6]

Weed	AWRAM Score[1]
Hydrilla verticillata	74
Ceratophyllum demersum	67
Egeria densa	64
Lagarosiphon major	60
Vallisneria spp.	51
Elodea canadensis	46

We have already heard that hydrilla is on its way to eradication, so it can be crossed off the list because there is nothing for biocontrol agents to eat at the moment, or very soon there will not be. The remaining species are widespread and costly to control using the current techniques, so biocontrol could certainly play a part in managing these weeds.

Lagarosiphon, egeria and ceratophyllum are the three worst aquatic weeds. Lagarosiphon comes from South Africa and is a noxious weed in many parts of the world including Ireland where it is a biocontrol target. **(Slide 6)** There is collaboration between Irish and South African scientists. They discovered the Chironomid midge (mentioned earlier) and they have also found a *Hydrellia* fly which they have named *Hydrellia lagarosiphon*. For both of these agents we have funding from the National Biocontrol Collective, which is a collective of regional councils and the Department of Conservation. This funding has enabled us to sub-contract the researchers in Dublin to include New Zealand test plants in their host range testing. That work has been completed for *Hydrellia lagarosiphon* and we

Slide 6

[6] Champion, P.D., Clayton, J.S., 2000. *Science for Conservation* 141**,** 48 pp.

know that this fly will not attack any New Zealand native aquatics. We can soon apply for EPA funding to bring this fly to New Zealand. But we need additional funding to complete testing of the second agent, the midge. Testing that has been done so far in Ireland suggests that it is highly specific, so it looks really promising.[7]

There have been studies in Ireland looking at the impact of the fly and the midge which work together nicely. The fly lays eggs on the bits of the weed that stick out of the water, the 'topped out' plants, whereas the midge lays eggs that sink in the water and then the larvae emerge into plankton. In theory, the midge can attack the submerged weed, whereas the fly will attack the 'topped out' plants.

The next potential target is egeria densa (right) which is a major weed in other parts of the world. It is native to South America and the potential for biocontrol in the USA is currently under investigation by Argentinian and USDA scientists. They found another *Hydrellia* fly which may not have been described yet, and called it *Hydrellia* sp. 1. It is highly specific to egeria densa and potentially damaging.[8] Hopefully there are no parasitoids than can attack it in New Zealand.

The big aquatic weed problem in New Zealand is hornwort (left) which has an almost global distribution. Looking at the DNA, hornwort in New Zealand is identical to hornwort in Australia so it must have come from there.[9] But because it is native virtually everywhere else in the world it is not really considered a problem elsewhere. It has not been studied as a biocontrol target and virtually nothing is known about species that might eat it. A biocontrol programme against hornwort would have to start from scratch. Where it is an indigenous species it rarely causes problems.[10] So from a biocontrol perspective that is a good sign because it may mean that invasiveness here is a symptom that it lacks enemies here and that is why it is such a bad weed.

Four years ago a report by Deloitte[11] looked at the economics of aquatic weeds and found that the annual control cost for hornwort in New Zealand was $3.3 million a year and about $1.4 million a year for lagarosiphon. There was no reliable data for egeria. Biocontrol programmes for lagarosiphon and egeria should be cheaper as agents are already developed overseas. But a programme targeting

[7] Earle, W. et al., 2013. *Biocontrol Science and Technology* 23**,** 1267-1283.
[8] Cabrera-Walsh, G., Y. M. Dalto, F. M. Mattioli, R. I. Carruthers, and L. W. Anderson. 2013. Biology and ecology of Brazilian elodea (*Egeria densa*) and its specific herbivore, *Hydrellia* sp., in Argentina. *BioControl* **58**:133-147.
[9] Paynter, Q., 2013. Feasibility of biocontrol of *Ceratophyllum demersum* and *Egeria densa* in New Zealand., *Landcare Research Contract Report LC 1492*. Landcare Research New Zealand Ltd, Auckland New Zealand.
[10] Clayton, J., Champion, P., 2006. Risk assessment method for submerged weeds in New Zealand hydroelectric lakes. *Hydrobiologia* 570**,** 183-188.
[11] Deloitte. 2011. *MAF - Didymo and other freshwater pests: Economic impact assessment.* http://www.biosecurity.govt.nz/files/pests/didymo/didymo-and-other-freshwater-pests-eia-aug2011.pdf

hornwort is likely to cost over a million dollars because we must start from scratch. However, economists at Landcare Research suggest that a biocontrol programme would only need to reduce the current annual control costs for these weeds by around 3 or 4% for the programme to break even.

To summarise, recent developments indicate that submerged aquatic weeds in New Zealand may be amenable to biocontrol. I have talked with NIWA about developing a programme for the three worst weeds. But there is no guarantee of success, agents might fail to establish or they may not build up to highly damaging numbers. Maybe there is a parasitoid out there, who knows. But prospects do look good for lagarosiphon and egeria and the cost benefit analysis does indicate that the bar is quite low in terms of a biocontrol programme paying for itself.

We have secured funding for the release of the first agent for lagarosiphon but the biocontrol collective has many other weed priorities. We are looking for additional funding sources. A worst case scenario would be that we divert funding currently going to other forms of weed control and then the biocontrol agents do not work. Ideally we need a brand new form of funding or ask people currently funding weed control to dig a bit deeper in their pockets. If anyone has got any ideas or just won the lottery please let us know! It could be a consortium of stakeholders to spread the cost and the risk. If you would like to have more details about the proposal just send me an email, PaynterQ@landcareresearch.co.nz.

SPRAYING AS A SOLUTION

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Deborah leads research projects that focus on solutions for aquatic weed issues, such as screening aquatic herbicides for use in New Zealand, assessing the impacts of grass carp and the potential development and use of more selective bio-control agents. Trials have been completed on the efficacy of a range of products and weeds as well as a range of non-target native plant species. Research seeks to improve the tool-box for weed control options in New Zealand with new research on the use of grass carp, and the development of more selective bio-control options for New Zealand. Deborah contributes to the assessment of aquatic plant species that are new to New Zealand or in the aquarium trade to predict their potential threat to the environment, and inform legislation where appropriate, and she has a special interest in the conservation of native flora and fauna which can be better protected through understanding the consequences of aquatic weed invasions and management.

ABSTRACT

When invasive aquatic weeds establish in a lake, they usually result in detrimental effects on native biodiversity, amenity and utility values. Once a weed species or weed issue has been recognised control options are often sought to protect amenity and utility functions of aquatic systems. There is also a growing desire to control invasive plants to support the restoration of lakes, improving biodiversity and habitat values. The tools or methods that can be utilised for the control of invasive aquatic plants can be broadly described by the following categories; habitat manipulation; biological, chemical, mechanical and manual, and integrated weed control. The selection of which tool to use is primarily determined by the target weed, characteristics of the lake or waterbody and the management goals or desired outcome. Herbicides can be used to provide effective, selective and targeted weed control. This paper describes the products available, how they work and the environmental benefits that can be achieved with their use.

TRANSCRIPT

We really need to look at the necessity to control aquatic weeds and the control with herbicides in particular. This paper covers some information on products, testing, efficacy, selectivity possibilities and outcomes and the way forward.

Three species of submerged plants are of particular importance in the Rotorua Te Arawa Lakes:-

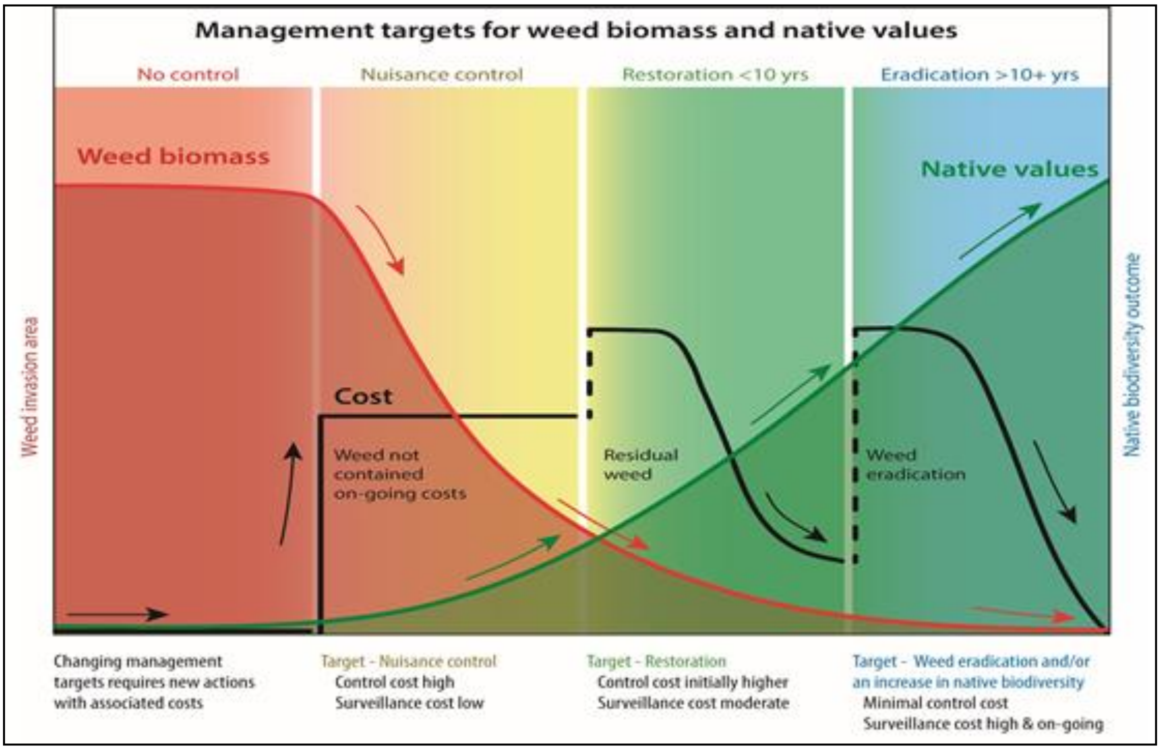
- *Egeria densa,*
- *Lagarosiphon major*
- *Ceratophyllum demersum*, (Hornwort) and one of the worst weeds shown here on Lake Rotoehu in a weed drift on the shore line.

There is a fourth weed, *Elodea canadensis*, of lesser threat compared with the other three, but it is an invasive (non-native) plant species.

These invasive species have quite significant impacts, they displace native plants, they alter habitats for native fauna and they can reduce amenity/utility values in the lakes they have invaded. Weed control policies need to address management targets and outcomes for weeds in particular lakes. The challenge starts with key questions right at the beginning in terms of identifying weed issues and the required action. Is it a case of continuing to 'mow the lawns' thus providing control of nuisance weed beds? Or is restoration the long term goal to improve bio-diversity or native values, or weed eradication?

In **Slide 1**, the first panel on the left hand side of the diagram shows peak weed biomass which will continue if nothing is done. Between each panel on the diagram, new decisions are required to move to the next stage (to the right), and there are associated actions. If the aim is nuisance control, then that is like mowing lawns, a repeat action step. The red line (indicating weed biomass) will decline which is great if that is what the target is. But if the target is the improvement of native values and bio-diversity (green line), then a new decision that sustains a low level of that weed biomass is necessary so restoration can be considered. We have heard about the decline of native seed banks under dense weed beds. Thus consistently reduced weed biomass is necessary for restoration in lakes after having an invasive weed species. Eradication is another end point (fourth panel in the diagram) which is a much longer term goal. Again, further action steps are likely required to remove the last pieces of weed once the restoration goal is achieved.

The next question is how can this be achieved? There are three primary areas that are determinants in terms of how control tools are selected:



Slide 1

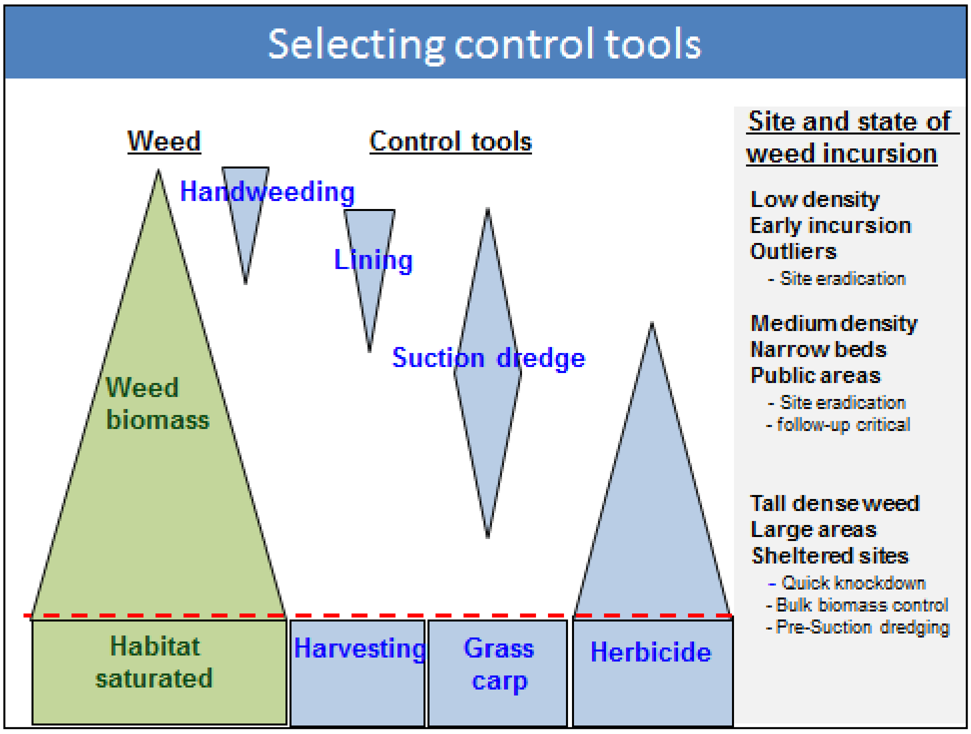
(1) The target weed is important because there are specific things about the target weed that may determine why one tool is better than another. They can be factors like life form types that dictate when or how control can be targeted for that particular plant. For example, the particular submerged weed species in the Rotorua region (*E. densa, L. major, C. demersum*) do not have seeds, which enables a different approach compared with submerged weeds that do have seeds or similar long lived propagules (eg., the tubers of h*ydrilla verticillata*).

(2) The water body characteristics are important, size, shape, depth and water movement. For example, harvester use in a water body with strong currents, or submerged obstacles may not be suitable.

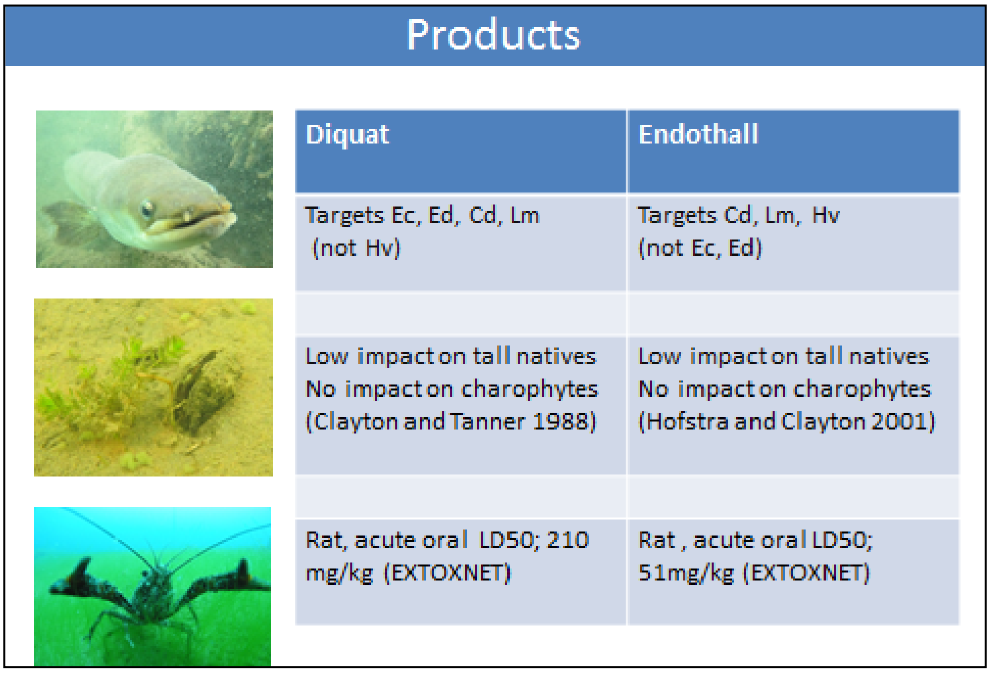
(3) The third determinant, in terms of the selection of tools, is about management goals and the desired outcome. How is success to be measured? Is there a desired outcome with regard to bio-diversity, amenity, utility values? What are the time frames and costs for the required solution?

These important points are considered further in **Slide 2**. The green area indicates the weed biomass; in the top, of this green area, is the situation of a small amount of weed biomass where solutions like hand weeding can be the best tool from the weed-control tool box. These are situations of low weed density where for example, there might be an early incursion response or maybe there are smaller outlying populations after site eradication.

Slide 2



Where the habitat is saturated and there is a large amount of weed, the bottom of the diagram, control options of harvesting, grass carp or herbicides need to be considered. Water body specifics are really important here. As an example, grass carp are highly effective grazers and very effective at removing weeds. But if they cannot be contained in the water-body then they are unlikely to be a suitable control tool. So it really is about matching up the weeds, the site and the goals or targets.



Slide 3

Considering herbicides and especially those for submerged weeds; we have two products in New Zealand that are registered for aquatic use; diquat and endothall. **(Slide 3)** Both of these products have a long history of use. Diquat has been used in New Zealand and the

Rotorua lakes since the 1960s. Endothall has an equally long history of use in the USA but has only been recently registered in New Zealand for use on submerged aquatic plants. For both of these products there is an extensive database on environmental safety and a snapshot of some of the information that is shown here.[1]

Slides 3 compares the two products, and the different weeds here in New Zealand that they can be successfully used on. The slide shows that diquat works on *E. canadensis, E. densa* and *C. demersum*; Endothall is good for *C. demersum, L. major* and *H. verticillata*. Both of these products have comparatively less impact on our tall native plants and no impact on charophytes.

How do they work?

- Contact herbicides, desiccants, result in plant collapse
- Rapidly lost by deactivation, dispersion, uptake and breakdown by micro-organisms
- Short lived in the environment

What about toxicity?

- Both are diluted with water for the rate used to kill weeds (ca 1ppm for diquat, 5ppm or less for endothall).
- Field studies – no changes in kakahi, koura, inanga, shrimps and bullies
- No effect on fish or eels kept caged in treated areas
-

With regards to biota for New Zealand, a number of different field studies have been done that have looked at kakahi, koura, inanga, bullies, fish and eels in terms of impacts and there have been none[1].

<u>Where does this information come from?</u>

The information such as the toxicology data is generated by the companies or agencies who want to register their products with the likes of EPA, but we at NIWA also have a research facility. **Slide 4** shows some of NIWA's facilities and where we have carried out testing on aquatic plants; those which would be good targets, those native plants considered non-target species, and assessed what impacts are there likely to be on the plants. In these photographs there are a range of different tank sizes, from really small pots through to much larger tanks that have been used.

[1] Further info, see Clayton and Severne, 2005. Review of Diquat reports of relevance to iwi values in Lake Karapiro. HAM2005-136.
Clayton, 2004. Diquat Summary – use and safety
Clayton and Tanner, 1988. Selective control of submerged aquatic plants to enhance recreational use of water bodies. Verhandlungen des Internationalen Verein Limnologie 23: 1518–1521.
Hofstra, D. E., J. S. Clayton & K. D. Getsinger, 2001. Evaluation of selected herbicides for the control of exotic submerged weeds in New Zealand: II. The effects of turbidity on diquat and endothall efficacy. *Journal of Aquatic Plant Management* 39: 25–27.

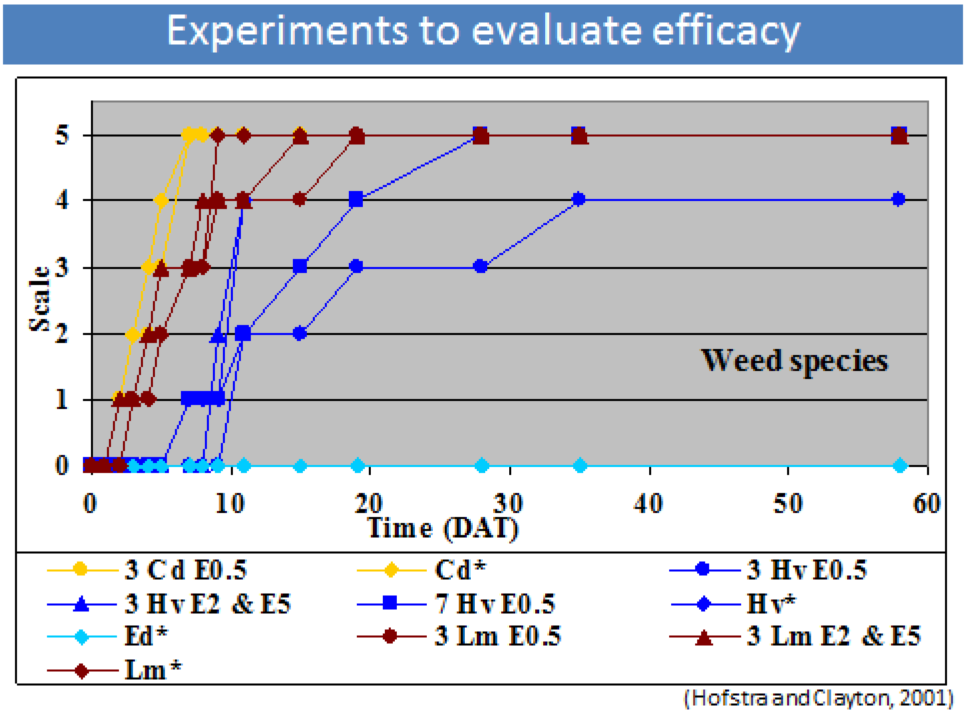
Slide 4

Slide 5 is an example of earlier work on *C. demersum* with endothall. C. demersum was growing in each of the small pots initially, but at the end of the study (after treatment with endothall), most pots have very little or no plants compared with the control pot (not treated). We also have larger tanks where we have assessed the efficacy of products. **(Slide 6)**

Slide 5

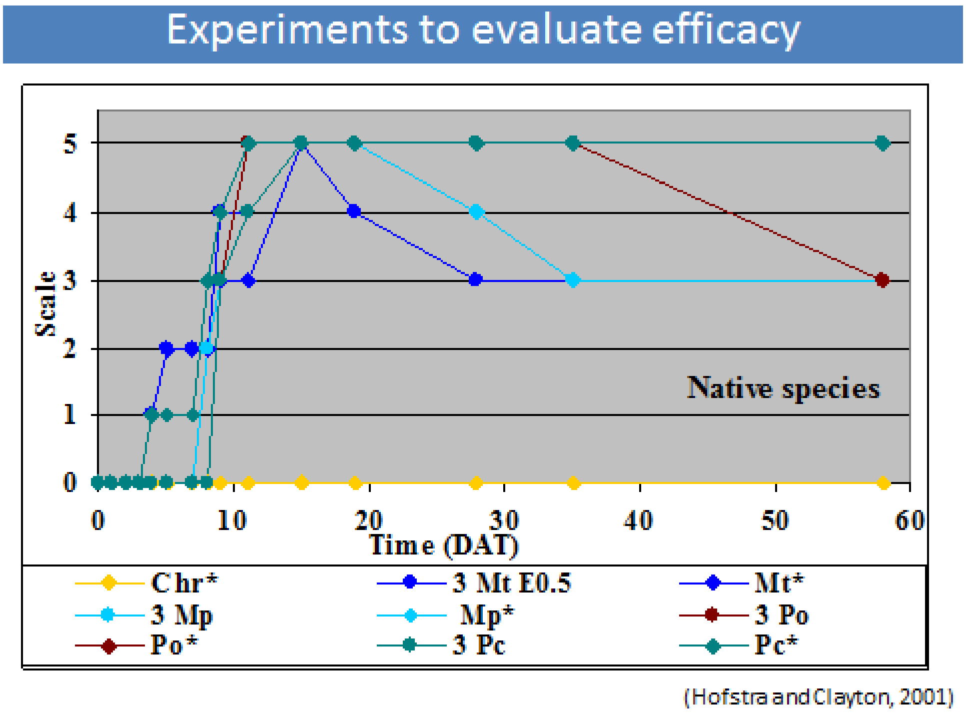
Slide 6

Slide 7



Slide 7 shows the score (vertical axis, 0 represent no impact, 5 represents large impact/plant death) given to plants over time (horizontal axis) representing their state of health or recovery following endothall treatment. All of the weed species, apart from the *E. densa* (Ed)*,* were killed at the higher rates. *E.densa* was unaffected in all treatments (light blue line). *C. demersum, L. major* and *H. verticillata* were all susceptible to endothall, although for each of these species there was variation in the timing of plant death (DAT, days after treatment) and the rates or exposure periods used on the plants. The yellow line is the *C. demersum* result showing that it was highly impacted by endothall, which is a

Slide 8



desirable outcome for a target weed species.[2]

Slide 8 graphs the score given to native plants over time representing their state of health or recovery following endothall treatment. The native milfoils (*Myriophyllum triphyllum* and *Myriophyllum propinquum*) here are represented by Mt and Mp, the P is native pondweed (*Potamogeton cheesemanii* and *Potamogeton ochreatus*). The milfoils and pondweeds varied in their susceptibility to endothall. For example *Potamogeton cheesemanii* (green line) was controlled at all rates, whereas some *Potamogeton ochreatus* (brown line) recovered. *P. ochreatus* is an example of how understanding the relationship between concentration and exposure time and plant susceptibility can provide selective weed control outcomes. The products can be used when their impact on one plant versus another is understood. They can be used at rates where impacting the weeds is known relative to the native species. It is also important to note that the native charophytes (represented by the yellow line) did not exhibit any endothall symptoms.

Another point is that these weed species may invade a lake with native plants, but once a dense weed bed is established, the native plants are replaced by the weeds. Long term native seed banks become depleted under alien weed beds.

Other than selectivity around the products in terms of their effectiveness (or not) on different plants, there is another suite of research being done on smarter use of products Essentially this includes methods of application of the product, to get it where and when it is needed, and how a successful application can be predicted to achieve the desired outcome. It is also desirable to minimise the environmental load of the products being used, and there is an economic cost/benefit associated with that.

Selectivity

Target submerged plants

- Diquat – hornwort, lagarosiphon, elodea, egeria
- Endothall – hornwort, lagarosiphon
- Do not affect native charophytes (desirable plants)

Smarter use

- Application, product placement, tracking, predictors of success

Purpose

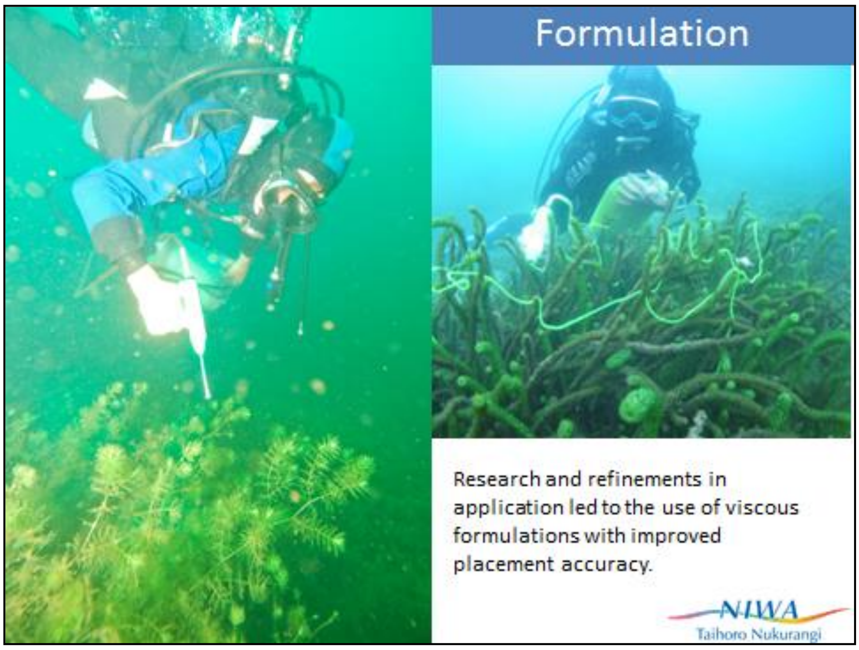
- to achieved desired outcome while minimising environmental load and economic costs

There has been research on the use of gelling agents seen here (**Slide 9)** being applied specifically to the plant.[3] Other examples show the use of containment nets to contain an

[2] Hofstra, D. E., J. S. Clayton & K. D. Getsinger, 2001. Evaluation of selected herbicides for the control of exotic submerged weeds in New Zealand: I. The use of endothall, triclopyr and dichlobenil. *Journal of Aquatic Plant Management* 39: 20–24.

[3] Clayton, J., 1986. Review of diquat use in New Zealand for submerged weed control. In *Proceedings of EWRS/AAB 7th Symposium on Aquatic Weeds*, Loughborough, UK: 73–79.

Slide 9



application in a particular target weed bed and within a larger water body (**Slide 10**).[4] Again this is about maintaining that contact time to ensure a result and minimise dispersion of product. Herbicides can be applied by helicopter or by boat with underwater booms or submerged trailing hoses to optimise product placement on the weed bed.[5]

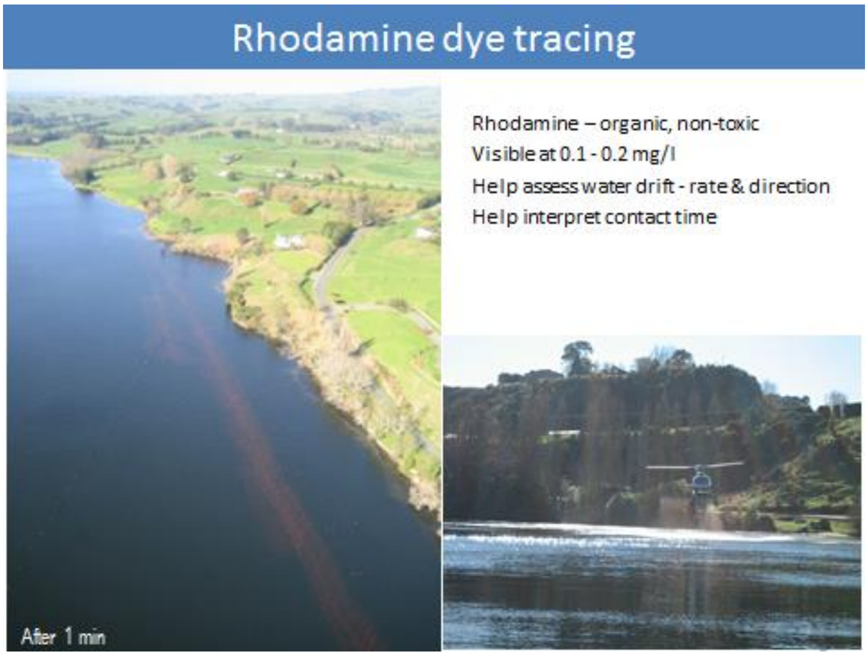
Slide 10

[4] Clayton and Matheson 2008. *Partial treatments in New Zealand Lakes*. Aquatic Plant Management Society Conference, Charleston, South Carolina.

[5] Clayton, J., Matheson, F (presenter). 2014. *Improving Underwater Herbicide Placement*. NZ Biosecurity Institute NETS conference. New Plymouth, 30 July-1 August 2014.

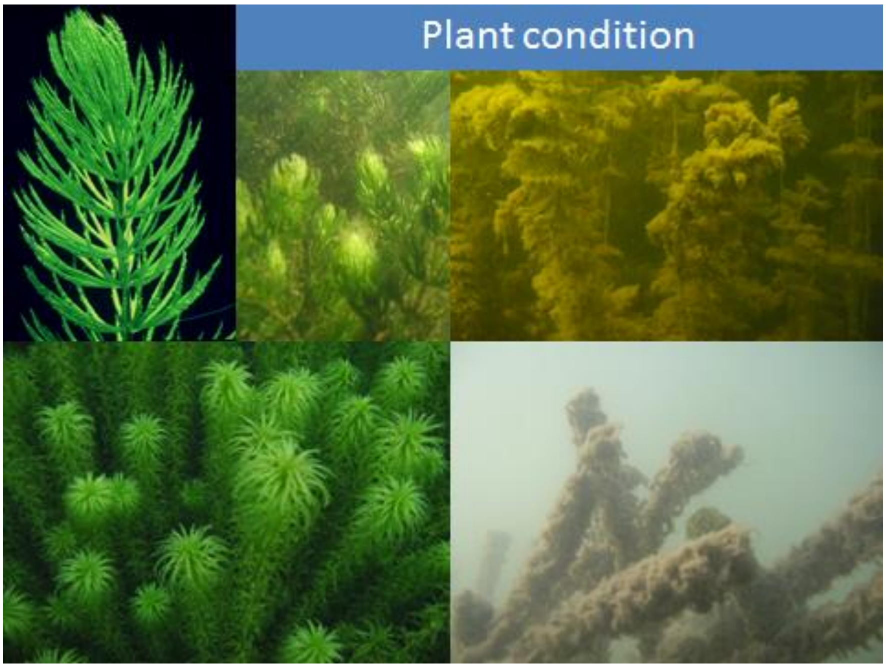
Slide 11 shows work done by Dr John Clayton and Dr Fleur Matheson using rhodamine dye. This is a product that can be used to assess the rate and direction of water movement and interpret contact time and the results of an application.

Slide 11



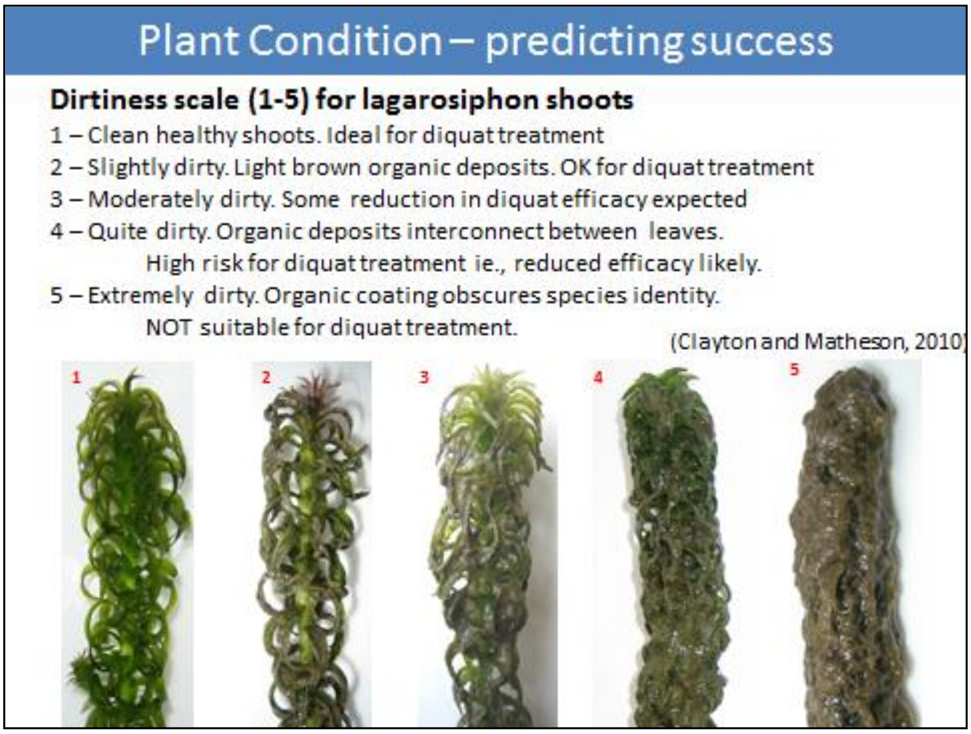
Slide 12 shows clean plants (left) versus really dirty plants (right) which is important with respect to diquat, because it will not work on dirty plants. **Slide 13** explains how dirty plants can be used to predict the right time to treat that particular weed with diquat, based on the state of the plants.[6] Again this is about being able to predict success.

Slide 12



[6] Clayton and Matheson, 2010. Optimising diquat use for submerged aquatic weed Management. *Hydrobiologia* (2010) 656:159–165 DOI 10.1007/s10750-010-0423-4.

Slide 13



Slide 14 shows the outcomes of a weed bed in Lake Wanaka, before and after treatment with diquat – from the green healthy plants to the total weed bed collapse.

Slide 14

Slide 15 is an example from Lake Okataina where the diver is touching a piece of plant which at first looks to be intact, but it disintegrates readily when touched. It has no structure or integrity left in it. The bottom pictures shows native milfoils (left) and native pondweeds (right), which have recovered once that particular weedbed was removed. In the bottom right hand picture the lagarosiphon is re-sprouting. Once the weed biomass

Slide 15

has significantly declined, follow-up work is needed to support the continued regeneration of the native plants.

Slide 16 is a similar picture that shows results with diquat (left) and endothall (right). Both of these products work particularly well on *C. demersum*.[7]

Slide 16

[7] Wells et al 2014. Potential for lake restoration using the aquatic herbicide endothall. Proceedings Nineteenth Australasian Weeds Conference.

We are always interested in evaluating new products that come on the market and what is happening in other countries. We look to see if there is a fit with a product that might give us a better solution here in New Zealand. We will evaluate those products that have better environmental properties. This comes down to expanding the toolbox so that we have options when it comes to weed beds, or to new incursions, and rapid response. The EPA recently modified approvals for the use of 4 products for marginal aquatic plants. It considers these substances beneficial in the control of aquatic pest plants and more effective than other methods of control (EPA, March 2013. Using herbicides to control aquatic pest plants).

Always at the end of the day it is about optimising the use, so that selective targeting and predictable outcomes for all weed control decisions are made.

QUESTIONS

Dr Clive Howard-Williams, NIWA: With the prerogative as chairman I will start this off by asking Quentin about the 3% to 4% reduction. Is it enough to pay for the programme and how does that compare with terrestrial aquatic bio-control that you have done a lot of work on?

Quentin Paynter, Landcare Research: That really depends on the weed. There are some agricultural weeds that have been successfully bio-controlled. A classic one in Australia, whose name escapes me at present, is a pasture weed which invades cropping areas and that was successfully controlled. The cost benefit ratio was thousands to one so it can be done.

Dr Clive Howard-Williams: In relation to John Madsen's plenary talk this morning which has been referred to all the way through the day, Fleur and Deborah's diagram showed a triangle and all the options going down as you increase in volume. We are talking about multiple options and if you can even knock back aquatic weeds a little then suddenly some of the other methods may become more effective. You could get a double whammy.

Te Taru White, Trustee, Pukahukiwi Kaokaoroa Incorporation: This trust is a small agricultural farming forestry operation on the shores of Lake Rotorua and Rotoiti. When I look at the spectrum mentioned by the last speaker it is lawn mowing, restoration or eradication. I have no doubt that eradication is what we would want to pursue. Having said that, I have always thought that there might be opportunities to use the bi-product of weed harvesting for other uses. But given that lake weed is high in arsenic and other heavy metals it probably has no commercial application. I feel it is a very expensive lawn mower and question the cost efficiency of continuing with that type of operation.

At the other end of the spectrum is eradication being the longer term goal, what might the environment look like in a weed eradicated environment? Would restoration see the koura population re-established or the inanga population in the Ohau Channel? I sense that we are in the ambulance at the bottom of the cliff and that it is a combination of on-land solutions and in-water solutions that ultimately provide us with the best possible long term solutions.

Dr Deborah Hofstra, NIWA: I was really interested to hear what you had to say but not entirely sure what your specific question is because it seems more directed at Fleur's area than mine. For me personally and passionately restoration is the best but it is not about my goals. It is about the management goals of the Rotorua Lakes and the people of this region to decide the most appropriate fit. Restoration means that it is better for the aquatic fauna and flora. John Clayton showed in some of his pictures that under those dense weed beds nothing lives at the bottom but a few Chironomids, little midges. Mussel beds die and koura do not live under those weed beds but when they are removed, even for short periods of time, even with some invasive plants, native plants do re-colonise, those seed banks replenish and with native plants are native fauna too. That has been my personal experience.

Barnett Vercoe, Onuku Maori Lands Trust, Rerewhakaaitu: Richard you mentioned with the Lake Rotoehu study that there has been land change on the Trust farm. Is there potential to study that in the mid to long term in terms of taking out a large amount of pasture to put back into trees?

Richard Mallinson, BOPRC: Thanks very much for your question Barnett. The impact of that land use change will be assessed by various Overseer models which are used to model the nutrient footprint coming off that land. All properties in the Rotorua catchment will be assessed. The Overseer system changes and as it does the nutrient footprint will change and constantly assessed. We have lake bed harvesting and in-lake interventions which are complimentary to that land use change as well.

Science is always changing and the Overseer model reflects that science as it comes on board. It may be that pine plantations are assessed at leaching 4 kgs of N per hectare, and that may change down the track, and those changes will be incorporated into the model and the whole lake catchment system will be assessed to see how much nitrogen is going in and what it can take.

Rowland Burdon, Rotorua Branch, Royal Society of New Zealand: What is known of the longevity of the seeds of native water plants and how might that affect the prospects of restoration?

Dr Deborah Hofstra, NIWA: The best person to answer that question is Mary de Winton because she has done a lot of seed bank studies on native aquatic plants. I can say they deteriorate over time so the sooner weed beds are dealt with the better, but Mary has really done the seed bank work. Thanks Mary.

Mary de Winton, NIWA: Thank you Deb. I can say from overseas research that the seeds of charophytes are termed oospores and they are very long lived. Overseas they have found viable oospores that are 60 plus years old, clearly some seeds are very long lived. I suspect that the vascular seeds, some of our very common native plants, have a much more restricted life span in terms of their seed longevity, probably years rather than decades.

Jane Penton, Lakes & Waterways Taupo: A question for Richard. We heard recently at a meeting about bio-fuel from weed as a possible option. There is also an engineering solution for lined vermi-compost ponds similar to landfills and/or composting systems. Is that not better than taking it to another catchment when we have ethical and practical considerations these days? One other thought which we did not hear is a comparison cost between chemical diquat use and weed harvesting?

Richard Mallinson, BOPRC: I will answer your last question first. It is very hard to compare the two. With broad acre spraying of Diquat it is around $1500 a hectare. For harvesting it is not easy to estimate a per hectare cost because there are so many variables involved. In an area like Rotoehu we can clean out a hectare of weed and then the wind turns around and a north westerly breeze blows in and that hectare fills back up again. So it is very hard to get a direct per hectare cost comparison between spraying and weed harvesting.

Your first question related to biofuels and there is a chap over at Waikato University, Shane Carter[1], who has done his PhD on using hornwort as a biofuel, breaking it down for methane or electricity production. It is quite early days for that research, but if you could get a product out of that weed worth money then it is definitely a goer. One of the problems with Shane's work is that with bio-fuel production you need a constant supply of weed. The weed we take out of Rotoehu is seasonal, over a short time frame of 4 to 6

[1] [1] Shane Carter, Engineer and Chemist, 'Anaerobic digestion of weed into biofuel', shane@interfacechemistry.co.nz

weeks. To make biofuel it would need to be baled for a constant supply. It is too early to adopt this technology, but who knows what is out there in the future. If it does become viable we would certainly go for it.

The second question about lining vermi-composting sites is an option. Composting does tend to be borderline economical, there is not a lot of money in it. If the operators have extra costs with either their operation, transport or supply of raw materials it can drive the price of the compost through the roof and no-one wants to buy it. At the moment we have a happy compromise sending it to Kawerau where it is mixed with wood pulp waste and kiwifruit and goes out onto kiwifruit orchards. We have recognised as a weakness in our operation that we are dependent on another commercial operation for our harvesting to proceed. We will be addressing that as we keep looking for alternate disposal options into the future.

Ian McLean LWQS: Dr Matheson do you consider that the Rotoehu harvesting operations have sufficiently dealt with the host of problems that you suggested harvesting has? With confidence could harvesting be used in other lakes where the cost of removal of nitrogen through harvesting is significantly less than the cost of taking the last bit of nitrogen out from sewage or the very last bit out from farming?

Dr Fleur Matheson, NIWA: It is a bit difficult for me to talk about the specifics of the Rotoehu harvest programme. That has all been put together by the Regional Council. It might be more appropriate for you to talk about what you think Richard?

Richard Mallinson, BOPRC: The cost figures that we did at Rotoehu pointed to around $29 a kilogram to remove nitrogen. To give you an example when we have to transport the weeds some considerable distance obviously our costs can go up dramatically. Looking at the analysis of weed from Okawa Bay it cost close to $120 a kilogram.

I think the question that you asked is a good one, probably best answered by an economist who can look at the whole spectrum of our options and say what a kilogram of nitrogen or phosphorus costs, either as an in-lake intervention or as a land use change or an adaption of a sewerage plant, and bring it all together, crunch the numbers and come up with exactly what is suitable for what lake.

The cost for harvesting is going to be variable between lakes. Looking at Rotorua as an option where there are big strandings coming up, it is possible to get weed out. There is a different mix of weed there which means different amounts of nitrogen coming out, and costs could also be considerably higher as well. As I referred to in my presentation on Rotoehu if you were going to design a lake to harvest, apart from the proximity of Rotoma which is a big negative, you could not get much better than Rotoehu. We are trying to make the best of a bad situation.

Prof David Hamilton, Waikato University: My question is directed to Fleur and maybe this time it might be more direct. The case of Whakamaru and those very dense ceratophyllum hornwort beds, is there oxygen below?

Dr Fleur Matheson, NIWA: We have not measured the oxygen directly but it is typical for those sorts of very dense weed beds to be pretty well de-oxygenated.

Prof David Hamilton, Waikato University: I was trying to equate your comment about flushing nutrients downstream and getting enough dilution. The offset is that the renewal of water was not sufficient to replenish oxygen to the bottom of those weed beds.

Presumably most people would need resource consent to increase nutrients to a waterbody. A comment around that perhaps.

Dr Fleur Matheson, NIWA: The nutrients contained in the weed relative to the whole flux of nutrients that move through the Waikato River system is a very small component. Our theoretical calculations and field testing, which was required under a consent, showed that there would be no significant increase in nitrogen, phosphorus or carbon, and we looked at arsenic too. Those calculations and tests indicated that there would not be any deterioration in water quality from mulching.

Session Four : Lake Weed – The Way Forward

SESSION CHAIR – Prof Chad Hewitt, School of Science, Waikato University

POTENTIAL LAKE ROTORUA SCENARIOS

Dr Max Gibbs
Water Quality Scientist, NIWA
Max.Gibbs@niwa.co.nz

Max was trained as an analytical chemist and has worked for NIWA (and its predecessor, DSIR) for 50 years, initially in the field of pesticides and forensic analysis and subsequently studying eutrophication in freshwater. For the last 42 years, Max has worked on lakes around most of New Zealand, primarily on Lake Taupo and the restoration of Lake Rotorua, and Lake Horowhenua. He was instrumental in the identification of the hydraulic coupling between Lake Rotorua and Lake Rotoiti, which eventually lead to the installation of the diversion wall. He has used his experience of iron cycling, obtained as a fellow at Edinburgh University and the Lake District in 1980, to help in the understanding of phosphorus interactions across the sediment-water interface in New Zealand lakes. He was awarded an Honorary Doctorate of the University of Waikato in 2010 for his work with lake restoration and the assistance and mentoring of students. Recently Max developed an internationally acclaimed forensic stable isotope technique that enables the identification and apportionment of sediment sources by land use in the catchment and he has extensive knowledge of the linkages between erosion and the impacts of fine sediment in lakes, rivers and estuaries.

ABSTRACT
Lakes need weeds, good ones (native species) not bad (invasive exotic species), although even exotic species are better than no weeds. Without aquatic macrophytes, a lake can become phytoplankton dominated with low clarity and high chlorophyll concentrations, a condition from which it is difficult to recover. The challenge is to manage the macrophytes to the advantage of the lake to obtain the highest practical water quality that is acceptable to lake users, within the financial constraints of a rates-based budget.

Lake Rotorua has sufficient surface area and depth that macrophytes, by themselves, are not likely to control water clarity and phytoplankton growth. However, their management may be a critical factor in the restoration of Lake Rotorua. In this talk I look at potential scenarios associated with managing aquatic macrophytes in Lake Rotorua. With the availability of a weed harvester dedicated to the Te Arawa/Rotorua lakes, there are a number of options that can be applied to Lake Rotorua that would be beneficial to the lake and the people who use the lake. For example, the weed harvester can be used to mow the weed beds to remove part of the nutrient load from the lake and thus improve the lake water quality. The Lake Rotorua Action Plan is looking to reduce the N load on the lake by an additional 50 t y^{-1}. Weed harvesting has the potential to achieve this. Removal of the tops of surface-reaching macrophyte beds around some stream mouths may improve trout fishing for anglers while maintaining the habitat that the trout need in shallow water. Clearance of boat ramps and maintenance of lake access are obvious applications. So is the mowing of the large areas of macrophyte beds adjacent to Rotorua city lake front to reduce plant break-off in wave action and thereby reduce the incidence of macrophytes washing ashore. These are just some of the potential Lake Rotorua scenarios.

TRANSCRIPT

The topic 'Potential Lake Rotorua Scenarios' is based on the study of weeds; undoubtedly, lakes need weeds, but too much weed can cause problems. So aquatic macrophytes/weeds, especially invasive exotic species (or alien species as they have been called) can cause problems. They smother native species, choke waterways and broken pieces wash up on shores after storms. Solutions to weed problems need careful consideration. Some options regard weed control as synonymous with eradication. The words 'spraying' for weed control conjures up an image of total de-vegetation leaving bare sediment. This is undesirable and can result in a lake flipping to a phytoplankton dominated system, with the potential to develop toxic cyanobacterial blooms.

Used correctly, exotic species sensitive to spraying can be eradicated while allowing more tolerant native species to re-establish. The use of Endathol can allow charophytes to re-establish while taking out hornwort.

Weed harvesting is a tool to use for management of lakes and waterways for boat access and recreational activities. However, most exotic weed species can grow down to depths of more than 5 metres; the weed harvester cutting depth is mostly less than 2 metres, so weed harvesting leaves the exotic weed bed intact to continue growing. Weed harvesting can also allow native species to become re-established; studies in Aratiatia Dam have shown native charophytes can re-establish after harvesting.

The consequences of spraying and weed harvesting need to be considered. With spraying, dead plant matter is left in the lake where released nutrients are returned to the water column and this can stimulate phytoplankton growth. The decomposition driven processes from collapsed weed on the lake bed causes anoxia and so legacy nutrients from the sediment are released. If phosphorus is released under these conditions it can stimulate cyanobacteria growth. Leaving cut weed in the lake from weed harvesting has the same issues.

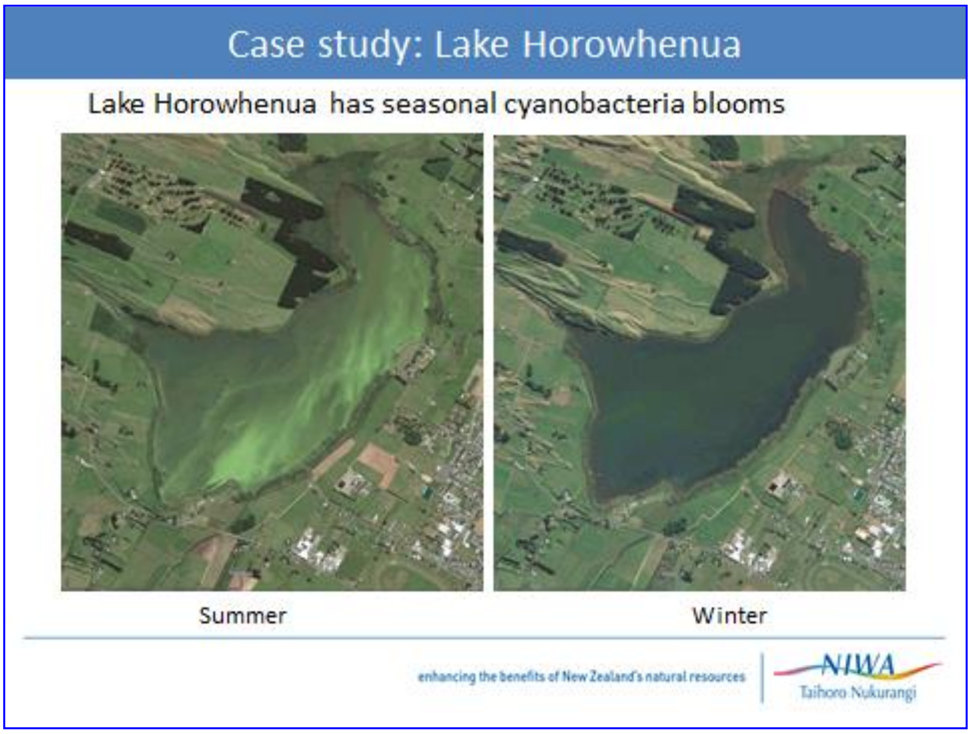
Control or manage?

Clearly management of exotic weed is an option, but management for what? Can we use these tools to re-establish native weed species? Spraying? Yes. Weed harvesting? Yes. Can we use these tools to manage nutrient loads in the lake? Spraying? No. Weed harvesting? Possibly. John Madsen reported in 2000 that, 'Harvesting aquatic weeds is not an effective tool for reducing nutrient loads in a lake.'[1]

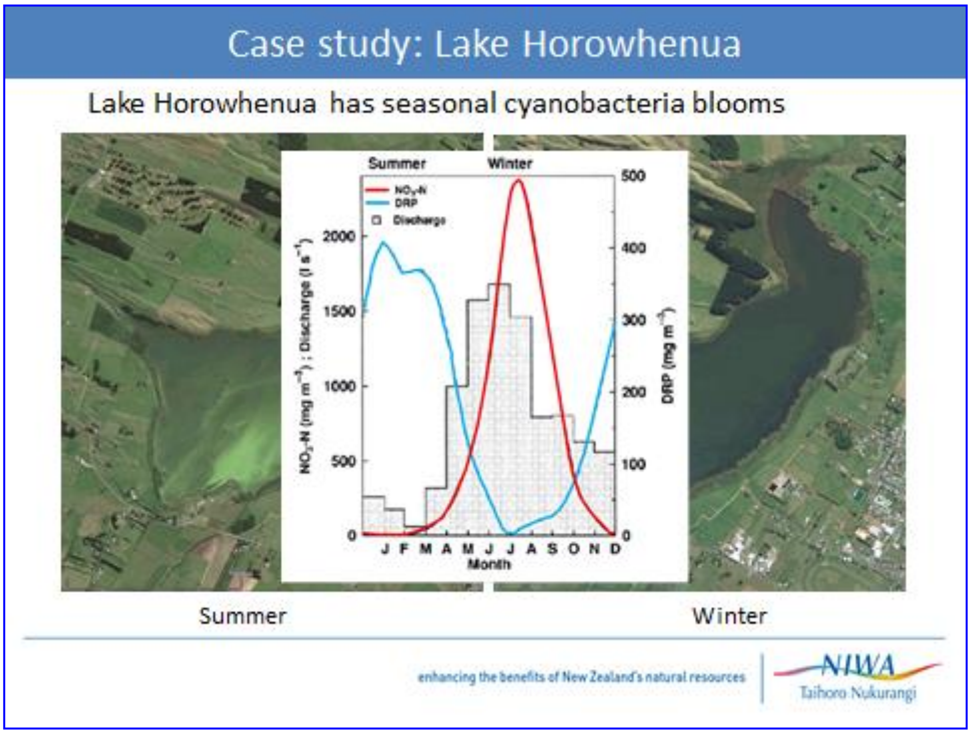
How else can these tools be used? First of all the problem must be understood before intervention. **Slide 1** (over) looks at the case study of Lake Horowhenua with a seasonal cyanobacteria bloom problem. **Slide 2** shows that in summer there are cyanobacteria blooms and in winter there is clear water. Cyanobacteria are favoured in their growth if there is excess phosphorus over nitrogen.

[1] Advantages and disadvantages of Aquatic Plant Management Techniques, *Lakeline* 20 (1):22-34

Slide 1

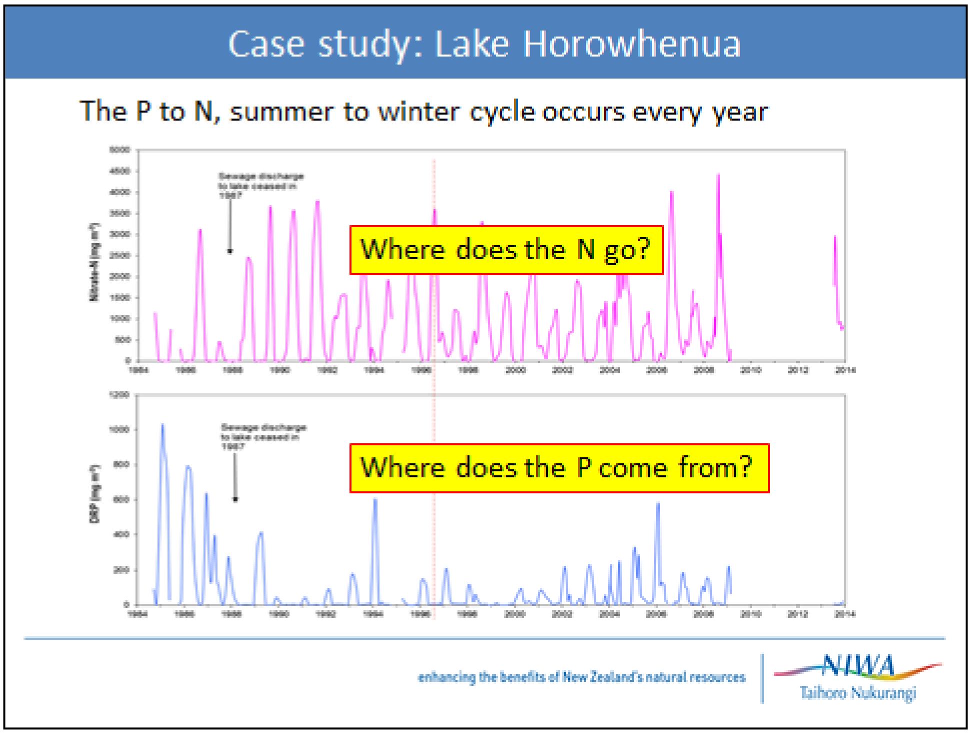


Slide 2

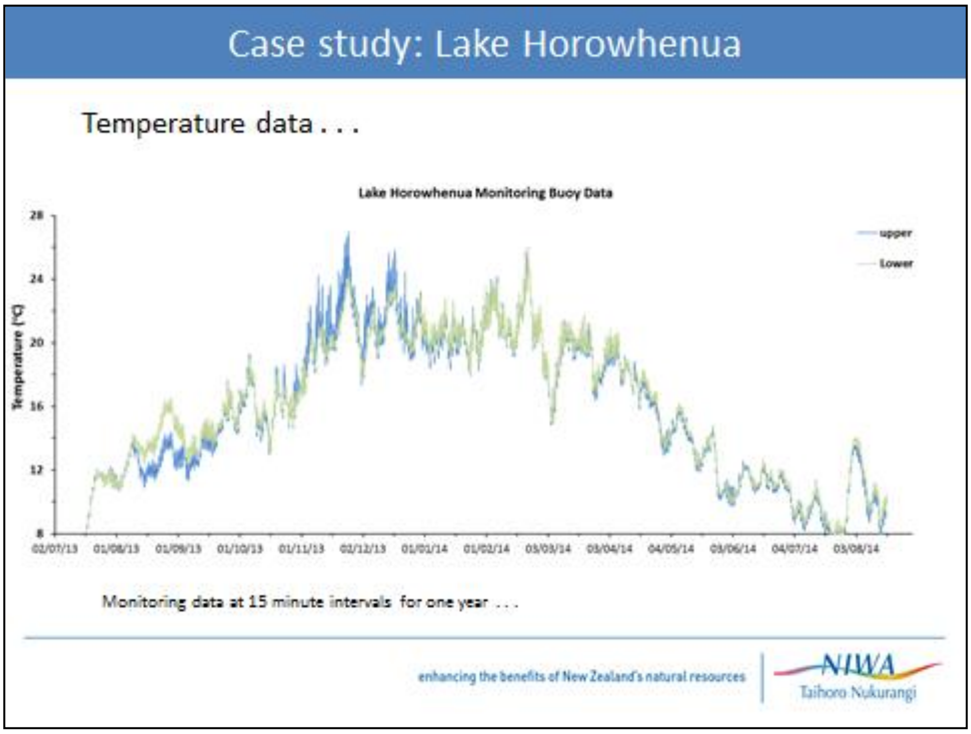


Slide 3 shows that there is very high phosphorus in summer with no nitrate, but very high nitrogen in winter with no phosphate. This cycle is a summer/winter cycle and occurs every year. In the period from 1985 to today, even after the removal of sewage, nitrogen always appeared in winter and, although less after the sewage removal, phosphorus appeared in summer.

Slide 3



Slide 4

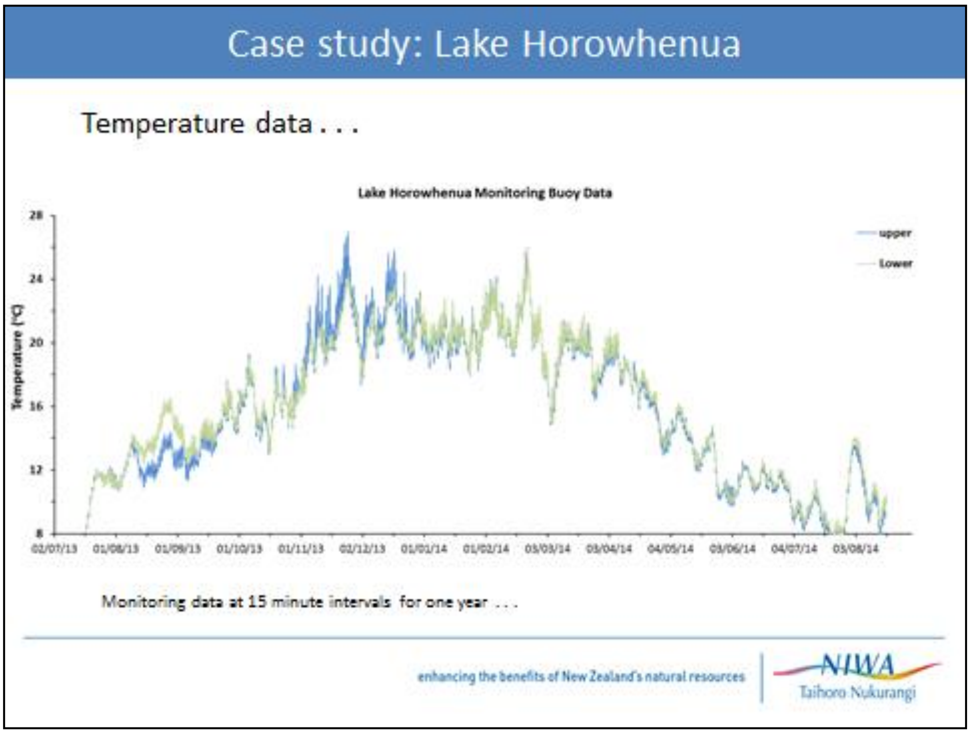


Where does the nitrogen go and where does the phosphorus come from? Normally phosphorus is released in lakes under anoxic conditions. **Slide 4** is the temperature data

from a monitoring boy in the lake and shows that there is very little difference between surface and bottom temperatures in the lake. The lake has a maximum depth of just 2 metres so thermal stratification and anoxia would not be expected.

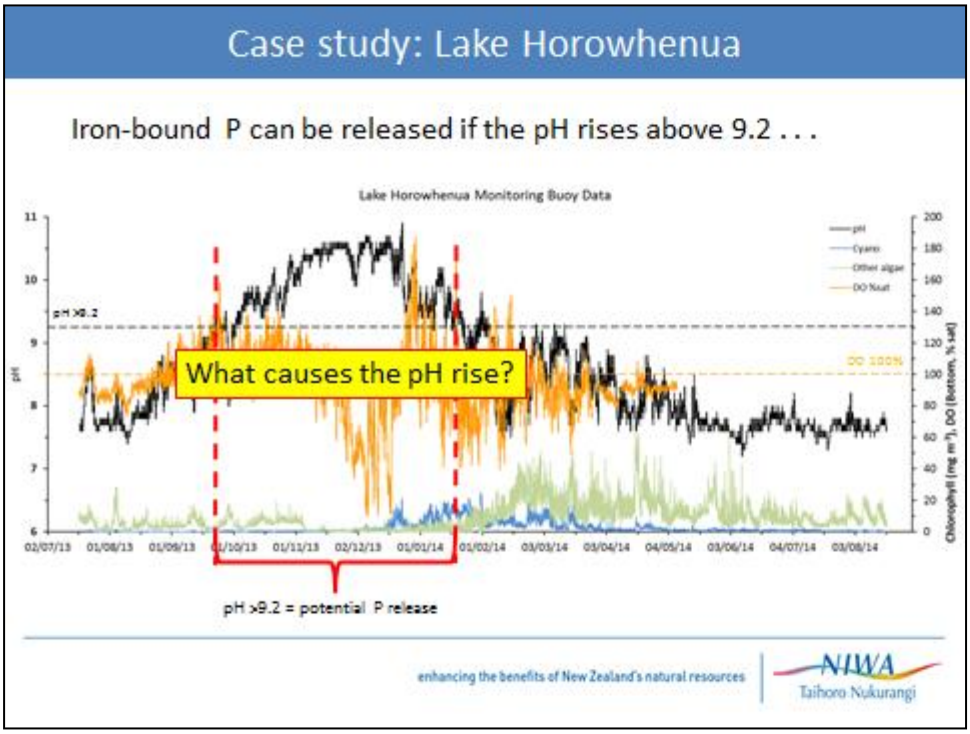
Slide 5 shows the oxygen data as the orange line, with a very short period where oxygen concentrations go very low. That is probably not long enough to establish the amount of phosphorus that is released in this lake in summer.

Slide 5

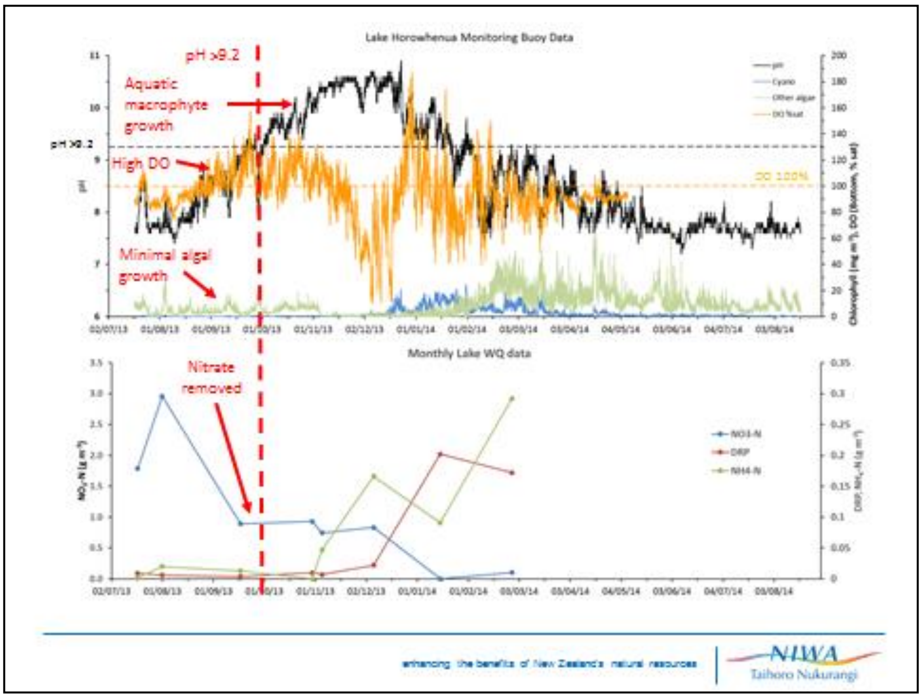


Slide 6 looks at the phosphorus bound into the sediments of the lake by iron and which can be released if the pH rises above 9.2.

Slide 6



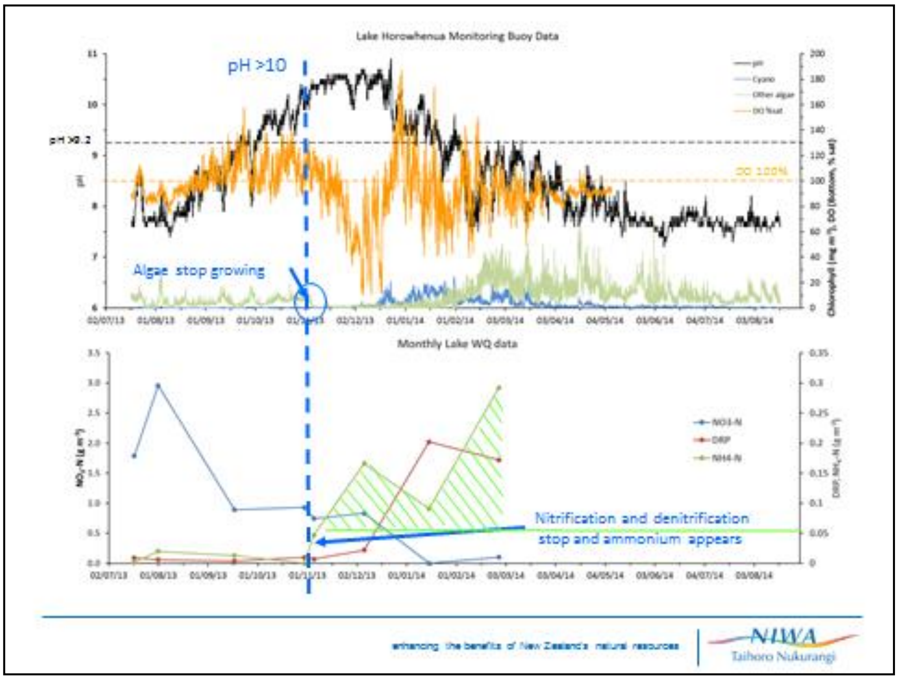
Slide 7



In **Slide 7** it is seen that pH goes above 9.2 for a considerable period of time. During this part of the year there is a potential for phosphorus to be released from the sediment purely by the rise in pH, even if oxygen is present.

What causes the pH to rise? Looking at the whole system, including the nutrients, there is the winter nitrogen period in the lake and then there is the pH effect. When the pH exceeds 9.2 the dissolved oxygen increases; dissolved oxygen becomes greater than 100% and that indicates photosynthesis. The nitrate is removed; that indicates that a plant is removing the nitrogen from the system. Looking at the algal content, as in green algae rather than blue green, it is seen that there is only minimal algal growth, so it cannot be increasing algal biomass that is producing the high pH. The simple answer is that there is aquatic macrophyte growth in the lake and the macrophytes are pushing up the pH.

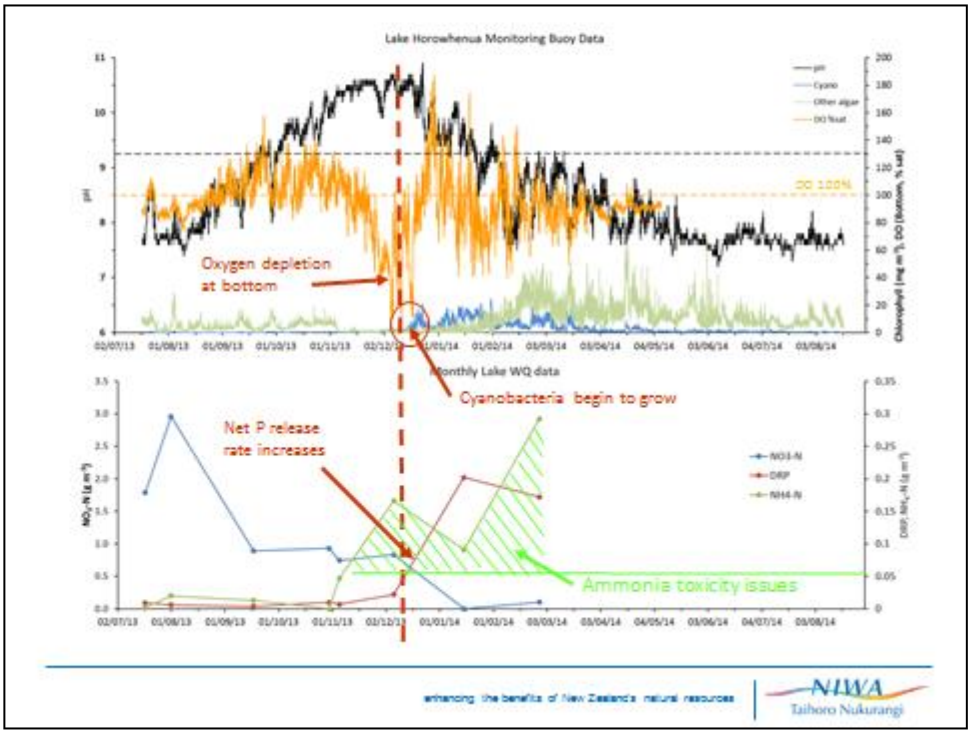
Slide 8



Slide 8 An interesting side issue is that green algae, like most native aquatic plant species can only tolerate a pH of about 8.5 for photosynthesis. Higher than that they start to decline in growth. The pH is greater than 9 and to achieve that requires a bicarbonate adapted plant species. Cyanobacteria, potamogeton and elodea are all in the lake and all have this capability of pushing the pH greater than 9.2. When pH reaches 10 the point where green algae can survive is exceeded and they stop growing.

Slide 9 The point is exceeded where the bacterial conversion of ammonia to nitrate (nitrification) stops and ammonia starts coming out of the sediments. Continuing along that trend or the timeline it is seen that pH has stopped increasing. There is a short period of oxygen depletion at the bottom, net phosphorus release in the sediment is seen and nitrate has decreased. Unfortunately this data is from monthly samples and so the exact time frame may not be accurate. Within the restrictions, it can be said that under these conditions the trigger for cyanobacteria beginning to bloom has been reached.

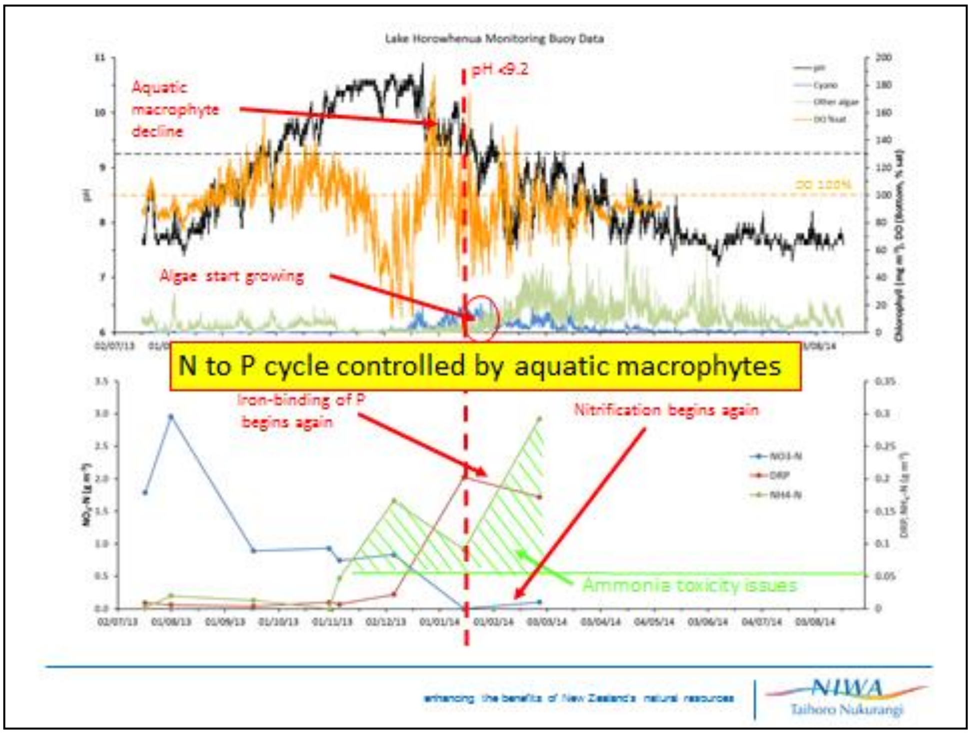
Slide 9



Slide 10 Assuming that this is all driven by macrophytes, the macrophytes are beginning to decline, pH has dropped down to 9.2, the threshold point is reached where green algae can grow again and iron will bind the phosphorus back into the sediments. So a cycle is completed, nitrification begins again because the toxic pH zone is over. Thus the N to P cycle in Lake Horowhenua is controlled by aquatic macrophytes.

The phosphorus in Lake Horowhenua is a legacy from disposal of treated sewage effluent in the early 60's, 70's and 80s. The effluent discharge stopped in 1987 but the water quality has not improved. The phosphorus source to the lake now is associated with the soil erosion from cropping. Land erosion of fine sediment carries phosphorus into the lake where the P can be recycled from the sediment out of the fine particles.

Slide 10

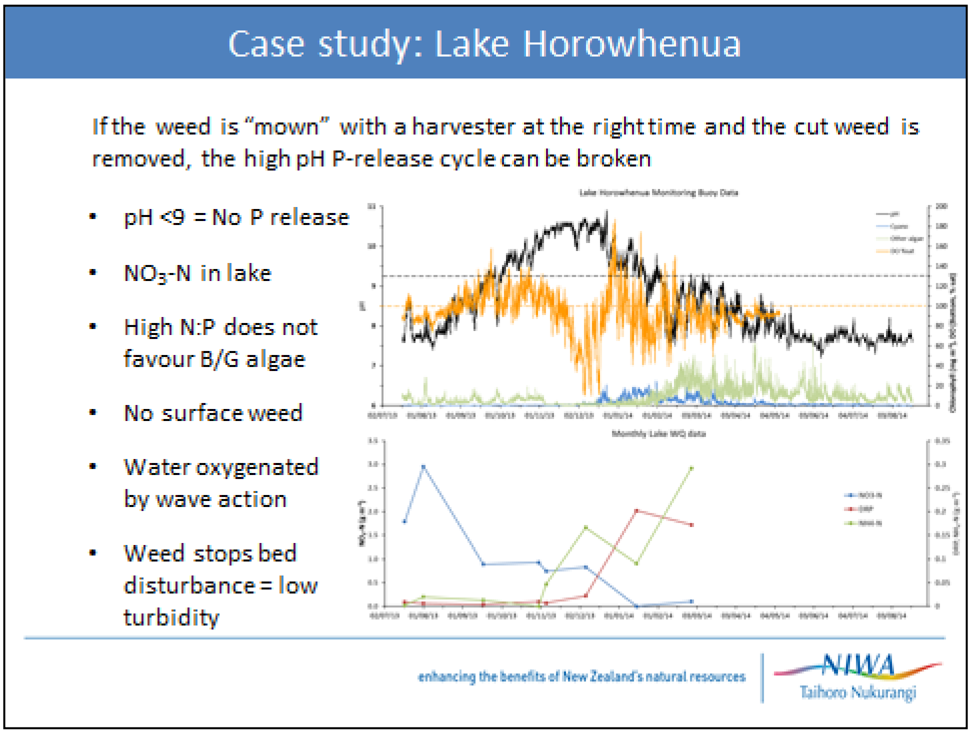


What are the management options?

Reducing the source of phosphorus by reducing sediment erosion from cropping is a priority. If the source is known, the impact on the lake can eventually be reduced. Spraying the weed was thought not to be an option, but in light of earlier presentations, that statement may need to be reconsidered.

Harvesting the weed to stop high pH has the potential to reduce the incidence of cyanobacteria. In this case the top of the plants have been mowed at the right time of the year to slow down the photosynthesis and therefore keep the pH below 9.

Slide 11



Weed is both the problem and part of the solution. If the weed is mown with a harvester at the right time and the cut weed removed, the pH release cycle can be broken. **(Slide 11)** At a pH less than 9 there is no phosphorus release, nitrate remains in the lake because there is not enough weed to remove it all, so therefore there is a higher N to P ratio which does not favour blue green algae. The lake does not have surface weeds and wind action can mix oxygen down to the bottom so there is no anoxic event. The weed that remains in the lake after cutting stops the bed disturbance, resulting in low turbidity.

Bay of Plenty Regional Council has an overall objective of improving the maintenance of the water quality in the Rotorua Te Arawa lakes. To achieve this, BOPRC uses a number of rules set out in a Regional Plan to manage the nutrient loads entering each lake. There is an Action Plan for each lake that sets out the remedial acts required to achieve a specific water quality based on its Trophic Level Index. Each Action Plan is based on good science and the water quality goal was agreed by a Technical Advisory Group or TAG Group of water quality specialists and scientists. Management strategies to achieve the water quality goal for a lake may use a combination of land based in-lake processes and interventions.

For example nutrient N and P loads in Lake Rotoehu support the growth of cyanobacteria and the invasive exotic weed hornwort. Cyanobacteria production is favoured by the high P relative to N concentrations in the lake. The P sources are the spring waters, sediment release under anoxic conditions and suspended sediments from land erosion. Nitrogen sources are from land run off, ground water and the lake sediments. Management strategies for P include P-locking the spring water inflows with alum and the investigation of aeration to stop the occurrence of anoxia. Management strategy for nitrogen is to remove the hornwort using a weed harvester and introduce land management changes. The weed harvester removes on average about 4.1 tonne of nitrogen and 0.55 tonnes of phosphorus each year.

Nutrient N and P loads in Lake Rotorua come from the natural cold and hot springs, from farming, forestry, urban development and treated wastewater. Strategies for the lake must encompass all of these factors.

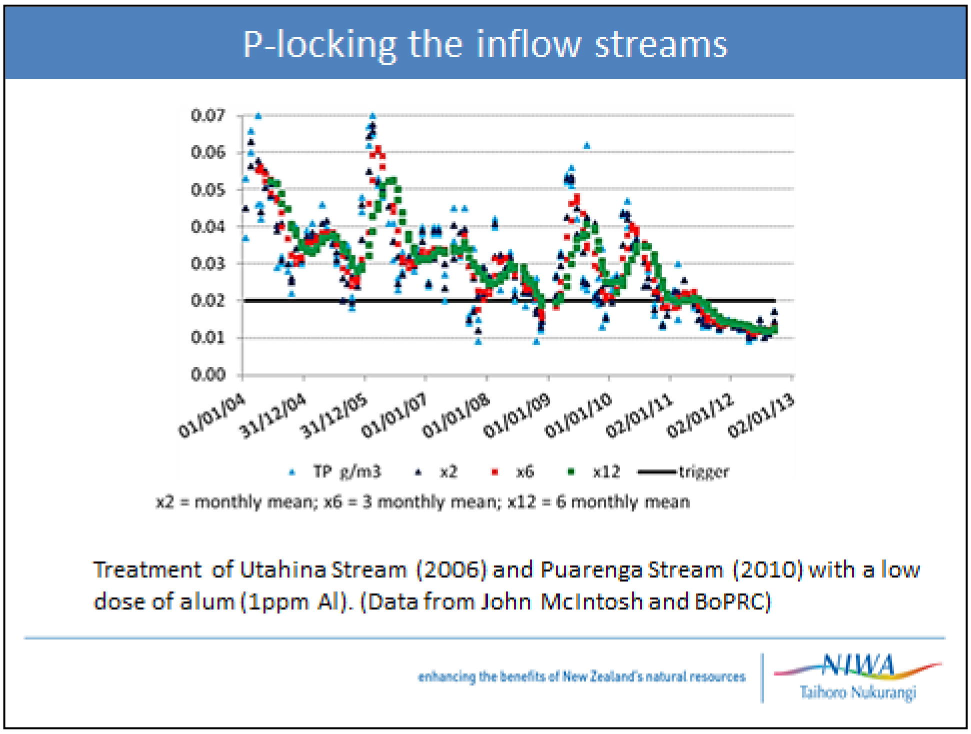
The Rotorua Action Plan states that nitrogen inputs into the lake need to be reduced by a total of 320 tonnes per year. The phosphorus inputs need to be reduced by a total of 10 tonnes per year and the impact of nitrogen and phosphorus loads in the lake also need to be reduced. Management strategies include P-locking of the inflow streams, removal of nitrogen from Tikitere, sewerage reticulation of septic tanks around the lake, land use changes and more recently, weed harvesting in the lake.

P-locking the inflow streams has shown that phosphorus in the lake can be reduced, and reduced substantially, by just locking up the phosphorus going into the lake from the Utahina and Puarenga Streams. 40% of the phosphorus that goes into the lake has DRP's from spring water. **(Slide 12)**

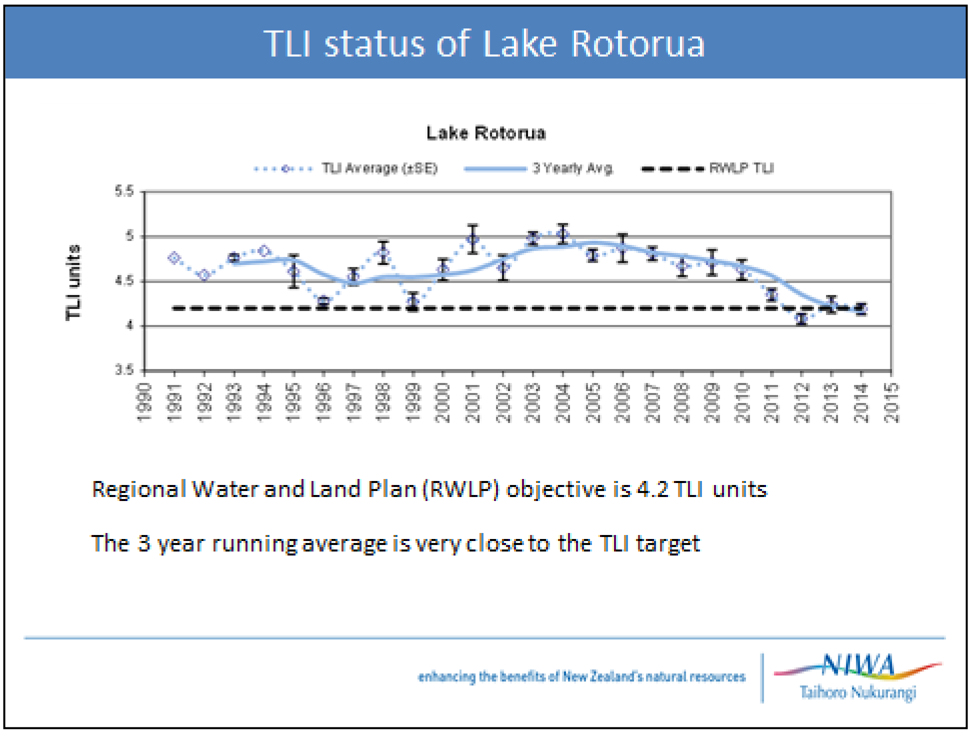
Slide 13 graphs the TLI status of Lake Rotorua (its indication of health), which over time gradually meandered. The blue 3 year average is now reaching a level of 4.2 TLI units, almost meeting the objective target of the Regional Water and Land Plan. The Action Plan target for P reduction of 10 tonnes per year has been met; in fact about 11 tonnes is being removed. To meet the Action Plan target for nitrogen a further reduction of about 50 tonnes of nitrogen is required; one option being considered is the weed harvester. This option would remove weed from the lake together with nutrients in the plant material. But it

has to be remembered that nutrients in a lake cannot be effectively controlled by weed harvesting.[2]

Slide 12



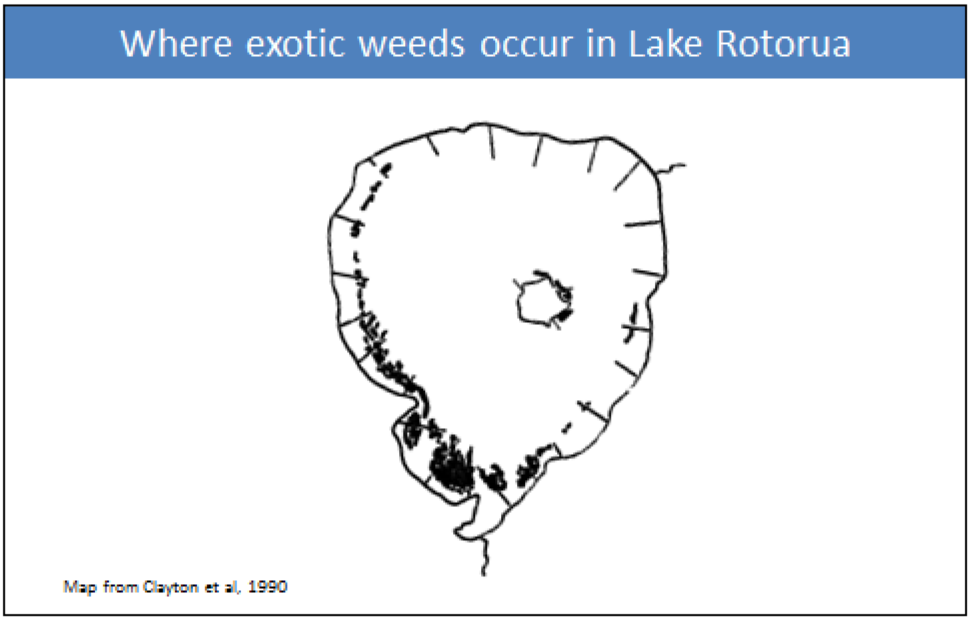
Slide 13



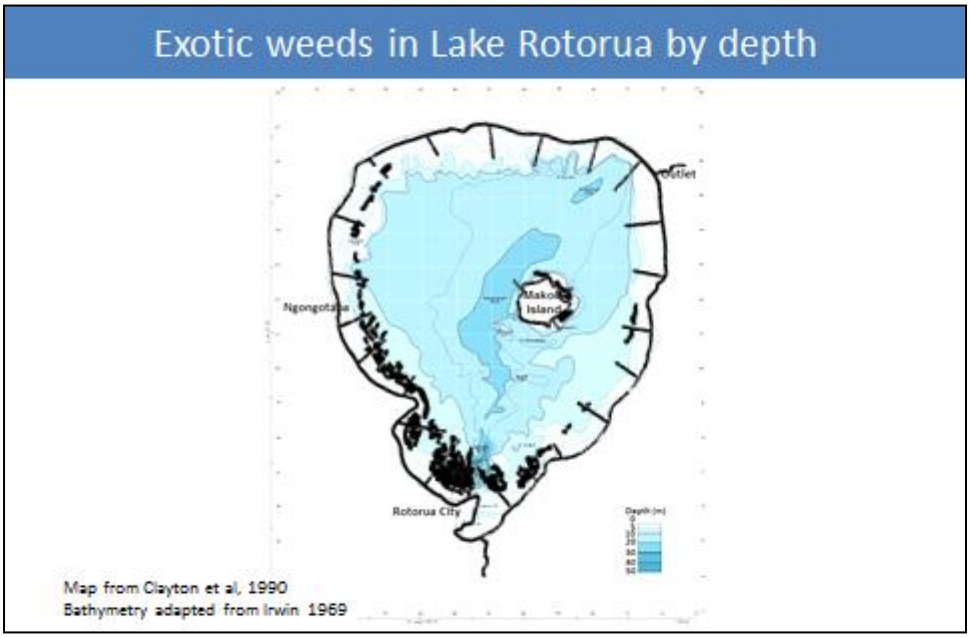
[2] Advantages and disadvantages of Aquatic Plant Management Techniques, *Lakeline* 20 (1):22-34

Rotoehu removed 4.1 tonnes a year of nitrogen and 0.55 of phosphorus; is it feasible to reduce nutrients in Lake Rotorua by weed harvesting? The aquatic weeds occur mainly on the southern western shores of the lake particularly in front of the city; they are there because the water depth allows them to grow. **(Slides 14 and 15)** Thus there is a depth restriction on where the weeds can grow and they happen to grow in those positions.

Slide 14

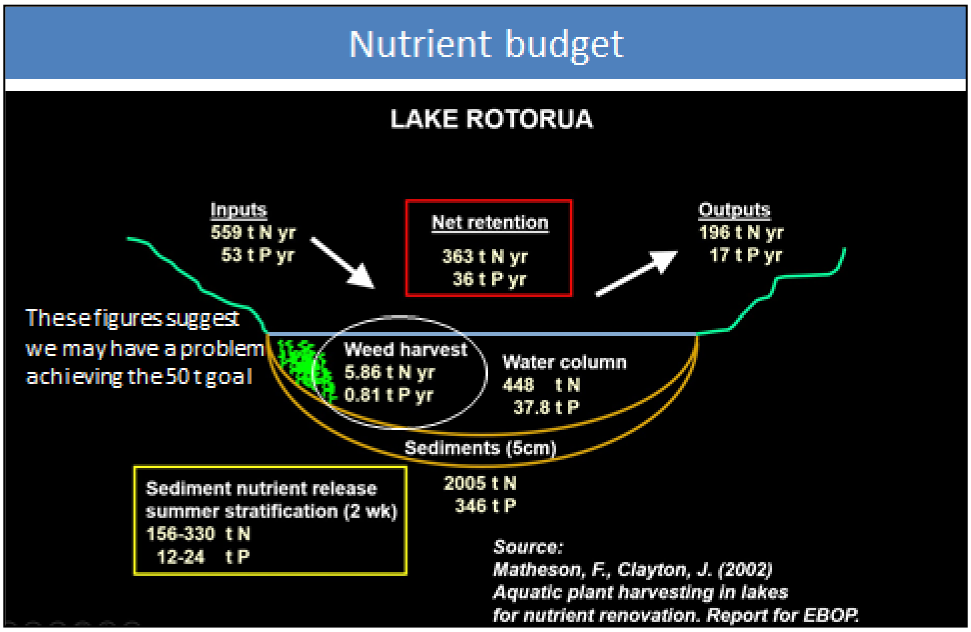


Slide 15

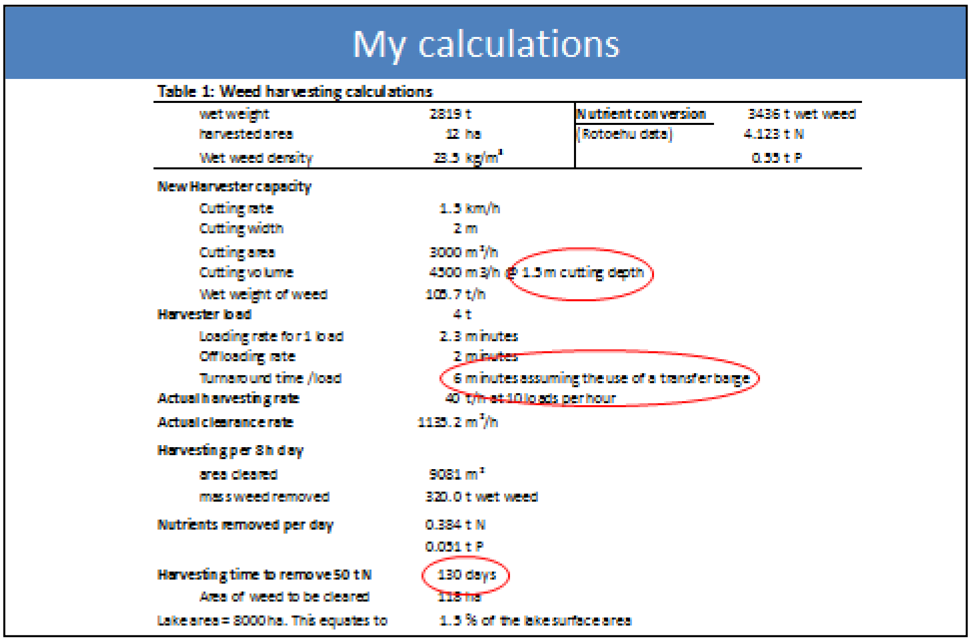


Slide 16 gives a rough idea of the nutrient budget in the lake, the inflows, the outflows and an interesting estimate of weed harvesting. Unfortunately these figures suggest that there may be a problem in achieving the goal of 50 tonnes. **Slide 17** show some calculations using a depth cut of 1.5 metres, a 6 minute turnaround from cutting to offloading from the harvester (based on the possibility of using a transfer barge) showed that to remove 50 tonnes, 130 eight hour days of harvesting would be needed. This is probably not feasible; 5 to 10 tonnes of nitrogen might be removed assuming there is enough weed to harvest. And that would be worth removing.

Slide 16



Slide 17



My calculations

Table 1: Weed harvesting calculations

wet weight	2819 t	Nutrient conversion	3436 t wet weed
harvested area	12 ha	(Rotoehu data)	4.123 t N
Wet weed density	23.5 kg/m²		0.55 t P
New Harvester capacity			
Cutting rate	1.5 km/h		
Cutting width	2 m		
Cutting area	3000 m²/h		
Cutting volume	4500 m3/h @ 1.5m cutting depth		
Wet weight of weed	105.7 t/h		
Harvester load	4 t		
Loading rate for 1 load	2.3 minutes		
Offloading rate	2 minutes		
Turnaround time /load	6 minutes assuming the use of a transfer barge		
Actual harvesting rate	40 t/h at 10 loads per hour		
Actual clearance rate	1135.2 m²/h		
Harvesting per 8 h day			
area cleared	9081 m²		
mass weed removed	320.0 t wet weed		
Nutrients removed per day	0.384 t N		
	0.051 t P		
Harvesting time to remove 50 t N	130 days		
Area of weed to be cleared	118 ha		
Lake area = 8000 ha. This equates to	1.5 % of the lake surface area		

The success of the P-locking programme has improved water clarity. This reduces light limitation to weed growth and the weed beds are likely to expand. As the weed beds expand they will also take up nitrogen. By my calculations, it would require an additional weed bed area of about 35 hectares, 5 metres deep to lock up 50 tonnes of nitrogen. Therefore the weed harvester might not be used to remove the nutrients but it could be used to manage the inshore spread of the weed and reduce the weed breakoff and drift to shore after storms. Perhaps it may not be necessary to remove those 50 tonnes of nitrogen if they can be held so they are not available to the algae in the water.

RECOGNISING THE NEGATIVE IMPACTS OF AQUATIC WEED MANAGEMENT: OKAWA BAY, LAKE ROTOITI CASE STUDY

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After completing an undergraduate degree in Geology at the University of Auckland, Paul headed for the mining mecca of Western Australia. There he brokered a career in geotechnical engineering before chasing the gold veins under the Kalgoorlie Goldfields. His geologist stint ended with a period working in the Super Pit, the largest man-made hole in the southern hemisphere. Returning to New Zealand, Paul completed a Masters in Resource Studies though the School of Natural Resources Engineering at Lincoln University, after which he applied his newfound skills on the Manapouri Tailrace Tunnel II project in Fiordland. Moving into local government Paul worked for two years in Gisborne as a Soil Conservator, followed by brief spell at Carter Holt Harvey Tasman Pulp and Paper Mill as an Environmental Engineer. He currently works for Bay of Plenty Regional Council and over the past 11 years has been heavily involved in the Te Arawa Rotorua Lakes Programme as an Environmental Scientist.

ABSTRACT
The Te Arawa Rotorua Lakes Programme continues to implement measures to maintain and restore lake water quality in line with trophic level indices (TLI's) for respective lakes. In Lakes Rotorua and Rotoiti this has also meant not only reducing nutrients to and in the lakes but also managing periodic cyano-bacterial (blue-green) algal blooms.

Restoration measures in the Rotorua and Rotoiti catchments have included land use management efforts to arrest nutrient inputs; diversion of Lake Rotorua waters from entering Rotoiti; sewage reticulation of lakeside communities; and treatment of inflows with aluminium sulphate (alum). While restoration efforts have produced water quality gains in both lakes, in recent years, cyano-bacterial blooms have occurred in the shallow embayment of Lake Rotoiti, known as Okawa Bay.

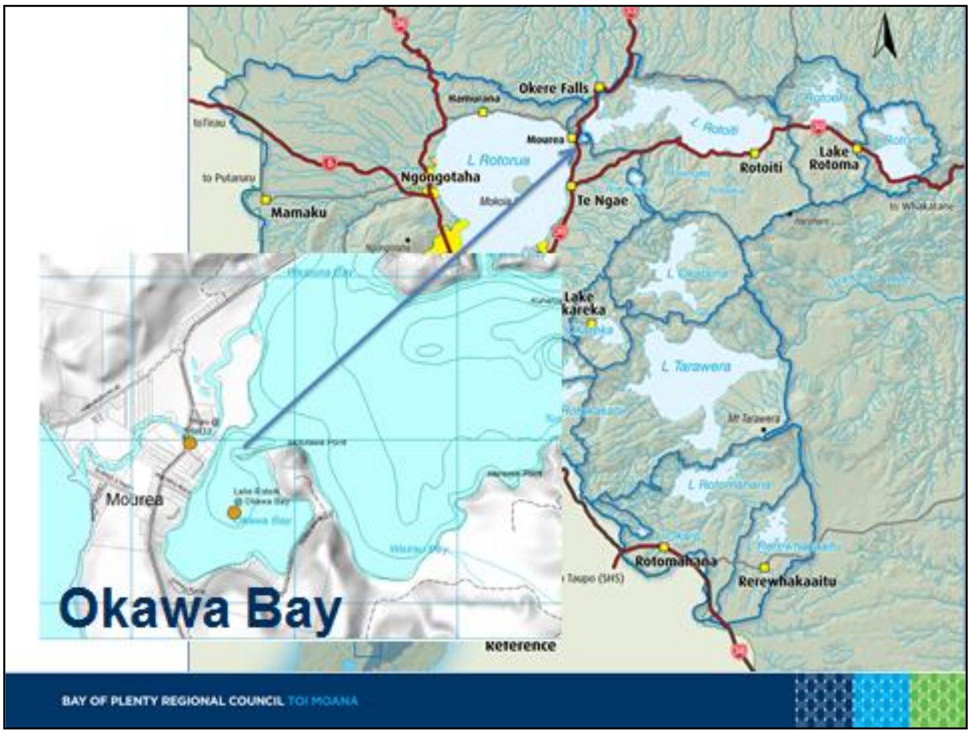
These water quality gains have not come without a cost. Submerged aquatic weeds such as Hornwort are an increasing problem in the Rotorua Te Arawa Lakes and significant resources are needed to manage infestations primarily for aesthetic and recreational amenity. Control of exotic aquatic weed is mostly with application of herbicide. Herbicide treatment leaves a decomposing biomass in the waterbody, potentially increasing the nutrient status.

We examine the impact aquatic weed decomposition has had on Okawa Bay's nutrient status and the cyano-bacterial blooms over recent summers, and Bay of Plenty Regional Council's response to reduce localised bloom development.

TRANSCRIPT
This paper looks at the interest in weeds, water quality and resulting actions over the last decade in Okawa Bay. How has lake weed management contributed to the water quality in this lake?

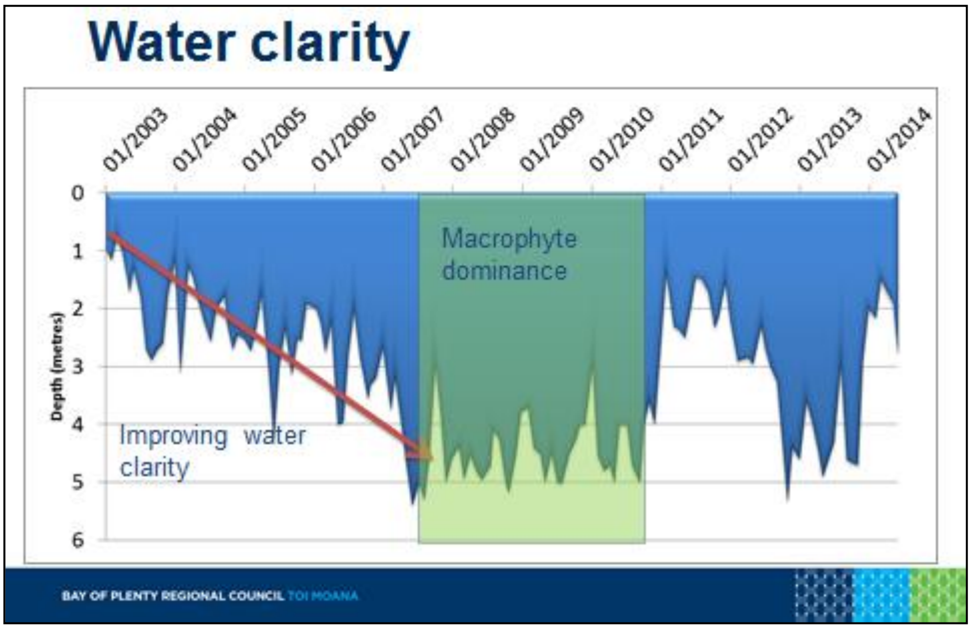
Slide 1 shows Okawa Bay on the western side of Lake Rotoiti, a 45 hectare embayment connected to the greater lake of Rotoiti. Its maximum depth is just over 5 metres, so it is quite a shallow embayment. There has been some action in recent times to improve water quality; sewage reticulation in 2006 and, of course, the Ohau diversion wall. This has improved the water quality of the greater Rotoiti lake and it has had a flow on effect into Okawa Bay.

Slide 1



Slide 2 is a graph of the water clarity as measured by Secchi depth since 2003, and over the period 2003 to 2008 there has been a real trend of improving water clarity. The massive algal blooms back in 2002-2003 galvanised the LakeWater Quality Society and

Slide 2



the Council into action and water clarity improved. As a result of this, there was a shift in algal dominance to macrophyte dominance up until 2008. The result was scenes like these large drifts of hornwort washing up on shore. (**Slide 3)** This picture was taken in the autumn of 2008 and the increased water quality encouraged the hornwort to really take off.

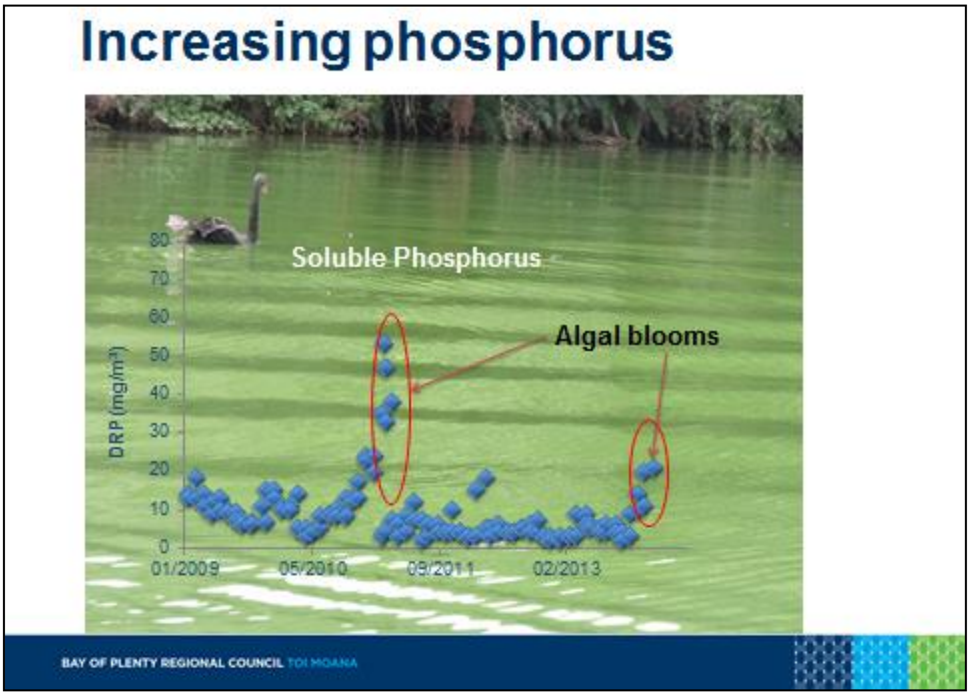
Slide 3

In more recent times that water clarity has dropped again. Small algal blooms appear, specifically a species of the nitrogen fixing algae anabaena. **(Slide 4)**

Slide 4

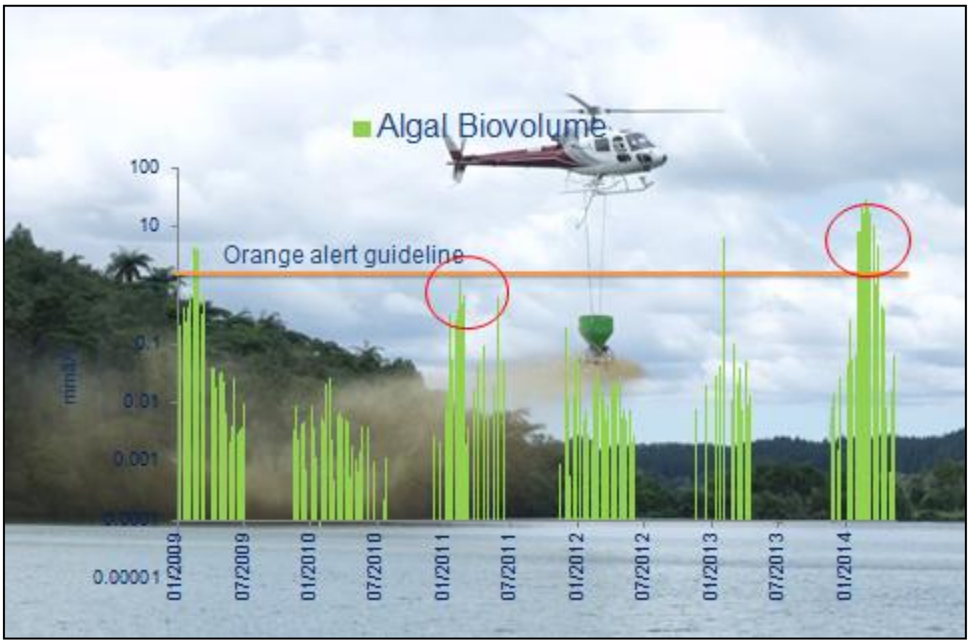
Why are these algal blooms appearing again?
Looking for causes, an obvious possibility is the increase in soluble phosphorus, seen at the time that these algal blooms occurred. **Slide 5** illustrates the concentration of phosphorus occurring over the early summer period when those algal blooms start to develop.

Slide 5



Slide 6 graph illustrates the prevalence of those blooms in the last few years. They have been decreasing and for the most part below the contact recreational guideline. The exception was last season's bloom where a warning status on Okawa Bay was reached.

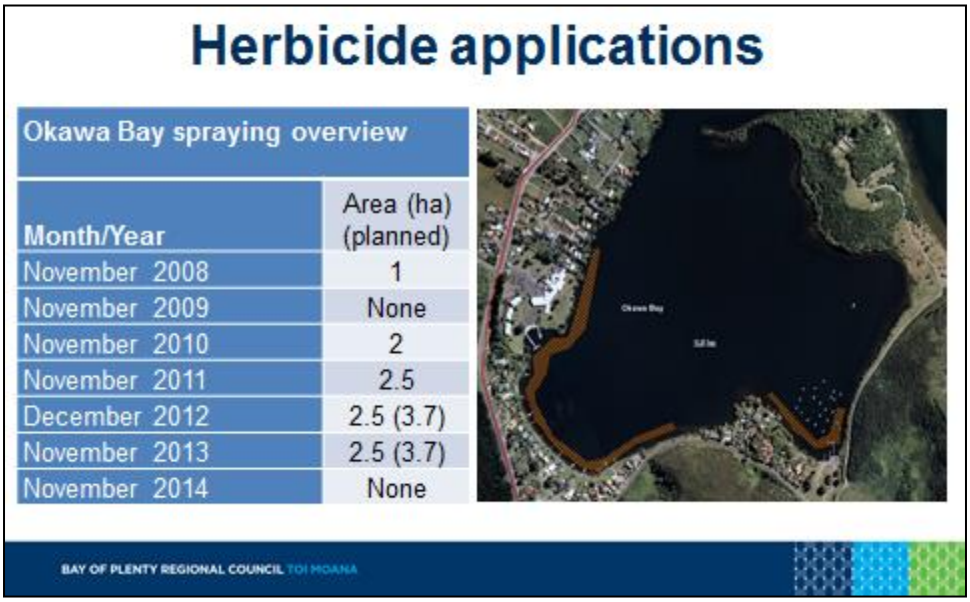
Slide 6



What might be the drivers of this recent increase in algal blooms?
Max Gibbs (NIWA) talked about anoxia, lack of oxygen in the bottom waters, as a potential for nutrient release in the sediments. Monthly monitoring in our programme shows little evidence of stratification, but this is not continual monitoring. Stratification events can happen quite quickly in these shallow systems, so anoxia could still be occurring. Max also mentioned sediment nutrient release with elevated pH, another potential mechanism.

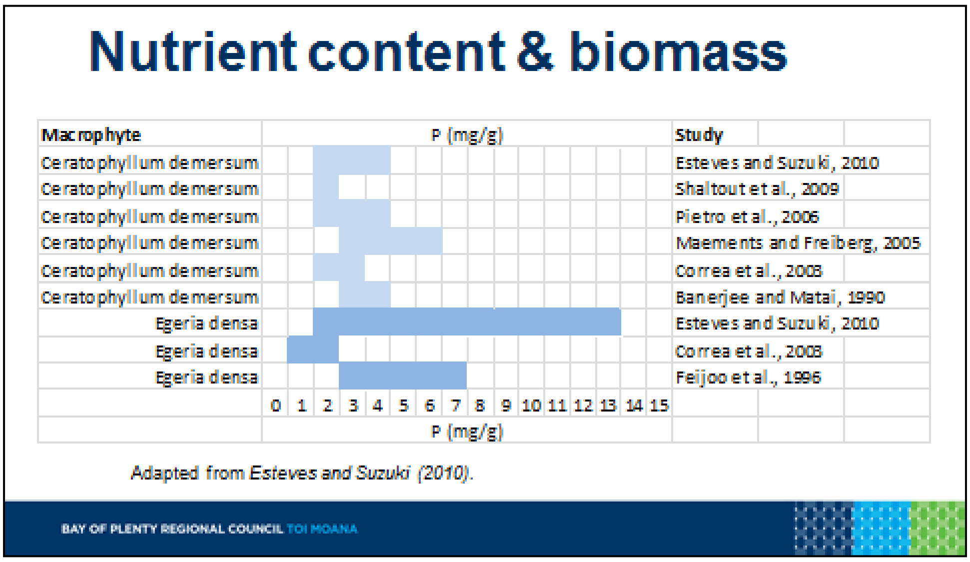
We have had a management programme of herbicide application in the bay for the last few years, and we explored if it had influenced these algal blooms. LINZ operates the spray programme through Boffa Miskell and the Regional Council. **Slide 8** shows the areas of about 2½ hectares, that have been sprayed in Okawa Bay since 2008. There was no spraying last season.

Slide 8

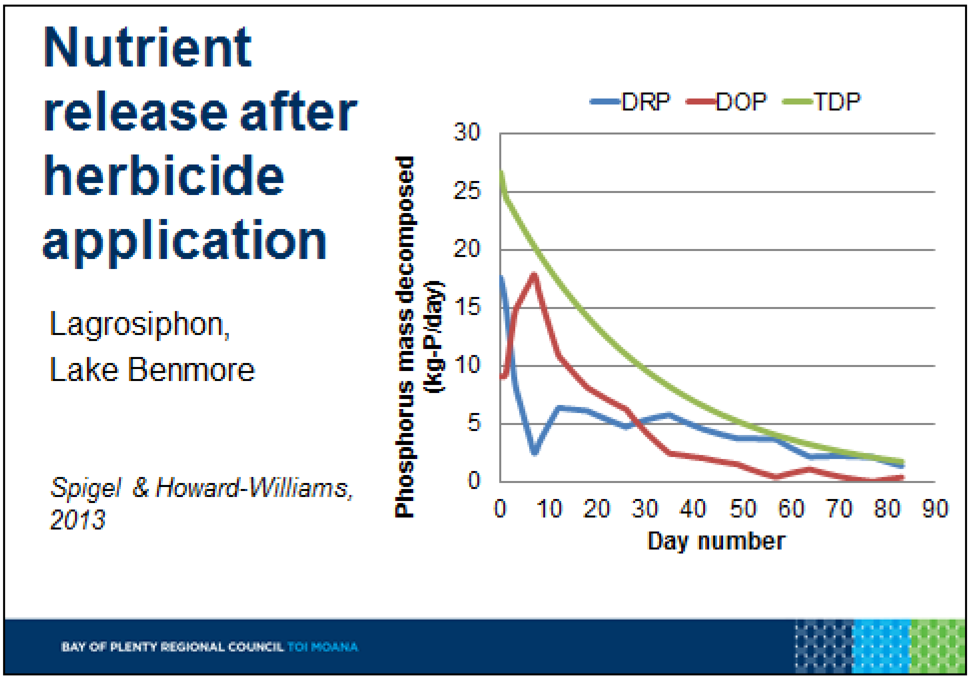


Slide 9 is evidence from the literature of nutrient contribution from a decomposing biomass of sprayed aquatic weeds which gives a picture of nutrient release into the water column.

Slide 9



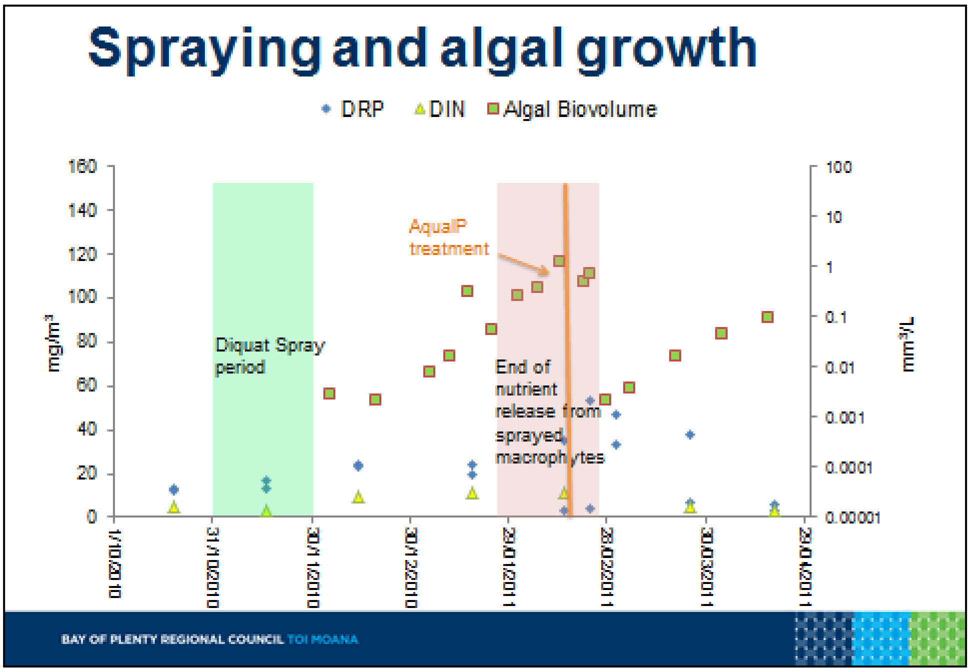
Slide 10



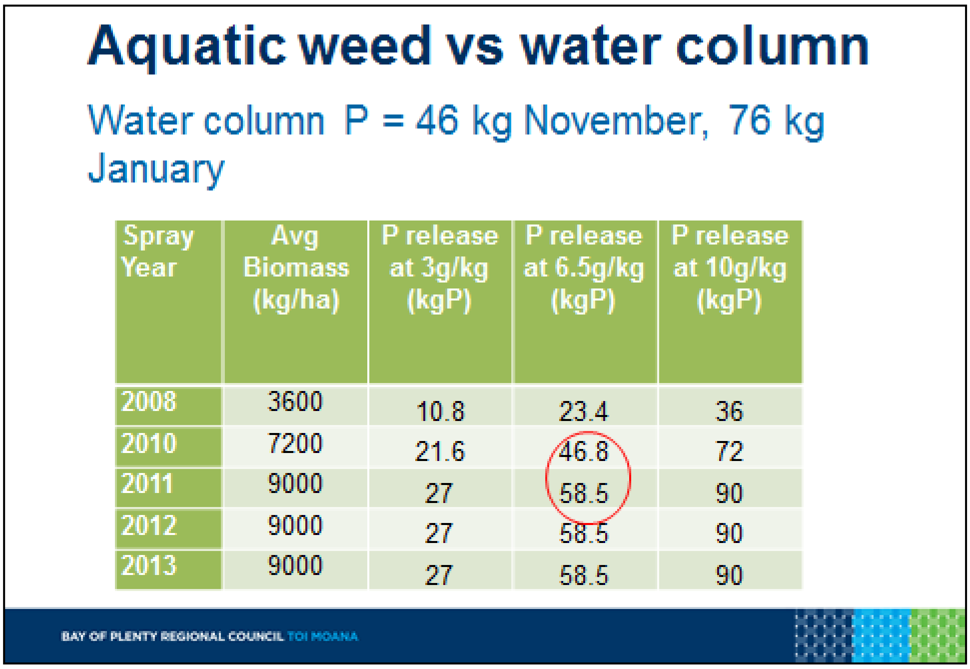
Slide 10 is some recent work by Clive Howard Williams and Bob Spiegl of NIWA at Lake Benmore. It shows that decomposition nutrients took around 84 days to be released into the water column in that system and probably most was released in the first 20 days.

What does that mean for Okawa Bay?
During the Diquat spray and potential release period, the biomass of algae increased slowly. **Slide 11** graphs the use of Aqual P treatment by helicopter to address the phosphorus and shows that it impacted slightly on the bloom at that stage. Conversely a similar treatment in 2014 using alum did not have the same effect, but that might be a result of timing and product.

Slide 11



Slide 12

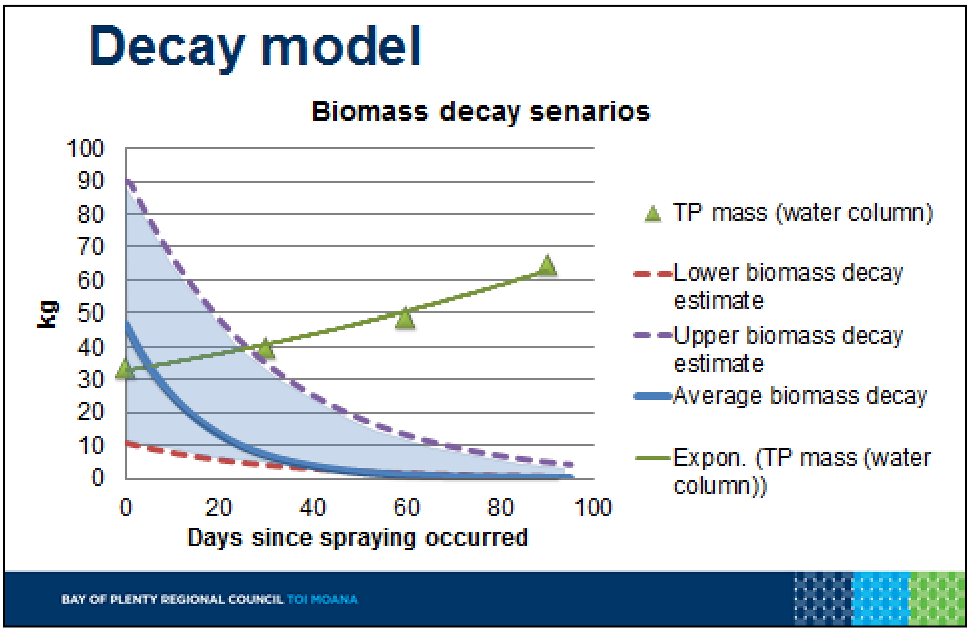


Spray Year	Avg Biomass (kg/ha)	P release at 3g/kg (kgP)	P release at 6.5g/kg (kgP)	P release at 10g/kg (kgP)
2008	3600	10.8	23.4	36
2010	7200	21.6	46.8	72
2011	9000	27	58.5	90
2012	9000	27	58.5	90
2013	9000	27	58.5	90

Slide12 shows a scenario of the estimated nutrient contribution from weeds compared to the water column phosphorus. A picture emerges of the possible nutrient contribution from 2½ hectares of weed mass compared with that existing in the water column, and it does not look like an inconsiderable amount.

Looking at a model of those limits we can estimate an upper and lower limit and also look at the increase of the summer phosphorus in the water column. **Slide 13** shows phosphorus in kilograms versus days since aquatic weed were sprayed. The water column for phosphorus mass is shown to increase as the plant decay biomass occurs, using the example of 84 days of decomposition that NIWA found. Looking at that relationship of increasing phosphorus, it is very similar to a mid-range of that decreasing biomass nutrient, in this case the phosphorus.

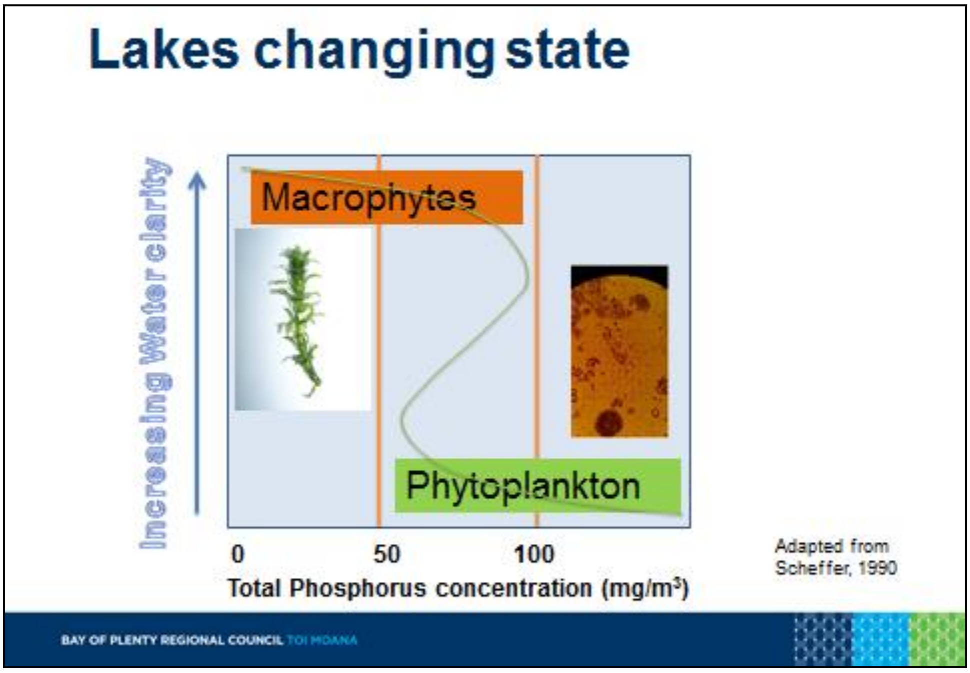
Slide 13



What does that mean for our management implications?

The spraying programme has introduced nutrients into the water column, coinciding with conditions when algae do best in the height of summer. **Slide 14** indicates the lake's changing state swinging from a macrophyte dominated system to a phytoplankton dominated one. With no spraying over the last 2 summers and a very steady warm summer, a bloom has not occurred to date (early March 2015), although it is just starting to pick up.

Slide 14



Looking towards the future we know that herbicide application can impact the trophic state of the lake depending on the situation. That is not necessarily so for some lakes, but **Slide 15** shows the recent example of how much hornwort can accumulate in Okawa Bay in a season.

Slide 15

There are probably two opposing drivers affecting management options. The need to supress algal blooms and increase water clarity, which in turn increases macrophyte growth. A lake management dilemma.

Some possible management methods for aquatic weeds are the use of alternative herbicides and changes to the time of year of application. There has been some mechanical weed management in Okawa Bay, but there are other potential management options which might include biological control, shading, and dredging.

SUCCESS STORIES AND THE WAY FORWARD

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Rohan has had 35 years in aquatic plant ecology and weed control research with MAF and now NIWA and has worked in virtually all significant accessible water ways throughout the country. He supervised the Rotorua lakes weed control programme from 1998 through the early 2000's for DOC and included pre- and post- SCUBA and sonar assessments of results for fine tuning the programme. He tested new United States aquatic herbicides fluridone and endothall for use in New Zealand and was involved with the aquatic registration of Aquathol K through ERMA (now NZ EPA). He was also involved with grass carp use and evaluation in lakes and drains, as well as evaluating bottom lining, mechanical harvesters and draglining for weed control. He was part of the didymo response team for the North Island and part of the TAG for the eradication of hornwort from the South Island. He supervised the eradication of hornwort from Centennial Lake Timaru, the last known site in the South Island.

ABSTRACT
This paper will cover what successful aquatic weed management looks like. It follows a range of historical management actions with numerous examples of 'success'. Successes include preventing weed problems arriving, detecting them early and, in some cases, eradicating them. There is no single best option for weed control; none of them are without potential environmental impacts. For each situation and in each location it is up to managers and the community to weigh up the option(s) and decide on an approach that best suits each weed issue and their desired outcomes within economic, political, cultural and environmental constraints particular to that situation. As history has shown, the way forward is to keep adapting and refining existing management tools, testing and, if deemed effective, adopting new control options. In all cases, the scientific rigour behind weed management options and evaluation of environmental impacts must be provided to the public, and authorities remain open to a rational consideration of the options available that could benefit the health of our lakes.

TRANSCRIPT

We are passionate about native aquatic vegetation in healthy lakes but unfortunately they are threatened by invasive weeds (spread by people) and eutrophication driven by catchment activities. NIWA is interested in all types of weed control and management options to maintain healthy water bodies.

Nutrients can have major effects on weeds. The Waikato Lakes have flipped from a steady state with native aquatic plants, to invasive weedy plants (and weed problems), to an alternative state with permanent algal domination. Weeds are preferable to algae. The Waikato lakes such as Lake Hotoananga were invaded by weedy plants (mostly egeria), and with excessive nutrients have flipped to an alternative state with permanent algal domination being (left) at the

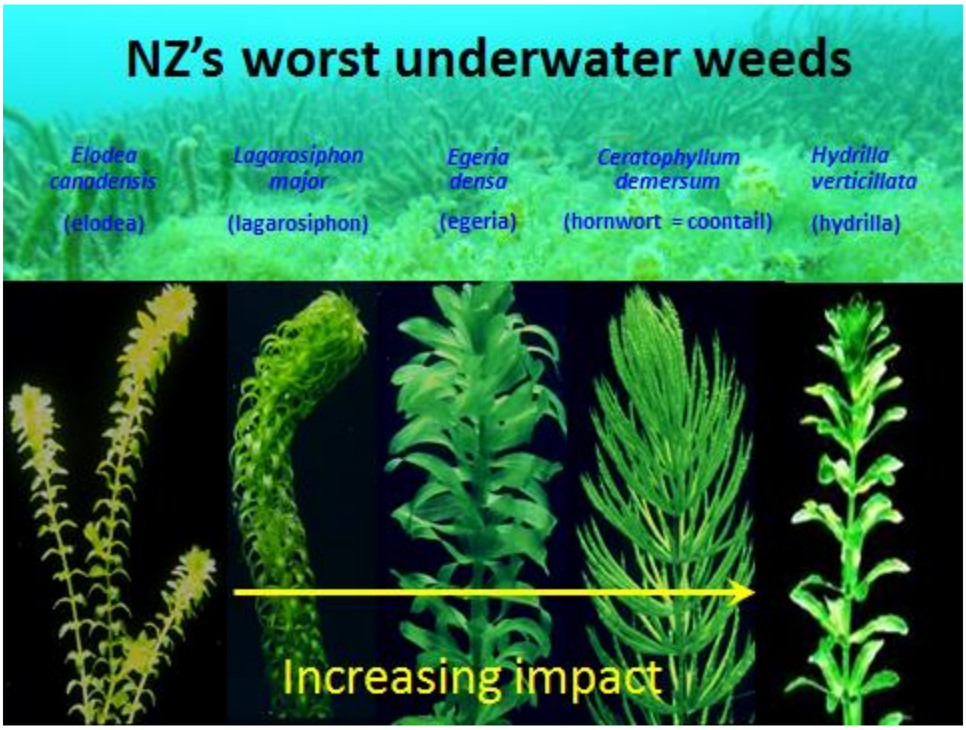
extreme high end of the scale on nutrient issues.

With 1.8 million dairy cows in the Waikato catchment, virtually all the lakes have lost their aquatic plants and have a problem with algal blooms. At the lower end of the scale there are a few lakes in New Zealand where there are insufficient nutrients for tall-growing macrophytes to establish including natives. These include Lake Taharoa in the Kai Iwi Lakes. Also in Lake Taupo, egeria cannot establish but is present in adjacent enriched marinas.

A question could be asked, 'Could we use nutrients to control weed problems?' Lake Rotokawau (Pouto) in Northland is an interesting example; when NIWA was monitoring that lake it had a band of dense egeria around the margin growing to 6 metres deep, but beyond that there were no plants. In early 2015 the egeria had virtually gone, but the natives went right across the bottom of the lake and down to 13 metres deep. We learned there had been a change in the catchment usage from pastoral farming to maize cropping. Nutrient expert Max Gibbs said, 'Ah, nitrogen stripping.' It could well be an example where nitrogen prevented from entering the system has removed the weed problem. More accurate data on losses to ground water from alternative land uses and practices compatible with clear lakes is needed for better catchment management.

Paul Champion and Dr John Clayton have produced the Aquatic Weed Risk Assessment Model[1] which enables managers to prioritise the weeds which are most damaging and assess the weed potential of plants before they reach the New Zealand border. **(Slide 1)**

Slide 1



The best success stories are those preventing weeds getting into lakes in the first place and the bar across the public entry to Lake Rotokakahi has meant that this lake does not

[1] Champion, P.D.; Clayton, J.S.; 2001. Border control for potential aquatic weeds. Stage 2 Weed risk assessment. Science for Conservation 185. Department of Conservation, Wellington.

have lagarosiphon, hornwort or egeria whereas the neighbouring lakes do. Banning entry to all lakes if they do not already have weeds is one way to keep them out. (left)

Education with the 'Check, Clean, Dry' message is obviously a help but it does not stop weeds getting in. Weed cordons can collect weed as boats are launched, however weed on the anchor or in the bilges of a boat will still escape beyond the cordon.

In the United States, a permit (costing ~ US$25 depending on boat size) is required to enter the water at Lake Tahoe. There are boat cleaning services provided (from ~ US$35) if decontamination is required. They have high pressure hot water (60ºC) hoses and chemical options like Virkon and Sparquat. A permit is needed to launch a boat. Should we be considering these lengths to protect high value water bodies in New Zealand?

The arrival of didymo increased the pressure for such protection, but that has reduced now that Dr Cathy Kilroy has demonstrated that didymo is an indicator of ultra-oligotrophic condition and phosphorus levels in the Rotorua Lakes are too high to sustain didymo blooms[2]. Also temperatures are likely too high and substrates also unsuitable in the central North Island. But introducing inspections may well need to be considered as we are spending ~$300,000 to rid weeds from lakes such as Waikaremoana. Our best defence is surveillance for early detection then, delimitation and control of the infestation. Without knowing what is there, you cannot manage it.

Problem weeds, such as lagarosiphon which established in the 1950s, require a scientific approach and careful consideration of the best methods of control. In the early days much of the work was done in Hamilton on Lake Rotoroa by army engineers and agricultural scientists. Ideally a control method must be target specific with no ill effects on other biota, and be time and cost effective. Eradication and restoration to native condition would be best outcome possible, but adverse effects on human health cannot be tolerated. Specifically for herbicides, bio-concentration within organisms is undesirable; organisms must be able to metabolise herbicides with relatively fast clearance rates.

[2] Max L. Bothwell, Brad W. Taylor & Cathy Kilroy (2014): The Didymo Story: the role of low dissolved phosphorus in the formation of *Didymosphenia geminata* blooms, Diatom Research, DOI: 10.1080/0269249X.2014.889041http://dx.doi.org/10.1080/0269249X.2014.889041

Herbicides should be short-lived and biodegradable to innocuous elements.

The photo above is a weed harvester – probably the first one in New Zealand. With continual refinement, they got bigger and more efficient. **Slide 2** The Lakeland steel harvester, manufactured in Rotorua, was the biggest harvester we have had in New Zealand. It was used on the Rotorua Lakes to remove water net (*Hydrodictyon*). It was used to clear a passage for the Lakeland Queen tourist boat to get out onto the lake. Water net infestations spread quickly and, unlike the macrophytes, only one cell (possibly spores) is all that is required for propagation. It spread quickly, even appearing in bird baths. It was like trying to contain foot and mouth. The techniques used for containing oxygen weeds are often inappropriate for algae.

Slide 2

Harvesters were evaluated on the egeria beds in Lake Rotorua in the 1990's. They were so dense that the harvesters just jammed up within 10 metres of starting to cut and they then had to back out.

In Florida weed harvesting of topped out hydrilla collected about 22 tonnes per hectare. It was taking too long and cost too much to be viable. **Slide 3** is a 21 metre Kelpin monster harvester which cuts to 3 metres deep. Cutting the hydrilla at a time of the year when the

Slide 3

weeds are at their lowest quantity reduced the harvesting required to 1 tonne per hectare. Cutting it right to the bottom prevented a weed problem throughout the year. So changing the strategy produced a cost effective solution, in Orange Lake (3 m deep with a flat bottom).

There is a lot of discussion here about how weed harvesting helps reduce nutrients in lakes. Weeds take nutrients out of the water and sediments but when they decay they return nutrients either to the water or sediment, depending on conditions at the time. To what extent are the weeds a nutrient sink or the sediments a sink? Even when nutrients are in the sediment they can be regenerated under anoxic conditions, so there is no clear answer for all situations.

At Hamilton Lake in the 1950s, the agricultural engineers came up with a chemical solution, sodium arsenite. It had been used in the USA since 1929 and was a common herbicide. It was also a health tonic and used for medicinal purposes. In **Slide 4** the guy who is opening up the tanks has no protective gear, three people were hospitalised and he was probably one of them.

Slide 4

In 1959 low level helicopter flying applied 5.5 tonnes sodium arsenite to Lake Rotoroa, Hamilton which was successful, i.e. no weed for five years but also no plants in the lake for five years. Then the weed problem re-surfaced, probably from a re-introduction. Sodium arsenite treatment cost about $0.5M in today's terms and arsenic levels still remain high in sediments and plants. It was tried in the Rotorua Lakes but was not effective with the target 10ppm concentrations not achieved; most likely due to dispersion.

Since then there has been 50 years of research and many herbicides including: diquat, endothall, fluridone, numerous algicides, additives, grass carp, MT (*Mycoleptodiscus*), *Hygraula nitens* moth, snails, nutrients, light, lining materials, etc. have been assessed at NIWA's Ruakura research facilities under controlled laboratory conditions.

In 1960 diquat proved that it could control the weeds. It was able to target the nuisance species, had little impact on natives and was bioactive for a very short time. It was an incredible success in the Rotorua Lakes. It controlled hornwort, elodea, egeria and

lagarosiphon. Used at the very low concentration of 1-2 part per million, it was about 10 times less concentrated than the sodium arsenite spray that was not effective.

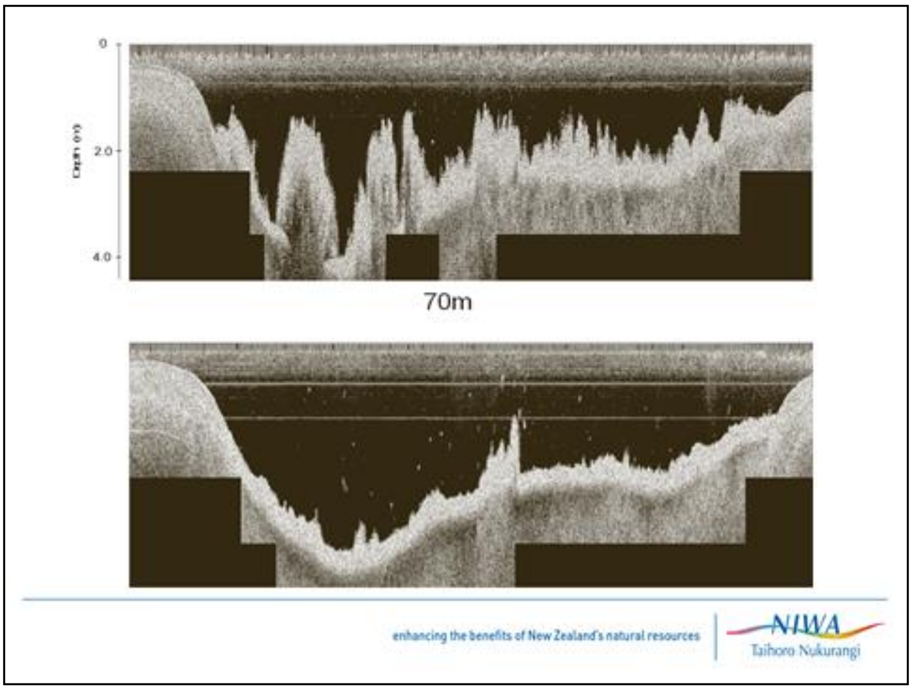
NIWA has worked on further refining herbicide formulations, some of which have been adopted by chemical manufacturers and applicators with incorporation into consent conditions for weed control. Today Aquagel is accepted as a useful additive that helps better target weeds growing in water below the surface. Diquat has been very effective. In Lake Okataina, hornwort was 8 m tall at its initial invasion site; but after diquat treatment no hornwort shoots were found at this site. In diquat trials, five months post spray, the tall-growing native species are left intact to become the dominant plant **(Slide 5).** Diquat is deactivated by sediment and it is ineffective on shoot buds located on basal stems and root crowns, so ultimately plants like lagarosiphon do recover.

Slide 5

Technology developments like GPS provide better targeting, tracking and recording of the work done **(Slide 6)**. Sonar developments now enable good records to be made.

Slide 6

Slide 7



Slide 7 at the top shows tall weed beds pre-spray in Lake Karapiro and below is post spray result – with little weed. The clump of weed in the middle is drift weed hanging around a cable for the ski buoy at the Piarere Ski Club. Sonar is an effective means of recording pre and post spray weed beds as a measure of herbicide efficacy. It is also good at the time for the applicator to know where the beds are so that he can be certain he is discharging the spray directly over a weed bed.

Considering water net again (**Slide 8)**; NIWA was driven to look at all sorts of ways of overcoming this problem. Copper based algicides seemed to be the only effective control. But copper accumulates because it does not break down. The answer for Lake Rotorua proved to be habitat manipulation. After investigating the habitat of the water net, we

Slide 8

found that it was growing on the egeria. Egeria was targeted with diquat and once the water net had lost its habitat, and with no protection from water movement, it was dissipated very rapidly. Then the big harvester for the Lakeland Queen was no longer required!

At Lake Okataina (left) we prepared plots on the waterfront for comparison of alternative control measures; a diquat treated plot, a suction dredged plot and a harvested plot cut to the sediment level. We compared the vegetation post treatment and also looked at invertebrates. Native species ended up dominating in all treatments. Invertebrate abundance levels compared with the controls were less, however the same species were present in all three test plots but more were in the herbicide treated plot than in the suction dredged and cut plots.

The world rowing champs were held in Lake Karapiro in 2010. With over 100 hectares of hornwort in that lake it was imperative that the rowing was not disrupted with big floating wads drifting downstream. This is the kind of thing Karapiro users have to contend with on a regular basis. NIWA was involved in formulating a plan that would alleviate these problems. With a targeted diquat programme hornwort problems were successfully prevented during the regatta.

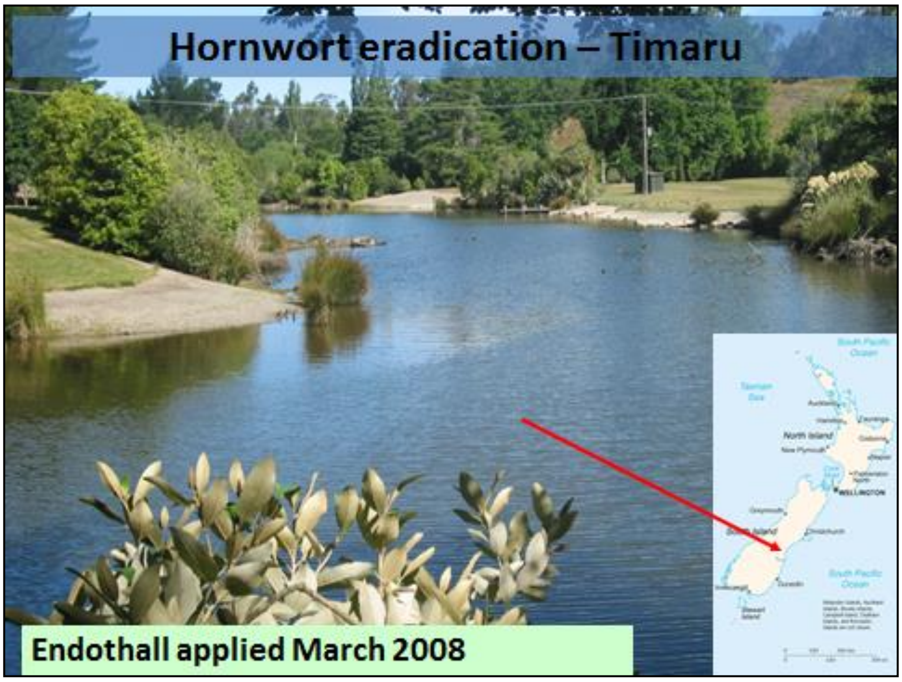
NIWA has evaluated endothall in the field. A number of cold water bodies up to 2 ha at the bottom of the South Island were tested targeting lagarosiphon. The tests were carried out using the maximum label rate of 5ppm down to 50 times less than that label rate. We achieved lagarosiphon eradication even in the very low rate treatment and it was all gone resulting in clear water with the natives plants unaffected[3]. Northland Regional Council has also used it successfully.

One treatment in Lake Phoebe (right) killed a dense lagarosiphon band; it is now 2½ years since the treatment and it is now an all native vegetation lake. Auckland Council is looking at eradication of about 16 sites on South Kaipara Head so more information about its use will become available in the future.

[3] Rohan D.S. Wells, Paul D. Champion and John S. Clayton 2014 Potential for lake restoration using the aquatic herbicide endothall. *Proceedings of the 19th Australasian Weed Conference* 143-146.

Slide 9 Centennial Lake in Timaru was the last remaining South Island site with hornwort. After trying and exhausting all other methods, it was decided to try endothall. The application for its use took a year's wait for a decision and meanwhile the plant had spread downstream. Fortunately one treatment at the maximum label rate for total water body treatment was all that was needed. Hornwort has been eradicated from the South Island.

Slide 9



Ten hectare Lake Otamatearoa in the Waikato catchment was full of hornwort with a third of the lake 'topped out' with hornwort. Waikato Regional Council helped with funding in this case study that considered the nutrient release implications and impacts of treating a whole water body with the herbicide[4]. NIWA monitored the oxygen levels which remained high over the 62 day period following treatment.

Slide 10 (over) shows that there was also an improvement in water clarity and reductions in chlorophyll *a*, phosphorus and nitrogen and consequently no algal bloom. Similar results were found off the city foreshore of Lake Rotorua and Lake Rotoroa in Hamilton. A number of papers are showing that most of the nutrients from decaying plants are going into the sediment[5] which must be the case if they are not going into the water.

NIWA conducted a trial on the egeria growing in Lake Parkinson with grass carp; they eliminated virtually all the plants in the lake. The fish were then removed using rotenone and a natural re-establishment of native vegetation from the seed bank was monitored[6].

[4] Rohan D. S. Wells, Paul D. Champion, John S. Clayton (2015). **Endothall for biosecurity and lake restoration.** Papers and Proceedings of the 19th Australasian Weeds Conference.
[5] D. S. Nichols and D. R. Keeney 1973. Nitrogen and phosphorus release from decaying milfoil. Hydrobiologia, 42:4, 509-525.
[6] Chris C. Tanner, Rohan D.S. Wells & Charles P. Mitchell 1990. Re-establishment of native macrophytes in Lake Parkinson following weed control by grass carp
New Zealand Journal of Marine and Freshwater Research
Volume 24, Issue 2, 181-186

Slide 10

	0 DAT	7 DAT	14 DAT	28 DAT	62 DAT
Temperature °C (top/bottom)	15.3/15.2	15.8/15.9	13.6/13.2	16.9/16.3	18.8/18.6
Secchi disc (m)	2.47	2.95	3.0	3.07	2.87
Turbidity NTU	2.2	1.7	1.2	1.4	
Total SS gm^{-3}	4.0	2.2	<2.0	<2.0	
Chlorophyll *a* gm^{-3}	0.0043	0.0078	0.0055	<0.0030	
pH	7.9	7.9	7.5	7.6	
Conductivity mSm^{-1}	25.5	24.7	24.4	24.9	
Total P gm^{-3}	0.11	0.0082	0.021	0.0048	
DRP gm^{-3}	<0.004	<0.004	<0.004	<0.004	
N nitrate + nitrite gm^{-3}	<0.002	<0.002	<0.002	<0.002	
Tot Kjeldahl N gm^{-3}	0.49	0.37	0.33	0.33	

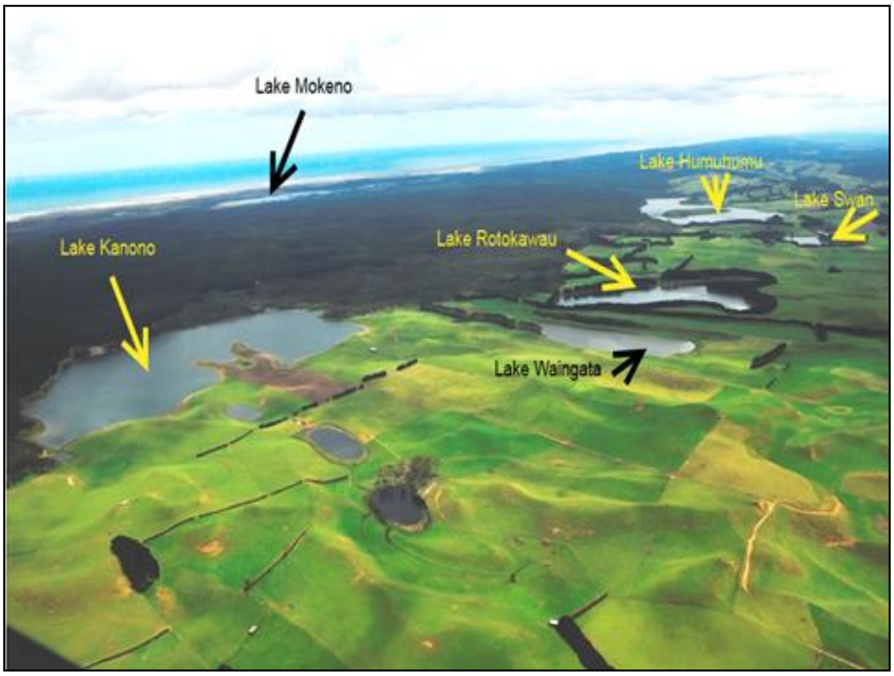
Northland is using grass carp strategically, for hornwort and egeria. They have been put in Lake Swan (which had hornwort and egeria) as it was a threat to very high value lakes in the immediate vicinity **Slide 11**.

Slide 11

Hydrilla was a major threat to the Rotorua Lakes and the rest of New Zealand. It was in four lakes in Hawke's Bay; Dr John Clayton's NIWA trial in Eland's Lake demonstrated it could be eradicated using grass carp, leaving only three lakes. The difficulty is this plant has turions and tubers that can last in the sediment for about a decade so the process takes time.

All the remaining water bodies with hydrilla now have grass carp. **Slide 12** shows progress in Lake Tutira with the hydrilla mainly gone. Total de-vegetation has not happened and milfoil beds are increasing; the grass carp do not seem to like the milfoil. At this stage hydrilla is no longer a threat to other lakes; it is a very successful operation.

Slide 12



There have been a number of successful eradications in the Rotorua Te Arawa lakes:

- water hyacinth, Lake Rotorua 1950s
- water poppy *Hydrocleys nymphoides* Lake Rotoehu 1976
- marshwort *Nymphoides geminata* Okareka 1984 to 1992
- eel grass, *Vallisneria australis* Government Gardens pond
- Mexican water lily, *Nymphaea mexicana* lilies in the Government Gardens pond

Another likely eradication is yellow flag iris. (left) NIWA conducted trials comparing metsulfuron with glyphosate at Lake Rotoroa.The metsulfuron-methyl had the greater efficacy and proved to be selective for this iris leaving the natives untouched**.** An autumn application of metsulfuron was very successful and this enabled BOPRC to eradicate it at an early stage of invasion at Lake Tarawera and Lake Okareka. Having sprayed a large area where yellow flag iris was predominant,

there are now just native species like the *Baumea* spp. and the raupo. But there is a risk of re-growth from seed load which can last 10 years or more.

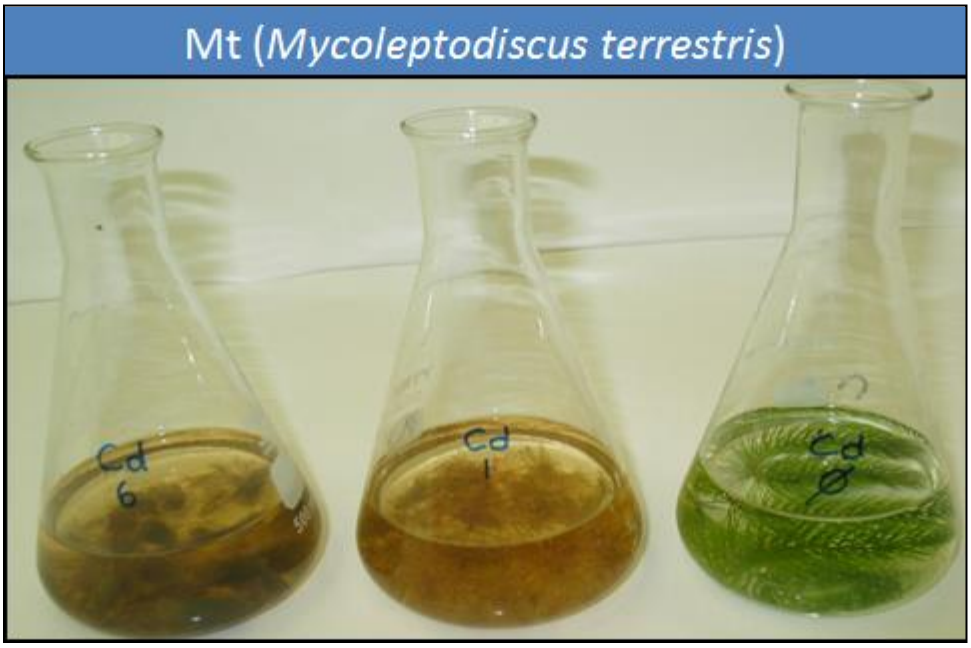
The black swans are doing a fantastic job in biocontrol. They are out there every day and probably remove more weed than we ever will. Swans graze to 0.8 metres, but then can be a nuisance by soiling lawns and beaches (left).

Visiting scientists from Germany, Dr Andreas Hussner and Ms Petra Redecop were doing plant growth experiments at NIWA's Ruakura research facilities; the larvae of aquatic moth *Hygraula nitens* very effectively chewed out all their experimental plants (right). This insect is a New Zealand native, its larva can excise a leaf in under 1 minute but was thought to eat only our native plants.

Choice feeding experiments showed that it found egeria and hydrilla very acceptable (below). But hornwort was the preferred species and the consumption rates were up to 4 times body weight per day. This is a revelation, we have an insect bio-control agent already in New Zealand; it is an insect that is capable of doing tremendous damage. That damage is not actually seen out in the field even though *Hygraula nitens* is very abundant and widespread throughout New Zealand.

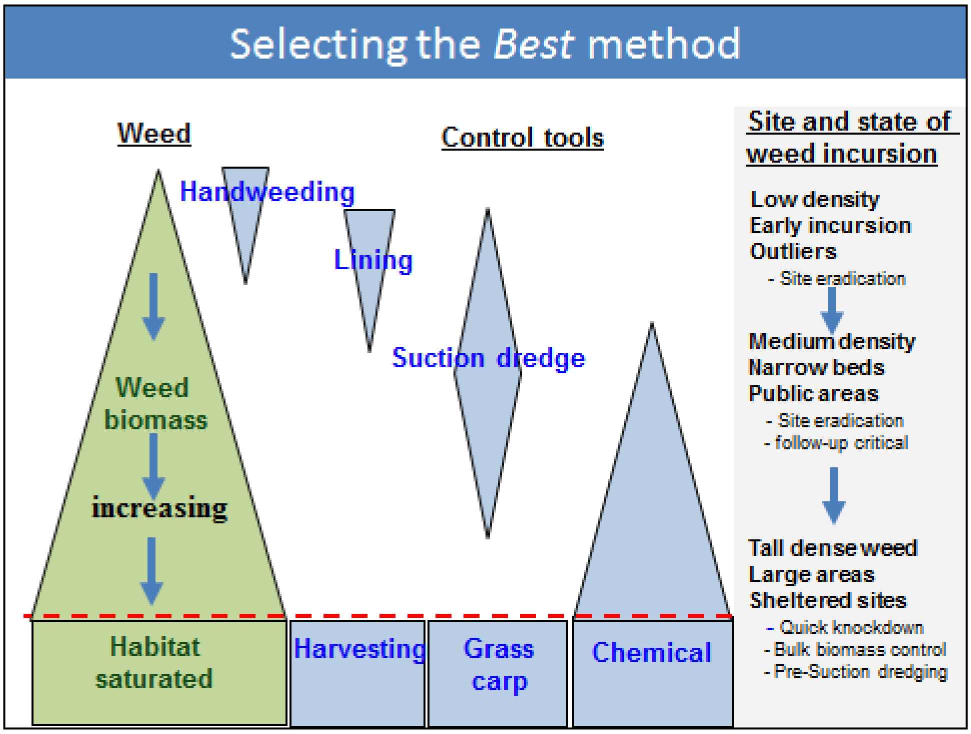
A naturally occurring fungus, *Mycoleptodiscus terrestris* (MT) can be concentrated and applied to hornwort with remarkable results, even more effective than a chemical herbicide in the laboratory. At this stage (March 2015) such success in the field has not been achieved. **(Slide 13)**

Slide 13



For the way forward (**Slide 14**), we have a range of control options BUT no one option is the best method. We have a whole range of control tools; but we must select the right control tool for the situation, the available resources and consideration of the required outcome. The quantity of weed biomass will eliminate a number of the control options, like hand weeding and lining.

Slide 14



There is still great potential for refinement with all the options. All management agencies need to be on the same page and it would be good to have a streamlined process, if that is possible. We do need early detection and we do need to be response ready. Management approaches need to be flexible, each site needs to be evaluated and suitable options selected for the desired level of control, but constrained by environmental, economic, social and use considerations. The learning never stops but rate of progress is dependent on the dollars available.

Biosecurity Management Overview

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Paul holds an MSc in biological sciences from the University of Waikato and has been a part of the aquatic plant management research team at NIWA since 1988, with over 25 years' experience in the field of plant ecology and biosecurity. He specialises in freshwater biosecurity, especially risk assessment and pest management. He previously worked with MAF, coordinating eradication programmes for nationally important noxious aquatic weeds. He also has experience in wetland ecology and management of nationally endangered wetland plants. He provides management advice to various government departments and regional authorities, and is a member of several Technical Advisory Groups with the Ministry for Primary Industries.

ABSTRACT
Today's symposium topic is the issue of water weeds in the Rotorua Lakes and their management. I will discuss how and where these weeds came from and how they got into New Zealand. The weeds discussed are only a small sample of potential weeds that could have additional or even greater impacts on Rotorua and New Zealand as a whole. I will discuss our legislation and how management at the border protects us from future weeds yet to enter this country. Unfortunately, it appears that our legislation has been too effective at keeping out new plants, with no new aquatic plants legally introduced since the mid 1990's but over 25% of aquatic plants in the aquarium/pond plant trade appear to have got here illegally. Several prosecutions have resulted from interception of smuggled plants.

Once inside our border, there are several biosecurity measures initiated that have kept a number of our worst weeds at bay. These include banning the propagation, sale and distribution of 30 aquatic weed species, national and regionally run eradication programmes for high-risk weeds, with the successful eradication of five species and great progress towards the eradication of around twelve other weeds. However, some of these plants, such as water hyacinth, are still illegally kept by some individuals and several new infestations have originated from such sources. Despite this, the programmes have successfully kept the volume of deliberate spread for a wide number of aquatic weeds to a trickle.

As previous speakers will have discussed, humans are the major cause of spread of aquatic weeds, with contaminated watercraft and trailers, fishing nets, diggers etc. all contributing to this spread. Bay of Plenty Regional Council have been proactively managing their lakes, identifying which lakes are threatened by which weeds, and then carrying out surveillance in order to detect and manage any new weed incursions. To assist with surveillance, they have designed and constructed weed cordons that effectively net off access points such as boat ramps (the main sites of new weed introduction) and have successfully detected and prevented establishment of new incursions of the weeds hornwort and egeria in Lake Rotoma. Each summer holidays an awareness programme run under the national 'Check, Clean, Dry' banner promotes inspection for weeds at boat ramps around the region. Additionally, surveillance of ornamental ponds near to high-value lakes has led to the detection of a number of potential weeds.

New Zealand is rightly heralded as a world leader in the field of biosecurity. We still have many iconic lakes close to their pristine state but these are under threat from a wide number of weeds. I have outlined a number of proactive management activities undertaken both nationally and regionally to prevent further weed incursions but it only takes one action or inaction to undo all of this.

TRANSCRIPT

I am going to take a step back from the Rotorua Lakes and give an overview of the biosecurity management system in New Zealand, talking about the origin of our weedsI will talk about our worst weeds, protection at the border, stopping the spread, surveillance and incursion response using the approach of the Bay of Plenty Regional Council biosecurity team as an example and then a few thoughts on what might have been and what could be.

Where do our Weeds Come From?

Slide 1 is the world's worst aquatic weed (water hyacinth Eichhornia crassipes) and can be bought for 5 Euros a pot in Europe. **Slide 2** is an aquarium in Auckland; all of the plants in the aquarium were illegally smuggled into New Zealand. Most of our current aquatic weeds were deliberately introduced. 75% of the 100 odd naturalised species in New Zealand were imported through the trade and similar figures are found throughout the world. Only 3 of our 30 aquatic weeds managed under legislation in New Zealand were not imported that way.

Slide 1

Slide 2

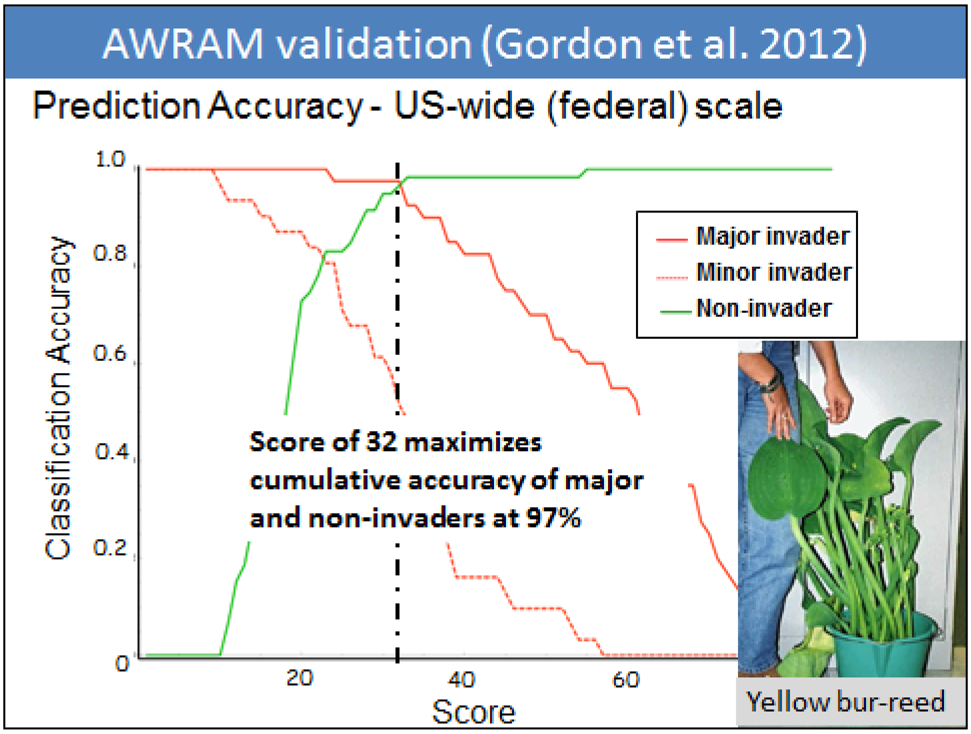
However we need a method to pick our worst weeds. There are over 180 species in New Zealand that have not naturalised, nor likely to. In the past weed history was the main way used to determine weed potential. If a plant was a problem weed in similar climates in Europe or North America we looked at managing it but of course the more times people introduce something the more likely it is to naturalise. Charles Darwin found this, Elton the father of invasion biology right up to recent papers shows that the more effort in introduction the more likely something is to naturalise.

John Clayton and I put together AWRAM (Aquatic Weed Risk Assessment Model) which is mentioned in several of the talks today (Champion and Clayton 2000). The model assesses:

- the invasiveness of the plant, its habitat versatility
- how competitive it is with other plants, both of the same life form and other life forms
- dispersal - propagule output, how it is spread, natural versus human, deliberate/accidental
- its impact, economic, environmental and recreational
- potential distribution - where it is now and where it could be – current versus uncolonised habitat
- resistance to management – scope of methods and effectiveness

The perfect aquatic weed would score 100. This model has been used in New Zealand, Australia, Micronesia and quite recently Doria Gordon has looked at its validation by applying it to a situation in the United States. **(Slide 3)** It is effective at distinguishing major weeds from non-invaders. A score of 32 maximizes 97% separation of non-weeds with major invaders. According to the Gordon et al. (2012) paper, the non-weed that was picked out as a potential major weed has already become a major weed in places like Queensland.

Slide 3



We need to protect New Zealand from aquatic weed invasions at the border and before the border because a lot of the potential problem weeds like Eurasian water-milfoil are not in New Zealand as far as we know. The weed risk model can evaluate potential weeds not present in a country by comparing them with existing weeds. The Biosecurity Act offers a couple of mechanisms to prevent the legal importation of species.

There are a number of notifiable organisms not yet in New Zealand, or were not when we did the work in the early 2000's. Two have since been detected in New Zealand and one has already been eradicated.

Notifiable Organisms – not in New Zealand

Species	Status in New Zealand	AWRAM Ranking
Ludwigia peruviana	Notifiable Organism (not in NZ)	64
Trapa natans	Unwanted Organism (not in NZ)	63
Panicum repens	Not known in New Zealand	61
*Typha latifolia**	Notifiable Organism	58
Najas marina	Notifiable Organism (not in NZ)	57
Typha domingensis	Notifiable Organism (not in NZ)	56
Najas guadalupensis	Notifiable Organism (not in NZ)	54
*Sagittaria sagittifolia**	Notifiable Organism	52

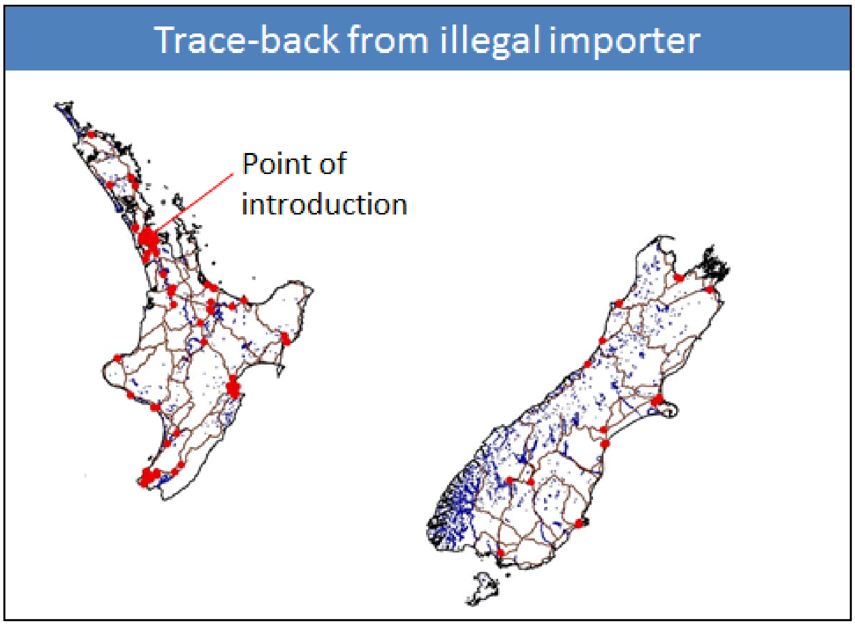
* Two of these species have since been detected in New Zealand and have been targeted for eradication

New Zealand management of biosecurity at the border is internationally renowned. At the border you think of beagles and people trying to find apples in your baggage. There are two pieces of legislation that guard us at the border, the Biosecurity Act, which is the border inspection, not only of passengers but also of mail in the international mail centre.

Then there is plant material brought into the country which has to be grown in quarantine for a growing season before it is released to check for regulated pests that might have been introduced with the plant. The Environmental Protection Authority (EPA, formerly ERMA) manage the importation of new organisms. You have to apply for the entry of these and pay for the privilege but no new aquatic plants have been introduced and very few other plants since the 1990s. The risk to New Zealand from legally imported aquatic plants has effectively been eliminated.

However, there is an issue with illegal imports. John Clayton and I (Champion and Clayton 2001) did a survey of the aquarium trade and surprisingly we found more than a quarter of the species in the trade were not in New Zealand in the 1970s when the last survey

Slide 4



happened. In 2006 the first successful prosecution of an illegal importer of aquarium plants was carried out and since then the world's worst submerged aquatic weed, *Hydrilla verticillata*, was intercepted at the border with some illegally introduced shrimps. It is probably one or two times a year interceptions like this happen.

Slide 4 (above) shows the impact of one importer in Auckland who sent material from Mangonui to Invercargill. This all came from copying his computer and noting what was sold on Trade Me. That one import action influenced the whole country.

So, some plants may have arrived in New Zealand illegally; the next step is managing the deliberate spread of them within the country. All of our top 15 weeds are traded internationally, all but one of them are exclusively human dispersed. 75% of naturalised aquatic species were imported in the aquarium/pond plant trade. Humans are the main agents of spread; both accidently and deliberately, especially long-distance dispersal. Trade of aquatic plants is a highly effective dispersal mechanism and repeated introduction.

The National Pest Plan Accord started in 2002. It is a national programme with nursery industries, central and regional governments buy in. Thirty aquatic plants are banned from sale and distribution nationally in New Zealand and it is hugely effective.

Slide 5 shows the top 16 ranked weeds, the red are being the big 3 in the Rotorua Lakes. They rank very highly as weeds.

NPPA – Top 16 ranked weeds

Species	AWRAM Ranking
Phragmites australis	75
Hydrilla verticillata	74
Zizania latifolia	68
Ceratophyllum demersum	67
Eichhornia crassipes	67
Egeria densa	64
Alternanthera philoxeroides	63
Lagarosiphon major	60
Nymphoides peltata	58
Typha latifolia	58
Gymnocoronis spilanthoides	57
Salvinia molesta	57
Myriophyllum aquaticum	56
Lythrum salicaria	54
Utricularia gibba	54
Iris pseudacorus	52

Slide 5

Slide 6 (over) shows the whole range including the water hyacinth that was eradicated from Lake Rotorua.

New Zealand is almost unique in the number of species under national or regional eradication programmes. **(Slide 7)** As well as the banning from sale and distribution we probably have the highest success rate of eradication internationally. It is akin to the work done on off-shore islands with mammals. Six species have been eradicated from New Zealand. There are also 6 programmes run by the Ministry for Primary Industries (MPI), National Interest Pest Responses including the hydrilla eradication programme. These are all national programmes, apart from Manchurian wild rice which is contained around Dargaville, and the other sites are targeted for eradication. Hornwort is widespread in the North island and is targeted for eradication in the South Island only.

Slide 8 shows plants detected in New Zealand last year that we thought had been eradicated nationally.

Slide 6

Eradication programmes

Species	Status in New Zealand	AWRAM Ranking
Nymphoides peltata	NPPA, eradicated by regional response	58
Typha latifolia	NO, eradicated by regional response	58
Potamogeton perfoliatus	NPPA, eradicated by regional response	55
Zizania palustris	Eradicated by national response	45
Menyanthes trifoliata	NO, eradicated by national response	45
Pistia stratiotes	NO, eradicated Class A Noxious Weed	42
Phragmites australis	NIPR	75
Hydrilla verticillata	NIPR	74
Zizania latifolia	NIPR (outside of Kaipara)	68
Ceratophyllum demersum	NIPR (SI only)	67
Eichhornia crassipes	NIPR	67
Salvinia molesta	NIPR	57

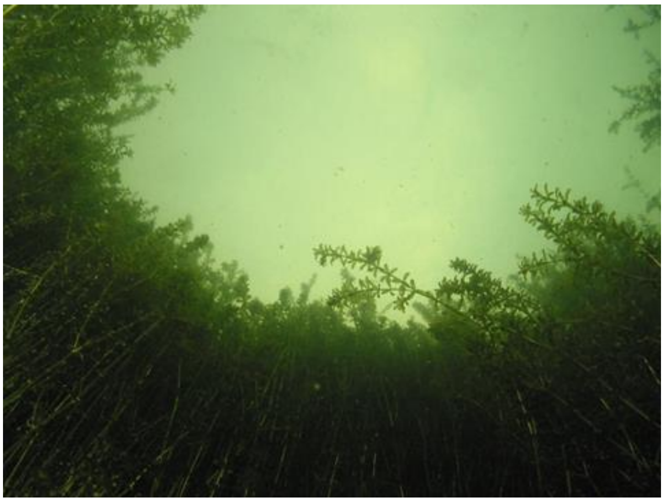
Slide 7

Slide 8

MPI found that Amazonian sponge plant (*Limnobium laevigatum*) **(Slide 9)** was being sold on Trade Me and we did not know it was in the country. We would have done something if we did. I acquired plants, grew them on and found them to be water lettuce (*Pistia stratiotes*) not sponge plant, and these plants may be held in cultivation even though all of the field sites have been eradicated.

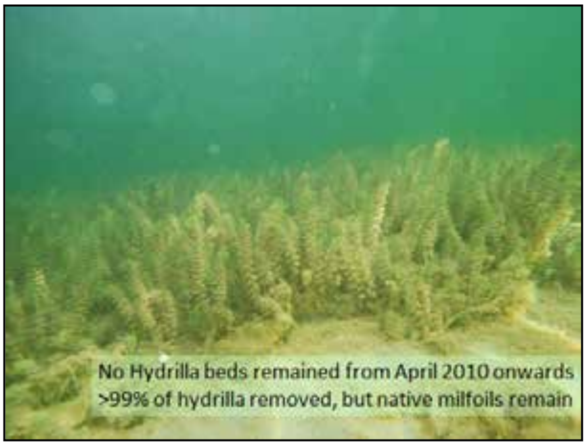
Slide 9

Hydrilla grew down to 10 metres in Lake Tutira, Hawke's Bay. **Slide 10** is a hole in the weed bed but shows how dense the growth is. The weed beds here are up to 6 metres tall. In 2008 an eradication programme began, led by MPI and taking in 20 years of research by NIWA using endothall and grass carp. The herbicide was used in November; grass carp were released a month later. The carp were around 25 cm long and less than a kilo when released. Last year the largest fish we caught was over 9 kilos and greater than 80 cm. **(Slide 11)** After 2 years there were no hydrilla beds remaining within the lake. More than 99% of hydrilla has been removed and we still have native vegetation growing under the browsing pressure of grass carp. Effectively the risk of spread of the worst submerged weed in the world has been averted. **(Slide 12)**



Slide 10

Slide 11



Slide 12

How do weeds spread?

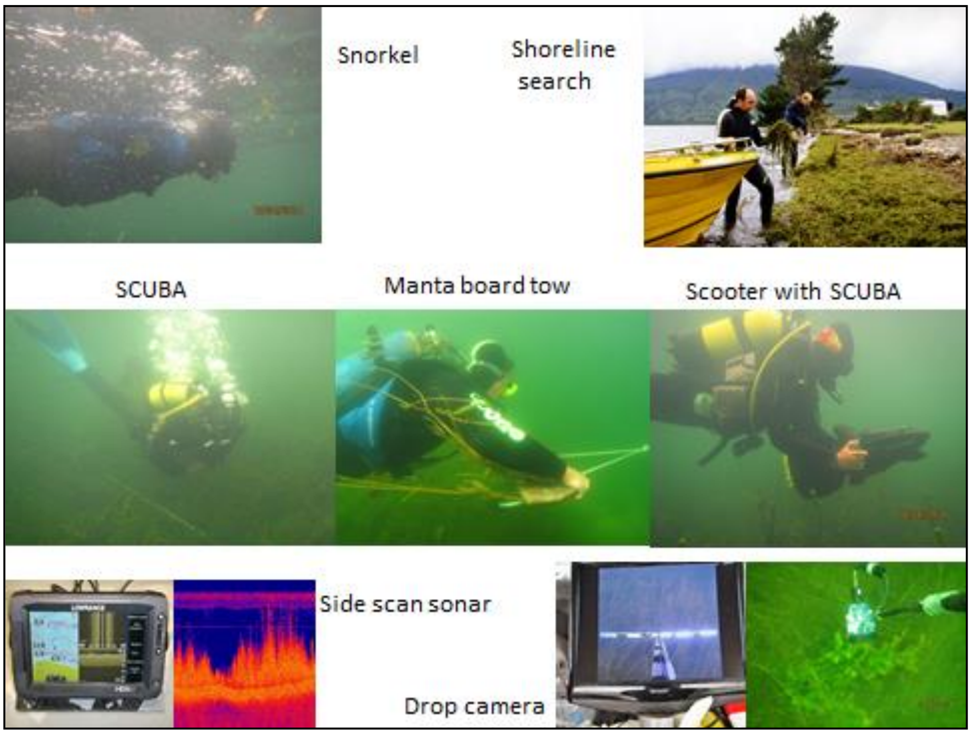
- Natural spread – seed production and adaption for spread
- Recreational craft, trailers, anchor wells, jet motors
- Fishing nets – especially fyke nets, mullet nets
- Contaminated diggers and harvesters
- Coarse fishermen
- Aquarium liberation
- Deliberate planting

There are some high risk weeds like the fringed water lily (*Nymphoides peltata*) which have flattened seeds with little spikes on their margins and they are adapted for spread by ducks. We have had only one field site and two other sites in the country. Fortunately they were removed before ducks could spread them around. In this case the eradication technique was called filling in the water body. The risk was so high that it was probably worth that approach.

Surveillance is carried out by the Bay of Plenty Regional Council who identify the high risk lakes; which lakes have which weeds, which lakes do not have the weeds. They detect new weed incursions, and weed cordons are an important tool developed right here in the Bay of Plenty. There is an awareness programme carried out around these activities.

A research programme in the Bay of Plenty over the last year looked at the best way of detecting new weed incursions. NIWA used totara branches as a surrogate for submerged weeds and had teams of divers either being towed behind a boat or with underwater scooters. It seemed to be the best or optimal method to detect these weed incursions. **(Slide 13)**

Slide 13



The weed cordon at Lake Okataina separates off the main body of the lake from the area where most of the weeds are likely to be deposited either from trailers or other boat parts. **(Slide 14)** In Lake Rotoma the two worst weeds, hornwort and egeria, have been detected within the weed cordon but have not established outside it. **(Slide 15)**

Slide 14

Slide 15

What if you find something? Find out how far it has spread. If there is any opportunity to hold it where it is, and eradication is deemed feasible, undertake a control programme

with hand weeding, suction dredging, bottom lining with opaque material, or in some cases herbicide application could be used to achieve this goal.

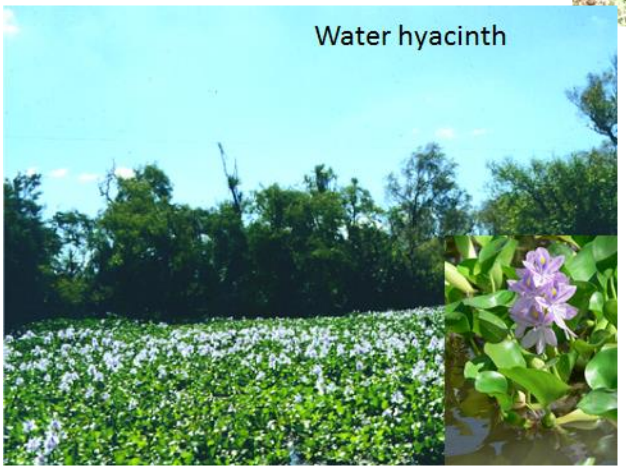
Check, clean, dry is a great message, it was developed under the didymo programme. There is also *Stop the Spread* which was the catch cry in the Rotorua Lakes. Essentially it is the same message from the didymo programme and equally applies to invasive weeds, pest fish and pests we do not have in New Zealand like zebra mussels. The message is out there but it needs to be reinforced. Every year the Council employs students to carry around promotional material, talk to people at boat ramps around the region and raise awareness. BOPRC are also carrying out inspections of ornamental ponds around the high risk lakes. They had detected one of the weeds, water poppy (*Hydrocleys nymphoides*), which had been eradicated from Lake Rotoehu back in the 1980s. We have to look at all avenues where weeds may come from.

There is a real conundrum with effective biosecurity. If it is successful then nothing changes which is ***not*** a great thing to sell politically. If you invest a lot of money to prevent a new incursion establishing you will end up where you started. But for me the way to look at it is to think what could have happened if this work was not undertaken? **Slide 16** illustrates what might have been when US$25 million a year was spent managing hydrilla in Florida. The risk of this is now negligible in New Zealand thanks to the programme outlined earlier tin the talk.

Slide 16

Slide 17

Slide 17 is water solider (*Stratiotes aloides*), a prickly horrible space invader plant that is a notifiable organism, hopefully never coming into New Zealand. We stop things even before they come in. It is also a very popular plant in the trade in Europe.



Water hyacinth **(Slide 18)** is a tropical weed but this is in Paeroa, not exactly tropical, and of course it was growing in Lake Rotorua in the 1950s.

Slide 18

Slide 19 is marshwort (*Nymphoides montana*) in Lake Okareka before it was eradicated by covering the whole area with black polythene. About a kilometre of lake shore was absolutely smothered by this plant.

Slide 19

Other weeds like alligator weed which is not known in the Rotorua Lakes but Bay of Plenty and Waikato are trying to stop this completely dominating marginal areas of water bodies and wetlands. **(Slide 20)**

Slide 20

Slide 21

The worst ranked aquatic weed in New Zealand phragmites (*Phragmites australis*), **(Slide 21)**

Manchurian wild rice (*Zizania latifolia*) **(Slide 22)** and North America's worst wetland weed, purple loosestrife (*Lythrum salicaria*), **(Slide 23)** which could all completely modify the lake shores of the Rotorua Lakes and elsewhere in the country.

Slide 22

This in fact is a photo of Lake Horowhenua before the work started on the management of it there.

Slide 23

Slide 24 is hornwort in Lake Whakamaru and what Mighty River Power have to put up with on the Waikato River hydro dams. Hopefully none of the South Island hydro dams ever have to deal with this thanks to successful eradication work carried out by DOC and MPI.

Slide 24

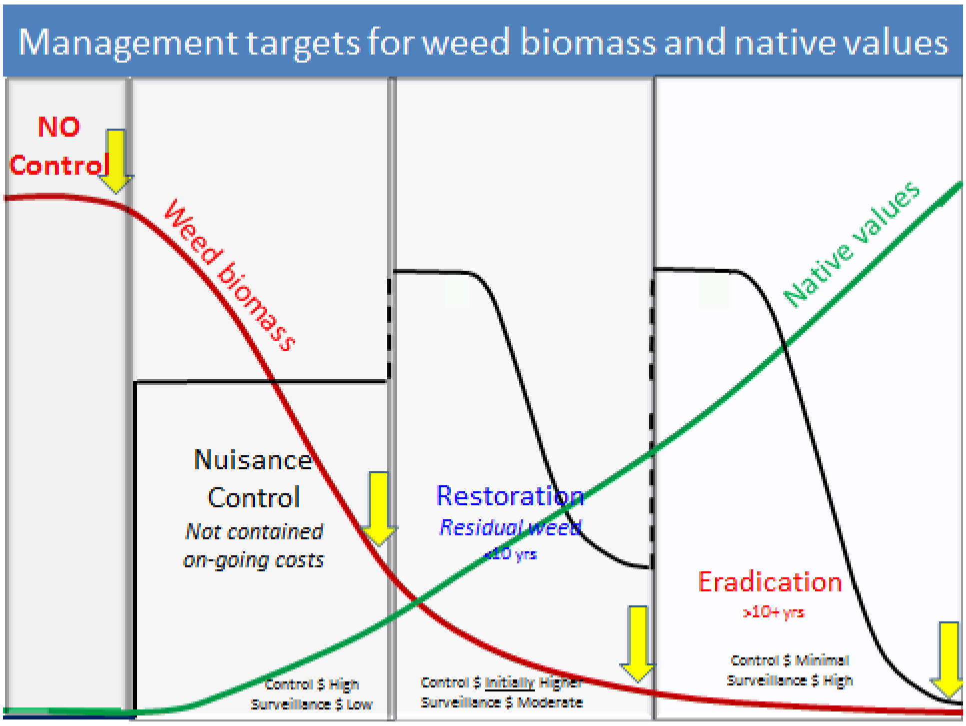
The key points of my talk are:

- Banning the importation of potential aquatic weeds helps keep the risk offshore, but when there is a will there is a way. If someone wants to get something through the border they probably can.
- Banning from sale is a highly effective management tool by restricting the dispersal of potential aquatic weeks. Even with plants kept illegally, the volume is incredibly reduced by the ban of sale, so the risk is reduced.
- Proactive management has been highly effective to date. Maybe we have not advertised it well enough, but funds are limited and memories are short.
- The gains made only require one action or inaction to undo all the good work.

We have worked with the Northland Regional Council to produce a lakes strategy that prioritises their highest value waterbodies as they have a large number of iconic pristine lakes. It is about protecting rather than restoring in this case, to stop weeds and other water quality issues. It integrates all management activities including catchment management and protecting endangered species all under the same umbrella, a holistic management. If you manage water quality there will still be weed problems, it needs to be looked at as a whole.

Current levels of aquatic weed management in the Rotorua Lakes are mostly reactive nuisance control because the funding for that is very low compared to the water quality budget. But scaled up to allow for restoration of native vegetation should be the desired outcome. Deb Hofstra talked about the scaling up of this reactive nuisance weed control using the graph in **Slide 25** and with just a little bit more money invested in herbicidal control we could end up with native plant restoration while still keeping the weeds at a low level. It is achievable but there is a cost involved. It is up to the community to decide their desired outcome.

Slide 25



Finally I would like to acknowledge all my colleagues at NIWA and the Aquatic Plant Group, the Bay of Plenty Regional Council and especially one person in the Ministry for Primary Industries, Victoria Lamb, who unfortunately for the country is no longer working in that organisation. She spearheaded all of those programmes that started in 2008.

QUESTIONS AND DISCUSSION

Don Atkinson, LWQS: From my point of view the challenge today was to find out how we attack these key weeds, hornwort and lagarosiphon in particular. We have not been able to eradicate them but what has been demonstrated is that the toolbox is significantly larger than we have been using. We have not got consent to use endothall here and yet we hear that it eradicates hornwort effectively in the South Island. Our tool box is pretty bare and we need to recognise that and work together on management plans that control these lake weeds properly.

Te Taru White, Pukahukiwi Kaokaoroa Inc: Kia ora, a question to Rohan and Paul around biocontrol and particularly the use of imported insects to fight the weed problem we have. We have heard about herbicides, weed harvesting and so on, but the revelations by Rohan about voracious insects gobbling up a specimen in a matter of minutes, or voracious imported insects roaming around the country, maybe a microscopic Godzilla eating its way through biomass. I know that is a script from movies but it is how a lay person will probably see it. What is NIWA's role in research in that particular area and what are the biosecurity constraints around the importation of non-native species insects to battle the problem we have?

Rohan Wells, NIWA: That will be a combination response from both Paul and me. In terms of funding it was some German scientists who were not even paid but interested in using our facilities, working down here in the off season, that came up with something completely new in the last couple of months and it is food for thought. They will continue working on it. It is interesting because the insect itself is a generalist feeder and if its preference food got down to low levels it could eradicate it because it would still be present in high numbers and be able to move on to other species.

Paul Champion, NIWA: The second part of that question should be addressed to Quentin but I will answer for him. There are really stringent measures needed to show that the species targeted by these imported insects for bio-control are really specific. If there is any damage to native species then it will not get across the border. I mentioned the EPA as the way of bringing in new plants into the country. Landcare Research have managed to bring in a number of bio-control agents for terrestrial species using that EPA system but there are a lot of checks and balances before something can get into the country.

*John Green, LWQS: C*an I describe the situation for spraying of weeds in the Rotorua Lakes and then ask your opinion without getting you into trouble with the authorities? At present we have LINZ, through Boffa Miskell, with a budget of around $100,000 targeting amenity values. With Lake Rotoehu a nutrient budget approach is targeted for stripping nutrients out and that forms part of the Lake Restoration Funding Programme.

We are obviously getting the nutrients down and the Rotorua Te Arawa Lakes Strategy Group is doing a fantastic job on that. Do you think a conflict of funding may cause our Rotorua Lakes to have a problem? Max, were you suggesting that if you have an increase in macrophytes and weed growth, in other words, not dealing with the weeds at the right time, we run the risk of getting an increased load of nitrogen and phosphorus, as with your Horowhenua example. That is, could we actually end up having nitrogen or phosphorus issues in our lakes because we did not spray early enough or at the right time. How do we release funding for spraying? I do not see us having an adequate weed spray plan like John referred to this morning.

I have really enjoyed today because it has shown us that you can plan for weed eradication and that there may be different ways of organising, managing and funding the spraying of weeds. Do you have a view on that?

Rohan Wells, NIWA: If I had had more time to speak the success stories just continue. I discussed with John that I would have liked to include a commentary on management approaches and use Lake Wanaka as an example. How you could have a weed that was wide spread and almost habitat saturated and divide it up into sections and target say the far end for eradication and then have different zones with a buffer zone where you might use a weed spray to reduce it. Gradually over time it would be eradicated. It may be a goal that might not be achievable but you can certainly get it down to a low level presence of weed.

There are quite different management programmes and they require different levels of funding. You need the expertise and knowledge of people who have worked in these kinds of programmes and understand the systems. I will perhaps leave it at that and let Max comment more on the nutrients?

Max Gibbs, NIWA: As I tried to demonstrate with the Horowhenua situation you need to understand the goal to achieve and the consequences of doing it. If you spray hornwort and get endothall as a way of treating the entire lake to eradicate hornwort with several applications, obviously there would be a nutrient release from the plants that occurred at that particular time.

To answer your question – is phosphorus going to come out? You will release phosphorus from the plants, as the plants die and synthesize on the sediment they will cause anoxia and phosphorus will be released from the sediments for one year. The next year those hornwort plants will not come back but we have demonstrated with the weed regeneration of natives will. Once the natives live on the bottom they stop the re-suspension of the sediment and hold the oxygen down low in the water column. The water column is not being smothered by a large canopy of decaying or growing weed which reduces the oxygen in the weed root zones. It is a time phase; either do it in stages or as one foul swoop and know that there will be a cyanobacterial bloom. Make sure you are not in the lake this coming year because all those nutrients will be released.

We need to understand the problem and the mechanisms. You do not go in and spray a whole lake without understanding that there are consequences in doing so. But I think we have demonstrated that it is possible to manage these things with the new toolbox.

Merehira Savage, Te Arawa Lakes Trust: May I commend all of the speakers for a very informative day. It is fitting for this session to move forward. I wanted to take the comment from Hon Dr Smith speaking about collaborative partnerships and finding a collective solution. Rohan you voiced that there is no one best method. We have listened to the speakers all individually saying this is the best recommendation, best method or approach with this specific weed or collective weeds. I am not sure who is going to comment on this and I agree with you Rohan, all management agencies should be on the same page. Could it be that all the speakers today sit in one room and look at a collective management plan simultaneously? I am aware it is going to take a lot of mechanical planning and structure to achieve, but your individual projects would be completed in time and that would assist you all collectively, kia ora.

Paul Scholes, BOPRC: That is a great idea and what this forum is for. The Hon Dr Smith mentioned with the National Policy Statement for Fresh Water that these conversations

are starting to happen. Council is going out to the communities asking what they want and bringing in experts to say what our best approach is and what tools we need in the toolbox. It is starting to happen collectively across New Zealand and has been a long time coming. As the Minister said, it has been sitting on central government's agenda for a couple of decades, but I think progress will be made. The aquatic weed situation has been at the bottom of the agenda so it is just a matter of getting it up there in high lights. Hopefully forums like this will do that.

WRAP UP SUMMARY OF THE DAY

John Madsen

I enjoyed hearing from Sir Toby and one of the things that really stood out from his comments was including all stakeholders. It is a great mistake not to hear from everybody and to ensure that everybody is included. If you overlook somebody that is the person most likely to object to whatever it is you finally decide to do.

Professor Hamilton demonstrated the importance of having good information on the lakes being managed, understanding the trajectory of those lakes and the causes of degradation as well as looking at which lakes are improving. He also made the comment that the morphology of the lake affects water quality and by implication we often think that pristine means the lake will be oligotrophic but that is simply not the case. Many lakes are not naturally oligotrophic, they might be mesotrophic or even eutrophic. Historically their water quality may never have been clean and they may naturally be very productive lakes.

The message I wanted to convey was that effective applied research can lead to long term management options and in fact control the population of invasive weeds. Also that prevention is more effective than waiting to see what weeds come and it is better to manage early than later on.

Dr Clayton pointed out that the status of the weeds is not necessarily a direct reflection of the water quality. Lakes with good water quality can have bad weed problems, and that has certainly been my experience as well. He indicated that native plants are very desirable for lakes which I totally agree with. The problem is that we introduced plants that created the problem and there are a number of threats to all vegetation including degradation of water quality.

The Hon Dr Nick Smith commented about the tragedy of the commons. While we may not all own the lakes, we are all responsible. It is probably wise as a foreigner not to comment too strongly on the direction your country is taking because that is your decision not mine. But I appreciated his comments and in particular that strong science underpins the decisions being made, and I wish that was more often the case in my own country. While I think good science is important the last thing I would advocate is a technocracy leaving it to the experts. It is important that all stakeholders understand at least the basics of the issues and make an informed decision.

Mary de Winton said that invasive weeds are the problem and that humans are mostly the cause of moving the weeds around. As my wise philosopher Pogo would say, 'That we have met the enemy and they'd be us.' She also said that nutrient enrichment or abatement will not solve the weed problems; they can access nutrients in the sediment, not necessarily just the water column.

Richard Mallinson talked of the harvesting project to remove nutrients. I think you have to devise your own goals and solutions for how to meet those goals. I wondered how you could separate the alum effects from removing nutrients from the harvesting?

Dr Paynter talked of biocontrol and noted that the hornwort programme must start from scratch. My unit also does biocontrol on aquatic weeds and our budget for just the biocontrol component is about $A1 million a year for about 4 to 6 insects. We plan to take anywhere from 10 to 20 years. They are expensive programmes but then that is the United States Government who specialise in wasting money.

Dr Hofstra talked about the herbicide tools. I liked your graphics and your drawings are much better than mine. She said that there are different goals to weed management; simply controlling the nuisance to keep it at some acceptable level versus controlling to ensure the natural restoration of native plants or to eradication. Moving from one step to the next step takes more input and effort.

Dr Gibbs said that lakes need aquatic macrophytes. I think that looking at the tools and trying to determine which tool is best for your given situation is very important.

Paul Scholes looked at nutrient release, trying to explain the phenomenon. Certainly any management is going to have other effects and sometimes they are unpredictable. I was curious why the algal blooms happened 3 months after a diquat treatment because the plants seem to fall apart much more quickly than that period of time. When I have used diquat I typically see complete degradation of plants within 1 to 2 weeks.

I liked Rohan Well's statement, 'The learning never stops'. We keep finding new technologies and tools. I also enjoyed your gaze into the past; we often forget things that have been done in the past. The use of sodium arsenate was used quite extensively in the United States. The toxicity of the herbicides we now use has really changed and that would be a good contrast right there.

Paul Champion looked at predicting which species might be the next problem which is a very effective tool. I know that the model you presented has been examined extensively. You mentioned the paper by the group in Florida that examined a number of different risk assessment tools. These tools are very important if we are to prevent the next introduction of a major weed.

That is a pretty precise and quick overview of the presentations today. I want to leave you with the thought that while it is important to have scientists and other technical experts give you their understanding of the causes and possible solutions it is really up to the stakeholders to make a decision rather than leaving it just to the experts.

Session Five : Ecological Health of the Catchments

SESSION CHAIR – Mayor Steve Chadwick, Rotorua Lakes Council

THE IMPORTANCE OF RESTORING THE ROTORUA LAKES

Mayor of Rotorua, Hon Steve Chadwick, JP
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Steve is the Mayor of Rotorua, a New Zealand city that is world renowned for its Maori culture, geothermal and spa heritage; and for its forests and lakes. Previous to being elected as the Mayor of Rotorua, Steve was a Member of Parliament in the New Zealand Government (1999-2011). During this time, she held the portfolios of the Associate Minister of Health, Minister of Conservation and Minister of Women's Affairs. One of her proudest achievements during her time in government was securing funding ($72 million) to undertake a water quality improvement programme for the Rotorua Lakes. As Mayor of Rotorua, Steve is driving an ambitious programme that will ensure that Rotorua reclaims its status as a world-leading health spa, resort and recreation centre based on its natural environment, and creative spaces.

TRANSCRIPT
Tena tatou katoa nga mihi nui kia katou and good morning. It is a thrill to have been invited by LakesWater Quality to address the Symposium because I have never done this before. It is lovely to be here with Regional and District Councillors because we do this together.

In November last year the Rotorua District Council resolved to change our trading name to Rotorua Lakes Council. This was passed at Council and caused a stir; everything I do seems to cause a stir because we did not consult the wider community. In retrospect I still believe it was the best decision to keep at the Council table.

This was deeply significant and is already proving to have a positive impact. The tourism marketing sector love it and slowly the change is being accepted. The nay sayers, and there were many of them, could not work out why. Why bother with it! That could be accused of being stuck in the mud. Slowly they are starting to understand that we are the lakes district of New Zealand. They are not yet embracing the change, but slowly over time they will understand it.

The rural sector was not slow in telling us that they again felt dropped off the Council radar and devaluing of their contribution to the wider district and economy. You, the science community, and lake side dwellers gave the most support as evidenced during the latest round of ratepayer and LakesWater Quality AGMs. The name is purely symbolic and it is a better description of what we are – a lakes district of many lakes; 14 that are all connected within a catchment in a volcanic caldera. What a sense of place that is internationally when you Google Rotorua. Rotorua District Council did not tell you much but Rotorua Lakes Council tells you about geothermal and water.

My first impression when I came back here from our OE in the United Kingdom in 1975 was a place of incredibly deep beauty. We explored and walked the edges of the lakes, looking for historical rock art, waterfalls, walking tracks and learned the historical tribal links with the lakes. I love the early artists' impressions of Rotorua, Rotoiti and Tarawera

and collected images of Burton photographs at Okere Falls and the pink and white terraces; such was my love of the place aesthetically. We enjoyed a bit of boating and skiing with friends and visitors but we are essentially land lovers. We hated the algal blooming of the lakes and I loathe trout flies. Paul East was our MP and he was attempting to gain national interest in the science of the district from a catchment perspective. I then became a councillor and lauded the bardenpho system of wastewater spraying in the forest and now I am in charge with finding a solution to that challenge.

Then along came Ian McLean who was the Chairman of the LakesWater Quality Society when I was first an MP in 1999. He was deeply troubled and worried as was the society about the water quality and he introduced me to the facts of the tipping of the quality of our lakes' waters. Council at that time was not that responsive to the science and the ecology of the lakes, but in response to Ian's call we decided that Graham Hall then as the Mayor, John Cronin as the Regional Council Chair and Anaru Rangiheuea, Chair of Te Arawa Maori Trust Board, and I would go off to Wellington to propose a collaborative programme to be part funded by the Crown, Regional and District Council. Minister Marion Hobbs, my friend, sent us packing and told us not to return until both Councils could work together. It was quite wise really, quite schoolmarmish.

Since 2002 we have all learned together how to gain the attention of the Crown and that was the start of the $235 million programme. I now see the lakes quite differently from that aesthetic lens and understand the complexity of this wonderful district in which we live. My experiences are not unique, the chance to enjoy our lakes is open to us all and we know that our lakes contribute to our sense of place and our economy. Our city and a number of communities are built around our lakes. When we opened an ideas shop at the end of last year there are some city dwellers that cannot get out to the lakes and asked for more bus services. They want to get out and enjoy the lakes. One young mother talked about wanting to take her child out to the lakes and have koro teach her child how to catch a fish, but as a solo parent she is unable to do that. There is a bit of disconnect between the city and the lakes.

We promote ourselves to the rest of New Zealand and internationally as having outstanding places to play and for our commitment to sustainability. We have set up a sustainability portfolio led by Janet Wepa and she is charged with a very big job ahead of her. We have restructured Council to support a councillor led portfolio on sustainability and watch this spot at the Local Government Conference. Rotorua more than most cities of our size contributes to the world's perception of New Zealand.

In preparing for this 2015 Symposium I was reminded of the 2001 Symposium 14 years ago. I particularly remembered the paper by Gerard Horgan on the social and economic importance of the Rotorua lakes. Gerard used trout fishing as an example of the economic value of our lakes. He estimated that at the time trout fishing primarily in the lakes was estimated to bring in some $25 to $35 million. Even today these are huge numbers and this was quite an eye opener for us all back then. It is interesting how you take something for granted that is simply amazing sitting right on your door step. For a long time that was the case with many us on the lakes.

In 2015 we know that the restoration of our lakes is hugely important to our sense of peace and our local economy. We have reached another landing place, there is so much more that we have to do especially with the unfunded lakes and we need a restoration plan for Tarawera and Mamaku which we have flagged in our long term plan.

But there is an even greater debate to be held to consider the value of water. In 2013 the International Water Management Institute produced a report on water, agriculture and food security which stated that while there remains a great uncertainty as to how climate change will affect any given locality it seems likely that it will have a profound effect on water resources now and in the future. Agriculture and food security depends on managing water, a finite resource, but variable in time and space. I believe that is the next national debate. Water underpins sustainable development and therein lays its value.

There are really innovative initiatives underway in our district that we are incredibly proud of. The Te Arawa Lakes Trust is leading a project to develop a Te Arawa cultural values framework to help explain why water is important to the Te Arawa tribes. Sir Toby Curtis said publicly that the project is aimed to make sure that everyone is included in the right to water. Since 2012 we have another wonderful collaborative effort between Ngati Rangiwerewahi, Te Arawa Lakes Trust, Bay of Plenty Regional Council, Fish and Game, Department of Conservation and NIWA and the Hamurana Springs Incorporated Society. It has led to a restoration plan to further prevent the decline of the koaro, a native fresh water whitebait species. This is the way we want to work in our community in the future.

A few weeks ago I attended a hui, along with 50 others, all with an interest in our Puarenga Stream and its upper tributaries. Councillor Wepa will lead the co-ordination with Regional Council and the community in the development of a plan for the Puarenga. The purpose of the hui was to share information on the health of the stream, acknowledge what has already been done and what is being done to revitalise the stream. They invited the community, Waiariki, stakeholders and other people interested in this stream and upper tributaries to come along and provide comments on their vision of what the stream should be like. To me the conversation that night expressed how we value our waterways in Rotorua and a giant leap from the original focus which was on the lakes only, not on the tributaries feeding into our lakes. It was heartening to see first-hand who attended this meeting. The variety of businesses and community stakeholders who recognise that the health of this stream impacts on themselves, our community, our businesses and our lakes, they understood the complexity of that picture. I think that those who attended the hui came away with a real sense of ownership. I have always worried about our city dwellers getting that ownership of the Puarenga as well as a sense of purpose to facilitate change.

I want to acknowledge Craig Morley from Waiariki who got the partners together for us and he is also the chair of our Keep Rotorua Beautiful. This sort of community action and engagement is a win win for everybody. It is healthy for our waterways and also for the wellbeing of our people. These 3 examples show what can be done through partnership. Partnership is the life blood of this Council. Our role is only one of guardianship. Kaitiakitanga, guardianship is our responsibility, it is a shared responsibility and that is our next journey, kia ora koutou.

NEW ZEALAND'S INDIGENOUS FORESTS - THEIR STATUS AND DRIVERS OF CHANGE

Dr Robert Allen
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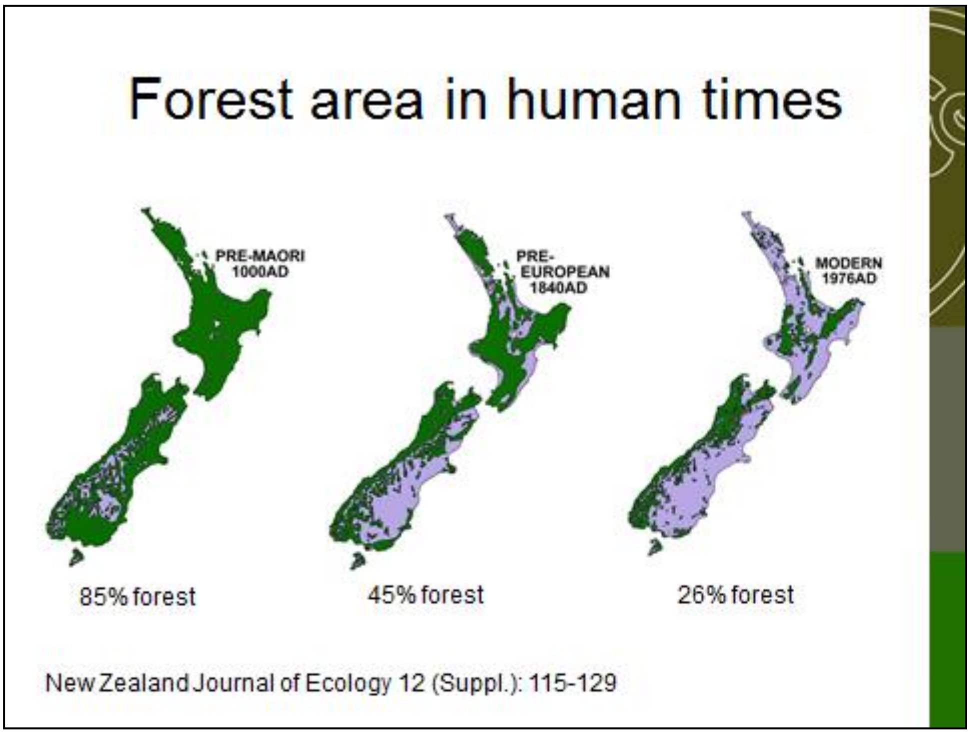
Rob grew up in Galatea, studied forestry (University of Canterbury), worked as a forester for the New Zealand Forest Service and then undertook a PhD (University of North Carolina) on the biogeography of Rocky Mountain forests. Returning to New Zealand he researched invasive species impacts, forest dynamics and biodiversity management while working as a Scientist, Science Team Leader and General Manager at Landcare Research. He has co-authored >130 peer-reviewed science journal publications and several books (e.g. Allen, R.B., Lee, W.G. (eds.) 2006. Biological Invasions in New Zealand. Springer, Heidelberg. p.457). He has also worked in Germany, China, Tonga, USA and Chile. The research in Chile focusses on forest dynamics on Tierra del Fuego and the impacts of invasive animals. He has been on several governing bodies (e.g. Australian Research Council), panels (e.g., Marsden Fund) and facilitation groups (e.g. for Te Kotahi ā Tūhoe).

ABSTRACT
New Zealand's remaining indigenous forests and shrublands are of immense cultural, environmental, and economic significance. A representative plot-based sample of these forests and shrublands has recently allowed an unbiased depiction of their composition and structure. This is necessary for international reporting, performance assessment and management prioritisation. Their composition, structure, and function are driven by a diverse array of factors, many of which are complexly interrelated. The imprint of disturbances is pervasive and it is necessary to understand disturbances to interpret human-related impacts. For example, understanding impacts of exotic browsing mammals is only possible within a context of forest ecosystem development and tree demographic processes. There are now extensive areas of shrublands successional to forest, often composed of mixtures of indigenous and exotic species. These shrublands expand the opportunities for ecosystem services from, for example, carbon sequestration to water quality. An increasing area of indigenous forests and shrublands are managed for distinctive Māori aspirations that include sustainable use.

TRANSCRIPT
I am not going to talk about wallabies specifically, but rather things relevant to wallabies. Some of the topics will be quite general and hopefully attractive to those who are not into forests. In some aspects I will get quite specific which will appeal to those who are interested in forests and may be of interest and more relevant to the wallaby.

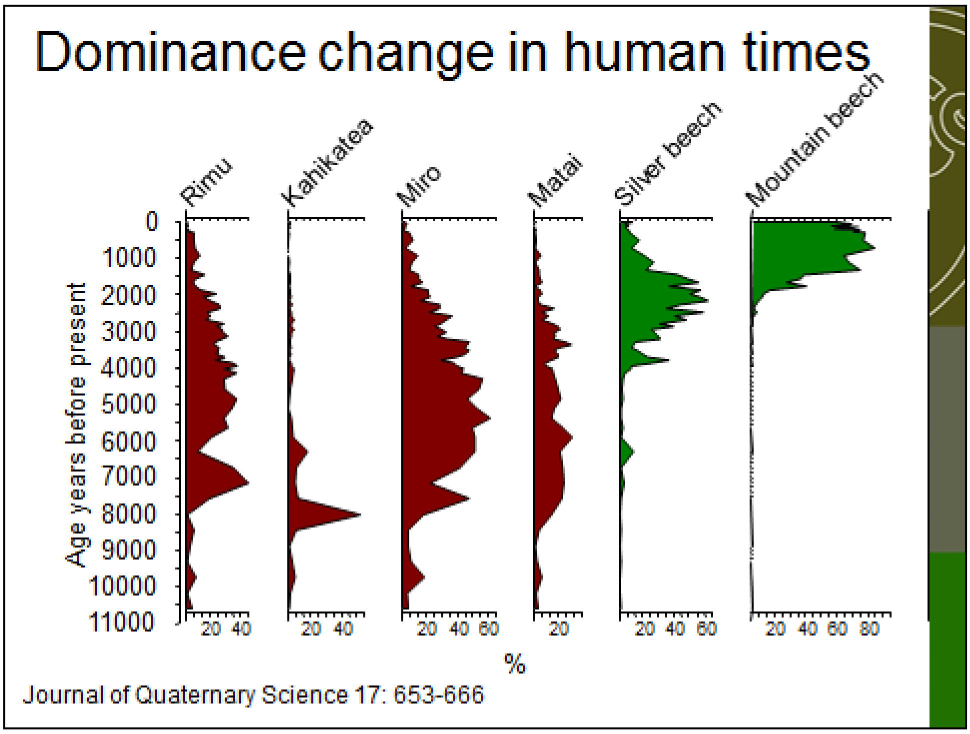
There are two parts to my talk - status and trends in indigenous forests and drivers of change. Probably the most profound change in the county's indigenous forests has been the loss of forest area. **(Slide 1)** In human times we have gone from 85% forested, marked in green, to 26% forested. We have lost the forest particularly in the drier eastern areas and at lower elevations.

Slide 1



People are interested in the changes taking place in deforested areas, but there is considerable change taking place in forested areas as well. One piece of evidence comes from pollen analysis. People who study pollen deposition in bogs can age the time it was deposited and build up a history of vegetation change. **Slide 2** is a pollen diagram from Southland showing time on the left and moving up to our present, and the percentage of pollen across a range of tree species.

Slide 2



In the last 1,000 years mountain beech has come to dominate this forest. In the 1,000 years before that they were dominated by silver beech and before that a range of podocarps**.** So in the last 3,000 years there have been dramatic changes in the composition of the forests unrelated to human impacts. Looking at matai, one of the podocarps, it is only 5 generations in 3000 years and so dramatic changes at short time scales in terms of the trees but of course not in human time scales. These background changes go on quite commonly when looking at history of the forests.

To summarise current forest and shrubland:

- 7.3 million ha (26% of area) of indigenous forest
  - 2.0 million ha of beech-broadleaf forest
  - 0.4 million ha of kānuka forest
- 1.5 million ha (6%) of shrubland
  - 0.5 million ha of bracken-gorse-exotic grass
- <0.001 million ha (< 0.004%) of planted indigenous forests[1]

We have been trying to plant indigenous forests for a long time. You will find in Roche's book on the History of New Zealand Forestry[2] large efforts to plant areas of indigenous forests were made in the 1880's and 1890's. Within the indigenous forest area are considerable beech forests, because they are left in mountainous, wetter areas. We also have large areas of kanuka, bracken, gorse and exotic grasses that are often successional back to forest. These are large areas naturally going back to forest and I will come back to that a bit later.

Slide 3

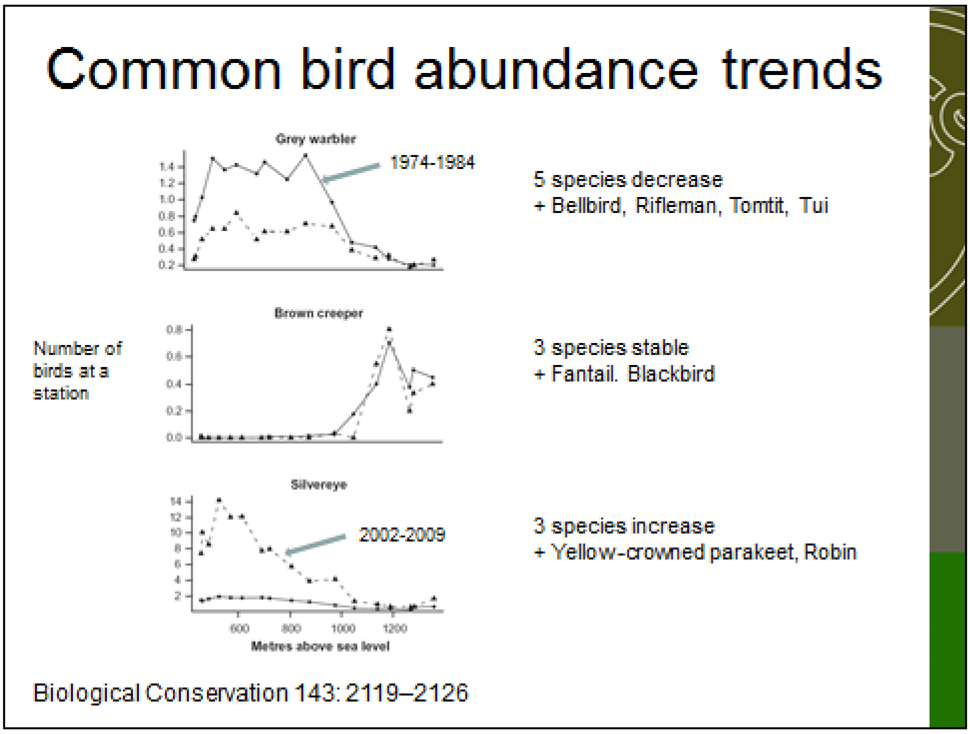
[1] Applied Vegetation Science 14: 505-523
[2] Roche, Michael; (1990) *History of New Zealand Forestry,* GP Print Ltd, Wellington.

Slide 3 looks at bird extinctions. The first birds here; moa were a large herbivore abundant in our forests, up to 250 kilograms for an individual bird. We were faced with a 400 year period of no large herbivores in our forest before we introduce others. The Haast's Eagle was a 15 kilogram bird with a 3 metre wing span which ate moa and many of the other larger birds. There was a South Island goose, a 20 kilogram bird that was flightless. North Island also had a goose but it was somewhat smaller than the South Island one.

Around 40 bird species have become extinct in human times, which is 30% of 131 bird species. In pre-European times they were large birds and in European times they were flightless birds. There are many reasons for the decline in birds. The loss of 75% of the forest was largely through fire and the odd feather was singed. Not only did we have fire as a factor leading to extinction, but also disease, fragmentation of habitat, small populations and predators. With around 2,500 native plant species we have lost one; the point being the loss of a very few plant species in comparison with the birds.

In European times we have lost 34 land bird species and 17 land bird species have arrived naturally, either flown or blown here. This emphasises that the role of the split up of Gondwana in New Zealand's isolation has been questioned. The New Zealand biota is quite new, often less than 5 million years since the arrival of the ancestors. Gondwana was 70 million years ago, so immigration has always been a feature on longer time scales.

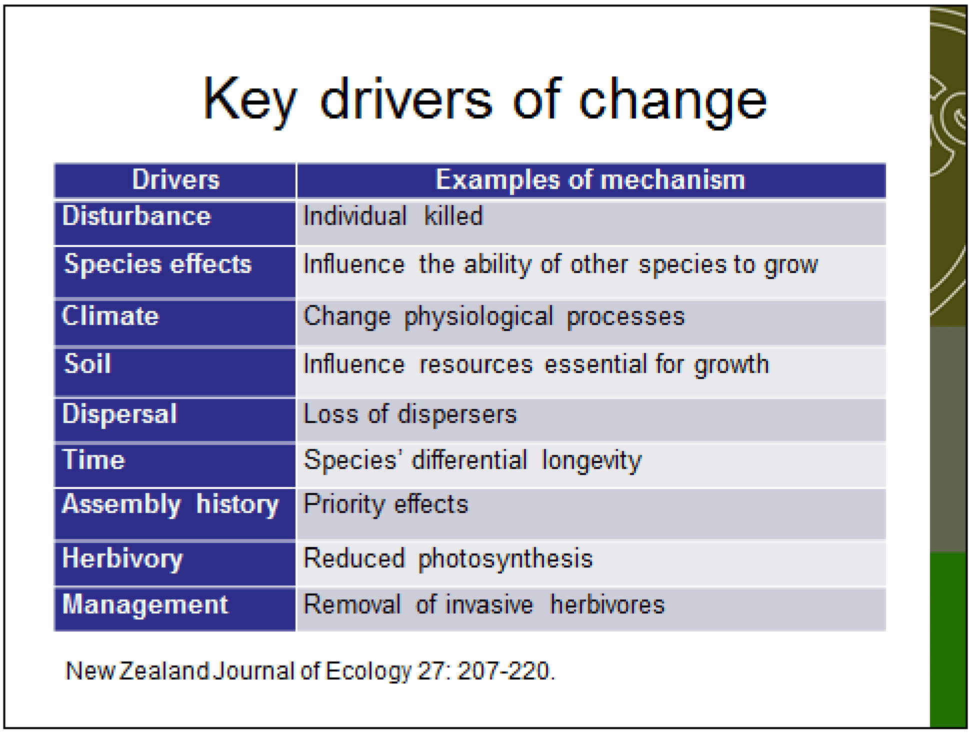
Slide 4



On shorter time scales we have very little information about the trajectory of bird communities for any length of time. **Slide 4** is one of the few studies on community level changes in bird abundance. It is from a ridge in Nelson Lakes National Park and counts the number of birds at a recording station. It shows the elevation going up the ridge. In the 1970s the grey warbler was more abundant at low elevations than between 2002 to 2009 and the other line indicates that this bird species has declined at low elevations. The silver eye has become more abundant at low elevations than it was back in the 1970s. Some

bird species like the brown creeper are high elevation species and have not changed in the last 30 years. Overall 5 species have declined, 3 have stayed the same and 3 have increased, one being the yellow crowned parakeet. We have different trajectories for species taking place in different parts of the landscape.

Slide 5



I have talked about status and trend but the topic that interests me most is key drivers of change and they are many and varied. **(Slide 5)** Many people study disturbance, an event that kills trees. Others have studied the effects of management. But few people have studied things like assembly history or species effects and yet they are as important in driving change as the more studied drivers of change. In sympathy with past work I am going to go with examples of disturbances as a driver of change and management but I do not want to belittle all those other factors, which to include would turn into a one day seminar.

Disturbances are pervasive and varied. In the South Island people are obsessed with glaciation as a remover of forests and landslides initiated by earthquakes. In the central North Island people are obsessed with volcanic eruptions in the long time scale in terms of dictating forest pattern and dynamics, and flood deposition. There are also climatic events like drought and wind, or fire, pest and diseases.

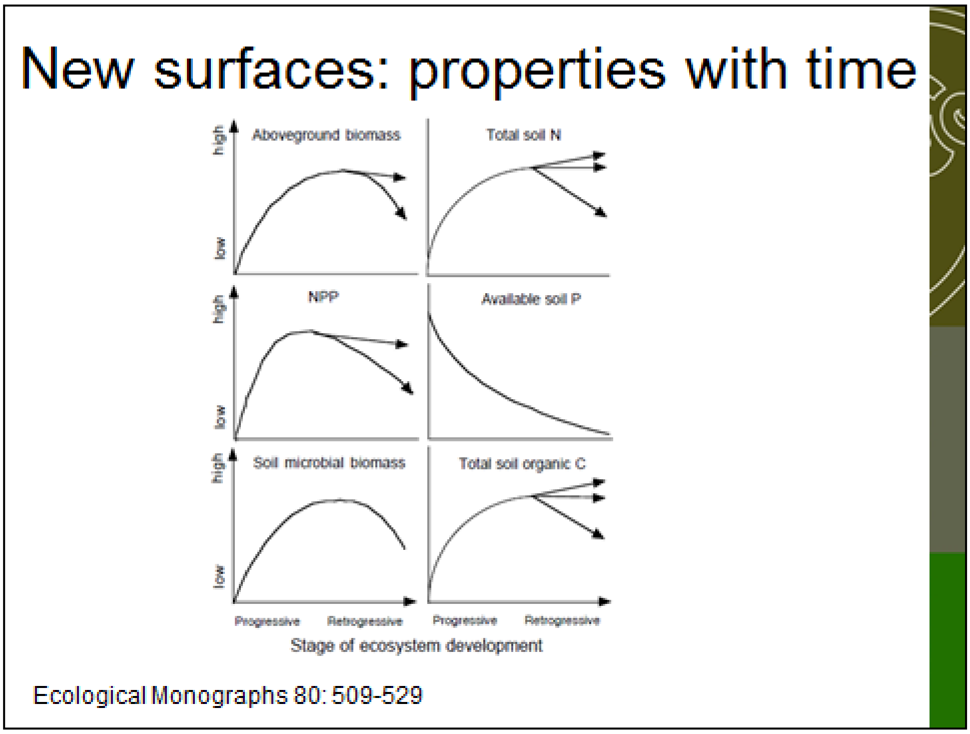
The impact that could be caused by these events is the creation of new mineral surfaces and the example in **Slide 6** is from a glacial recession in the South Island, leading to a fresh mineral surface with colonisation by plants.[3] There is an increase in biomass or a progression to a tall statured forest and in the final stage nutrients are lost from the system and the stature becomes less.

[3] Ecological Monographs 80: 509-529

Slide 6

This is also found on sand dune successions, volcanic eruption induced successions and has recently been summarised as a set of ecosystem properties through time (**Slide 7**). All else being equal these processes are occurring everywhere. There is a build-up in above ground biomass and in primary production. I want to focus on total soil nitrogen which accumulates and soil available phosphorus which declines. On a fresh mineral surface such as landslide surfaces or alluvial fans there is high available phosphorus and this creates opportunities for surface transport of phosphorus and movement in soil solution. This should be reflected in background patterns of stream chemistry to some degree but there are also other relevant processes.

Slide 7



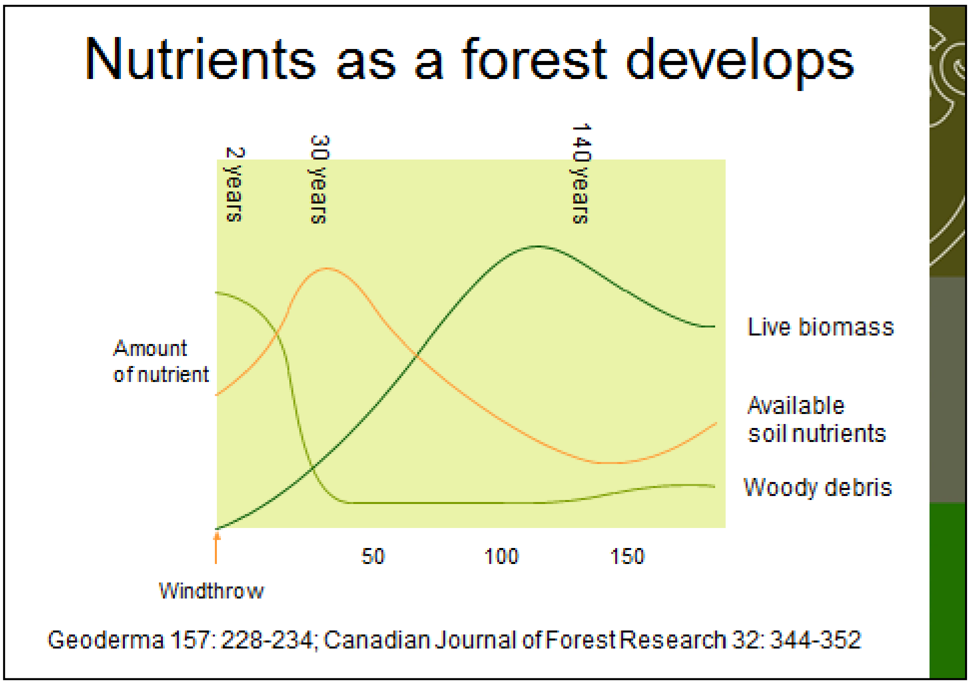
This is fundamentally altered where the disturbance leaves the organic material on the landscape, and **Slide 8** shows where a wind throw has put woody debris on the ground. The middle picture shows the woody debris quite decomposed at 30 years with young trees and then to the right more mature trees. This is a common sequence where you have wind throw. We have a set of soil nutrient availability trajectories taking place here.

Most of the nutrients are stored in the dead woody debris initially. As that woody debris decomposes those nutrients become available in the soil. Then as the biomass in the forest builds up, the nutrients move from the soil to the live biomass.

Slide 8

Slide 9 shows the amount of nutrients for each of these trajectories. Again we see declining available soil nutrients over much of this development sequence, suggesting that there will be patterns in soil solution chemistry consistent with this forest development pattern. In some of the forests around the lakes there will be even aged forests with soils developing in this way.

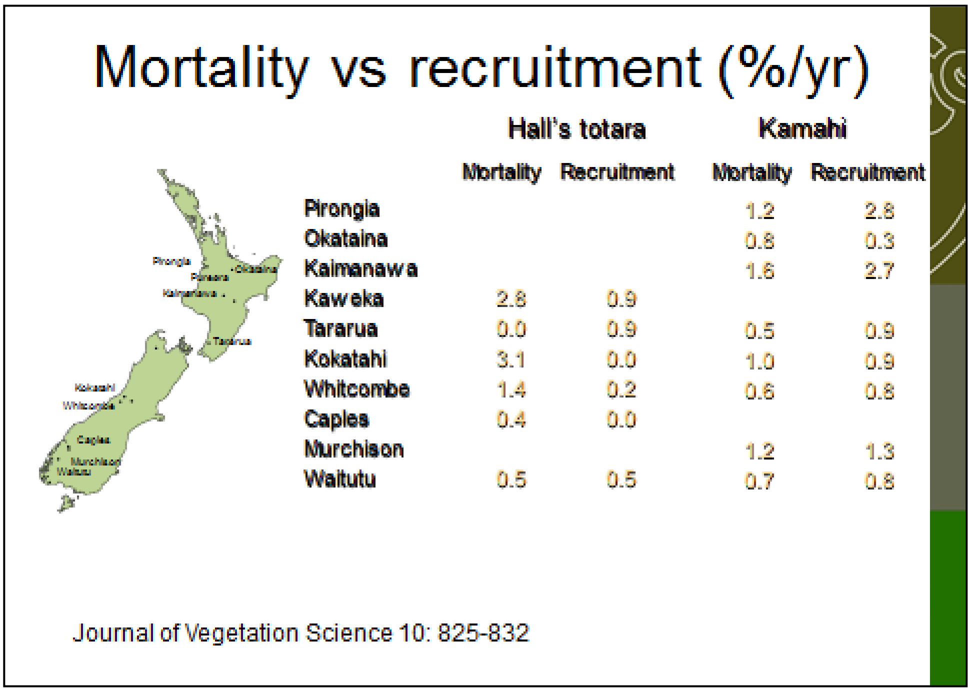
Slide 9



Slide 10 shows locations around the country where permanent forest plots have been established with tagged individuals to calculate mortality and recruitment. At each of these locations the sampling is representative, not biased. The mortality for Hall's totara in the

Kaweka Range exceeds recruitment. In the Tararua range the recruitment exceeds mortality. At Okataina kamahi mortality exceeds recruitment and in the Kaimanawa recruitment exceeds mortality. It indicates that the balance between mortality and recruitment in different locations around the country is varied, implying that the processes of nutrient and biomass dynamics are different in each location.

Slide 10



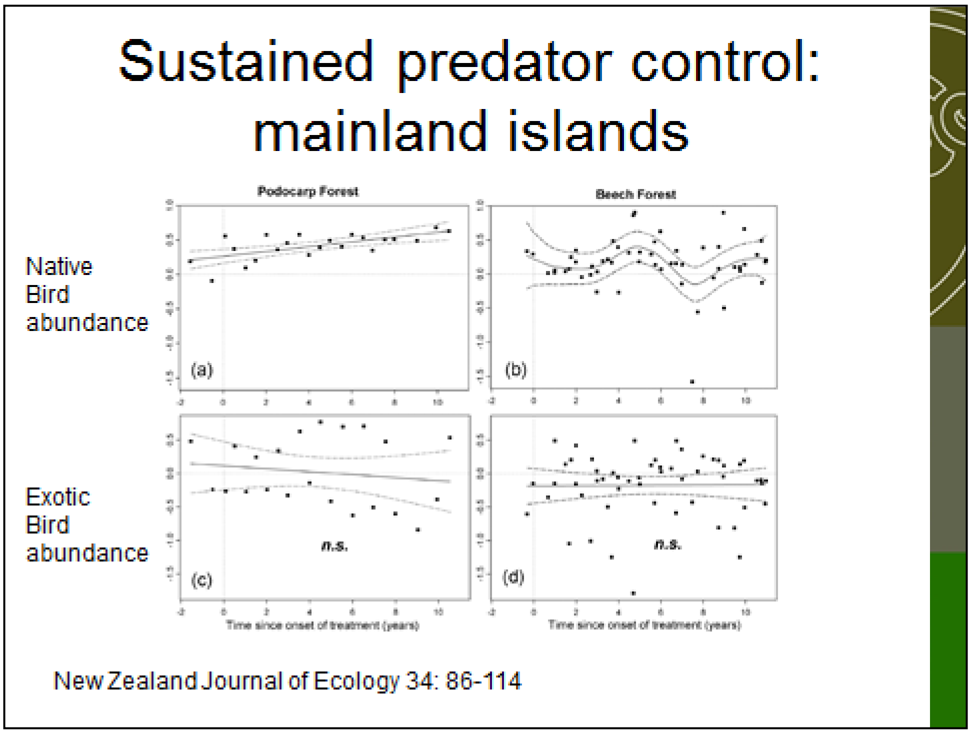
There are two ways that we manage our forests:

Threats
- Fire
- Invasive species
- Climate Change
- Fragmentation

Services
- Timber
- Water quantity and quality
- Carbon

Slide 11 is a study from mainland islands around the country looking at the impact of management of invasive species - as predators have been removed, as much as they can be. Two of the locations were in the podocarp forest of North Island mainland island sites, and two are beech forests in South Island sites. The graphs record the native bird abundance. In the North Island podocarps sites there is a slight increase in native bird abundance over the untreated area and no trend in the exotic bird abundance. Whereas in the South Island beech forests after 10 years of mainland island predator control there is no trajectory in native bird abundance over the whole period. We do have an oscillation in native bird abundance which is related to resource availability and no pattern in exotic bird abundance. So we have varying patterns around the country depending on the nature of the system.

Slide 11

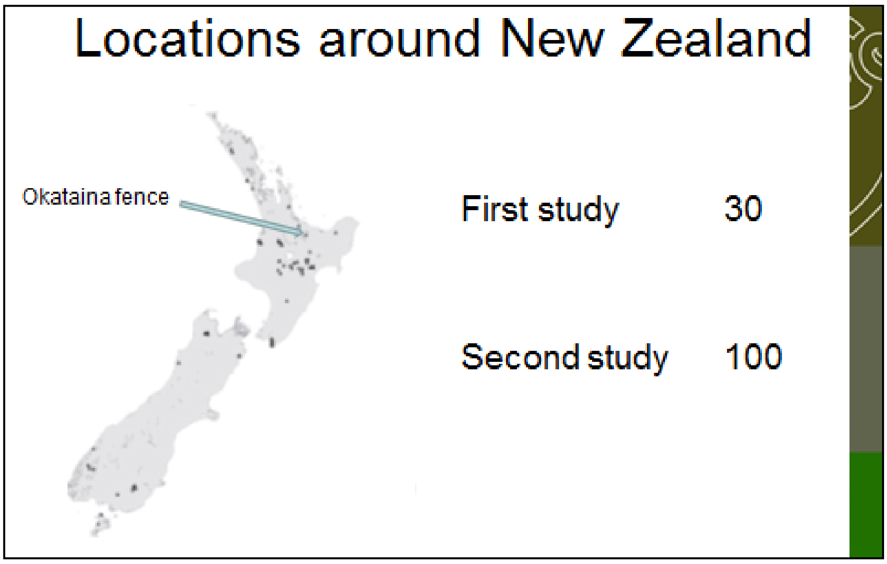


The second example of management is herbivore removal by fence plots, one is shown in **Slide 12** in Te Urewera. There are two studies I will talk about, one using around 30 exclosures throughout the country and one using around 100 exclosures throughout the country as shown on the map, including one Okataina site. **(Slide 13)**

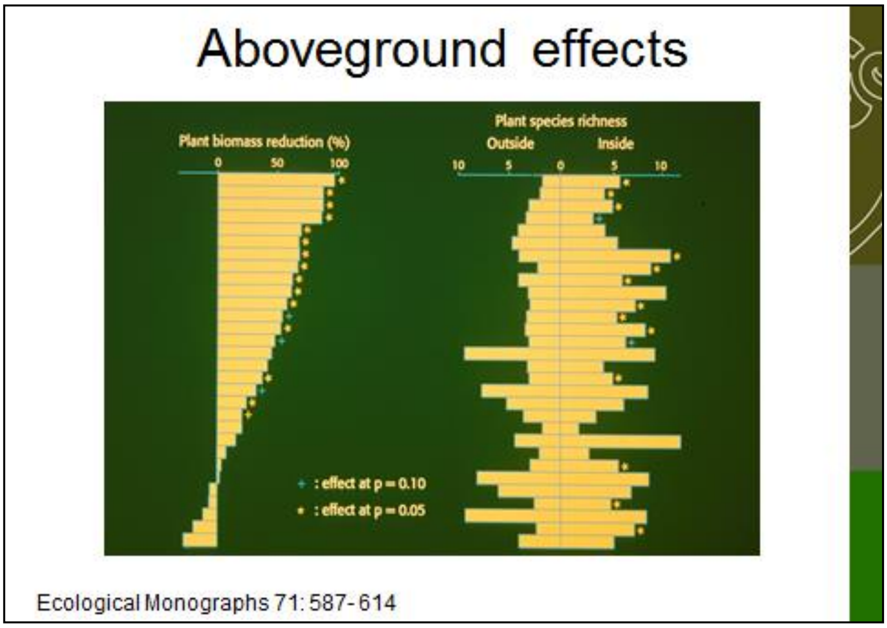
Slide 12

A comparison was made of forest ecosystem properties, both above and below ground, at one point in time after the exclosure had been established. **Slide 14** shows on the right hand side plant biomass reduction with a horizontal bar for each exclosure. Bars to the right show there is more plant biomass inside the exclosures, and the bars to the left, and at the bottom of that diagram, indicate more biomass outside the exclosures. The exclosures (horizontal bars) are ranked from the most biomass increase inside to the most

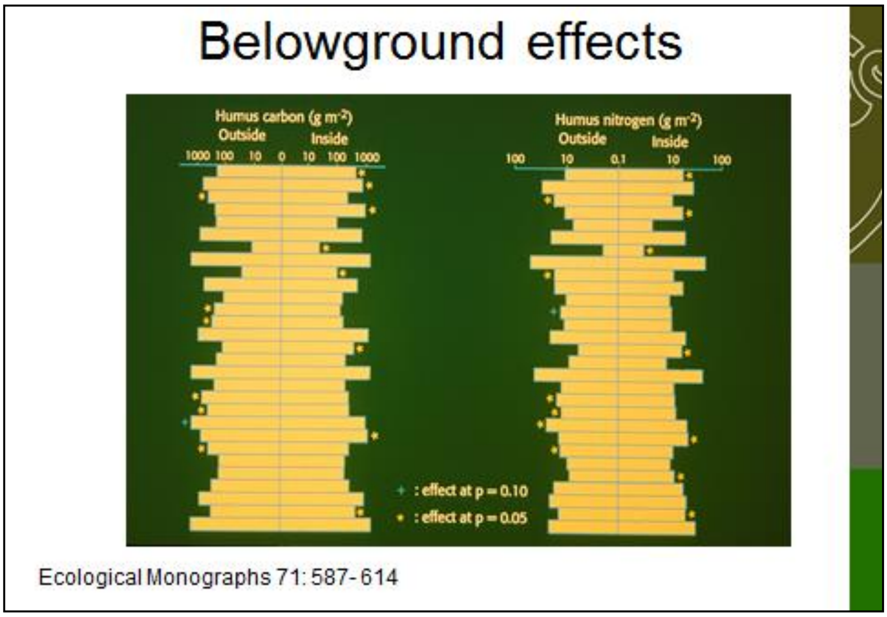
Slide 13



Slide 14



Slide 15

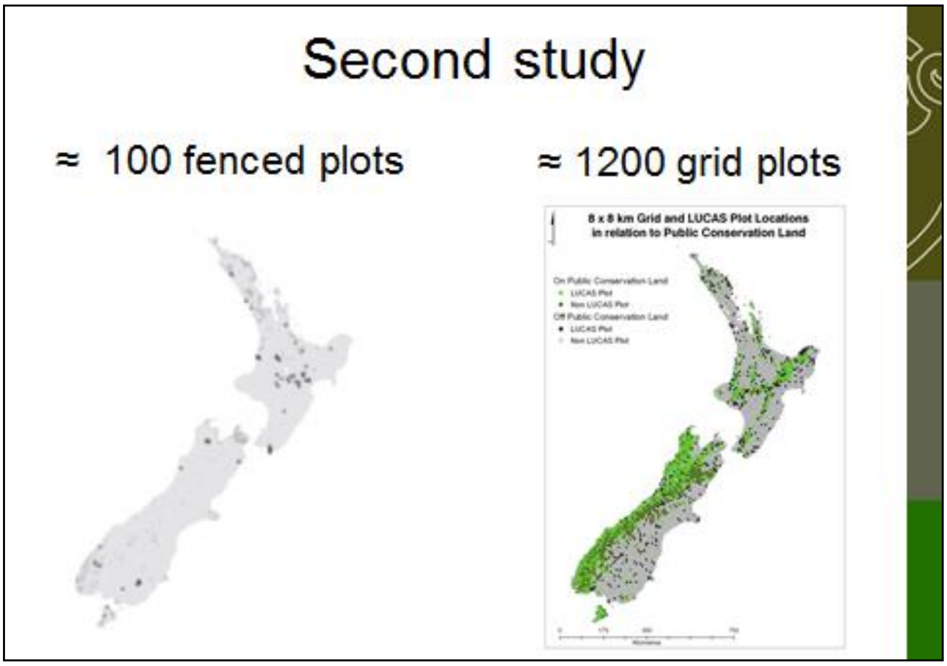


increase outside. Around 50% of the enclosures have statistically more biomass inside than outside. Looking at plant species richness on the left hand side, there is often statistically more species inside than outside the exclosures (That is the asterisk against the bar), but the order is unrelated to the biomass change effect. So where there is little above ground biomass effect you can have a significant species richness effect.

Slide 15 shows the below ground effect of exclosures on humus carbon inside versus outside. Some exclosures have more humus carbon inside and others more outside. There is no pattern related to the above ground response suggesting that it is not ordered by the above ground biomass pattern in the previous slide. So below ground is decoupled from above ground. Similarly, the pattern with humus nitrogen, sometimes has an increase outside, sometimes inside. It is important to recognise that below ground responses to herbivore removal do not always mirror above ground responses.

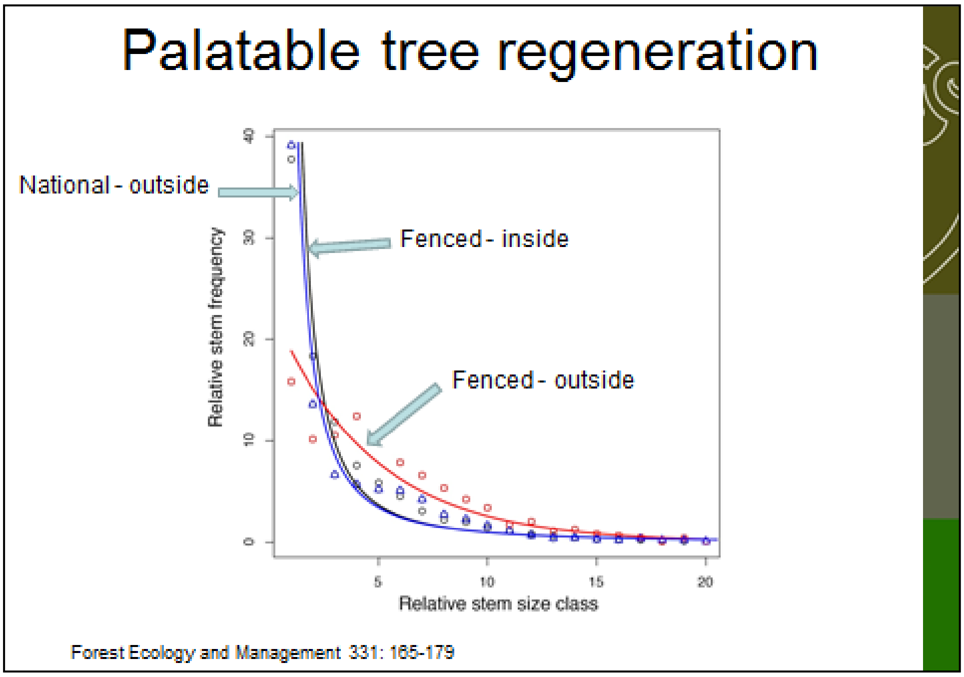
Slide 16 is the second study which used 100 fenced exclosures and compared the size-structure of palatable tree species inside and outside exclosures around the country with their size structure on a grid of plots initially established by the Ministry for the Environment but taken up by the Department of Conservation. The important point here is that they are a representative sample of the country's forests, unfenced, and on a fixed grid.

Slide 16



(Slide 17) Inside the fenced exclosures the blue line shows there were many small trees and a few large individuals. The red line is for trees outside the exclosure where there were a similar number of large individuals to inside the exclosures, but much fewer small individuals, just as we expected from looking at the photo in **Slide 12**. But when you go to the national grid sample of plots the size structure of palatable trees is similar to inside the exclosure. This suggests that the subjectively located exclosures are a biased sample of the country's forests. What has happened is that people go out and where they see intense impacts they put in exclosures, but they are strongly biased for what is happening in the country's forests.

Slide 17



But I have not talked about many species. In this country 31% of land birds are exotic. We have no idea about that for insects or moulds because we do not know our indigenous species.

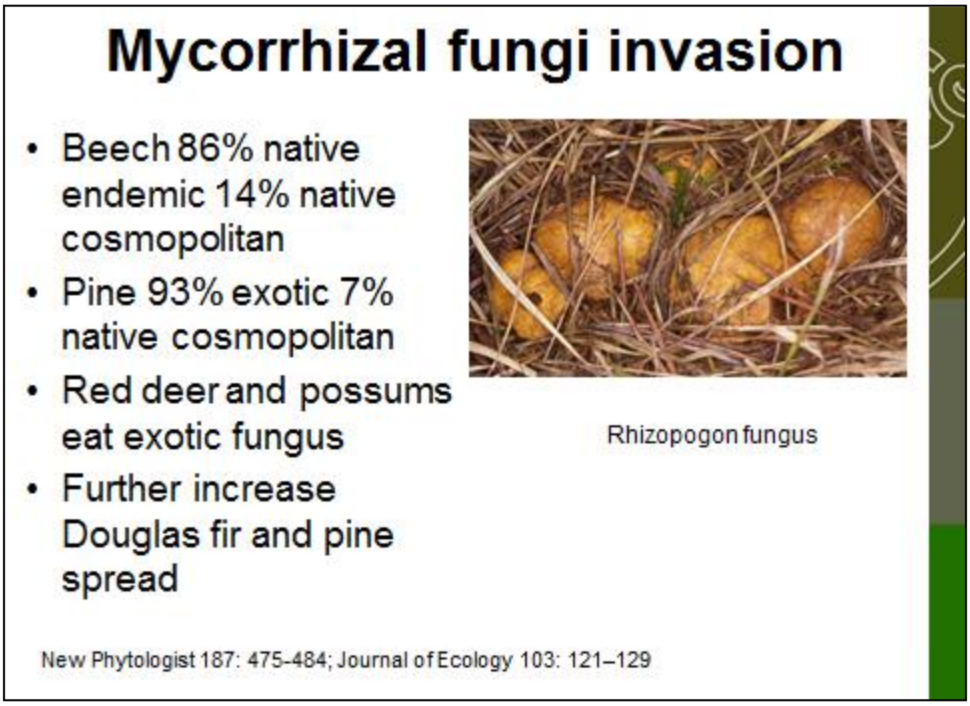
Forgotten Invasives - Diversity of introductions

- Land birds — 31% exotic
- Insects — ??% exotic
- Moulds — ??% exotic
  - Phytophthora taxon agathis — exotic?
- Bacteria — ??% exotic
  - Phytoplasma /cabbage tree — native?
- Fungi — ??% exotic

When it comes to kauri die back we do not know whether the implied agent phytophthora taxon agathis is native or an exotic. We have similar problems with bacteria. Phytoplasma was thought to lead to the cabbage tree decline 15 years ago we cannot be sure whether that agent was native or exotic. Not knowing means we are hard pressed to understand the effect of invasive species.

However, some of the invasives that are quite cryptic can have profound impacts. A recent study of native beech and exotic pine trees growing in mixture where both had mycorrhizal communities on the roots (**Slide 18**).These tree species have ectomycorrhizal fungi on the roots, one type of mycorrhiza. They are a fungus on the root of trees that help them establish and grow. In the beech trees 86% of the fungi were native endemics, a native species only found in New Zealand, and 14% were native cosmopolitan, a native species here but which also occurs in other parts of the world. The pines had 93% exotic and 7% native cosmopolitan. We are talking about the tree species growing in a mixture together; yet they do not share mycorrhizal species even though they are the same type of ectomycorrhiza in a broad sense. In addition, people are also looking at the dispersal of all these mycorrhizal fungi. Red deer and possums eat the exotic fungus but, not the native fungus, and disperse these fungi in the same way they do in their home countries.

Slide 18



This will allow the exotic tree species to better establish, spread and compete with native species. So as these processes take place we will be further shifting the balance and competitiveness of exotic and native tree species.

Talking about indigenous forests providing services, carbon has gone out of fashion but it remains important because there are ways that it might come back on the agenda. The amount of carbon stored in indigenous forests and shrublands has been estimated at around 5,600 megatonnes of CO_2 equivalents. If we were to remove the human effect on successions back to native forest, caused by clearing and grazing, it has been estimated that around 1,800 megatonnes would be added. That is without human disturbance stopping those successions. This is estimated at between 6 and 12 megatonnes of CO_2 equivalent per year for the period 2010/2022. New Zealand's gross emissions of CO_2 are expected to go from 74.7 to 83.5 mega tonnes a year between 2008 and 2020. What you can see is that one year of sequestration in these successional communities absorbs our anticipated increase in gross submissions for a 12 year period.

In conclusion I want to leave the impression that change is ubiquitous in our indigenous forests. Often these changes are driven by natural processes and can be the dominant force in driving change. To manage threats effectively and efficiently means picking battles that are valid and can be won, and there are plenty of examples of where we have not in the last 60 years in New Zealand. We need to understand that context matters and how systems change. Are changes that are undesirable reversible? Is it economically, socially and biologically feasible to reverse them and do we have a robust evidence-base for our actions? Too often we have subjective data that is biased and does not have the longevity to ensure it is robust for actions.

(Much of what I have talked about is summarised in a publication that can be found at http://www.manaakiwhenua.com/__data/assets/pdf_file/0017/77030/1_2_Allen.pdf).

An Ecological Perspective on 'Undisturbed' Lake Catchments in the Rotorua District

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William has been a practicing ecologist for more than 30 years, based in Rotorua for most of that time, with nearly 20 years in his current role. He has spent a lot of time on and around the lakes, for work and recreation. His wide portfolio of experience across New Zealand includes ecosystem and species restoration, assessments of environmental effects, natural area surveys, and assessments of ecological significance. He has particular expertise in ecological restoration and the assessment of land use effects, having undertaken assessments of environmental effects for a very wide range of land uses. Previous experience includes science roles with the Department of Conservation and Forest Research Institute of New Zealand, many years of field-based ecological survey work, and tertiary level teaching. He is the author of more than 500 reports, papers, sets of technical evidence, and articles.

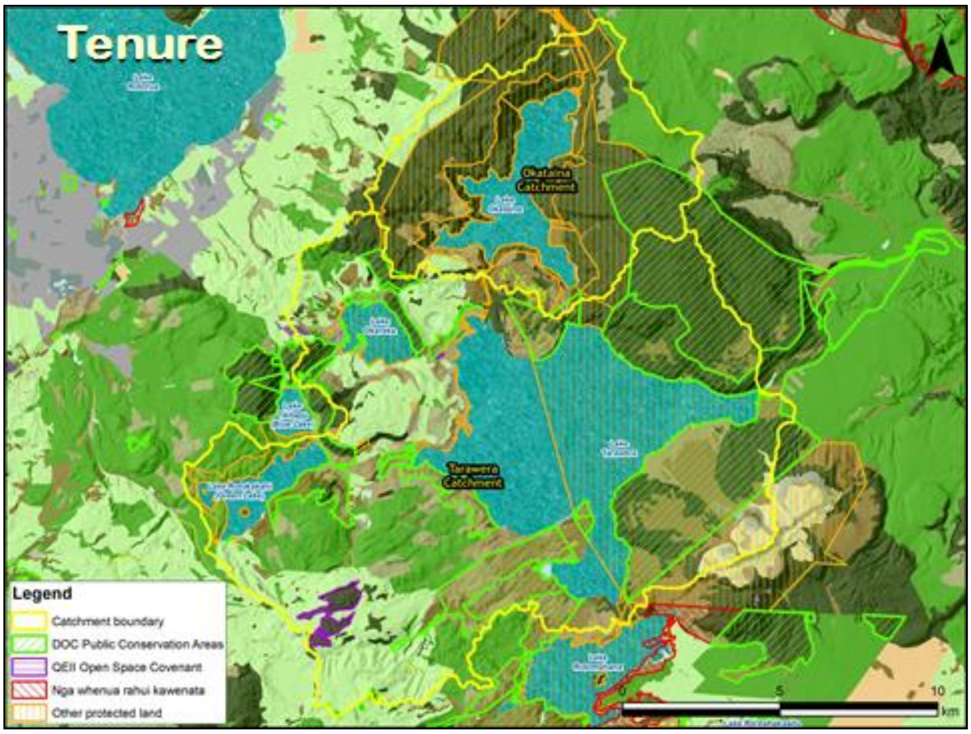
ABSTRACT
There is currently concern about trends in water quality in some lakes in largely natural catchments. Various potential contributing causes are under consideration, including pest animals, such as wallabies, and pest plants. This presentation provides an overview of aspects of ecological history and processes at work in the catchments of selected lakes. By necessity, this is largely an historical analysis, but this provides important background for current trends, and also to understand landscape-level processes. The effects of potentially threatening influences, such as pest plants and animals, need to be evaluated within various contexts, including landscape history, ongoing geomorphological change, human disturbance, vegetation dynamics, and the relative contributions of natural and human-induced changes.

TRANSCRIPT
This presentation is an overview of ecological processes in our lakes catchments, in relation to geology slope, soils, and vegetation history. I will briefly discuss current vegetation and habitats and then address pest animals, monitoring, and potential large scale sediment sources.

This is a photograph taken four days ago of Lake Ōkataina and this is how we picture our lakes: beautiful, natural, and unchanging stable systems. There is, however, quite a lot happening in this image: a fresh delta (due to recent sediment deposition), relatively recent landslides, and some kamahi dieback higher on the slopes.

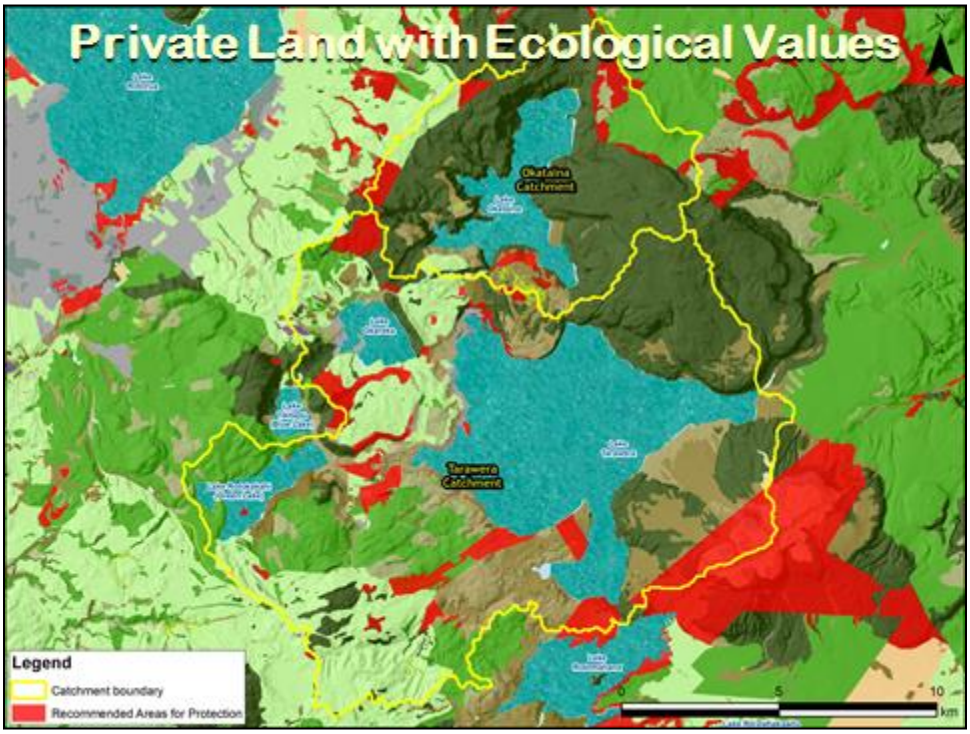
This is almost entirely secondary forest that has developed following fire, which has affected a large part of the Ōkataina catchment, with pohutukawa close to the lake shore.

Slide 1



Slide 1 shows the Ōkataina catchment which is largely Māori land, managed by the Department of Conservation. Large reserves also extend across Lake Tarawera and onto the slopes of the mountain, which is also Māori land. Large parts of the Ōkataina and Tarawera catchments are managed as protected land.

Slide 2

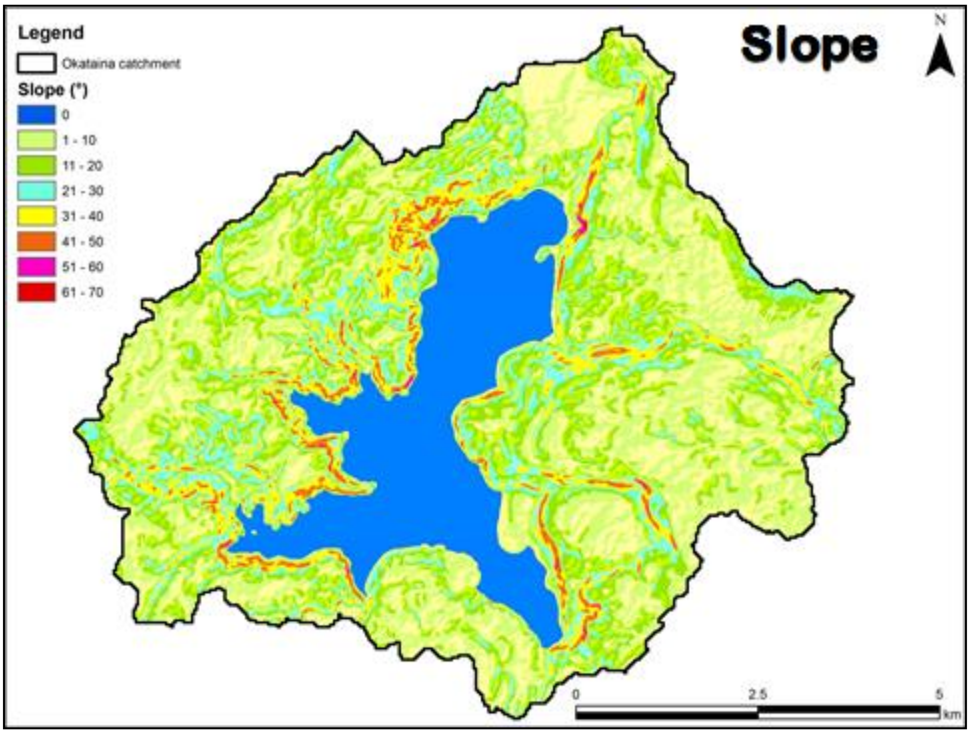


Considerable areas of land in Māori and private ownership have significant ecological values. **(Slide 2)**

Topography, geology, and soils

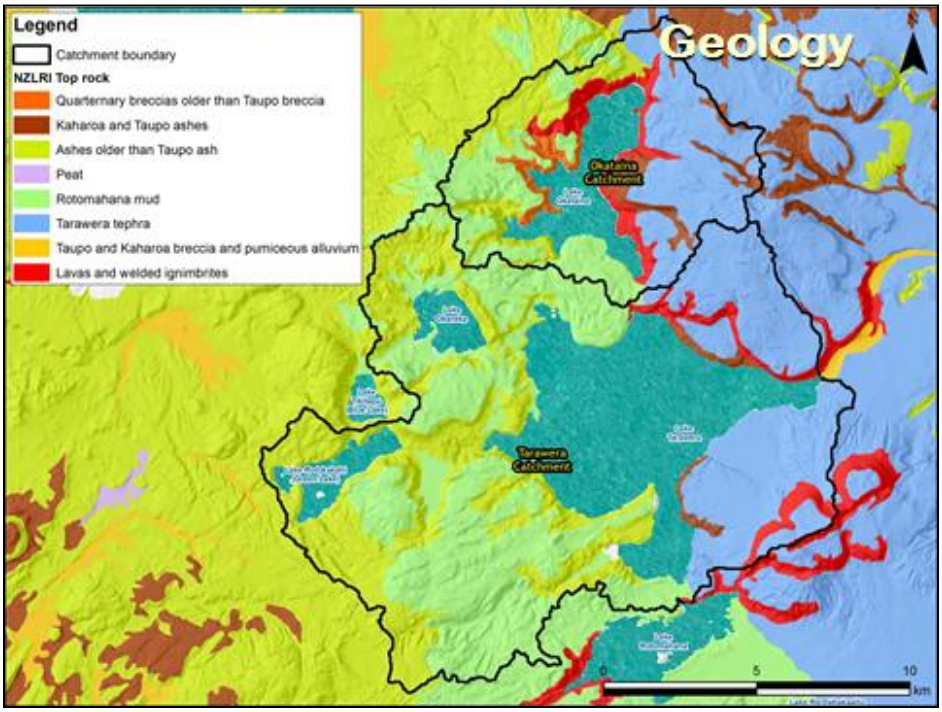
Much of the Ōkataina catchment is very steep land, with more gentle slopes on the southern side of Makatiti Dome. Adjacent to the western shores the landform is very steep, especially close to the lake and even on the eastern shores, which I will discuss further later in this presentation. **(Slide 3)**

Slide 3



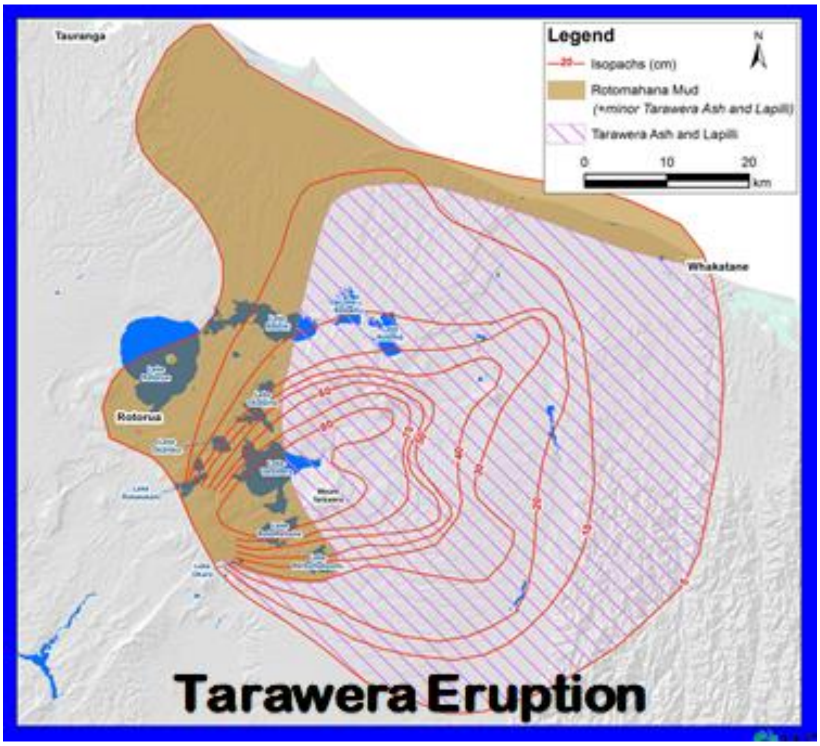
The fundamental picture is that the underlying geology is entirely volcanic, with large areas of tephra, much of which has originated from recent volcanic activity. This has important implications when combined with steep terrain. (**Slide 4)**

Slide 4



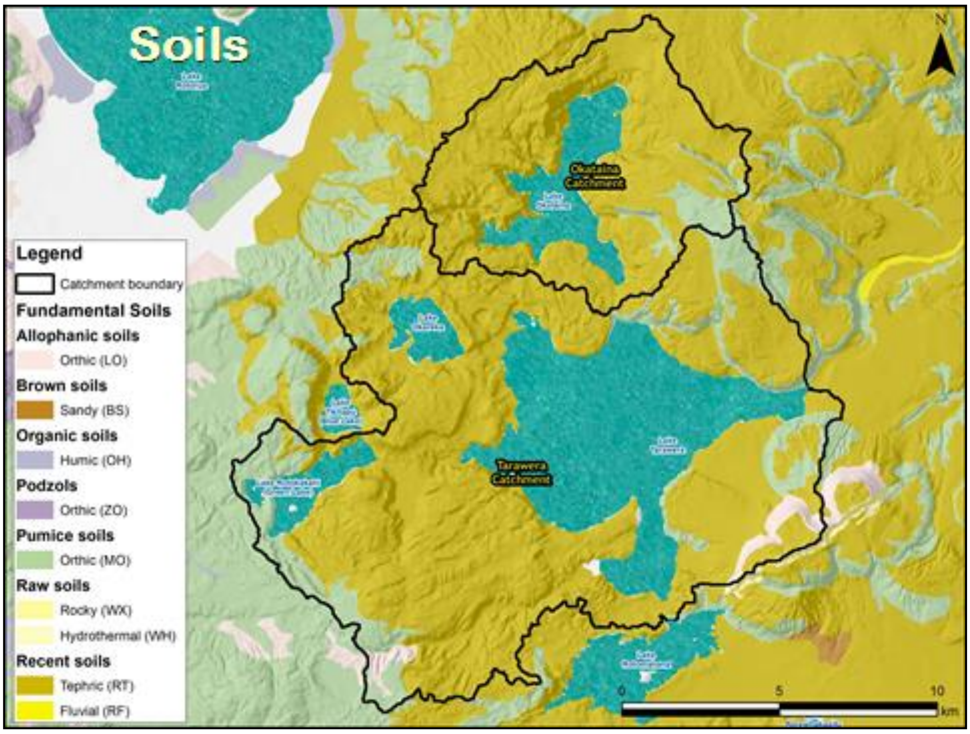
Slide 5 Shows the tephra isopachs from the Tarawera eruption in 1886. The Ōkataina area has quite deep layers of recent material and a sizeable footprint of Rotomāhana mud. Admittedly this latter material is relatively shallow, especially with increasing distance from the eruptive centre. The Tarawera eruption destroyed the indigenous forest cover relatively close to the mountain but the impact lessened dramatically with increasing distance from the eruptive centre.

Slide 5



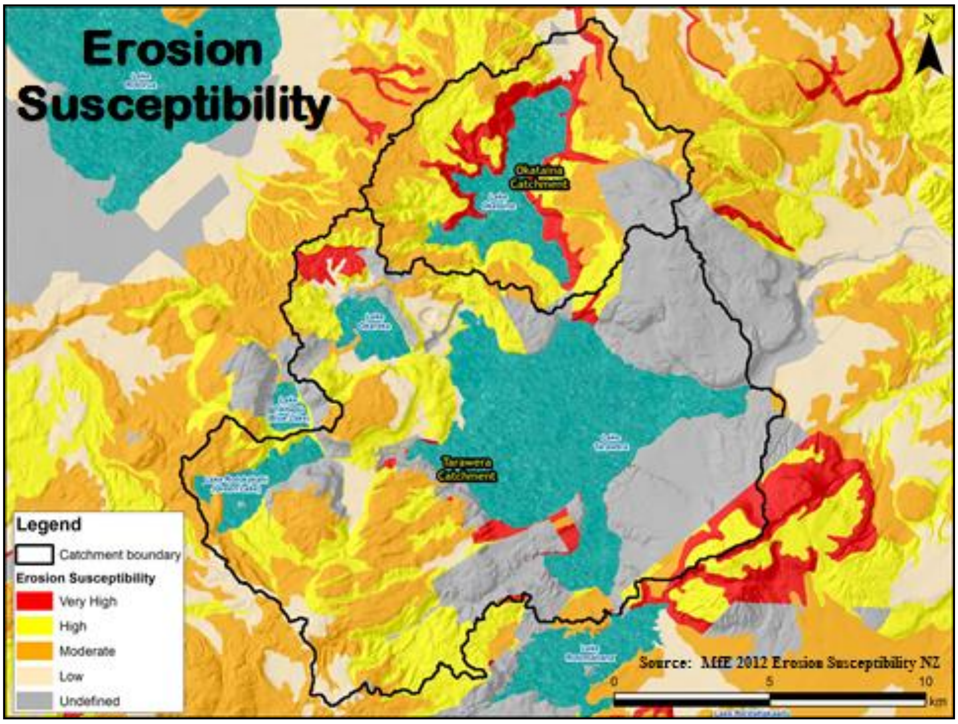
Slide 6 shows that the soils are almost entirely recent unconsolidated tephric soils.

Slide 6



The Ministry for the Environment Erosion Susceptibility map shows that Ōkataina has very high erosion susceptibility, with highly erodible substrates around the lake shores and on adjacent steep slopes. **Slide 7**

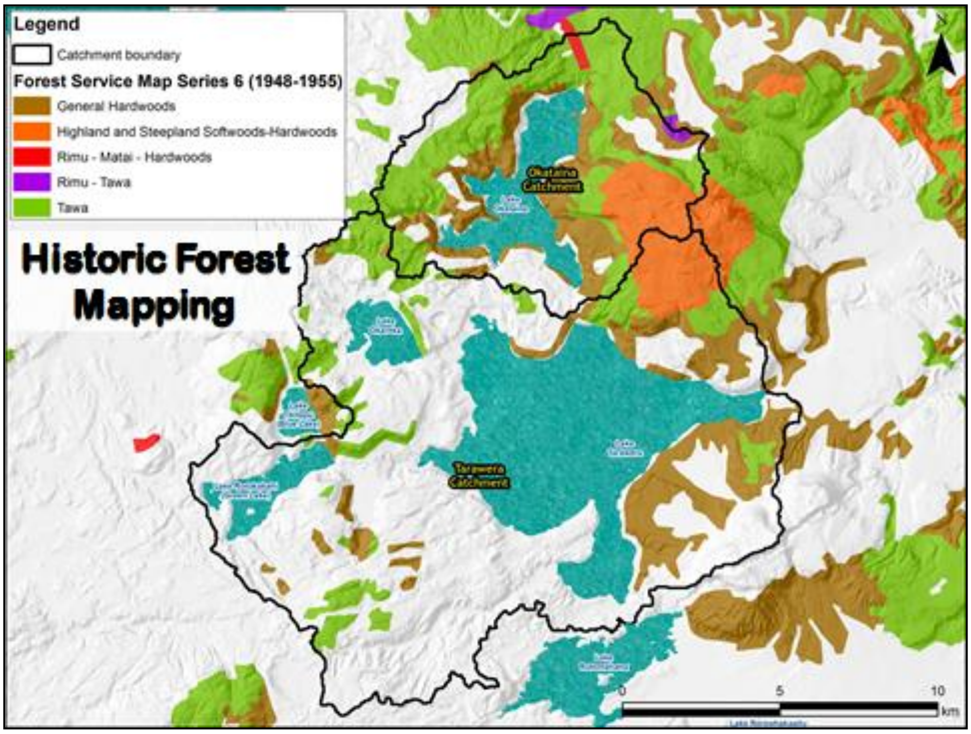
Slide 7



Vegetation pattern

Slide 8 The now somewhat historic Forest Research Institute (New Zealand Forest Service) forest class map shows forest a forest cover across all of this erodible substrate, which makes it look very 'natural'. I intentionally used this old map as it was compiled using aerial photography from the 1940s and 50s. The area of higher altitude forest on Makatiti Dome is of extremely high ecological value. The tract of tawa-dominant forest at lower altitude, which would have once covered most of the balance of the catchment, had already been logged by the 40s and 50s. Its classification as tawa-dominant, rather than podocarp/tawa, is due to the selective removal of podocarps by logging (and possibly crown fires in places). There has been a lot of logging activity in this catchment and logging tracks are now evident in many places within tawa-dominant forest. The general hardwood zone near the lake is secondary forest originating largely from fire. Overall this is quite a modified landscape with a heavy imprint of human activity across the catchment.

Slide 8

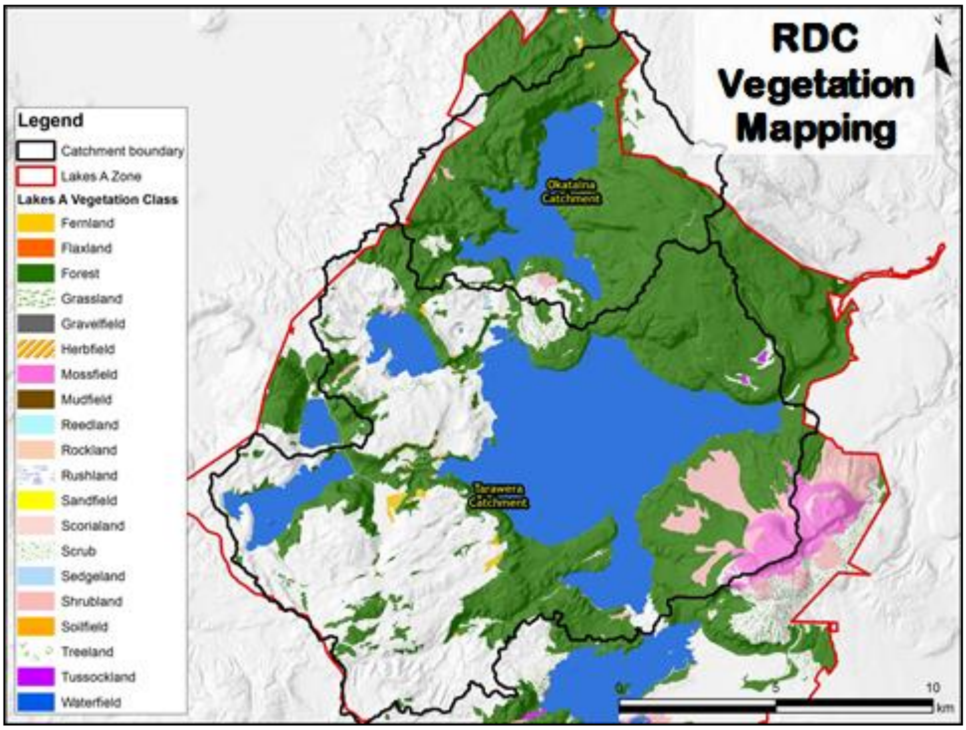


Slide 9 (over) is a more recent map which shows clearly that most of the catchment is currently covered in forest. Several hundred vegetation types have been mapped within the Ōkataina and Tarawera catchments but at a broad scale it is a relatively simple forest pattern with three key classes: highland forest, tawa-dominant forest, which has largely been logged, and secondary forest that has developed following fire.

Pest animals and monitoring

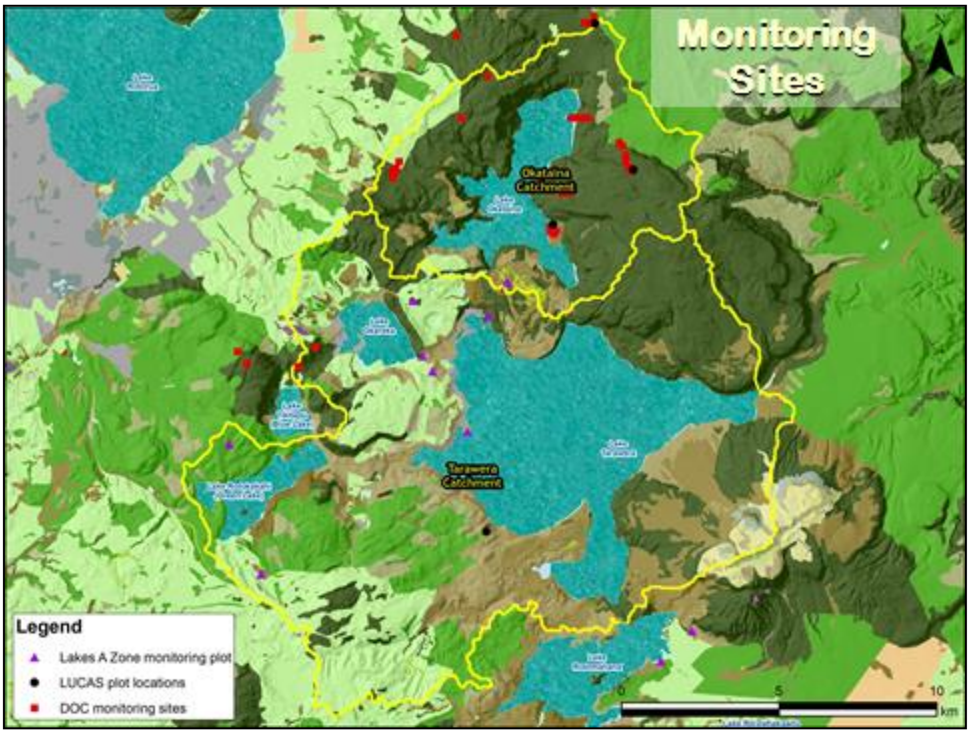
There are deer, wallabies, and possums present in these catchments and all have been present for about a century. The particular effects of each of these species vary by vegetation type. Wallaby effects are generally greatest in drier secondary forest, i.e. the kānuka-dominant forest. Possum effects are greatest for pohutukawa, rata, kamahi, and tōtara. Deer effects are pervasive but there are only very low numbers in these catchments. Wallabies, possums, and deer are all significant ecological threats, but do they significantly exacerbate sediment loss in this environment in their current numbers? This is unlikely but we have little data to support this opinion.

Slide 9



Monitoring started in the 1980s, mostly focused on the animal effects on vegetation. It was initiated by the New Zealand Forest Service, looking in particular at wallaby impacts. The Department of Conservation undertook vegetation plot remeasurements at Ōkataina in 1995. The Department also funded a PhD study through the University of Waikato in 2001 and assessed pohutukawa condition in 2004 (and earlier). Bay of Plenty Regional Council remeasured vegetation plots at Ōkataina in 2007. Department of Conservation carried out walk-through assessments in 2007/08 and there are DOC LUCAS 20 × 20 metre permanent monitoring plots, and exclosures. There are also some vegetation plots in both the Ōkataina and Tarawera catchments which were established as part of work done for Rotorua District Council in the Lakes A Zone.

Slide 10

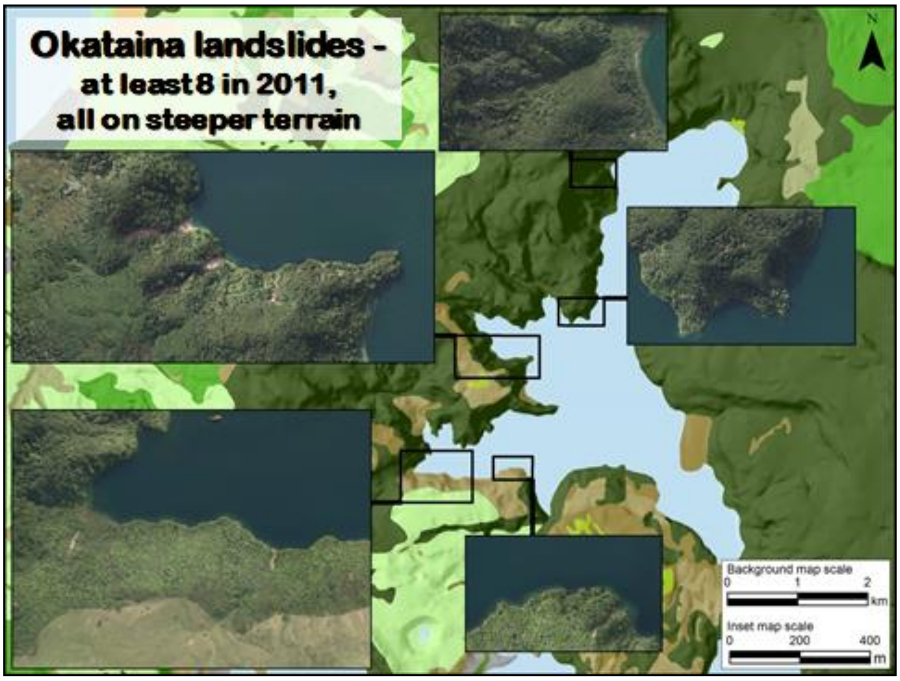


So there is quite a lot of information available and **Slide 10** shows the locations of those plots, which are scattered through the Ōkataina catchment.

Key factors and processes
To reiterate, this is a dynamic recent volcanic landscape, with a volcanic basal geology, steep slopes in parts of the catchment, and with erodible soils. Vegetation cover varies in composition and condition and reflects the impacts of reasonably large scale human modification by fires and logging. Pest animals are also playing an important role in terms of vegetation condition.

But what else is going on? Key stakeholders are currently very concerned about Ōkataina and particularly the potential effects of pest animals. While they are an ecological threat, there are, however, other potential large scale sources of sediment, such as mass movement (landslides) and lakeshore erosion.

Slide 11



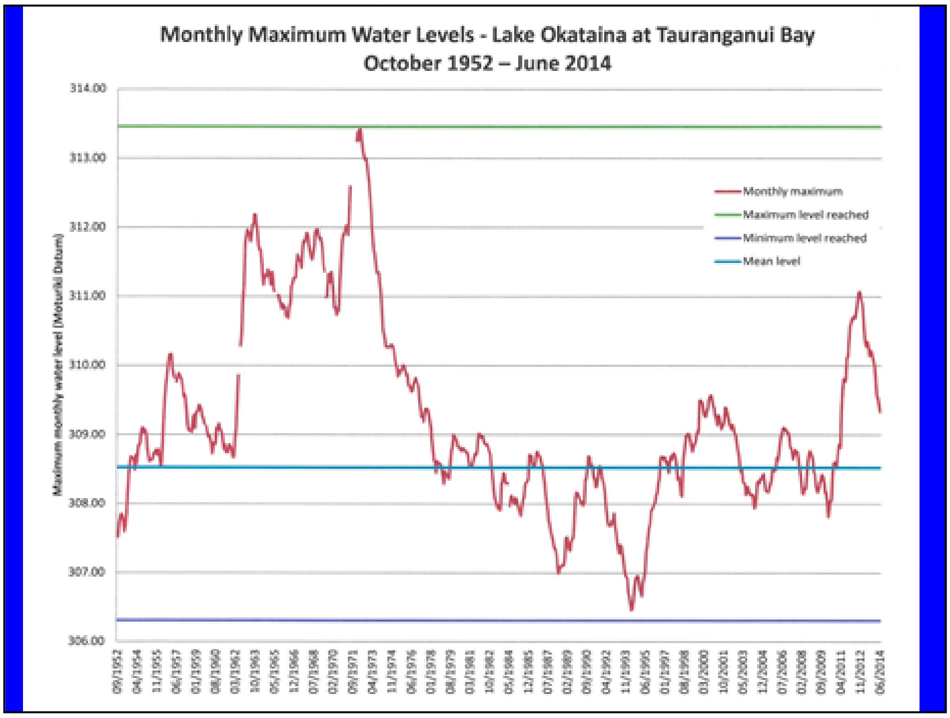
Slide 11 shows that in 2011 alone there were at least eight landslides, all on steeper terrain at Ōkataina and some slid directly into the lake. I have not had time to look at the weather records to see whether there were related weather events, but the landslides were probably triggered by a major weather event.

What about shoreline dynamics? What happens to the shoreline when the lake levels rise and fall? We must consider both of these processes and especially when they happen relatively rapidly. What about other influences such as wind, especially when combined with high lake levels?

Key parameters for Lake Ōkataina

The lake shoreline is 30.3 kilometres and the lake has no natural outlet. In that sense it is similar to Lakes Rotomā and Rotoehu as their levels also fluctuate relative to rainfall patterns (and their shorelines are also mostly unconsolidated material).

Slide 12



Slide 12 is a plot of lake levels for Ōkataina over the last 62 years, and is very interesting. The lake level peak in 1956/57 was regarded as being a really high peak in some of our lakes. There were much higher peaks following that though, particularly in 1971/72, with a very steep slope on the lake level plot for that event. The lake obviously rose relatively rapidly over quite a period of time and there was then probably a major event which rapidly pushed the lake level up to a very high level. In 2012, only three years ago, the lake attained the highest level recorded since 1972.

PHOTOGRAPH OF LAKE OKATAINA SHORELINE FOLLOWING HIGH LAKE LEVELS IN 1971-72.
(March 1973 MWD photograph, supplied by Horace Freestone.)

The overall natural range recorded over the last 62 years is seven metres, which is huge, and is about the same as the natural range for Lake Waikaremoana (where I have worked for many years monitoring shoreline vegetation processes for Genesis Energy).

This is a photograph of the Lake Ōkataina shoreline in 1973 following the high lake levels in 1971/72. It should be noted that the lake level shown in this image is about two

metres lower than the lake reached at the peak of that high level event. This degree of shoreline collapse is not unusual; in fact it is what I call 'business as usual' for a soft-shore lake margin. It can look ugly when it happens but this is what happens on these lakes and is a natural process.

Key lake level effects on margins
There are two types of effects on lake margins related to high level events:

- Inundation of vegetation and related mortality as a result of intolerance of submergence by the vegetation affected.
- Erosion of the soft shorelines.

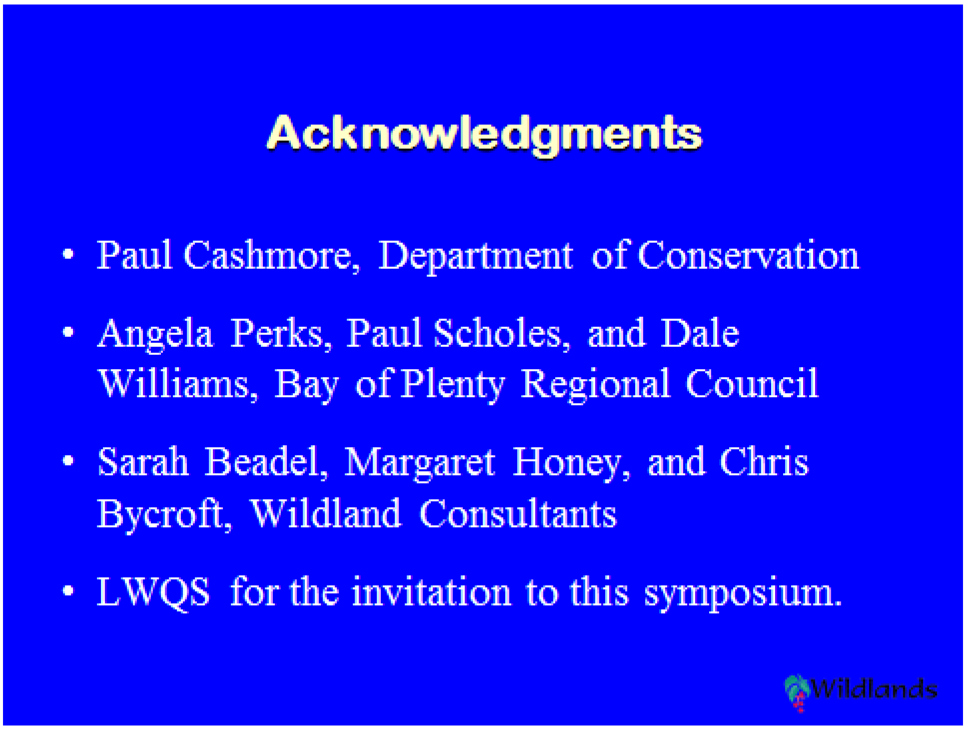
Vegetation dynamics relative to lake levels are summarised in a short paper by Roger Cameron in 1957 who studied high lake level effects at Rotomā. You will recall the peak shown in **Slide 12** on the lake level graph for 1956/57, which was not really that high, but the Rotomā margin was submerged and forest died there during that summer. Cameron cored those trees and found that they were about 45 to 50 years old. There were larger trees of 200-300 years old but these were *c*.0.6 of a metre above the 1956 flood level and he considered that the 1956 lake level was the highest since an even higher flood in 1905 or earlier. There was no indication of higher floods in recent centuries. It is notable that only 0.6 of a metre above the trees that died in 1956/57 Cameron found the shoreline vegetation to be quite stable. We now know that within 20 years of that high level on Rotomā there was a far higher level at Ōkataina.

Lake shore erosion is affected by wind-driven waves and occurs at all lake levels but the effects are obviously more pronounced during high level events. Saturated and wave-undercut banks can collapse when the lake levels drop. There may be no wind and bank collapse effects might result from the rise and fall of the lake (and associated saturation of bank sediments). If there are windy conditions, however, when the level is high, and the wind comes from different points of the compass then up to 100% of the shoreline could potentially be affected by wind action combined with high lake levels, exacerbating shoreline erosion.

How much sediment goes into the lake when levels rise and fall?
In my view a lot of sediment will enter the lake during high lake level events, but we do not know how much. Most of the Ōkataina shoreline is erodible and the worst case scenario is that most of the shoreline could collapse or erode. I have not measured the length of the beaches but out of the 30 kms of shoreline there would only be a few kilometres at most of beaches, which can also erode. This means that even modest shoreline erosion/ collapse could contribute thousands of tonnes of sediment per episode. Even being quite conservative, large events could be very significant in terms of sediment input to the lake.

Conclusion
What are the key take home messages? This is a dynamic volcanic landscape with an overlay of quite major human-induced effects even though the catchments outwardly look very natural. The system appears stable but it is nevertheless subject to ongoing significant disturbance. We need to understand how the system is operating and the relative significance of different components and processes over time. It is critical to understand <u>how</u> this is happening and also <u>what</u> is happening over time. We only have records of lake levels for the last 62 years, which is a short time period in terms of catchment history. Pest animals are definitely a significant ecological threat. Numbers do fluctuate but they have to some degree been a constant influence in the system for at least a century. We must not underestimate the potential effects of weather pattern and

extreme events on erosion, both on the shoreline and in the wider contributing catchment, even in a fully forested natural catchment.



THE CHANGING FACE OF LAKE OKATAINA'S 'PHOSPHORUS SCAPE': WHO IS THE CULPRIT?

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with support from David Hamilton, Adam Hartland, Daniel Laughlin and Chris Lusk
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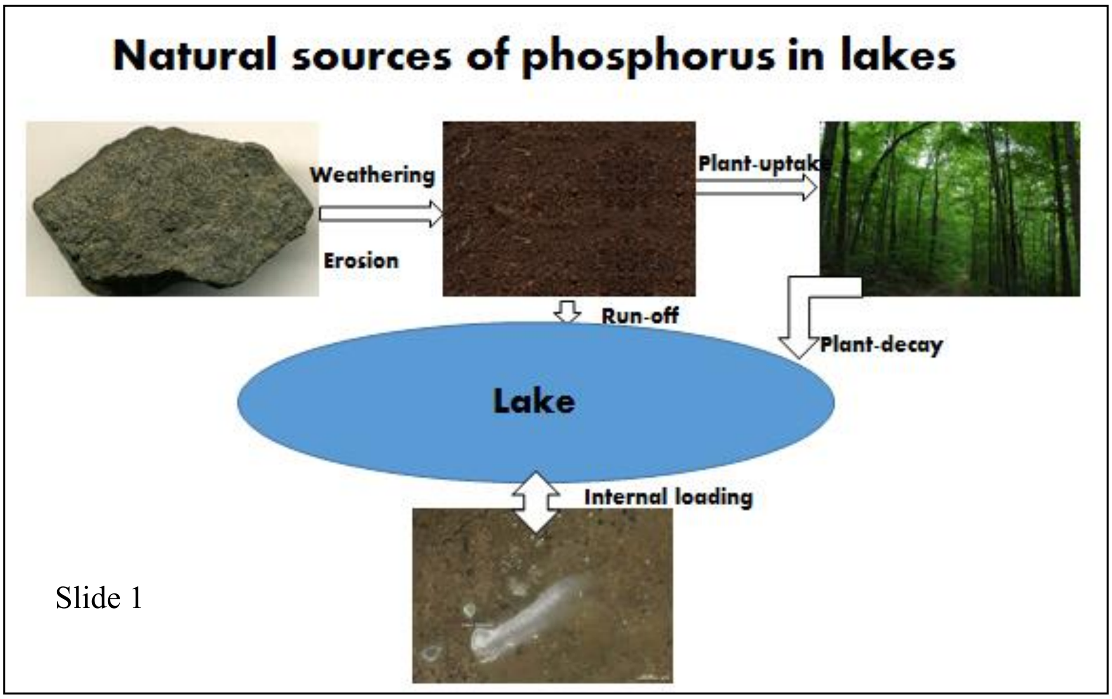
Theodore is currently a PhD student under the tutelage of Prof David Hamilton at the University of Waikato. He holds a Master of Science Degree in environmental resource management with specialisation in aquatic geochemistry. Prior to taking up the PhD studentship, he held an academic position in the University for Development Studies, Ghana, where he taught papers in limnology and watershed management, amongst others. During his tenure there, he carried out research into geochemical controls on nutrients in lake sediments, agricultural pollutants in lakes and phytoremediation of trace metals and pharmaceutically active substances in lakes. His current research interest is limnogeology, and nutrient and trace metal geochemistry in lake sediments. In recent conferences he has presented papers on phosphorus speciation in lakes, and trace metals from agricultural sources.

ABSTRACT
Lake sediments contain a great wealth of data on biogeochemical and limnological processes of historical importance, which can be used to interpret natural ecosystem dynamics, and climatic and anthropogenic impacts. In this study, this information was used to understand the dynamics of phosphorus speciation in deep Lake Okataina, to assist with understanding how changes in the catchment influence lake productivity. A 49-cm sediment core was retrieved from Lake Okataina and its depositional history was dated using ^{210}Pb and tephra chronology. Amongst New Zealand lakes, Okataina may be considered close to a 'reference' lake, with 89% native forest and without a significant change in its land use in the past c. 800 years. However, perturbations to the lake during this time may be due to expanding populations of invasive terrestrial mammals, earthquakes, volcanic eruptions and tree felling, which may alter the geochemistry of the soils in the catchment, composition of runoff and, ultimately, the composition of the bottom sediments of the lake. We hypothesised that changes in soil phosphorus geochemistry in the catchment will result in a changing phosphorus species in the lake sediments.

TRANSCRIPT
I will be talking about lake effects and the introduction of mammals into New Zealand on lake water quality, looking at phosphorus specifically, because one of the things that Professor Hamilton mentioned was nutrients: added nitrogen or phosphorus plays a big role in the quality of water. So there is the need to look at how catchments influence water quality generally.

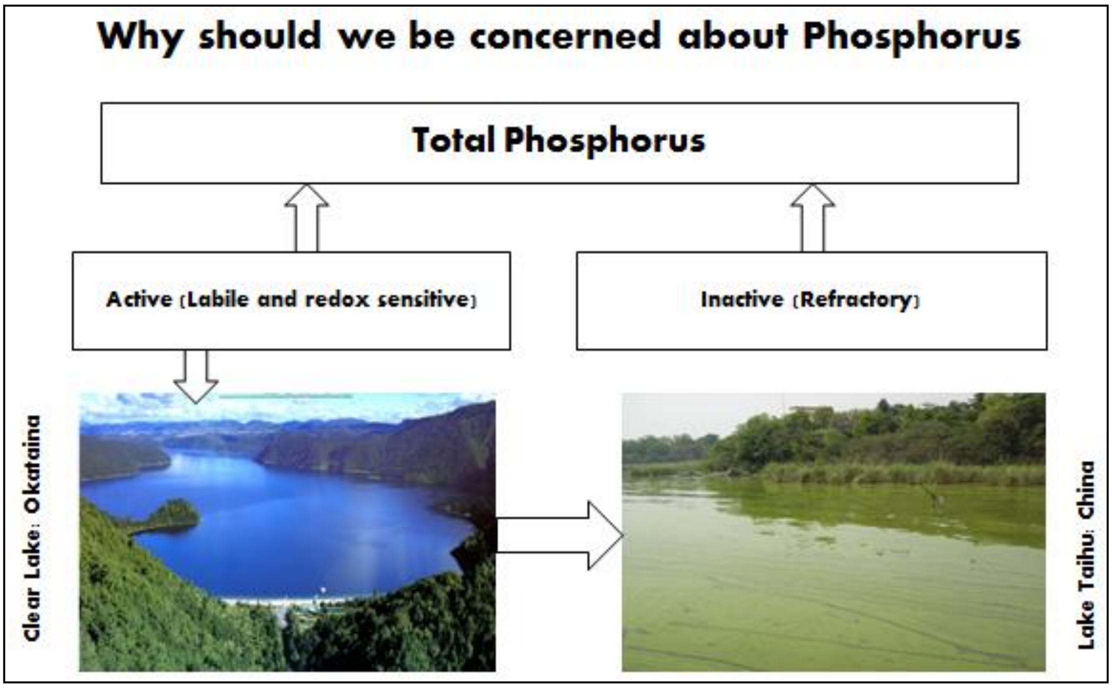
The main source of phosphorus is from weathering of rocks. When rocks weather soils are created and nutrients are taken up by plants, but some nutrients in the soils are directly routed into the lake. Plant decay also contributes nutrients to the soil and these can also be routed into the water or back to living plants themselves. When there is erosion, sediments and nutrients are washed into the lake. There is also the contribution of nutrients from bottom sediments into the lake directly. **Slide 1** is a simplified diagram of phosphorus cycling in a lake system.



Why should we be concerned about phosphorus? It contributes to productivity of the lake. If you have a lake that we know does not have a lot of nutrients and all of a sudden we see increases in nutrients then we should be concerned and say, 'Where is the source of the nutrients and what would be the effect of the nutrients on the water?'

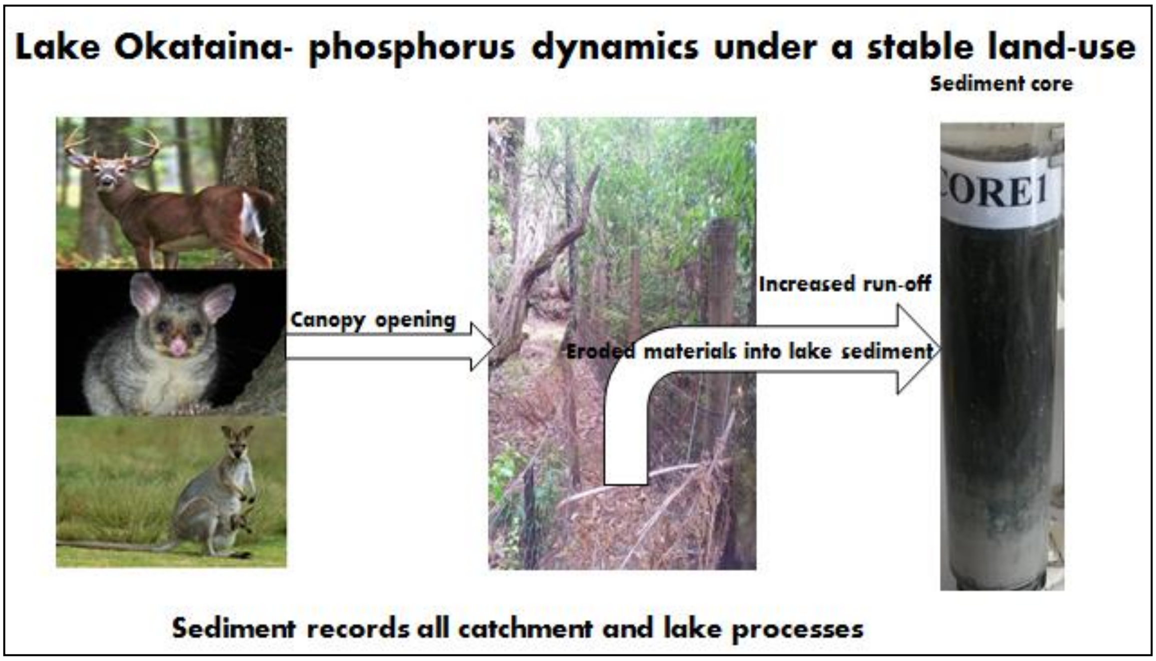
We talk about total phosphorus which has many aspects, classified as active and inactive. Active means the component that directly contributes to the lake productivity (bioavailable). The inactive component does not directly influence plant growth but can be recycled back to an active form.

In **Slide 2** we have active phosphorus going into a clear lake like Okataina, but a turbid lake like Lake Taihu in China already has a large biomass of algae. We cannot swim in it,



we cannot drink the water, we cannot take fish from it and the lake quality is terrible and it has a large bioavailable phosphorus supply. My interest here is to look at whether we have seen any changes in phosphorus in our lakes.

Because we are at a 'weed and wallaby symposium' I will look at the influence of deer, possum and wallaby. One of the things that occurs from their browsing is to open the canopy. In **Slide 3** showing an exclusion zone we can see that inside the fence are very lush plants but outside it is mostly dry and open. Changes in the composition or species numbers are therefore important to my study. It is important to evaluate these recent changes against influences of earthquakes and landslides, which also lead to instability in the catchment sediment and nutrient delivery. Anything that exposes the soil influences whether we have phosphorus entering the lakes or not.



Lake sediments act as an historian, an archive. They store data over thousands of years, so whatever happens in the catchment and the lake is stored in the sediment. We can make inferences about past history of the catchment and lake.

In Lake Okataina we have two recent tephra in the bottom sediments, Kaharoa and Tarawera. We know the Kaharoa eruption happened around 1314AD plus or minus 12 years and we know the Tarawera eruption happened in June 1886. We use other dating techniques lead-210 to be able to constrain the date. Every 1 centimetre of the core has a date, the top is 2009 and the bottom is the tephra of 1314AD. So between these two, 1314AD and 1886AD, there have been Maori and European settlements which would have influenced the forest.

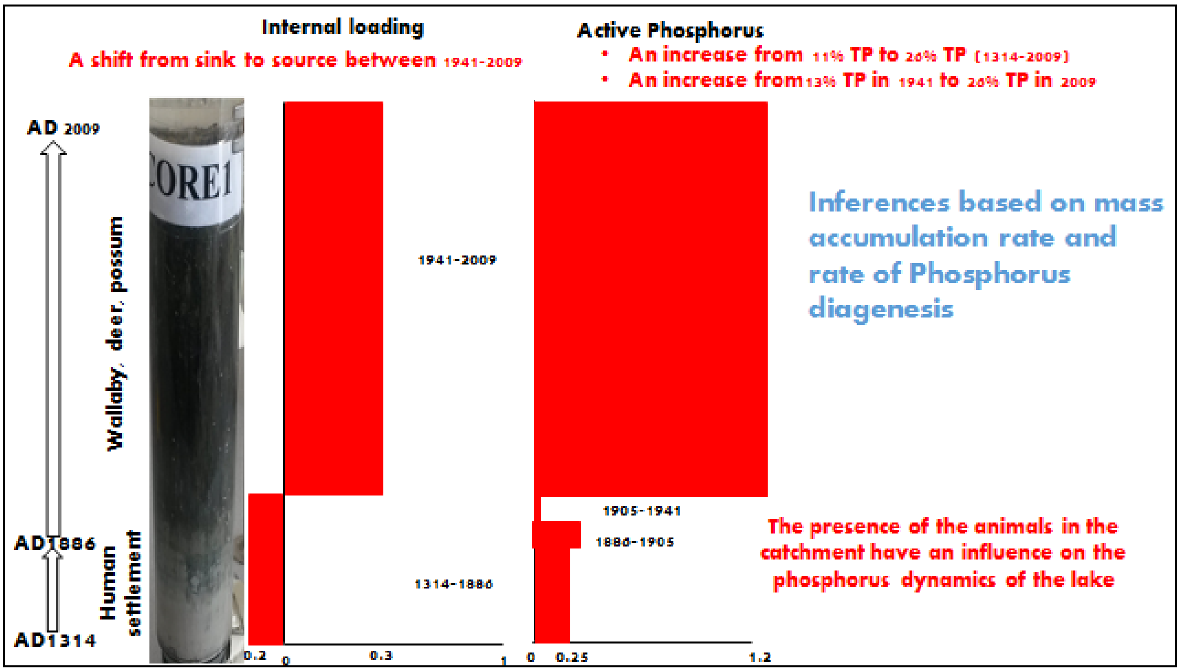
In 1931, for instance, there was an earthquake in Napier and a few days after that the lake height reduced significantly. In terms of sediment loading of nutrients prior to 1941 the lake was a sink of phosphorus. It means that whatever phosphorus that went into the lake was trapped and very little was released back into the lake. But after 1941 one of things we saw was that the lake sediment began to release phosphorus back into the lake.

We can also re-create erosion patterns in the catchment from the sediment cores. There has been an increase in erosion over time and increased inputs of organic material in the lake would remove oxygen from the bottom waters of the lake. Where we have decreased oxygen concentration in the sediment it leads to dissolution of iron that is bound to sediments and therefore to bound phosphorus, which is also released into the system. Aluminium also has bound phosphorus and depends on pH, which is mostly stable in Okataina.

Lake Okataina is anoxic in the bottom waters during summer stratification. You will find deeper bottom waters in deeper lakes like Tarawera and Rotoma are not anoxic. One of the reasons could be the V-shape of the basin itself, resulting in sediments accumulating, less water to buffer oxygen consumption, and therefore release of phosphorus. We found that the lake became a source of phosphorus after 1941 and this could be as a result of the disturbances in the catchment.

I have read quite diverse literature on increases in the animal population and other pests in the catchment. I learnt that from around 1935 the population of mammalian animals increased. Could that be a factor in the change in the lake in 1941? Or could it be shoreline erosion? We have examined remote sensing images in this catchment from the 1990s to see whether there is any opening of the canopy. We realise that there has been very little, not as much as logging would do. But the opening could also be a result of the landslides. The most obvious culprit for material going into the lake at a fast rate and internal loading still appears to be mammalian browsing.

Between 1314 and 1886 about 5% of the total phosphorus in the lake's sediments could be categorised as 'active phosphorus'. **(Slide 4)** Right after the Tarawera eruption this increased, but later we saw a reduction in the percentage. I would imagine that after the eruption there was regeneration of forest growth and therefore not a lot of erosion or materials going into the lake.



However we have seen a big jump from the 1941 baseline. We also cannot discount the effects of changes in climate and there are predictions of the lake's response for different climate change scenarios.

I would like to acknowledge the Bay Of Plenty Regional Council who have funded my PhD. The have also helped with provision of the data. I also want to thank the Lake Okataina Scenic Board. They have been very helpful and always want to know what is happening in the lake. I am grateful for the opportunity to talk to you, thank you very much.

THE LINK BETWEEN EROSION, PHOSPHORUS AND WATER QUALITY

Max Gibbs
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Max was trained as an analytical chemist and has worked for NIWA (and its predecessor, DSIR) for 50 years, initially in the field of pesticides and forensic analysis and subsequently studying eutrophication in freshwater. For the last 42 years, Max has worked on lakes around most of New Zealand, primarily on Lake Taupo and the restoration of Lake Rotorua, and Lake Horowhenua. He was instrumental in the identification of the hydraulic coupling between Lake Rotorua and Lake Rotoiti, which eventually lead to the installation of the diversion wall. He has used his experience of iron cycling, obtained as a fellow at Edinburgh University and the Lake District in 1980, to help in the understanding of phosphorus interactions across the sediment-water interface in New Zealand lakes. He was awarded an Honorary Doctorate of the University of Waikato in 2010 for his work with lake restoration and the assistance and mentoring of students. Recently Max developed an internationally acclaimed forensic stable isotope technique that enables the identification and apportionment of sediment sources by land use in the catchment and he has extensive knowledge of the linkages between erosion and the impacts of fine sediment in lakes, rivers and estuaries.

ABSTRACT
In lakes, the solubility of phosphorus (P) in water, and therefore its availability to aquatic plants (macrophytes and algae) for growth, is controlled by oxygen and pH. The supply of dissolved reactive P (DRP) to the lake water column is mostly from sediment release from decomposing plant material and iron oxides during periods of low oxygen, although in Lake Rotorua and most of the other lakes on the central volcanic plateau, spring-fed streams carry relatively high concentrations of DRP into the lakes. The mechanism for releasing iron-bound DRP from the sediment focusses around the oxidation state iron (Fe) and manganese (Mn). In well oxygenated conditions iron exists in the oxidised state as ferric ions which form ferric oxides that are insoluble in water. These oxides sequester DRP as they precipitate and remove it from the water column. When the oxygen concentration falls to zero (anoxic conditions) iron exists in the reduced state as ferrous ions, which are soluble in water. As the ferric form reduces to the ferrous form it dissolves and the DRP bound to the iron is released into the water column where it is used by algae for growth. The algae eventually senesce and die, returning the P to the sediment as particulate P, where it can be recycled during the next period of anoxia.

Apart from recycling of algal biomass, P also comes from the catchment, bound to the iron oxides in soil particles. The P content of the soil is greatest in the finest soil particles, which are the first to be eroded by rainfall and do not settle until they reach the calm waters of a lake. There they augment the P load from the senescing algal biomass, thereby increasing the amount of DRP that can be released during the next anoxic event. Because of the high background concentration of dissolved inorganic nitrogen in the lake water, the addition of any DRP will stimulate algal growth and thus result in a deterioration of lake water quality. Land management strategies to reduce soil erosion include changes to the way land is farmed and the interception and retention of fine sediment using detention bunds.

TRANSCRIPT
Sediment from land erosion is the largest contaminant of water and costs over $US500 billion per year. This is due to sediment costs for potable water and the treatment required cleaning it up. Sediment from land erosion represents threats to sustainable food production and the loss through soil from arable land and of course sediment can adversely affect the aquatic ecosystem affecting biodiversity and the water quality in the lakes.

My talk today examines the link between erosion, phosphorus and water quality. The previous speakers have talked about the cause of sediments, of landslides, bank erosion, flood events, etc. I am going to focus on fine sediment; the particle size is typically less than 20 microns, i.e. the clays, silts and muds, all very fine material.

Unlike an estuary where fine sediment flocs when it meets the sea water and settles, fine sediment entering a lake remains as a suspension of fine particles for extended periods. These suspended solids affect water clarity by reducing light penetration and cause light limitation for aquatic plants, native species and exotic species alike. In Okataina there could be weed beds smothered because fine sediment is coming into the water. Over time the fine sediment eventually settles to the lake bed and lake currents cause it to move into the deeper parts of the lake, a process called sediment focusing. As Theodore Knodonu referred, the sediment eventually gets to the bottom of the lake. The deeper parts of the lake may become anoxic below the summer thermocline due to decomposition of organic matter from weeds and algae.

Erosion is a process destabilising soil and causing it to move. Wind driven erosion (Aeolian) is common in the dry parts of the world. Water driven erosion is the most common form in New Zealand. If you take plants off the ridges and put in place grasslands, they cannot hold the soil on the steep slopes. If you have forests which are removed by clear felling the period of clear felling leaves exposed land which is not going to stop rain from eroding the soil. If you have farmers that cultivate the land right to the edge of the streams, in fact run their ploughs almost into the streams, nothing will stop sediment getting into the system. The common factor here is that bare soil washes away in rainfall events.

Sediment can come from land slips and we have already seen these. Willy Shaw showed close ups of slips in Okataina. We see bank erosion in Okataina and around other lakes. Theodore referred to the denudation of the forest understorey by animal grazing and the effects of wallaby in the Okataina catchment.

Sediment can come from land slips

Or bank erosion

Or denudation of forest understory by animal grazing

Erosion occurs at all stages of rainfall events with different parts of the landscape being affected depending on the previous rainfall history and intensity. In most cases it is the surface soil that is eroded first with the very fine particles moving even with light rain. The slip faces that came down in a big event continue to leach fine sediment with fine rain washing off that surface all the time.

The fine sediment in surface runoff may not be considered important. For example, in the Okataina water quality Background Information 2012 there is a surprising statement that says –

‘*There are small areas of bare ground and built areas in the Lake Okataina catchment, but it is thought that only a trace amount of nutrient input, (10 grams of phosphorus and 110 grams of nitrogen a year) is generated from these.’*

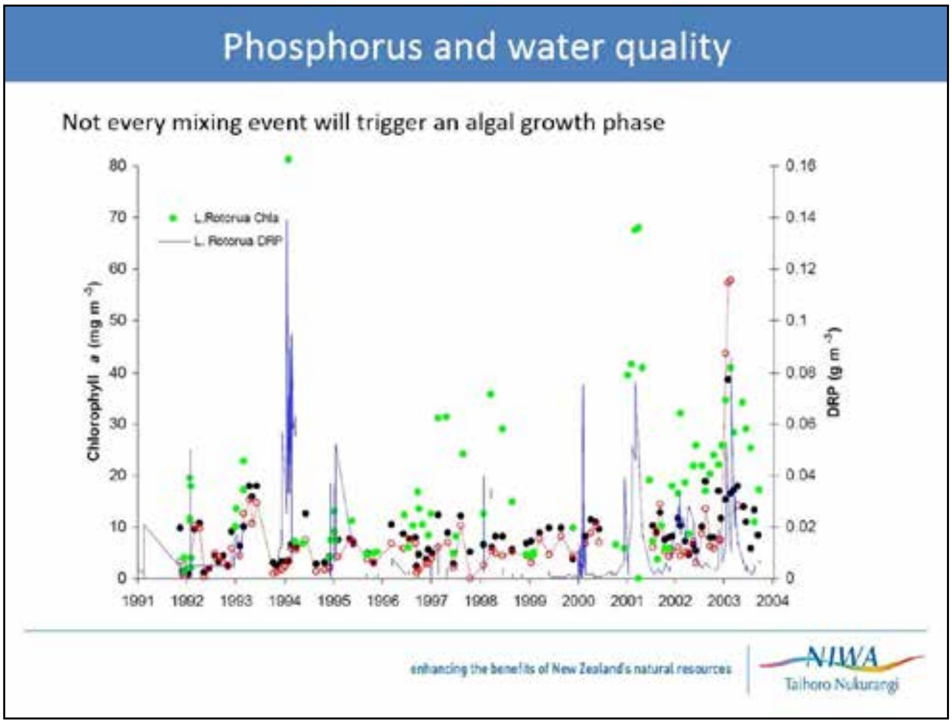
Where does the P come from? Fine sediment has the highest concentration of phosphorus P of any sediment. Pumice soil is naturally high in phosphorus and that is due to the feldspars that are in the pumice. Elsewhere farm fertiliser application and animal waste applied to land can be a major source.

Phosphorus as dissolved reactive phosphorus (DRP) is rarely found in abundance in freshwater streams or lakes. The exceptions are the natural spring waters of the central volcanic plateau. Theodore referred to these as the mineralisation leaking from the rocks. Lakes are thermally stratified with anoxic bottom waters which also produce phosphorus. Phosphorus concentrations are controlled by dissolved oxygen (DO) concentrations in the water. With high DO concentrations minerals, such as iron, form insoluble oxy hydroxides or oxides which sequester the phosphorus to their surface, in other words iron binding. These remove the phosphorus particles from availability to algal plants in the water column. With zero oxygen, in other words anoxia, the insoluble iron oxide dissolves and releases the phosphorus as DRP into the water column where they are available for algal growth.

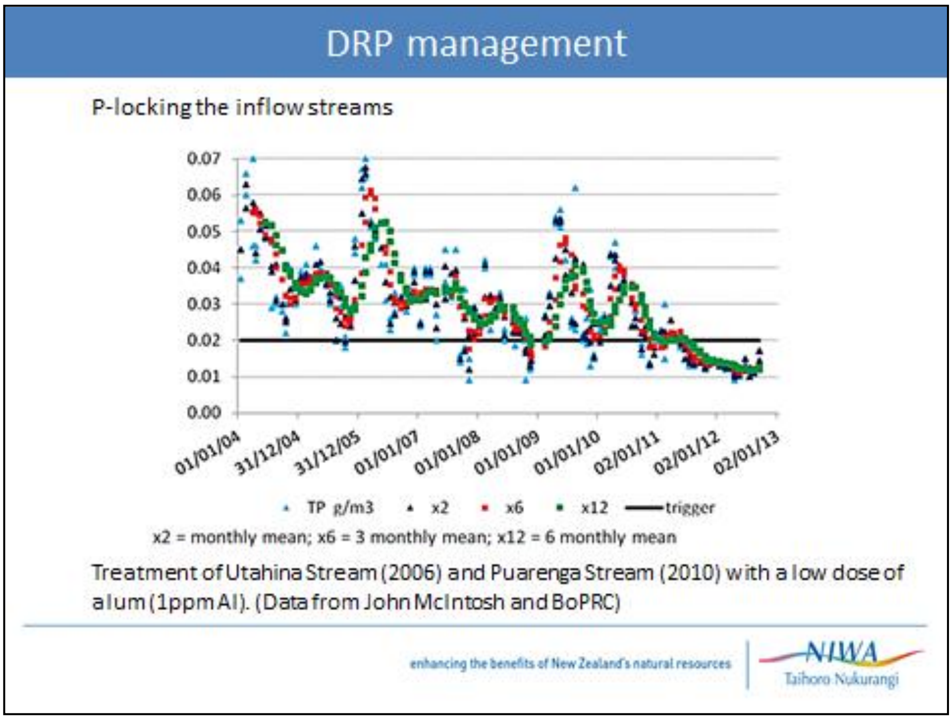
What is so special about phosphorus? All plants need phosphorus and nitrogen for growth, typically in a mass ratio of N : P of 7.2 : 1. These are as dissolved inorganic nitrogen (DIN) and phosphate, i.e. DRP, not total phosphorus or total nitrogen. If either DIN or DRP are in short supply plant growth may be limited. In most New Zealand lakes there is an elevated concentration of dissolved organic nitrogen and low concentrations of phosphorus. This implies that phosphorus is the nutrient most likely to limit algal growth in lakes. It also implies that if phosphorus is added algae are likely to grow and sometimes quite rapidly. Consequently after thermal stratification with bottom water anoxia (DPR) phosphorus concentrations will increase in the lake when the lake mixes and algae will grow.

Lake Rotorua is polymictic; it thermally stratifies and then mixes. Historically it has produced high phosphorus concentrations when stratifying and these are released into the overlying water column when it mixes. In **Slide 1** the data set ranges from 1991 to 2004 and we can see events where the blue line is phosphorus; the green spots are the chlorophyll concentrations. Phosphorus release chlorophyll. Not every mixing event will trigger an algal growth phase. We have situations here where there is phosphorus release but no algal growth. I do not know why, it just happens that way. We saw in previous talks yesterday the way of managing phosphorus in a lake. If you treat the streams you can reduce the phosphorus entering the lake from the streams. **(Slide 2)**

Slide 1



Slide 2



Fine sediment is a bit more difficult to manage because it comes off farm land, slips and other sources. The Bay of Plenty Regional Council has developed detention bunds which are stretched across an ephemeral channel in a paddock. **(Slide 3)**

Slide 3

Slide 4 looks downstream in a paddock towards an ephemeral detention bund.

Slide 4

The device in **Slide 5** is the outlet for the water level control for the detention bund. They hold water with fine sediment eroded by rain allowing most of the sediment to settle in the

Slide 5

paddock. A surprising amount of fine sediment is washed off pasture. It does not look like a major source but 80 to 90% of the catchment in pasture produces a tremendous amount of very fine sediment with very high concentrations of phosphorus.

In conclusion, the link between erosion, phosphorus and water quality is fine sediment. Fine sediment is eroded from the land even with light rain, so just a light shower and phosphorus is moving. Fine sediment carries the highest concentration of iron-bound phosphorus. It is the vector for inorganic phosphorus from land to the streams and lakes. The fine sediment is very slow to settle making this a one step process. It does not move down a bit and wait for the next rainfall; it goes with the rain the full distance. Fine sediment is focussed into the deeper parts of the lake by lake currents and the bottom waters are more likely to become anoxic in summer. Anoxia releases iron-bound phosphorus which may stimulate algal growth when the lake mixes. An excess of dissolved reactive phosphorus in a lake favours the growth of cyanobacteria and there goes your water quality.

QUESTIONS

Eugenie Sage, Green MP: Thank you, they have all been very interesting presentations. In terms of climate change and intense storm events, it seems that we have to really lift our game with erosion control and ensuring that sediment does not get into lakes. What thinking has been done about significantly stepping up our work in this area?

Max Gibbs, NIWA: The work that Bay of Plenty Regional Council are doing using detention bunds, traps and other actions in the catchment is designed to reduce the impact of fine sediment or any sediment coming down. There is nothing you can do about a weather bomb, it will come through, but it is vital to employ good farming practices and such things as the timing of bare ground. Our climate change seems to have given us a wet season and a dry season, so these things need to be considered when managing farms and developing farm plans. Knowing that the rainy season is coming, you would not harvest your corn crop and leave it bare, you would want the paddock covered fairly quickly.

Ian McLean, LWQS: I would like to ask the speakers who described processes that have gone on since the Tarawera eruption, with change taking place in the soil and forest, why is the water quality in Lake Okataina getting worse? What is making the change? Why is something changing right now when these processes have been happening for many decades?

Theodore Kpodonu, Waikato University: If you look at the chlorophyll *a* data of the lake it seems to be stable. However in calculating the TLI, we use other indexes like total phosphorus and total nitrogen and there is an increase in both. However if you look at the productivity of chlorophyll *a,* the lake data does not change in quality per se. Going back to a thesis from the 1950s and research in the 1970s there was gradual change from the 1950s through the 1970s. But from the 1990s until now there has been stability in the water quality. But because we use various indexes in the calculation of the TLI it shows the quality of the water going up and down.

Don Atkinson, LWQS: Is the suggestion of moas' grazing in earlier pre-European occupation comparable to the current grazing from our introduced species of mammals?

Rob Allen, Landcare Research: You raise an ongoing discussion there, probably the most recent statement is from the Feathers to Fur Symposium, run by the New Zealand Ecological Society in 2010, in which one of the papers presented compares the diet of moa and deer, and there is huge overlap.[1]

David Hamilton, Waikato University: Part of the significance of Lake Okataina is that it is a reference lake. The concept of a reference lake is that it is an un-impacted lake. In terms of the National Policy Statement for Fresh Water Management we want these reference lakes because there are impacted lakes around the country that we are trying to return to the condition that approximates somewhere between where it is now and a reference lake. I wondered if Willie, Rob and Theodore would comment on the concept of 'reference state' and with so much variability when should we consider things to be in a reference state? Here is a lake that has 89% of its vegetation in indigenous forest and for us in the Rotorua Lakes that would be the reference state almost.

[1] David M. Forsyth, Janet M. Wilmshurst, Robert B. Allen and David A. Coomes, 2009. *Impacts of introduced deer and extinct moa on New Zealand Ecosystems,* http://newzealandecology.org/nzje/2913.pdf

Rob Allen, Landcare Research: I do not support the notion of a stable reference point, it should be a changing reference point. In many respects I agree with what you are saying, it is a lake that is operating without a dominating human influence driving those changes. But we have to be careful to partition out the fact that humans are not the driving force. One of the aspects I talked about was the even aged nature of the forests and that drives nutrient dynamics in the systems. Those forests to some degree have not even aged as an artefact of past human activity. So you have to keep an open mind and think what the lake is like and what are the driving factors and are they different from a set of factors in another lake. I have not had much to do with the Rotorua Lakes but I look at 13 lakes and think – hmm, a pity they did not have a few more to partition out the variants.

Willie Shaw, Wildland Consultants: It is fine to use the concept of reference lakes but you have to understand what is going on with them and their catchments in particular. For Okataina we do not understand the variation over time of what appears to be a very natural system. All the preparation on my presentation did for me was raise question after question about what IS going on. The session this morning has added another level of complexity because there are not only erosional processes carrying core sediment into the lake, but as we heard from Max, the fine sediment processes as well. Look at the steepness level increases and we can relate that to simple measures like bank collapse or landslide occurrence, but what about the fine sediment carried through all those high rainfall events. There has certainly been some accumulation of high rain events which have led to those spikes and the related effects around the shoreline. So the concept is fine but we have to understand what is going on in the system as a whole.

Theodore Kpodonu, Waikato University: The concept of reference used in restoration; restoring the lake to pre-disturbance period. What is the definition of pre-disturbance? Is it pre-human disturbance? Is it pre-climatic disturbance? Pre-what disturbance? I look to what Rob is saying that there should be an evolving concept. I looked at a 10 year window of Lake Okataina water quality data in terms of climate change and how much control climate has. We have about 50% variability in the data explained by climate alone which is quite high, compared to many lakes in other places.

We could see that climate plays a major role and so, what is pre-disturbance? We need to look at our 3 year TLI concept again and the reference conditions for restoration. Maybe it needs a bigger forum to look at what we should do with lakes' restoration or we will be taken by surprise one day. We think we are doing all the right things with no dairy farming, no this and that, but the lake is still deteriorating. We should look at reference conditions in terms of climate, natural drivers and anthropogenic drivers of ecosystem change and then we can set good conditions for our lakes.

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Session Six : Control of Animal Pests

SESSION CHAIR – Dr Ken Hughey, Chief Science Advisor, DOC

CONTROL OF PESTS IN LAKE CATCHMENTS – THE DEPARTMENT OF CONSERVATION'S PERSPECTIVE

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Alastair began his career working as a Science Technician for the Ecology Division, DSIR, after getting a degree in biology from Waikato University. He then went overseas, working as a wildlife ranger in Scotland and as a Wildlife Biologist for Raleigh International in Chile while studying for a PhD in ecology at the University Of Aberdeen. On returning to New Zealand, he joined the Department of Conservation. Alastair is currently a Technical Advisor in the Transformation and Threats Unit providing advice on animal pest issues. The work includes developing best practice for pest control, registration and use of pesticides, and advice to staff conducting pest control operations.

ABSTRACT
A key part of the Department of Conservation's (DOC) work is to ensure the diversity of New Zealand's natural heritage is maintained and restored. However, is a huge task and DOC's resources cannot stretch to do everything everywhere. DOC therefore has to make decisions about what work to do and not do, juggling limited resources while meeting both biodiversity and community needs.

To help make these decisions, DOC has developed the Natural Heritage Management System (NHMS) Programme which identifies the highest priority sites (both terrestrial and freshwater) that need to be protected and where work needs to be done. For NHMS to correctly identify the priority sites and what work it needs to be done at the sites, it relies on good information. For the freshwater sites, the data came out of the Freshwater Ecosystems of New Zealand (FENZ) dataset. This data set describes the environmental and biological patterns in NZ's freshwater ecosystems (rivers, lakes and wetlands). Once priority sites have been identified, it is important to understand what pressures the sites face and what activities, including pest control, need to be undertaken to reduce these pressures.

In this presentation, the Rotorua lakes, with particular reference to Lake Okataina, will be placed in the context of this prioritisation process, the pressures they face and pest control activities DOC has identified as necessary to ensure the priority lakes are protected.

TRANSCRIPT
My presentation will give the Department of Conservation's (DOC) perspective on when terrestrial pest control may be an appropriate management activity in lake catchments to improve the lakes' ecosystems. However before deciding on undertaking pest control in lake catchments a decision is made on whether the lake is a priority and whether pest control is really needed.

I have therefore divided this presentation into three parts. Firstly I will provide context around how DOC selects lakes for management and how it prioritises the work that needs to be undertaken at those sites. Then I will talk about when pest control in the catchments may be an appropriate management activity to address the lakes issues and finally we will use Lake Okataina as a case study.

The Government and the public have increased demands for accountability on Government Departments, therefore DOC like all other Government agencies is required to work within the Managing for Outcomes framework. This means DOC's work focus is on achieving long term results that have clear outcomes. DOC's overarching Outcome Statement is that:

> *New Zealanders gain environmental, social and economic benefits from healthy functioning ecosystems, recreational opportunities and living our history.*

Sitting under this overall outcome are what we call five intermediate outcomes and these relate to how DOC intends to do its work in the areas of natural heritage, history, recreation, engagement with the public and business opportunities. The key one relating to the protection of lakes and other ecosystems is:

> *The diversity of our natural heritage is maintained and restored.*

To maintain and restore New Zealand's natural heritage DOC has identified six things that need to be achieved:

- 1.1) A full range of New Zealand's ecosystems is conserved to a healthy functioning state
- 1.2) Nationally threatened species are conserved to ensure persistence
- 1.3) Nationally iconic natural features are maintained or restored
- 1.4) Nationally iconic species are managed to ensure their populations are maintained or restored
- 1.5) Locally treasured natural heritage is maintained or restored as partnerships
- 1.6) Public conservation lands, waters and species are held for now and future generations

The first two objectives 1.1 and 1.2 are about preserving representative functioning examples of ecosystems and preventing the extinction of threatened species. These are decided at a national level on cost-effectiveness and I will explain later how lake ecosystems fit into this. Objectives 1.3 and 1.4 are about nationally iconic features and species and what New Zealanders as a whole value. They will be prioritised based on input from the public. That is still to be done, but it is anticipated that a lot of the nationally iconic features are going to be in National Parks or big scale landscape features.

Objective 1.5 is about local treasures which are what communities value in their area, and it will depend on community interest and involvements. For example if a community values a lake that is not considered a national priority this is where the community can engage with DOC to protect it. What is still to be decided is the priority for resources in this area and the ones chosen may partially depend on their ability to draw on external funding.

Finally there is Objective 1.6. This covers the rest of DOC managed land. These sites will get basic management, for example, biosecurity, fire, legal protection and maybe fencing,

but not much else. This sounds really bad but it is not dissimilar to the current situation for much of public conservation land.

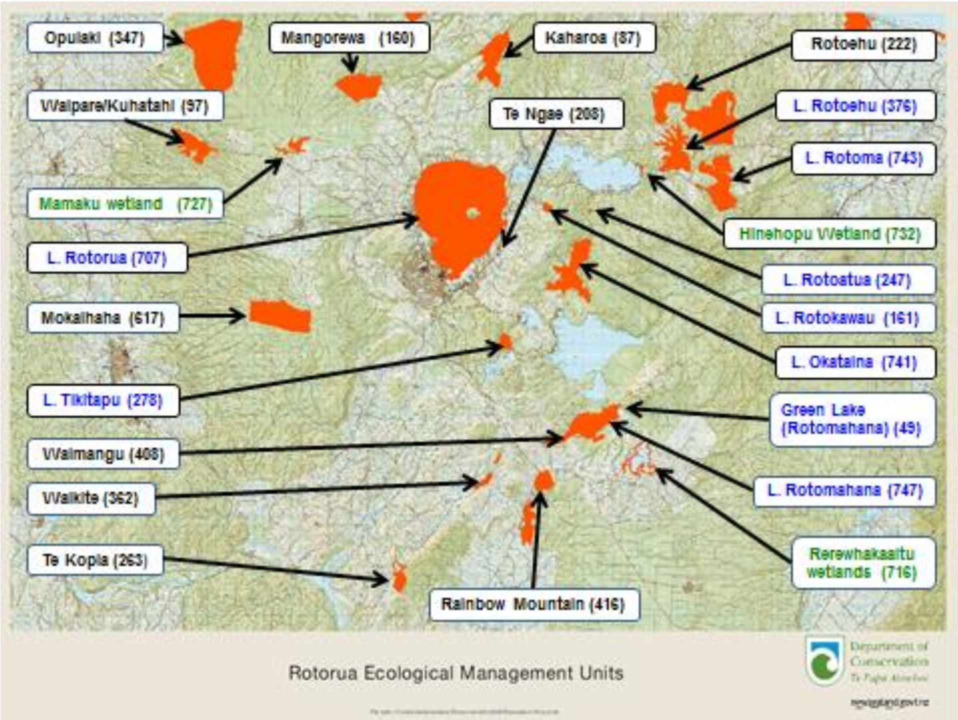
Addressing the first 5 objectives is a huge task. DOC's resources cannot stretch for everything everywhere. DOC therefore has to make decisions about what work to do and what not do, juggling limited resources or meeting both diversity and community needs.

How do we juggle these resources? Returning to Objective 1.1 'protecting national ecosystems', to help make decisions on which nationally important ecosystems need protection, and to identify the most cost effective projects at these sites, DOC has developed a national process called the Natural Heritage Management System, NHMS for short. It aims to maximise the conservation returns within a given budget and management constraints. It identifies the highest priority sites, both terrestrial and freshwater, that need to be protected and what work needs to be done at these sites.

To ensure that there was a full representative set of lakes in the best ecological condition included in NHMS, an expert working group considered information on about 3,800 lakes throughout New Zealand. The information used came from a number of sources including the Freshwater Ecosystems of New Zealand's data set. The type of lake, how pristine it is, its biodiversity and potential for recovery were all important considerations when making recommendations on which lakes should be included into NHMS.

In NHMS there are just over 1,000 terrestrial and freshwater sites that have been identified as important. Approximately 140 of these sites are lakes. All the sites were ranked as a whole, not separately for terrestrial sites and freshwater. For all the sites that are within NHMS DOC has looked at what pressures each site faces, what work needs to be done to address those pressures and a potential cost of the work. Currently DOC is at the point of prioritising which sites will have work undertaken. Unfortunately the amount of public funding will not extend to all of these 1,000 sites. There is going to be some hard decisions on what is the most cost effective work at which sites.

Slide 1



To give you a local flavour **Slide 1** shows the 23 ecosystems within the Rotorua Lakes area that are considered a national priority in NHMS. Nine of these are lakes and their national rankings range from 49 for Green Lake at Rotomahana to 747 for Lake Rotomahana itself. Admittedly there needs to be more fine tuning and over time some sites may be added and others dropped.

Once the lake has been identified as a national priority, or a local priority, it is important to understand what pressures the lake faces and decide on what work is required to address these pressures. There is no point undertaking work that will not address the problems that the lake actually faces.

Some examples of pressures identified for different lakes around New Zealand include:

- Loss of native catchment vegetation resulting in higher run offs, turbidity and declining water quality
- Invasive species such as macrophytes, pest fish and pioneer plants such as willows surrounding the catchment which in turn affects biodiversity, water turbidity and water quality
- Damming, inflow/outflow diversion altering the lake's hydrology and impeding fish passage
- Urbanisation, agriculture and animal pests surrounding the catchment altering water quality by increasing nutrient loadings in the lake

Leading on from this, DOC has identified what work is required to address the pressures. Examples here are:

- Advocacy through the RMA process whether it is submissions on regional plans or resource consents
- Riparian plantings
- Changing water management regimes for the lake
- Stakeholder education around pest species and surveillance control of pest species
- Fencing off water ways
- Pest control in lake catchments.

When might terrestrial pest control on a catchment scale be important for the lake? There are 4 potential areas where pest control may benefit the lake:

- Soil erosion and sediment yield may be affected by pest control
- Potential water run off rates into a lake
- Water quality
- As a holistic catchment based management approach.

While historical New Zealand science literature suggests pest animals were a significant contributor to erosion at a large catchment scale, much of it was anecdotal and non-quantitative. It is now considered largely incorrect. Natural influences such as tectonics, storm intensity and soil geological features have a far greater influence over erosion rates and animal pests at a catchment scale. The largest non-natural influence on erosion rates and sediment yield has been deforestation by humans.

The impacts of pests have largely been discounted when compared to other processes, so animal pest control for catchment scale is unlikely to address erosion issues and reduce sediment yield in a lake.

Deforestation can lead to increased water run off during rain fall events by up to 30-40%. However research indicates that there are unlikely to be detectable changes in water yield unless more than 20% of the catchment is deforested. So the effect of browsing on water yield is unlikely to be significant unless there is large scale canopy collapse and the forest is replaced by grass vegetation.

There is also some minor increase in run off rates as a result of animal pests significantly removing the understorey. However, it is probably not enough to affect lake water levels. Therefore if water yields are key, pressure on the lake pest control is unlikely to be effective in managing this and resources would be better directed to, say, re-vegetation.

The impact of animal pests on water quality is potentially important, however wild animal density is usually 2 to 3 orders of magnitude less than livestock. Their low biomass compared to livestock generally makes it a relatively minor factor in the overall catchment context. Therefore there is probably little point in undertaking pest control in catchments where a large part is under agriculture if you are trying to influence water quality levels in the lake. However, in catchments that are predominately in native forest the impacts of animal pests on water quality may become important and at that point pest control could help. There is also the issue of faecal contamination from pest animals but again magnitude between pest animals and livestock means it is probably going to be fairly minor.

The lack of direct evidence linking animal pests to changes in large scale catchment water quantity and quality does not suggest that they have no impact. All it shows is that their impact is smaller than other influences such as tectonics, large storms, deforestation and intensive agriculture. Therefore one cannot rule out completely pest control in catchments because accumulative impacts could still occur that

currently cannot be measured.

Environmental quality may be changing at a local or small scale that could be locally important, particularly to small lakes. There may be biodiversity benefits for native species that use the lake ecosystem. For example, terrestrial pest control in the Lake Hauroko catchment has been undertaken to protect mottled petrels that breed on the islands in the lake. Of course pest control will benefit the health of the forest ecosystem and the surrounding lake in an holistic approach.

What does this mean for Lake Okataina? It is a good example of a volcanic deep oligotrophic lake that has been ranked 741 in NHMS. It has a 6,290 hectare catchment and between 81% and 89% of the catchment is in native vegetation. While the lake itself is ranked in NHMS the surrounding catchment is not because the vegetation has been so highly modified through extensive logging. Additionally, pest numbers are high and the understory is in a poor state.

DOC staff have identified 3 main pressures that could affect Lake Okataina:

1) Lake macrophytes: lagarosiphon is present and hornwort is being controlled at the moment. But if other aquatic weeds are introduced they would alter the ecosystem.
2) Invasive fish: none, excluding trout, are present, but could have a significant impact if introduced.
3) While the water quality is high, phosphorus levels have increased which could potentially lead to a decline in water quality. I suspect that DOC staff may have talked to staff of both Bay of Plenty Regional Council and Rotorua Lakes Council when determining the pressures Okataina faces as these are the ones that have been identified through the LakesWater Quality Symposium and in council documents.

DOC has identified work required at Lake Okataina to address the pressures. For lake macrophytes and pest fish there are two key management tools. Advocacy work through education and stakeholder involvement is essential. It is far better to keep the invasive species out of Lake Okataina as it will be difficult to eradicate them if they become established. Hand in hand with the advocacy work there needs to be ongoing surveillance and if necessary control to prevent any more invasive species establishing.

There are two areas of work that have been identified to maintain and improve water quality. DOC sees advocacy work as critical to maintaining water quality. DOC has identified that promoting covenance and private forest remnants in the catchment, education, stakeholder involvement and engaging in the RMA process are particularly important. Secondly, since the majority of the catchment is native vegetation pest control in the surrounding catchment may help improve water quality at Lake Okataina.

An Animal Control Plan has been written, Cam Speedy is going to talk about that later, but if pest control is going to occur at Okataina to address water quality there needs to be ongoing monitoring to confirm that the pest control is effective at achieving the improvements required. In addition pest control has linkages to a region wide management of wallabies as part of a holistic approach, and Dale Williams will be talking about this in the next presentation.

In funding the work at Lake Okataina, the advocacy, and ongoing surveillance and control work is seen as a Rotorua Lakes' wide issue and will continue to be supported by DOC.

However a decision is yet to be made on whether DOC has the resources to undertake pest control in the lake's catchment as part of the NHMS process. Unfortunately the lake's ranking of 741 suggests there will be insufficient national funds available to do the work. However there is the ability to move the lake and its catchment into DOC's 1.5 Local Treasures priorities. The concept is that DOC would rate the lake highly under Objective 1.5 if there was significant community interest in it, including a willingness to contribute to the management costs.

In summary DOC has a process for prioritising where work will be done to achieve maximum benefits to New Zealand's natural heritage. Nine Rotorua Lakes including Lake Okataina have been identified as nationally important. DOC also recognises that even if lakes are not considered nationally important they may have local importance. While the impact of animal pests on water quality is generally considered small there may be a case for pest control in catchments that are predominately in native forests and where a holistic approach has been taken.

Finally DOC has identified pest control may be necessary in the Lake Okataina catchment if the lake's water quality is to remain high. What needs to happen now is a discussion between the Department of Conservation and the various Lake Okataina stakeholders on how to fund that control.

DAMA WALLABIES: THEIR HISTORY OF COLONIZATION AND CONTROL AT OKATAINA/TARAWERA

Dale Williams
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Dale began work for the New Zealand Forest Service in 1980 as a Science Technician with the Forest Research Institute in Rotorua. Following a restructuring of Crown research, he was transferred into Manaaki Whenua - Landcare Research. As a technician, he supported scientists studying indigenous forest ecology, threatened species such as kokako and pest animals such as rats, possums, and deer.

In 1993 Dale joined the Department of Conservation, as a Technical Support Officer, advising DOC staff on pest animal management within the Bay of Plenty Conservancy. While in that role he completed a Post Graduate Diploma in Wildlife Management through the University of Otago. As part of that course of study, in 1997, he completed a research report, "Evaluation of bait stations and management options for control of dama wallabies (Macropus eugenii) in the Bay of Plenty. University of Otago Wildlife Management Report Number 85". Between 2001 and 2010, he facilitated a national biodiversity training programme for DOC, taking a one year break to work as the Threatened Fauna Programme Manager for the Chatham Islands. Since 2010 he has worked as a Land Management Officer for the Bay of Plenty Regional Council (BOPRC), based out of Rotorua, and advises landowners about Biosecurity, Biodiversity and Sustainable Land Management. Part of this Biosecurity role with the council is to take regional responsibility for issues relating to wallabies and he is part of a multi-agency Wallaby Management Team, which has representatives from DOC, BOPRC and the Waikato Regional Council.

ABSTRACT

Dama wallabies (*Macropus eugenii*) were liberated near the southern end of Lake Okareka in 1912. By the 1970s their numbers had built to high levels in the forests surrounding Okareka, Okataina and Tarawera and the damage they were causing to the forest understorey was marked.

In 1984 the New Zealand Forest Service established a pair of 'exclosure plots' at Okataina designed to isolate the impacts of wallabies from those caused by deer. A decade later when the vegetation plots were remeasured, species diversity had increased by 142% where both deer and wallabies were excluded. Diversity had increased by 57% where wallabies were excluded and continued to decline by 7% where browsing was unrestricted.

Between 1988 and 1999 three aerial poisoning operations and some ground based pest control, targeting wallabies and possums, were carried out around Okataina and the Makatiti Dome.

Though these operations were highly successful at reducing wallaby numbers (93-95% reductions based on cleared-plot faecal pellet counts) remeasurement of permanent 20x20 metre vegetation plots showed no response in the forest understorey. To some extent this is not surprising as the control operations were effectively 'one-offs' in separate areas and only limited follow-up control took place.

Whether the depleted nature of the forest understorey has a significant impact on declining water quality in the Central North Island lakes is a question that will be extremely complex to answer, and to see marked recovery in these forest ecosystems, pest control would need to target a suite of pests and be sustained in perpetuity.

With regards to wallabies, a multi-agency Wallaby Management Team (including staff from the Department of Conservation, the Bay of Plenty and Waikato Regional Councils) are facing a number of issues. The wallaby feral range currently covers approximately 180,000 hectares and continues to expand. A tiny proportion of New Zealand's vertebrate pest research has concentrated on wallabies, so the Management Team faces significant knowledge gaps around wallaby behaviour and they have access to few robust monitoring tools and control methods. A low level of public awareness about the threat to biodiversity posed by wallabies and increasing public concern about some pest control methods exacerbates these issues.

Though monitoring and control methods for wallabies are limited, recent advances include the successful deployment of digital trail cameras, DNA analysis and a wallaby indicating dog to confirm the presence of low density populations in new areas. Bait development work with captive wallabies has identified a number of areas where traditional possum baits can be modified to improve their acceptance by wallabies.

As the Wallaby Management Team plans to proceed with control operations, targeting new incursions and populations outside of the feral range, an "Adaptive Management" approach will be followed. This will maximise the benefits from knowledge gained during the course of the work. To help limit further dispersal of wallabies, the Wallaby Management Team also requires some 'pure science' research on dispersal behaviour, so invasion pathways can be identified and managed.

TRANSCRIPT

My association with the forests of the central North Island goes back to the early 1980s when I began work for the Forest Research Institute as a technician. My dealings with Dama wallabies started in the early 1990s when I took up a role as Technical Support Officer with the Department of Conservation. My return to Rotorua in 2010 to join the team at the Regional Council gave me a chance to take on some unfinished business with wallabies.

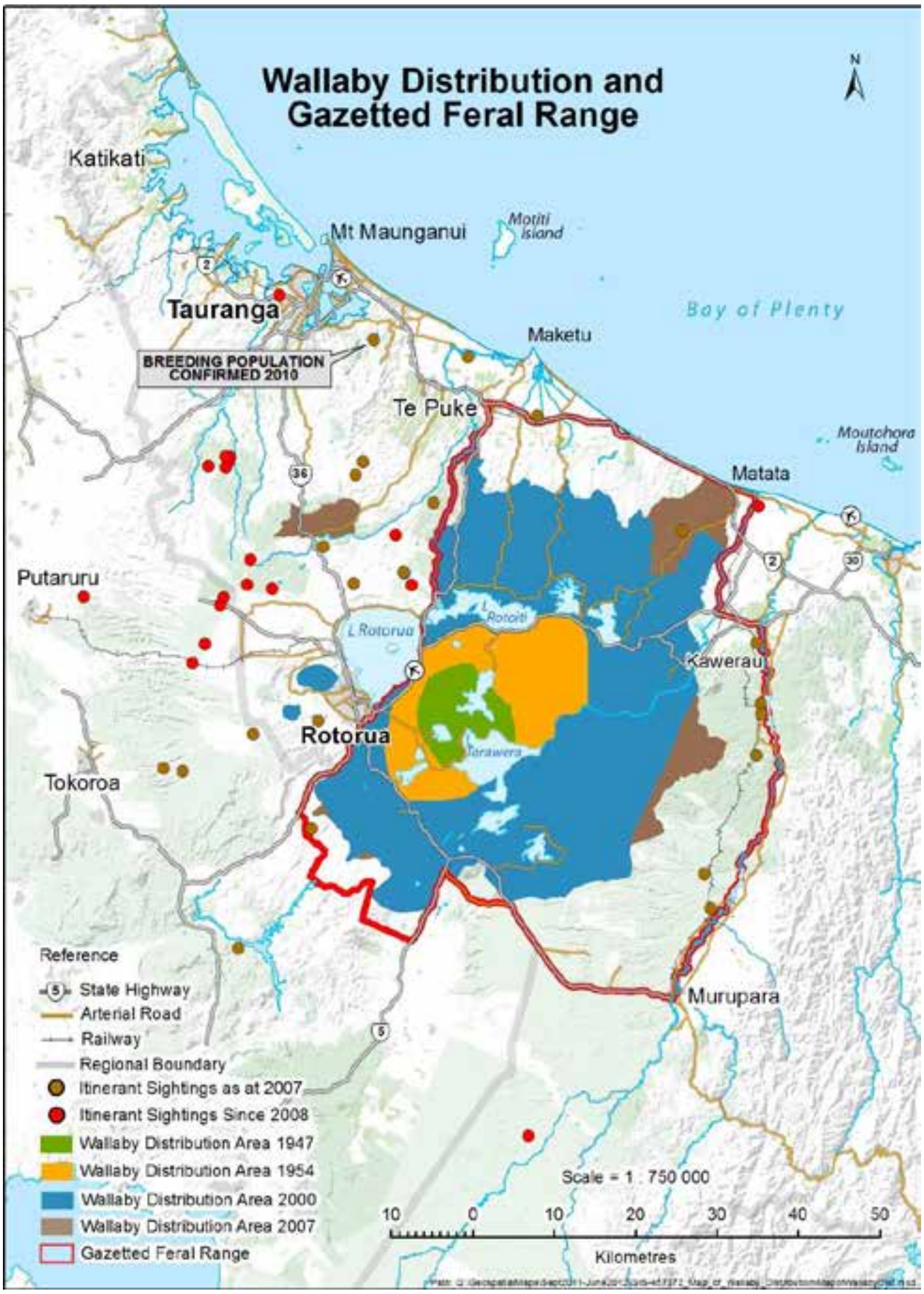
I will talk firstly about the critter and give you the history of their colonisation in the Bay of Plenty and the impact they cause on the forest understorey at Okataina. I will also give a history of the results of past control operations at Okataina, some of the issues inhibiting us from managing wallabies and recent advances, the 'good news' stories, and our future challenges going forward.

The most common statement I hear about Dama wallabies is, 'I didn't know we had wallabies'. They are the smallest of the five species that were introduced to New Zealand. A large male reaches 7 kilos and most of the females are less than 5kg. Compare that with the Bennett's wallabies found in South Canterbury which can be up to 25 kgs. Coincidently, every photograph of a wallaby I have seen at this symposium so far, apart from the one on the front of your document, has been a Bennett's wallaby, so clearly

Google images are lacking a few photos. Because they are small and nocturnal they prefer a scrubby habitat and they are very cryptic. It is not uncommon for land owners who may spotlight their property for deer and possums to be unaware that they have wallabies on their property.

There is a low level of public awareness that we even have feral wallabies in the Bay of Plenty and what is even worse is that people that do know we have wallabies do not see them as a problem; they are often regarded as being cute and harmless.

We have had these animals for 100 years now. They were liberated near Lake Okareka in 1912 and since that time have expanded to cover nearly 180,000 hectares.



Probably of most concern is those little red dots on the western side of the big red line which are confirmed sightings of individual wallabies. I will come back to this map later on.

Wallabies were introduced into New Zealand by Sir George Gray in 1870 when he put four species of wallaby on Kawau Island. In 1912 dama wallabies were transferred from Kawau Island down to the Bay of Plenty where they were let go near Lake Okareka. The orange blob on the map is the distribution in 1954; by that stage they completely surrounded Okareka, Okataina, Makatiti and three sides of Lake Tarawera. By the 1970s the New Zealand Forest Service had already identified they were having a serious impact in the forest understorey.

The photos above show the comparison of the vegetation within an exclosure plot put in by the Forest Service in 1984 and when the plots were re-measured by the Department of Conservation a decade later. The fenced area that excluded both deer and wallabies showed 142% more species diversity (above right). There is also a plot with a lower fence where the wallabies are excluded but deer can hop over the fence and that showed a 57% increase in diversity. Where both deer and wallabies had access diversity continued to decline by 7% (above left). Rob Allen talked about the biased nature of the exclosure plots which are deliberately sited to get a response. Rob said this may not be typical of all Okataina. It would, however be typical of all the second growth kanuka forests, the dry habitat that Willie Shaw referred to.

There has been a history of animal control, in this area, going back to 1962-63 when eight aerial poisoning operations were carried out to 'protect rateable land' between Lakes Tarawera and Rotoma. In 1987 there was another aerial operation using 1080 Mapua cereal bait carried out over the east and south of Lake Okataina. The following year that work was extended to include the Makatiti Dome and part of the Tarawera Scenic Reserve. Following on from that in 1989 through to 1991 various ground based control operations were carried out using a variety of methods - 1080 gel, 1080 cereal bait, cereal containing brodifacoum and hand laid cyanide. This work covered areas missed by the previous aerial baiting operations. In 1999 the last operation was carried out at Okataina, it used 1080 carrot and covered the western side of the lake. Bait stations containing Pindone was used in sensitive areas.

We have no idea of the results of the operations in the sixties as they were not monitored, but the other aerial baiting operations achieved high percentage kills ranging from 93% through to 95%:

- 1987 - aerial 1080 **95% reduction in wallabies**
- 1988 - aerial 1080 **93.7% reduction**
- 1989 - 1080 gel foliage baiting trial **87.2% reduction**
- 1999 – aerial 1080 carrot **93% reduction**

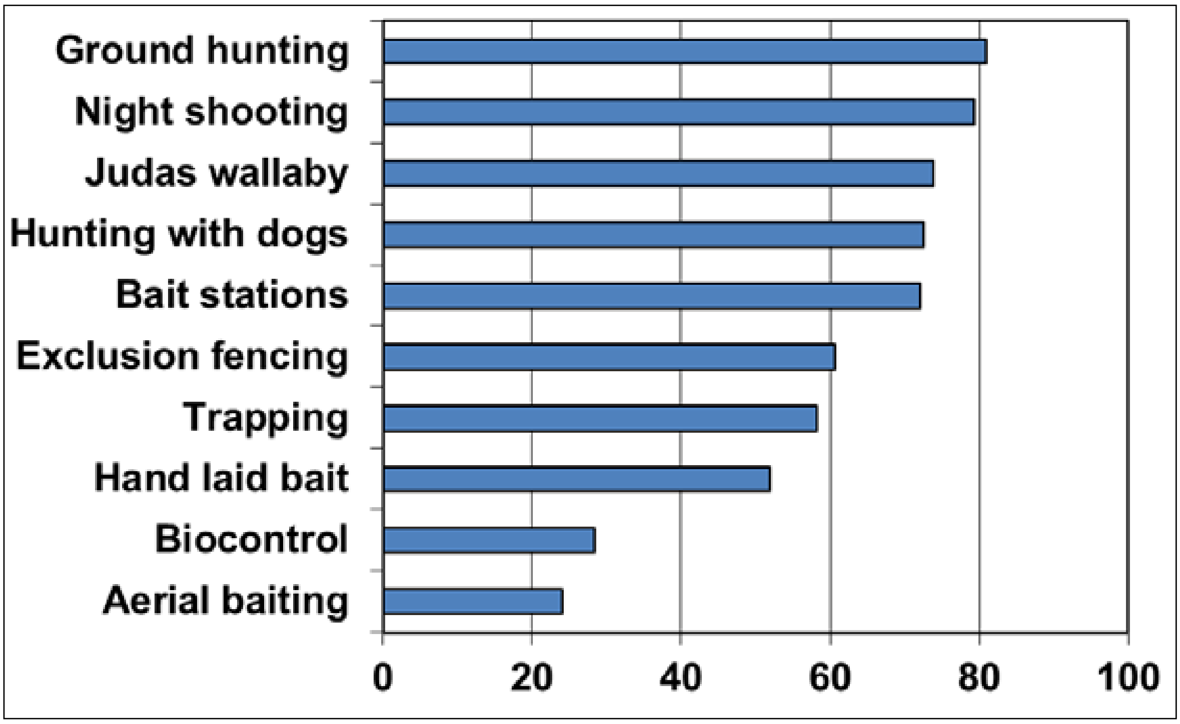
The only ground operation where results were monitored was Bruce Walberton's trial with 1080 foliage bait. That achieved 87.2% kill. These percentages are worked out using cleared plot faecal pellet counts and if any of you had the misfortune of doing faecal pellet counts they are the worst case scenario. You have to remove the pellets from the plot, go back a month later, search for pellets, count the ones that are recruited then do your control operation and repeat it all again. It is my understanding that in the 1999 operation the monitoring cost more than the aerial baiting operation. Despite the cost it is a good tool for moderate to high density wallaby populations but it is not suitable for picking up wallabies in low numbers.

All of these operations had a good result in terms of animal kills but, and that is a very large but, looking at the outcome in terms of forest regeneration, despite the dramatic reduction in wallaby numbers, the re-measurement of a whole series of 20 by 20 plots throughout Okataina showed no significant response in the forest understorey. To some extent that is not surprising because all of those operations were in different areas and there was little or no follow up control. They were essentially 'one offs'. Expecting to see change after doing just one control operation and walking away…it will simply not happen.

Another thing that I believe is going on out there, and Graham Newton saw this with fallow deer in the Blue Mountains, prior to those baiting operations a diet study carried out on wallabies showed they ate a large amount of 'leaf fall mahoe'. If you assume that leaf fall mahoe is less palatable than the small seedlings growing in the understorey, it is likely that the few surviving animals will reject the leaf fall and continue to eat every palatable seedling.

There are still a lot of questions to answer. How do we deal with the impacts of browsing mammals? How low do we need to push wallaby numbers at Okataina to see regeneration of palatable species in the understorey? What other critters do we also need to deal with? And the million dollar question, will sustained multi-species pest control actually improve water quality? More will be said about this in the next presentation and other speakers have already pointed out that even if improved water quality is not one of the outcomes, from multi-species pest control, there are other reasons for doing animal control.

There are some issues inhibiting wallaby management. We only have a handful of baits registered for wallabies and two pesticides (1080 and Cyanide) and clearly 1080 has a high level of public concern. In 2006 APR Consultants carried out a survey of public awareness about wallabies and they asked people about their support for a range of potential wallaby control options. As to be expected, aerial baiting was at the bottom with a low level of public support. Unfortunately it shows an inverse correlation between public support and the method's effectiveness.



Night shooting which had a high level of public support is not effective for broad scale control of wallabies in a forest situation. It is however effective on farm country with small patches of forest. We are reasonably confident that we have eradicated a small population of wallabies on Okere Farm using night shooting.

It is quite reassuring to see that bait stations, which I am a fan of, get around 75% public support, but there are a few issues with wallabies and bait stations which I will come to later.

Another issue inhibiting wallaby management is the low level of public awareness about wallabies. For any control programme to be sustainable the public have to be on side or it is a waste of time.

Wallabies are seen as a regional rather than a national issue so the amount of money spent on funding control operations, developing control techniques, and any sort of research and development, is just a drop in the bucket compared to the millions that have been spent on other pests such as possums and other predators. Unfortunately we are on our own here.

As a result we have very limited control methods available to us. We have a limited understanding of what drives dispersal and that could be helpful in the future. One thing we do know is that wallabies are very timid and neophobic. Neophobic means they are afraid of new things in their environment which also has implications for methods such as bait stations.

I have had some mileage out of this photo over the years. It shows competitive exclusion between possums and wallabies. In 1996 when I took this photo it was part of a pilot study I did to see which bait stations might be best for wallabies. Physically there is no reason they cannot feed from any of these three bait stations, their skull is about the same size as a possums so there is nothing stopping them. But I found that they completely emptied the Marley downpipe bait station, before taking a single bait out of the other two stations including the Philproof feeder.

The Philproof feeder is the best possum bait station on the market for a number of reasons. There is a big veranda on the front which effectively keeps the bait dry. It appears that wallabies do not like putting their head into the bait station because the veranda covers their ears and eyes. Unlike a possum which can climb the nearest tree when danger comes along, a wallaby has to pick up any source of danger with enough advanced warning to run away. Wallabies are very wary and they are constantly listening and watching out for danger. Enlarging the entrance hole on the bait station helps but it is still not ideal. The other issue seen in this photo is that possums will actively exclude wallabies from the bait station. Possums are half the size but twice as stroppy.

The photograph above was taken on Mt Tarawera and a wallaby is feeding quite close to some possums and it is probably a wee bit nervous. In most other video sequences you see the wallabies will depart when possums arrive.

These photos show some good news stories relating to recent advances in wallaby surveillance and monitoring. Firstly an ancient technique (left), a dog. Dogs have been around a long time but we are just starting to make good use of them. This specialised wallaby indicating dog and it handlers have been very successful in locating new wallaby populations on the margin of the range.

The other device shown is a trail camera (right) that is mainly used by deer hunters to get pictures of stags on their favourite wallow. We use these as a surveillance tool to record the presence of wallabies and determine if it is more than one animal. Also as a monitoring tool, by placing them systematically at 500 metre intervals to monitor the success of our control operations. This was how we located the wallabies on Okere farm, an unexpected spin off also recorded the first kiwi in the Rotorua district in the last decade. We also used the cameras to monitor the success of our night shooting operation (i.e. no wallabies have been recorded since).

We have also recently carried out a bait development trial, under contract with Ray Henderson from Pest-Tech Ltd in Lincoln. We have a captive holding facility here in Rotorua. Ray tested and developed various baits, lures and bait delivery systems for control of wallabies. He found that wallabies are strongly neophobic and upset by new things in their environment. He identified the ingredients that wallabies preferred, which were; wheat germ, bran, linseed meal, maize, brown sugar, salt and rolled oats, and combined them to make a palatable paste bait. When doing bait trials we used Connovations' 213 paste, as the comparison or "Control bait". Anything that is as good as that product scores a 50, if it is better it scores higher than 50. Ray's paste bait was a significant improvement on that commercial bait. His cereal bait was only slighter better than 213 paste. By comparison RS5 (the best commercially manufactured cereal bait) only scored 19.8% for wallabies. Ray confirmed that carrot appears to be a good bait for wallabies.

Ray tested 98 different lures. He found that the best wallaby lures were mixed herbs - tarragon, oregano, cloves or eucalyptus and wheat germ oil. Their interest in eucalyptus oil clearly indicates, even after 100 years, they are still pining for home.

One interesting outcome from that work was that cinnamon, which is in the majority of possum baits, is a repellent to wallabies. The only thing worse than cinnamon, that Ray trialled, was persimmon.

The results on delivery systems showed that placing the bait directly on the ground had the highest consumption. Strikers are a little potato starch container with a paste bait inside which are stapled to trees (left) and were also an effective way of distributing bait to wallabies.

At the end of the bait development we offered the wallabies bait with a feratox cyanide capsule inserted in it. Unfortunately the results were really poor. I believe we need to pre-feed with baits containing placebos that closely replicate the cyanide capsules to reduce the chance of the wallabies rejecting the cyanide capsules when the toxic baits are presented to them.

Looking forward, we still need some good wallaby specific control tools. We need to calibrate our monitoring methods. We have two good methods but we do not know their detection probability. We need better understanding of wallaby behaviour and dispersal which is important to improve the efficiency in our surveillance and control.

We need to improve public awareness, but this can be a double edged sword. It is all very well for us to generate motivation from the community but if they then say, ‘What are you doing about it?’ And we say, ‘Mmm not much, we haven’t got the tools’. It can come back to bite us, so it is really important to use the current control tools to get some runs on the board.

So what is our end goal? At the moment we are trying to stop further spread of wallabies. The red line on map (see map of distribution) was the gazetted feral range under the old Wild Animal Control Act. We now call that our containment area. The Kaituna River (the north western boundary) and Lake Rotorua itself, has formed an effective barrier to stop wallabies going west. Both the Tarawera River and the Rangitaiki River are good physical barriers and they form our line in the sand as defendable boundary in the east. In the south there is not much stopping them. Unfortunately where wallabies have dispersed west of Rotorua, all the streams are pointing towards the Waikato and are not a physical barrier.

Following our goal of ‘stopping the spread’, we are trying to eradicate isolated populations such as the Okere population (which we are reasonably confident is gone now) and a isolated population behind Te Puke (which was the result of someone keeping wallabies illegally for export). Once outlying populations are eradicated we can push back towards the middle of their range.

While this is happening the land management team need to decide whether wallabies are having a negative impact on resources within the containment area. If that is the case, it is sustained control, which involves pushing wallaby numbers to low enough levels that they do not impact on those resources.

Finally once making that kind of progress, then it is possible to step back and review whether eradication is achievable over the whole range.

There have been lots of cute photos of wallabies and I will leave you with this one because protecting bio-diversity is about killing things, it is not pretty. But we do need to get some serious runs on the board in pushing back the tide otherwise we run the risk of losing the support of our stakeholders.

I would like to finish up by thanking Guus Knopers and Lynell Barnett, our dog handlers, Lotte the dog and Phil Commons who is my 'go to' man for all wallaby issues. Ray Henderson did the bait trial, Cam Speedy and Nick Singers wrote an awesome report on animal control options for Okataina, which I have plagiarised for this presentation. Thanks also to the Department of Conservation and the Waikato Regional Councils are co-signatories to our wallaby management plan.

PERSPECTIVE OF A CONSULTANT AND CONTRACTOR

Cam Speedy
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Cam is a free-lance Wildlife Biologist with 30 years management experience in a wide range of both native and introduced wildlife, from roles in the New Zealand Forest Service, Department of Conservation and in both the corporate and private sectors. He is the director of Wildlife Management Associates, a business committed to working collaboratively with stakeholders to find practical, sustainable solutions to New Zealand's unique wildlife management issues. Cam developed and project managed the eradication operation for more than a dozen introduced mammalian species from the Maungatautari Reserve between 2004 and 2008. Perhaps his greatest passion is sika deer, which Cam has studied for 25 years.

ABSTRACT
Pest management can be a very polarising issue. Every pest management operation is different, reflecting variations in terrain, accessibility, ecology, the types of pests present and the nature and scale of previous pest management. Most importantly, stakeholders often seek different outcomes based on very diverse drivers and beliefs. There is no 'one-size-fits-all' approach to pest management. From experience with a wide variety of pest management operations within diverse communities, a pest management regime specifically developed for the Okataina Scenic Reserves is described. One that will contribute positively to water quality, the sustainability of forest ecology and to community engagement.

TRANSCRIPT
Kia ora no tatou nga mihi kia koutou katoa e tena hui. Thank you for that introduction. Having heard from Alastair Fairweather, DOC, and Dale Williams, the Bay of Plenty Regional Council, I have been asked to give you an independent perspective. I will give you my background so you can make up your own mind whether it is independent or not. I will talk about my perspective around stakeholder considerations and how the social science of pest control has a long way to go. We will look at some of the pest management considerations in this part of the world and the key local pest issues as I see them. I will conclude with a brief look at a pest control proposal that my colleague Nick Singers and I prepared for Nicky Douglas when she was here with DOC a couple of years ago.

I am Rotorua born and bred and went to Massey University where my academic training was in zoology and wildlife management. I did 20 years in the public service (NZFS/DOC) before it got too much for me and then I worked for Roger Lorigan at EPRO for a few years. He taught me a lot. Since then I have been working for myself and often work in the renewable energy industry for Genesis Energy, particularly around biosecurity, tuna which has become a new passion for me and whio (blue duck) which has always been a passion for me.

My first love is sika deer and probably always will be; I have been a student of sika deer for 30 years. But I do have a background in biodiversity, particularly forest ecology and more recently with the energy industry in fresh water ecology. I have had direct involvement in planning and managing more than 70 aerial operations all over New

Zealand. So I do know a little bit about what goes on out there. When I worked for Roger I managed 700,000 hectares of ground based pest control annually. We operationalised a deer repellent for 1080 baits which we tested over 3 different deer species and a whole lot of other critters like possums, rats and wallabies.

I project managed the eradication at Maungatautari and Wairakei sanctuaries and have done a lot of work with iwi and hapu groups in conservation and management planning. That level of pest management experience has given me a lot of interaction with various stakeholder groups and many and varied; conservationists, various iwi, hapu, whanau groups, hunters, researchers, farmers and land owners, anti-toxin lobby groups and then agency staff for a lot of different agencies (Councils, DOC, Ministry of Health, Food Safety Authority, Animal Welfare, etc.). There are a wide variety of perspectives, values and desired outcomes out there.

There is always a strong consensus on the need for pest control but very rarely is there a consensus on how we should do it, because there are a whole lot of different methods of control. They have all got advantages and disadvantages but there is no 'one size fits all' silver bullet. It simply does not happen like that. You cannot use a rat trap to catch a wallaby and you cannot use a Victor No. 1 to catch a wallaby. Bait stations are good for some species but wallabies do not like all bait stations. Night shooting is good on farmland but do it on Makatiti Dome and you will be struggling. **(Slide 1)**

Slide 1

That is a really important take home message, there is no silver bullet. It is about using a mix of tools to deliver the right outcome. The right method for a given operational area depends on a whole lot of things including what outcome is sought. Other considerations are the terrain and habitat, the size and scale, stakeholder and landowner requirements and the types of pest present as well as considering the past. What have these guys been exposed to previously in control operations?

It is the pests that are important here and there are plenty of them; wallabies, mustelids, possums, rats, cats, pigs, deer. **(Slide 2)** Which ones are the important ones?

Slide 2

That really depends on what is to be achieved. In my view the key management requirements we must have for a place like Okataina are the protection of those local iconic tree species like the pohutukawa, rata; mature forests as seed sources for wider recovery. **(Slide 3)**

Slide 3

It is also important to maintain the ecosystem services provided by the remaining keystone bird species like the bellbirds, tuis and kereru, those pollinators and seed dispersers. Without them the recovery of the Tarawera forests, impacted by fire and logging, will not occur. Forest succession following the Tarawera eruption means that the forests are young, they are even aged, and they are still developing. It is also obvious that the healing of all those slips that Willy Shaw showed us is critical to reduce sediment and phosphorus run-off. These are key management requirements in designing a pest management regime for a place like Okataina.

In my view these are the three key critters that we must look out for. **(Slide 5)** Possums are not only chewing at the totara, rata and the kamahi, they are also taking off the flowers and the seed sources for future recovery. If there are no berries for kereru to disperse then that seed dispersal ecosystem service has no foundation. Ship rats are devastating predators on those keystone bird species reducing their numbers, their productive output

of offspring. Every little seedling that eventuates from a seed or fruit pooped out by a kereru will not turn into a tree while there are dozens and dozens of wallabies nipping them all off. In my view these are three critters that we have got to address. Unfortunately wallabies, because of their subordinate behaviours, come third on the list when you put a device out there. They will not turn up until the rats and the possums are dealt to, so that creates operational headaches as Dale has already described.

Slide 5

Possums do a lot of habitat damage; they take a lot of forest resource like flowers and fruit as well as destroying the canopy. They are a predator on insects, bird's eggs, nestlings, reducing those ecosystem services. They are a competitor for our native wildlife taking food resources that other species would otherwise have.

Ship rats cause habitat damage by the destruction of fruit and seeds. They are a predator of insects, bird's eggs, nestlings and again the reduction in the ecosystem service and a competitor for native wildlife.

Wallabies cause habitat damage; they browse seedlings and destruct the understory of the forest. Most of the Okataina Reserve is below a metre high as many of you would have seen on the field trip on Wednesday. There are not even filmy ferns, it is just hollowed out. There is a lack of regeneration particularly around the slip scars from climatic events, but also the natural forest succession processes recovering from the Tarawera eruption.

What are the pest attributes? Possums are widespread at moderate density. There has not been a lot of pest control in that area since 1999 and 15 years is a long time in pest control. They will be an environmental equilibrium in balance with whatever resources the forest contains. They are vulnerable to most pest control methods. One of the things that makes possums so successful is their investigative behaviour, a willingness to try stuff out, and it is also their Achilles heel which makes them relatively easy to control. Populations take 5 years to recover after control.

Ship rats are very wide spread but fluctuate in density from one year to the next. When we have a mast[1] year of forest seeding and fruiting, rodent abundance booms. They can occur in very high densities when we have a big rimu or podocarp fruiting. They are vulnerable to most of the toxins we use and have preponderance for any toxins given them. They can be trapped but it needs a large fleet of traps during a mast year to make a difference. You need regular intensive control for rodents because they breed very prolifically, the average litter size is 6 or 7 and they can be breeding themselves at just 3 months of age, so they proliferate very quickly and come back very quickly.

Wallabies are currently at an environmental equilibrium with the forests out there. They have not been controlled for 15 years and they are spreading. My mum lives up in Tarawera and I am always getting hassled about the possums eating her roses. But when she tells me she has a funny looking wallaby kangaroo on her front lawn eating her grass, and she has never told me about it before, it tells me that things are changing. They have got limited vulnerability to many of our pest control techniques and that is an operational headache, but also it is subordinate behaviour. If you want to remove wallabies where there are possums and ship rats at any sort of a density you are up against it.

It has been many years since there has been any effective control. That previous control was small scale and localised with no repeat work done. There are large areas of adjoining habitat which remain untreated and will remain untreated, such as vast areas of forestry plantation to the east. Ongoing reinvasion from both sources is inevitable. It is not about eradicating; this is about starting on a journey that does not finish. If you are going to bite the bullet and undertake expenditure on pest control in the Okataina Reserve it will require sticking at it forever otherwise all the benefits unravel and it will be back to square one if it is stopped. I cannot emphasise that point enough, there must be sustained control for any sort of benefit; a long term commitment for decades to come to see outcomes achieved.

But there are some opportunities here. There are a lot of positive community initiatives and motivation in the Tarawera community with their pest control work and at Rotoiti. There are good physical boundaries. Dale showed you the effects that Lake Rotorua, the Kaituna River and the Tarawera River have for wallabies. They create nice geographical features to limit reinvasion if we get the geographic scale of our pest control right. The unknowns of course are things like pigs and deer. There are not large numbers of deer in this landscape but they do browse. Some will argue they are an analogue species for moas and that our forests without any browsers are not natural anyway, so who knows. But for me the three that we need to look after are possums, wallabies and ship rats.

The potential pest regime that Nick and I have considered is a combination of localised intensive control, targeting ship rats and possums to enhance key bird species sites supported by landscape scale pest control. Most of the localised control can be done at ground level and be community led involving stakeholders. If it is targeted on the high value mature forests which provide seed sources for keystone bird species that have those ecosystems services for dispersal then there is the opportunity to support the larger landscape. The big stuff, the 5,000, 10,000 hectare areas, by its very nature will have to be agency led which will need some sort of secure funding. The logistics of managing

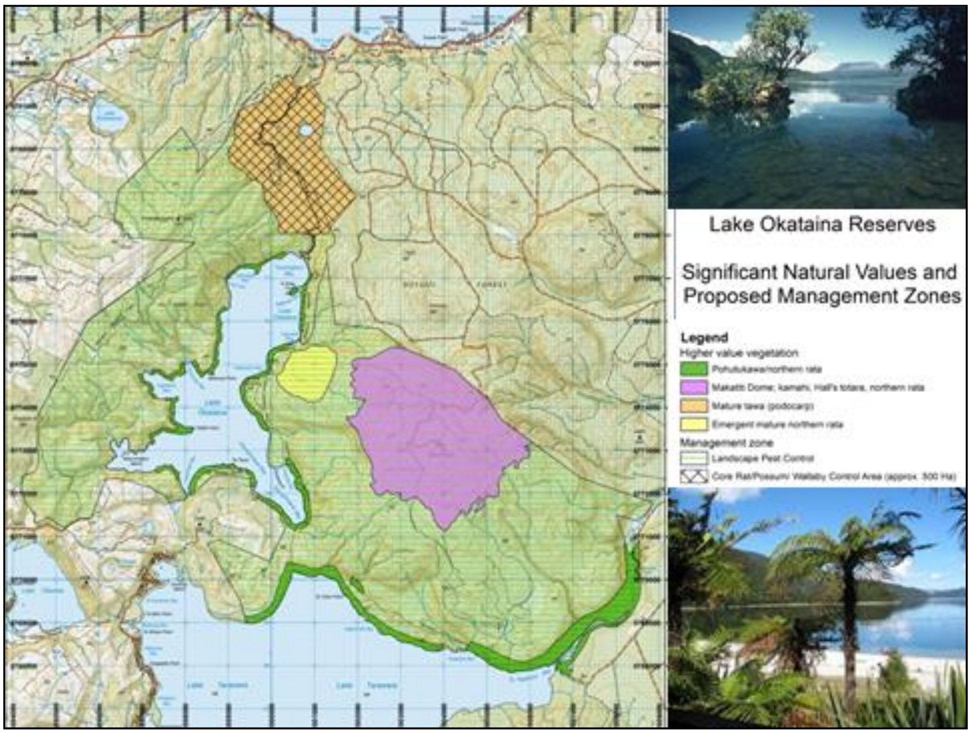
[1] mast year (noun)a phenomenon when the fruit (mast) produced by trees in a given year is exponentially higher than the average; by extension, a year in which vegetation produces a significant abundance of fruit. dictionary.reference.com/browse

possums and wallabies on large landscape scale, whether by aerial or ground means, requires a level of complexity that cannot be handled by community groups.

A pest management regime would require regular landscape scale pest control at 3 - 5 year cycles over a large area, supported by more intensive community led pest control in smaller localised areas of high quality habitat. For effective forest recovery control it would require 4 to 6 cycles, a 20 year time horizon, to get any outcomes. Are funding agencies and communities ready to take on that sort of an endeavour? It is a serious endeavour which, if you want to deal with, you need to go into it with your eyes open.

Slide 6 is a map of how a regime like this might be structured. Our thinking was that there is some very high quality tawa/podocarp forest which is relatively accessible (brown cross hatched) where there is an outdoor education camp. This is a sitter for some sort of community led ground based regime that is ongoing.

Slide 6



Here ship rats would always be suppressed, as would possums, so that birds like kereru and tui and bellbird could thrive in that environment, from where they can take the seed sources from those mature forests and spread them into the surrounding recovering landscape. There are some very important resources in places like Makatiti Dome (purple) and some of the pohutukawa (dark green) rata (yellow) forests, but as already discussed most of this is developing second growth forests (bright green) which have been impacted by the Tarawera eruption, fire and logging. We want to see a wider recovery of this area. An effective landscape scale pest control area might well be much wider and even have to involve the production forestry to the east where there is a sea of pests. If you want to create an island of very low pest density (and pest impact) it is vital to manage this sea of pests which will be a source of reinvasion forever.

We have good physical pest boundaries like the Tarawera River and lake shores and a very active community group at Tarawera who are doing great things with community led pest control bringing back birds to their settlement. This provides an opportunity for birds

to help repopulate the wider area with vast numbers of seeds. However, if you do not remove the wallabies out of this wider area those seeds will be nipped off as cotyledons[2] and none of them will turn into understory that will support the healing of those slip scars, the healing of that lake shore erosion and the recovery of the Tarawera eruption forests back to tall forest.

In summary, there is no 'one size that fits all' approach in pest management. It is about selecting the right tools for the right place, for the right reasons based on the sorts of outcomes that you are after. If you do not do that it is wasting your time even starting.

The most appropriate methods depend on the outcomes sought and the attributes of each operational area, stakeholder requirements and pests present, and again I cannot over emphasise that enough. For Okataina it is a combination of methods over a sustained period of time, localised community led pest control projects supported by landscape scale projects. We have a really good one at Turangi where Project Tongariro manages pests on Lake Rotopunamu over a 500 or 600 hectare scale. It is a magnificent place to go and see what New Zealand forests used to look like in terms of birds, but they would not be as successful if they were not supported by TB Free New Zealand landscape scale Tb vector control in the 20,000 hectares of forest all around it. It is the sort of example that Nick and I think has application here at Okataina, based around our experience at Mount Pihanga and Tongariro National Park.

The cool thing about that approach is that it provides an opportunity for stakeholder engagement and an active community like you have here. To me it is a bit of a no brainer and critical for sustainable outcomes.

[2] A **cotyledon** is a significant part of the embryo within the seed of a plant. Upon germination, the **cotyledon** may become the embryonic first leaves of a seedling. http://en.wikipedia.org/wiki/Cotyledon

QUESTIONS

Ken Hughey, DOC: I am confused about the issues of water quality and biodiversity. If we achieve, for example, a 95% reduction in wallaby densities in these forests or get to the level required where seedlings survive would that achieve a water quality outcome? But if we only achieve a 50% reduction which might achieve a water quality outcome but unlikely to achieve a biodiversity outcome. We need to be clear about these questions and what we seek to achieve.

Dale Williams: BOPRC: The whole density thing is academic. Those 95% reductions mean diddly squat, the important slide was the next one, are you getting the forest regeneration? To do that you have to measure the forest. We believe that it is more important to know how many possums are left rather than how many have been killed. Our trail cameras may be giving us that for wallabies. We want to see very few wallabies in the cameras after our controls. To answer your question about achieving outcomes, you have to suck it and see, which is what Cam was saying, give it a go and find out.

Cam Speedy, Wildlife Management Associates: I will also make a comment about how low you can squeeze things down. I think back to the Pureora Forest operation in my last year at EPRO with 83,000 hectares and two pre-feeds before the operation, afterwards possums were very hard to find. People 20 years ago would never have thought they could get possums down that incredibly low. But with advances in technology you can, and I am confident that with trial and error and a bit of work you could get wallaby numbers down too. The challenges will be to understand the dispersal mechanisms and how quickly they come in from adjoining uncontrolled landscapes. So there is a lot of work to do in the wallaby space and having tools to measure abundance and density, but I am confident that we can come up with a regime on a landscape scale that would squeeze wallaby densities down to infinitesimally low levels. That would make a difference in the forest understory.

Alastair Fairweather, DOC: The only way to determine if the operation is a success is to monitor the outcomes; monitoring forest plant species, bird species and water quality. Only then will you know the effectiveness. I question whether water quality will be influenced by pest control. Numbers are quite low and there are other natural processes in effect that are probably more important in the long term.

Rob Allen, Landcare Research: We have been controlling pests in this country for many decades but can someone pull out a list of achievements from all that investment? I believe we are surprising lacking in that, but there are reasons for that. Whatever these benefits are, and we will come to them in a minute, were they possible and then, if you undertook an action, could it be achieved? I would say we are littered with the lack of demonstrable achievements. We need to go into these things very carefully; are the benefits possible and can we achieve our desirable outcomes?

I will give a few little examples. One of the long term pest controls in New Zealand is the control of red deer in the Murchison Mountains in the name of protecting takahe. That has been done for more than 30 years and good quantitative data has been collected on the vegetation. Recently there was a publication on that which struggled to demonstrate any recovery in the understory. That parallels Dale's presentation where they are struggling to detect a change in the forest understory with a mish mash of pest control at Okataina in the past.

That is one aspect. I was pleased that Alastair made comments about the pests. There is a biodiversity outcome there and we have been talking about the water quality outcome. In the fifties and sixties water quality was a major driving force of pest control. We gave up on it for a couple of decades and it is now coming back. But Alastair's specific words, and I will not hold him to this, were, 'Water quality impacts of pests is generally low'. There have been quite a number of studies and when you average across these studies there is a pattern, whether it be wallabies or deer. When I see the word 'pests' I think they mean 'across all pests'. We do not have data on those species because there would not be a quantitative study in New Zealand demonstrating a water quality impact of pests. I accept we can control pests dramatically, that is repeatedly demonstrated, but can we achieve the outcomes we are interested in after investing a lot of money in places and not achieving them?

To paint a picture of this introduced biota as always being bad is not entirely correct. In Banks Peninsula the best distributer of matai seedlings, which was widely distributed in the area, are now pigs. If we want our matai forests back and want pork should we be allowing the pigs? Are benefits possible and are they achievable?

Willie Shaw, Wildland Consultants: Monitoring is essential as Alastair said and the results will always surprise. There will be unexpected results from any monitoring to do with pest control, especially dealing with multi species groupings and varied vegetation and habitat cover.

Rowland Burdon, Royal Society of New Zealand (Rotorua Branch): Dale you mentioned that there were very successful poisoning operations in terms of % kill with wallabies but they were generally one-off operations in particular areas. My question is what is known about how follow up poisoning operations might decline in effectiveness?

Dale Williams, BOPRC: In terms of wallabies almost nothing is known because most of those operations were one-offs. Cam raised an important point about sustained control. There is no point in starting unless you intend to carry on. To me it was almost criminal that those operations were not carried on. We might be having quite a different presentation today.

I would like to take this opportunity to talk about eradication because that is a term I have heard a lot over the last 2 days. The scientists in the group understand what eradication is, but there may be a few people who do not realise there are very defined rules around eradication. Considering the wallaby distribution map I put up, we are trying to eradicate the isolated populations and ideally eradicate them completely.

The rules state that:

- your pest has to be vulnerable to your control technique
- you have to expose all your pests to the control technique
- you have to kill them faster than they can breed
- in the case of weeds you have to keep on killing the propagules as they pop up

Then there has to be either no or a very low chance of reinvasion.

Pest control falls into two camps. Site led control trys to get the benefit that you are after. When you are trying to limit dispersal or eradicate you do not care about a conservation outcome specifically in the site where you are killing the things. Targeting the animal we call pest led control. At the moment with wallabies our control is pest led. We are trying to

limit dispersal and eradicate those isolated populations. Our monitoring is based on finding the last individual.

Angus McKenzie, Latitude Planning Services: Thank you very much for that informative summary. I like what you were saying Cam around achievability and it being a long term game. You touched on the social science around pest control and mentioned that it has a long way to go. I wonder whether you could just explore that a little bit more and maybe outline a couple of successful approaches in that sphere.

Cam Speedy, Wildlife Management Associates: I am not sure I can because folks have a very different perspective on everything based on their own personal world view and there is no consensus around what is the best approach to controlling pests. Some people are happy with toxins and some are not, and that will always be the case. When working with communities, if we have a shared vision about what we are trying to achieve then we can work our way through the ins and outs of how to get there. But it is sharing the vision which is most important. I have got away from trying to work out the journey and just get everybody on board with what we are aiming for. I do not profess to be a social scientist, I just know that there is a lot of debate in New Zealand about pest control and how it is done and I think there always will be. But I think we should all focus more on a shared vision of what we want our place to be.

Hilary Prior, LWQS: Dale do you know why the Bay of Plenty Regional Council Draft Long Term Plan has a significant decrease in effort for wallaby control?

Dale Williams, BOPRC: No. I guess there are always limited resources. My slide said that we have not got enough runs on the board, we are losing stakeholder support and that might well be an example of exactly what is going on.

Theodore Kpodonu, Waikato University: Two quick questions. The first is that these animals have been around for about 100 years. From an ecological point of view are we seeing them as being integrated into the ecology of New Zealand? For instance Rob gave an example of peak dispersals of seeds of certain plants, so are we looking at them as just pests or are we looking at them as becoming an integrated part of the ecology of New Zealand? My second question is for any wildlife to have an impact on an ecosystem they should exceed a certain threshold. Do we have numbers of populations for the different animals for each catchment or we are just eliminating, eliminating, eliminating and do not have a threshold.

Dale Williams, BOPRC: I think the threshold question was the same question I asked - let's see. The first part was about what we call technically 'recombinant ecology'. Are these species now a part of New Zealand's heritage?

I guess they are, and some introduced species people rate highly, such as deer, which Cam mentioned as a deer hunter, and so am I. We live off sheep and beef which are introduced species as well. So it is a value judgement. In terms of being an integrated part of our ecosystem, Rob mentioned that we used to have a lot of native browsers and the argument is whether these modern introduced herbivores are simply replacing the extinct ones. It is one of those arguments that could go on forever. Looking at introduced species that we should consider bringing in, Rob's photograph of a bird that looked very much like a Cape Barren goose, why don't we bring that back? There was a duck that looked very much like the Australian Wood duck, why don't we bring that back? There is a sub species of the New Zealand quail that lives in Australia, why don't we bring that back? It would be something that might fit into our ecosystems a bit better than wallabies do.

Max Gibbs, NIWA: Would it be appropriate, rather than to eradicate wallabies, to convert Lake Okataina into a Maungatautari type situation where we exclude within a certain range from the lake the impact of wallabies. In other words the exclusion cages are 20 x 20 metre control plots within the forest, if we took that around the entire lake would that make a difference. Then the understory regeneration would reduce sediment run off which is the fine material taking phosphorus into the lake. It is lateral thinking, but would the cost be achievable and better spent that way?

Cam Speedy, Wildlife Management Associates: I will have a crack at that since I was involved with the Maungatautari pest eradication. The fence was $200 a metre to build, how many thousand hectares did you say the catchment was? 6,290, Maungatautari is 3,500 hectares more or less and it has cost in excess of $10 million so far. The regeneration in the forest understory is unbelievable, within the first 18 months all the slip scars and even the tracks that were put in the southern enclosure vegetated overwhelmingly. That would achieve exactly what you are talking about. There would be prolific regeneration at every square inch of the catchment. But at a catchment scale of 6,290 hectares I would really question the economic viability and the long term maintenance costs. Looking after a 40 kilometre Maungatautari is a huge undertaking and not without its problems. A fence would be twice or three times that around Okataina. But if there is the political will, and the finances available, it is achievable absolutely.

Dale Williams, BOPRC: On a smaller scale there is a peninsular in Lake Rotoiti that is an ideal case study. It would only cost about $200,000 to build a fence across the isthmus. It has wallabies, possums and rodents fringed by pohutukawa, very similar vegetation to Okataina but whether you could monitor the benefits to the lake from an operation that small would be anyone’s guess.

Jacqui Aimers, Freelance Scientist: A question about dama wallabies. They are a nasty pest here but they are endangered in their natural range, virtually extinct in mainland Australia and there was a repatriation attempt made some years ago that had limited success. Is there any potential for some repatriation taking the pest back to South Australia and whether that would be a positive PR story that could counteract any negative PR with the extermination of a very cute pest?

Dale Williams, BOPRC: You are right. A decade ago there was a reasonably lucrative export going on. I suspect a lot were going to game parks and possibly the freaky pet trade in the States. About 40 animals went back to South Australia because the ones that came to New Zealand were from the Australian mainland and genetically they are already extinct. Dama wallabies still exist on the offshore islands of the southern coast but the ones we have are the mainland gene type. Recently we processed permission under the Biosecurity Act for wallabies to be exported to zoos in the States. They have got a genetic breeding programme and there were two shipments of about 40 animals. But one of our requirements was an indication from the Australian Government that they see these zoos supporting the conservation of their wallabies and we did not receive that. There is potential but it could be a double edged sword because it is back in the cute and cuddly thing.

Ken Hughey, DOC: Before we take another question I am reminded Max that there has been a request from Maungatautari for an additional injection of $600,000 per year to operate that sanctuary over and above the costs that they thought they had budgeted for. These mainland sanctuaries are huge investments and something the communities must enter into pretty carefully, but they do have a lot of benefits as you talked about.

Don Atkinson, LWQS: The last kill was about 15 years ago. Are we now at a sustainable population level or will it get worse if we do nothing?

Dale Williams, BOPRC: It has not been measured, but Cam inferred those wallabies will probably be back to some equilibrium. From what I understand the numbers are way lower than they were prior to those operations, they will probably never get back to those levels. They have already eaten themselves out of house and home, but they are spreading and that is our biggest concern. From a wildlife management background, when resources become limited it is one of the factors that drive dispersal.

Session Seven : Responsibilities and Funding

SESSION CHAIR – Ian McLean, LakesWater Quality Society

WATCHING FOR INVASIVE SPECIES: PUBLIC ENGAGEMENT

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Tracey is a scientist in NIWA's Freshwater Biosecurity team with more than 15 years' experience in undertaking and designing aquatic vegetation surveys, with a focus on the use of aquatic plants as indicators of lake ecological condition. In her role Tracey is also the regional co-ordinator of NIWA's education and public outreach activities and is currently exploring the potential for citizen-science volunteers and community groups to assist with the early detection of invasive aquatic species.

ABSTRACT
Invasive species continue to be one of the greatest threats to the Rotorua lakes and include not only water weeds and wallabies, but other organisms too. Invasive molluscs such as zebra and quagga mussels have the potential to cause wide spread devastation to our freshwater ecosystems and are just one example of other invasive aquatic species not yet found in our New Zealand lakes.

The management of invasive species is a shared problem that requires the cooperation and support of a diverse range of stakeholders, interest groups and members of the general public. The early detection of an invasive species is critical and may make the difference in being able to appropriately manage, control or eradiate a species before it has a chance to spread.

Anyone can help prevent the incursion and spread of invasive species into our lakes. In New Zealand, we can learn from the success of programmes in other countries where they are recruiting citizen scientists to look for anything new or unusual. Citizen science, broadly defined as the involvement of volunteers in research, provides a means of combining research activities with environmental education and public engagement in science. Volunteers are able to increase their knowledge and understanding of the environment, learn more about local issues of importance, and contribute to science based recommendations. In addition, observations collected by citizen scientists can provide valuable records and knowledge that otherwise wouldn't have been available.

TRANSCRIPT
Good afternoon, today I am going to talk about the importance of watching for invasive species, look briefly at what is here and what is not and look at ways in which the public may be able to help with watching for invasive species in their lakes.

Yesterday we looked closely at the weeds in the lakes and today have learnt much about the potential impacts of wallabies but we do not want to gloss over other invasive species that have the potential to pose a serious risk to the Rotorua region as well as the whole country. There are weeds not here yet that are much worse than the ones we have

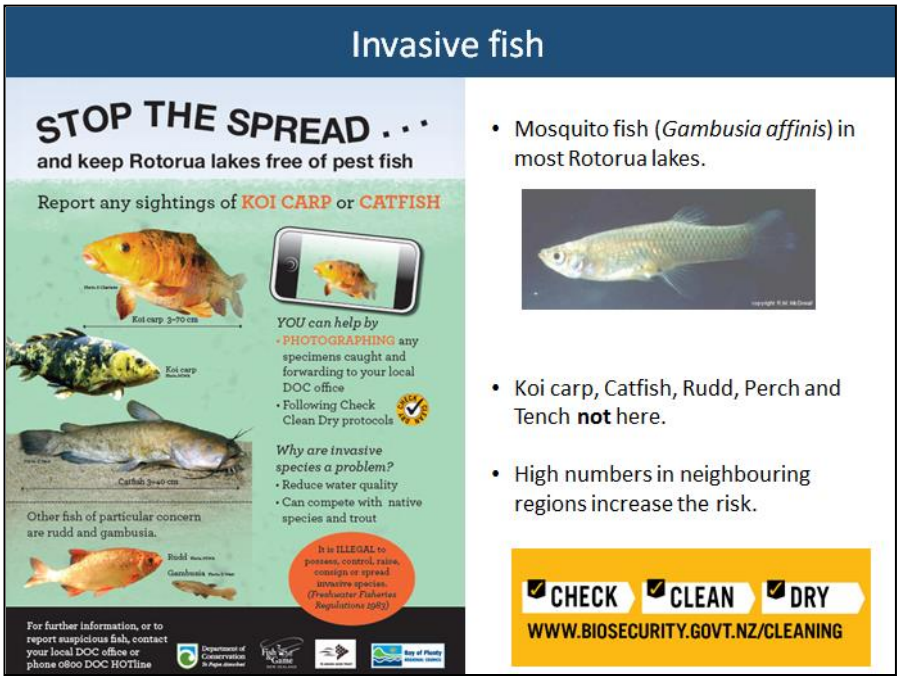
already. We also have concerns for the spread of invasive fish into the Rotorua lakes. Didymo is in the South Island. So we need to remain vigilant in watching for these invasive species that are already on our doorstep.

There are other invasive species not yet in New Zealand that we must also be on the lookout for. **(Slide 1)** Freshwater invasive snail species and other molluscs such as the zebra and quagga mussels have the potential to cause widespread devastation to our freshwater ecosystems should they make their way here.

Slide 1

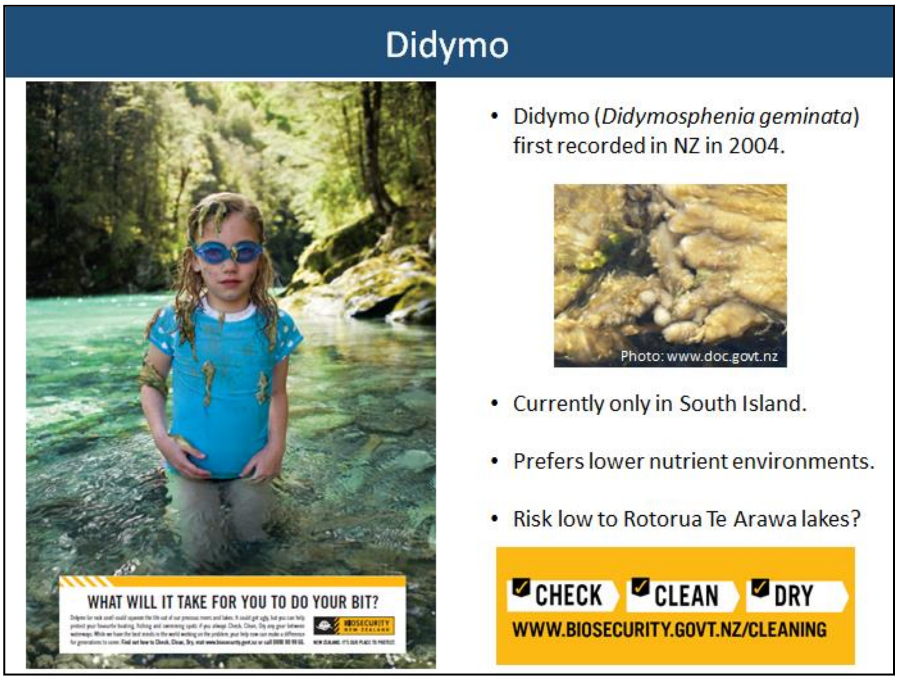
We do not have any of the major pest fish species in the Rotorua Lakes now but we do have the invasive mosquito fish. A programme this summer using students to carry out interviews around boat ramps focused on pest fish awareness and some suspicious fish sightings were reported. Luckily the only one that required validation was a goldfish found

Slide 2



on the edge of Rotoiti. However these reporting's should serve as a reminder that we need to watch out for invasive fish. Koi carp, catfish, rudd and perch **(Slide 2)** are well established in the Waikato Region and pose a great risk to these lakes. All lake users must remember the 'Check, Clean, Dry' messages that can help prevent the introduction or spread of pest fish and other invasive species into the lakes.

Slide 3



Didymo (rock snot) was first recorded in New Zealand in 2004 **(Slide 3)** and is still only in the South Island, likely because of its preference for lower nutrient environments and colder waters. There is research now suggesting that it may not pose a significant risk to the Rotorua Region should it make it up this far but the message is the same, 'Check, Clean, Dry'. Before didymo hit the South Island it was given little thought and its impacts were not appreciated until it arrived. The strong message from this is that we do not know the impacts of invasive species until they arrived so we always need to remain vigilant. It is easier to prevent the arrival of new species into a lake than to try and control or eradicate them once there.

The apple snail (top left) can literally grow to the size of a small apple and the ear pond snail pictured at the bottom is one that I have a personal interest in. These two snails are both available through the aquarium trade in New Zealand and at my local markets near Cambridge there is a man who sells bags of ear pond snails, 10 for $10, readily available. Despite their availability only one apple snail has been found outside of the trade, in the Waikato River in 2010. Following an extensive search of the river carried out by the University of Waikato no more were found. It was most likely released from someone's fish tank into the river and hopefully a one off.

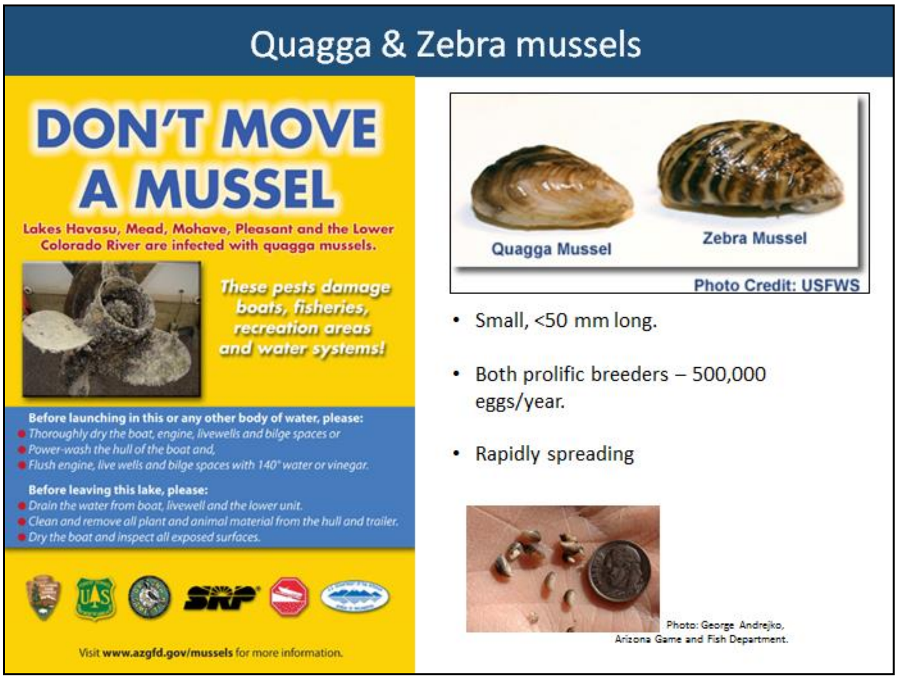
These invasive ear pond snails can grow to about 25 mm wide, about the size of a 50 cent piece, and were recorded for the first time by myself and John Clayton during a survey of Lake Rotomahana in 2011. Since then they have naturalised in Lake Pupuke (Auckland), Lake Roundabout (a small lake in the South Island), and four other Rotorua Te Arawa Lakes, Tarawera, Rotoehu, and this year for the first time in Lakes Rotoiti and Okaro.

We carry out aquatic plant surveys in these lakes with scuba gear once every two years so are confident that these snails were not previously there. They are moving quickly between lakes. In Lake Rotoehu, the sheer numbers of these snails present in one of the bays was alarming. If I had been a swimmer in that bay I would have been crunching at least three of these snails with each foot step. We do not know enough about these snails to assess the risks involved. There may also be potential human health impacts associated as they can be vectors of different parasites but we are not sure.

There is also the Malaysian Trumpet snail (left) which might not pose a significant threat to a lot of New Zealand lakes because it has temperature requirements. However because of the thermal inputs in some of the Rotorua lakes, they are already in the Golden Springs area, more work needs to be done to see what the potential risks could be.

In my opinion one of the worst invasive species not yet found in New Zealand are the freshwater zebra and quagga mussel. **Slide 4** at the top shows an adult quagga and zebra mussel which are smaller than our native mussels (kakahi), at less than 5cm long. Both alien mussels are prolific breeders. Adult mussels, some only as big as a grain of rice, have been known to produce between half a million and a million eggs each year. These snails are present in the United States and still making the news as they continue to spread. They were first reported in the Great Lakes in Northern America around 1988, and have since spread through many states. They were found in Lake Mead in Colorado for the first time in 2007 and in October 2014 quagga mussels were found in a reservoir in

Slide 4



the Heathrow area in London.

Slide 5

Slide 5 illustrates some of the problems resulting from these mussels which are of real concern. One problem is that while they are prolific breeders they are also great water filters. The immediate impact of abundant populations of these mussels is that water clarity improves. John Madsen talked about mussels in waterbodies causing a threefold increase in the water clarity which might be seen initially to be a great improvement. The problem is that they filter out the phytoplankton and suspended solids thereby interfering with the food web cycles. Suddenly the zooplankton and fish have nothing to eat. In the United States some fishing communities have completely collapsed as a result.

These mussels can fix on to any hard surface as can be seen in the photos above. Imagine the money involved in clearing mussels off hard surfaces: intake pipes, dams, harbours, jetties and other places. They have the potential to damage boats, propellers, anything that remains in the water for a long period of time. Boats are the main vector of spread between lakes.

Also disturbing is that because mussels fix onto any hard surface they could potentially attach to our native kakahi (freshwater mussels). Overseas they have been shown to climb on top of other species and push them into the sediment until they suffocate. The photo of a fresh water crayfish, looking very similar to our native koura, illustrates the disturbing consequence that they could be fouled by numerous small alien mussels; not very pleasant. But the problems created by these molluscs do not stop there. The once pristine sandy beaches surrounding lakes impacted by zebra and quagga mussels can become smothered in jagged smelly deposits of shells.

So weeds and wallabies are not the only thing that we should be on the lookout for when watching for invasive species in the Rotorua Lakes Region. Early detection is critical and can make the difference in being able to appropriately manage, control or eradicate a species before it has a chance to spread. We need to know where it is before we can do anything about it. Surveillance for invasive species is carried out by the Bay of Plenty Regional Council who are doing a great job. Last year they asked NIWA to look at their

surveillance practices and we concluded that they are doing everything right in terms of best practice and methods used. The study determined that the most successful methods for the early detection & delimitation of submerged invasive weed species continue to be in water visual methods using divers.

But it is not just a regional council or other authority's job to watch for invasive species. The management of invasive species is a shared problem that requires the cooperation and support of a diverse range of stakeholders, interest groups and members of the general public. Everyone has a role to play in preventing the incursion and spread of invasive species. Invasive species are spread predominantly by people; boaters, anglers, and even swimmers can unintentionally spread invasive species from one water body to another when invaders hitch a ride on their equipment. We have seen over the last couple of days the devastating consequences invasive weeds can have on the recreational, cultural and economic values. Fresh water systems are the most threatened globally and invasive species are the biggest threat to biodiversity loss in the Rotorua Lakes.

Anyone can help prevent the incursion and spread of invasive species into our lakes. A term loosely used at this symposium and gaining recognition around the world is citizen science. Citizen science can be defined as the involvement of volunteers in scientific research. It combines research activities with environmental education and public engagement in science. The main aim is to get any one interested from young children right through to those that are now retired to help answer real world questions about our environment and take ownership of the problem. Citizen science is not new, it has been happening since at least 1900s when community groups helped with bird counts.

Today's technological advances are increasing the popularity of citizen science around the world with tools such as GIS-enabled web applications that allow for the collection of large volumes data. Smart phones, which allow observations to be recorded and validated using photos and apps. There are online portals for free data sharing and a raft of free online resources which means setting up projects and getting information out is suddenly cheap and assessable for so many people.

The benefits for citizen science are numerous but most importantly it increases the community's awareness of local issues; advances their learning, knowledge and understanding of the issues and can change attitudes. It is a philosophy change on how people connect with the environment and take ownership, and gives them some responsibility for their patch. Volunteers can participate in making science based recommendations which is important because they want to be involved. However, a successful programme involving citizen science must be a two way thing; it is not just people giving the scientists lots of data. It should benefit both parties. Scientists can use citizen scientists to provide valuable records and knowledge that otherwise would not have been available while volunteers can receive feedback and the benefits of seeing their data and knowledge contributing to something positive – they can make a difference. Some of the examples of citizen science occurring around New Zealand are:

- *King Tides Auckland Project* – 'Snap the coast: see the future' - asks members of the public to upload photos to help researchers work out what many coastal areas will look like in the future and to plan accordingly.

- *Annual Garden Bird Survey* - is an initiative set up to monitor the distribution and population of common garden birds around New Zealand. www.landcarerresearch.co.nz

- *NIWA Snow Project* - asks volunteers in Christchurch to take regular measurements of snow fall and submit information via a phone app. www.niwa.co.nz

- NIWA Steam Water Quality Project - involves community volunteers in monitoring stream water quality and ecosystem health, in parallel to data collection by regional council staff.

Easily the biggest example of citizen science working in New Zealand was Nature Watch, a website run by the NZ Bio-Recording Network Trust which allows nature watchers to record and share information on birds, insects and plants. In the last 18 months over 85,000 photos have been uploaded with 5,000 observations from 785 observers. These types of initiatives are attracting great interest.

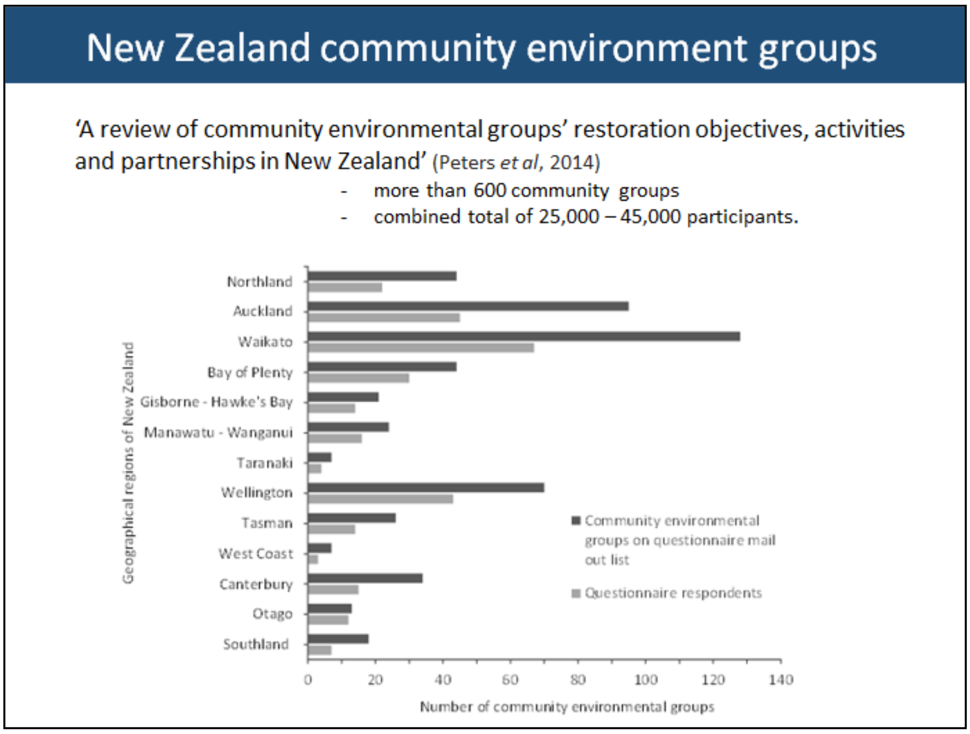
www.naturewatch.org.nz

Another example that sits on the cuff of citizen science is Weedbusters which is a weeds awareness programme that aims to protect New Zealand's environment from increasing weed problems.

www.weedbusters.org.nz

Slide 6 and 7 show some results obtained from a review carried out by Monica Peters et.al. from the University of Waikato looking at community environmental groups in New Zealand. Her results showed that in 2014 we had more than 600 community groups active throughout New Zealand. Furthermore from questionnaires completed by 288 of these groups Monica's review was able to show the wide range of community activities that environmental groups are involved in. These types of activities also reflect the type of work being carried out by community groups in the Bay of Plenty Region.

Slide 6



Slide 7

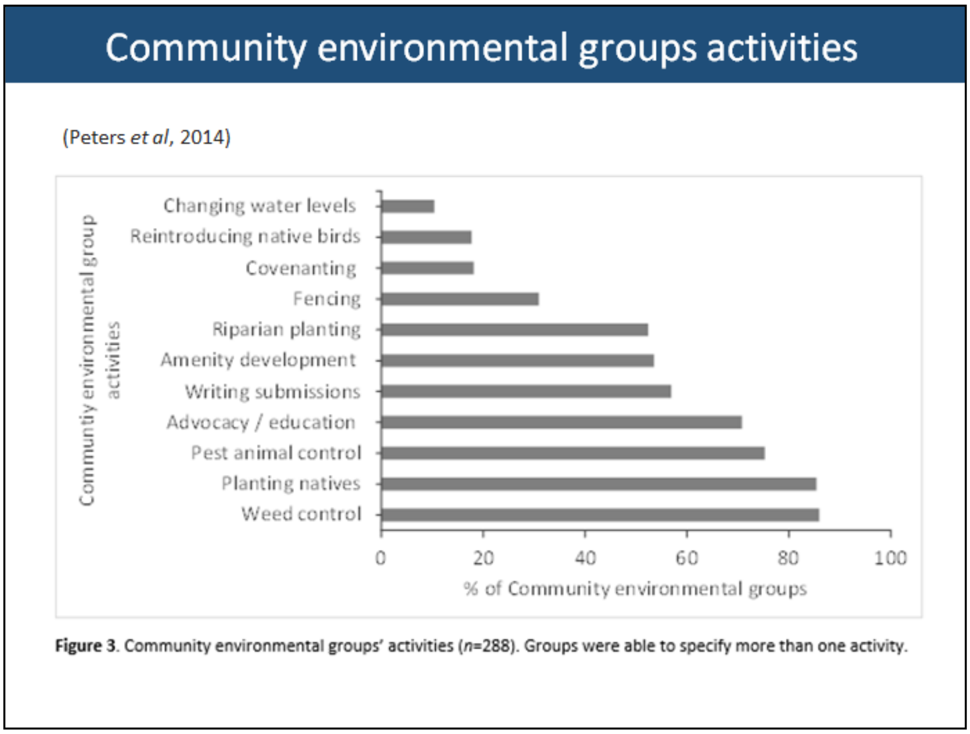


Figure 3. Community environmental groups' activities (*n*=288). Groups were able to specify more than one activity.

Most of the active groups listed with the Bay of Plenty Regional Council include:

- Tarawera rat control programme – increased dabchick and native bird populations
- Landcare Ōkāreka - pest plant and animal control programmes around the lakes to benefit native bird populations including the dab chick
- Tikitapu Forest and Bird – pest animal control
- Ōtautū Bay, Lake Rotoehu – rat control programme benefiting waterfowl including dabchick

I think these programmes show that we already have people within the region who are interested in helping with environmental issues and perhaps the same groups could be utilised to help in the war against invasive species. The more eyes watching for invasive species the better.

In New Zealand, we can also learn from the success of programmes overseas where they are recruiting citizen scientists to look for anything new or unusual. Some of my favourites include the ‘Clean Boats Clean Waters’ programme in Michigan, USA, which aims to prevent the spread of aquatic invasive species in Michigan lakes. With more than 11,000 inland lakes you can see why they need as many eyes and ears for information on new incursions as possible. This programme offers volunteers training to educate boaters about where they are most likely to find aquatic invasive species. Based on a roster system they are present at the lakes year round and educate lake users on how to inspect their boats and trailers and demonstrate cleaning techniques as well.

CLEAN BOATS CLEAN WATERS

http://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/cbcw/default.aspx

The Oregon Lake Watch Programme is another good example of where the public are able to help with the early detection of aquatic invasive species. Volunteers help with the detection of aquatic invasive species, the collection of long-term water quality data and encourage an appreciation of Oregon’s Lakes. This programme has had some great success stories with the finding of three aquatic invasive plant species in 2013 as well as Chinese Mystery snails and Asian clams.

Oregon Lake Watch

www.pdx.edu/oregon-lake-watch

Another great example of public engagement is the hydrilla hunt which happens in several states throughout the United States each year. Over a week volunteers, including school groups, help search local waterbodies to locate undiscovered Hydrilla infestations. They get in with their rakes, boats and underwater cameras all looking for hydrilla to map its distribution and presence. A webinar is used to instruct volunteers on the skills needed to identify hydrilla, what to do if they find a suspect plant, and how to record the areas that have been searched.

For example:

http://www.niipp.net/hydrilla

http://www.lakegeorgeassociation.org/what-we-do/Citizen-Science/LakeGeorgeHydrillaHunt.asp

Other great initiatives overseas include newsletters such as that put out by the US Fish and Wildlife Service called Citizen Science (www.fws.gov/pacific/iq/Spring2014). Others such as the Maine volunteer lake management programme (www.mainevlmp.org) offer a range of practical workshops including one on how to build a water scope, how to carry out surveys from a canoe and for carrying out courtesy boat inspectors. The Texas Invaders Programme (www.texasinvasives.org/invaders) is an innovative campaign where volunteers are trained to detect the arrival and dispersal of invasive species in their own local areas. Advances in technology have also seen a whole new wave of citizen scientist initiatives such as phone apps like that from the Invasive Species Strike Team (www.njisst.org) in New Jersey.

No matter where you look overseas the messages are the same as here. 'Stop Invasive Species from Spreading', 'Stop Aquatic Hitchhikers', 'Don't move a mussel', Stop Aquatic Aliens'. **(Slide 8)**

Slide 8

So we have established that the management of invasive species is a shared problem but what can ‘you’ do about it? What can our communities do about it?

The first thing is to know your enemy. We have to know what we are looking for and how to identify it before we can react and do anything about it. **(Slide 9)**

Slide 9

There are plenty of resources that can be used to find this information out. The New Zealand Freshwater Pest Identification Guide is available on the NIWA website (www.niwa.co.nz/freshwater-and-estuaries/management-tools). It has guides and fact sheets for all the invasive species of concern here and is a great place to start.

Know your lake by looking at the information available for each of the lakes on the NIWA LakeSPI (Lake Submerged Plant Indicators) reporting website (www.niwa.lakespi.co.nz). This site provides information on the types of submerged plants known to be in the lakes including invasive species so you can gain a better appreciation of what you might be looking for.

Watch for invasive species. If you know what invasive species look like that is great, but either way, always be on the lookout for anything different. Actively look, ‘Oh, that looks a bit different’, ‘I haven’t seen anything like that before’, or ‘That’s a funny looking shell’. Spot things that are unusual and do not assume that somebody else will know about it. If you find anything suspicious contact the biosecurity officers at the regional council.

Help ‘prevent the spread’ is one of the most important things that anyone can do. The ‘Check, Clean, Dry’ message was originally promoted in New Zealand to help prevent the spread of didymo. More research is needed to validate this message for other aquatic pests in New Zealand but in general the principles are the same.

CHECK - Before leaving any lake or waterway always check your boats, (including the anchor wells and bilges) trailers, fishing gear and other equipment and machinery

CLEAN - Remove any weed or other debris and wash thoroughly all equipment (e.g. nets, machinery and footwear). Evidence supports the benefit of also using detergent or salt water mixes.

DRY - Once cleaned, dry completely inside and out then leave for at least a couple of days before moving onto a new waterbody.

Slide 10 shows operators of the Rotorua Duck tours checking for invasive weed species after visiting each of the lakes. You can see the guy up in the top corner is under the vehicle checking every little bit of space where weed could get caught. This is a great example of responsible eco-tourism in the region. The Rotorua Duck Tours were the first ones to detect the invasive weed hornwort in Lake Okareka.

Slide 10

In conclusion, we do need to remain vigilant against invasive species. It is not just weeds and wallabies that pose a risk to the Rotorua lakes. Management is a shared problem and we all have a part to play in the process. We already have community groups in the Rotorua region so there is an opportunity to harness their potential. We need to look at ways in which we can provide them with the knowledge to look for invasive species and be a part of the process. A successful citizen science programme needs to benefit both parties, it is not a one way process. Local residents and community groups have an important role to play in watching for invasive species. They are the ones on the front line, at the lakes on a regular basis, boating and fishing, swimming and walking around the edges. They need to know their enemy, what signs to look for and act on anything different or strange that they find.

I would like to thank my team at NIWA, particularly John, Paul, Mary and Rohan for their contribution to this talk. Thanks also to Stephanie Bathgate from the Bay of Plenty Regional Council who was a big help yesterday, and to the Lakes Water Quality Society. This has been a really valuable symposium, thank you.

STATUTORY RESPONSIBILITIES AND BARRIERS TO ACTION

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Guy has worked as an environmental policy specialist in consulting, policy advice and research roles. He leads the Ecologic Foundation, a think tank which focuses on the challenge of integrating economic and environmental perspectives in decision-making. His research on environmental decision-making in the Nordic countries has contributed to the recent focus in New Zealand on collaborative policy-making. Guy is a member of the Land and Water Forum

ABSTRACT
Looking at the context of current policies and institutions, this presentation will explore possibilities for enhancing the effectiveness of control actions for lake weed and wallabies.

TRANSCRIPT
It is a great pleasure to be back with the LakesWater Quality Society which is an inspirational organisation for me; it would be wonderful to see some of its attributes picked up by environmental groups in other parts of the country because there is so much to be learnt from the success story here. The Society gave me quite a broad brief and essentially it is this. We want to step up to a new level of ambition and performance in controlling lake weed and wallabies and sort out the barriers to actually doing that. I have tried to boil this down into three questions.

The first is to look at the statutory responsibilities of all the different agencies in this area and ask if there are too many outfits, too many cooks spoiling the broth? Is co-ordination good or are things in a bit of a muddle?

Secondly, looking at the toolbox that we have to solve problems, the science and technology, are there gaps here? Is there a lack of energy and commitment behind it all?

Thirdly, are the communities themselves properly engaged with these issues? Or have they got the wrong mental picture about some of their problems, and for that reason have become complacent?

This is a big field to cover very quickly. I make some hasty judgements based on phone conversations with various people and a bit of knowledge of the area. But it is intended as a discussion starter.

Slide 1 shows the list of organisations, which have all sorts of statutory responsibilities. But it is worth saying that some of the most important influences are not statutory organisations. The LakesWater Quality Society or Professor David Hamilton (who is sort of an institution in his own right) should perhaps be on the list. Some of the statutory players are a little understated. The Te Arawa Lakes Trust has ownership of the lake beds, but that seems a bit of an understatement of its role in this community.

Slide 1

Too many organisations, too much muddle?

ORGANISATION	ROLE
BOP Regional Council	Pest management rules, weed harvesting, wallaby control, water quality, public engagement
Te Arawa Lakes Trust	Ownership of lakebeds
LINZ	Weed management in water column by spraying
DOC	Indigenous fish & their habitats; deer & possums; advocacy
Fish & Game	Sports fish & game & their habitats
Rotorua District Council	Supplementary control work; reticulation of sewage
NIWA	Freshwater & biosecurity science
Rotorua Lakes Strategy Group	Strategic governance & co-ordination

Another significant point is that there are some funny splits of responsibility. For instance, a weed is growing on a lake bed owned by one party, but the control of that weed in the water column belongs to another party and there are two different outfits involved with that control. One of them does harvesting and another does spraying - which looks like a real muddle.

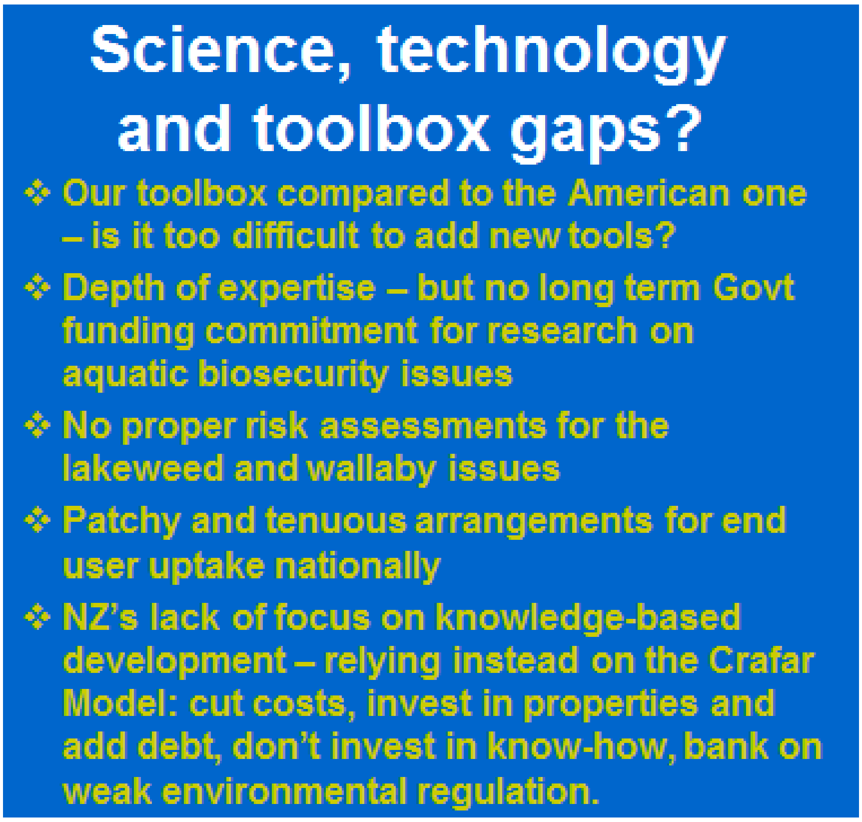
In phone discussions to suss out whether this works, I got the contrary impression to what I had expected. People told me that coordination was reasonably good with everyone more or less pulling their weight. 'This is not a muddle, we've all got clearly defined roles and it does work', they said. I gathered no evidence to make me feel it was not working. There appear to be no barriers to moving ahead on these issues that would be solved with New Zealand's favourite remedy of 'restructure everything'. Maybe we can just tune up what we have already and make it work better.

Then I looked at the science and technology and the toolbox that we have; those who have attended this Symposium would come away with a vivid sense of existing uncertainties and unresolved problems. But in a way that is not the question; the real question is do we have a science team, an establishment and a nexus with the policy community that is sufficiently strong and expert to solve those problems and narrow the uncertainties over the next few years. Overall my impression, a little bit qualified, is that we are strong in the science and technology area.

Having said this, we have all seen some excellent people producing excellent stuff. However there are still a few issues that we ought to think about. Clearly there is a difference between the list of chemicals, for instance, which is in the toolbox for use in New Zealand and the list for North America. Talking with people, I find that part of the reason is that it is quite difficult to get a new tool added to the toolbox in New Zealand.

Perhaps the procedure for doing this does not have a strong enough sense of the benefits of adding these things and is too focussed on the disadvantages or costs. This is an area with the Environmental Protection Authority, and perhaps it needs more attention.

Slide 2



Another disconcerting factor is that, while we have very good scientists in NIWA working on this, they do not have a permanent government funding commitment. They are operating off a cross subsidy within NIWA plus earning a bit of commercial money on the side. There is a certain insecurity about this scientific establishment and workforce. This signals lack of political commitment and recognition that this is a big, long term issue for New Zealand. We need to talk to the politicians. They need to know that this temporary way of funding is only just working OK, but we ought to put it on a permanent, long term basis and expand it.

Why do we find it difficult to get this long term commitment? Possibly part of this comes down to a lack of robust risk assessments. One of the striking things about the United States Environmental Protection Agency is the way they do enormous risk assessments to understand the situation. They ask, 'if this trend continued uncontrolled or if this invasive species arrived in the country, what sort of scenarios could we construct and what are the cost implications of reversing or controlling it?' Considering the issues of the lake weed and the wallabies, we do not have proper risk assessments for either of them.

Supposing that the wallabies spread across the Rangitaiki River and into the Ureweras or the Mamakus and Kaimais and progressed up those chains of mountains. Do we know what would then happen? Do we know what the cost would be in terms of environmental damage? Do we know what the cost would be in terms of trying to reverse that problem? Are we putting sufficient weight on the risks of wallabies continuing to spread? The same kinds of questions can be asked about lake weed. As a South Islander I am very

conscious of the fact that we are not yet grappling with some North Island pests but they could easily get there.

I believe that this lack of awareness of risk, and lack of propensity to properly study risk and look at risk scenarios, is underpinning a failure of national commitment to put adequate funding into biosecurity research, in particular aquatic biosecurity research. This is a problem that needs to be looked at in the large picture.

When I was a director of Landcare Research for 6 years in the early to mid 1990's one of our rather dubious duties was to reduce the science research effort in soil conservation; this happened because the funding was cut off. When pressed for reasons why the funders said, 'Well, nobody is taking up this science. You have produced all sorts of solutions which farmers could use to stop their soil eroding on the 5 million hectares of North Island soft rock hill country but nobody much is using it. Regional Councils don't seem to be interested in taking the lead on this work, so why are we funding the science?'

That is a problem for science in the biosecurity field. We rely very much on the regional councils to use this science, but the uptake is quite patchy. There are some councils like the Bay of Plenty - blessed with an extremely profitable port investment - which is able to do things that other regional councils cannot do. Then there are some quite poorly-funded regional councils that nonetheless are very aware of aquatic biosecurity issues, like Northland. The great majority of councils however, are just not using this science, and they need to be galvanised. They are the same councils that need to be galvanised on almost every other environmental issue as well.

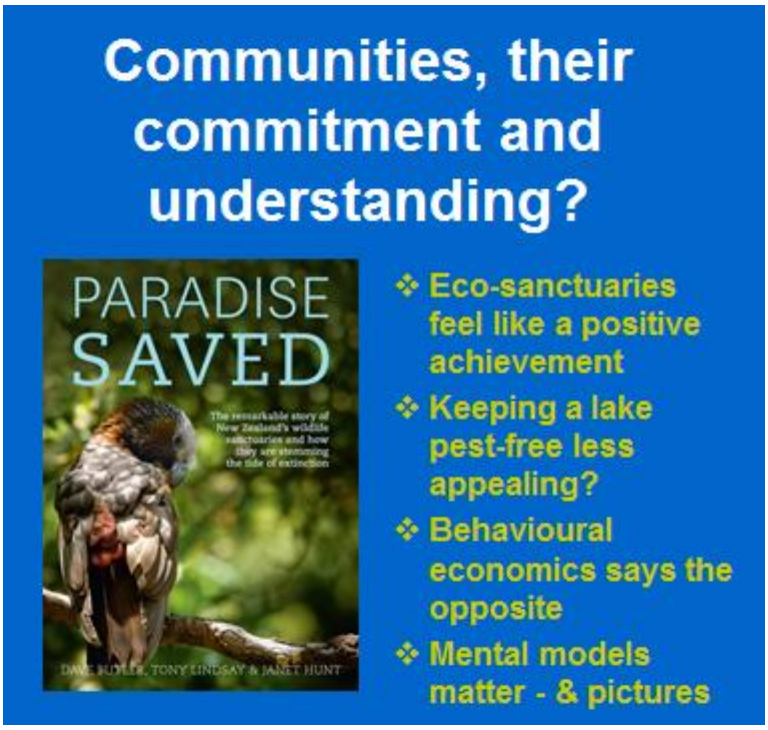
So there is a problem out there which can be driven partly by local environmental activism, gingering up the councils, and perhaps partly by more national policy statements and national environmental standards out of central government, which would force the regional councils to do more about these issues. Until we strengthen the regional councils and their role as our main environmental managers we are always going to have insecurity around the funding of the science and technology tool kit and the workforce in this area.

That leads me to my last point on this slide, which is perhaps a little general for this meeting, but it is something we need to think about. As a society we undervalue knowledge generally, and it is increasingly obvious that we are differing more and more from other small wealthy countries in the OECD in this regard. Looking at comparable countries like Finland, Singapore or Israel, they spend 2, 3 or 4 times as much as a percentage of their GDP on research and development as we do.

New Zealand has become trapped in a way of thinking about our national development which I call the Crafar model. Thus it is all about cutting costs, investing in more properties, building up more debt, non-investment in knowhow, and dependence on weak environmental regulation; we know where all that got the Crafars. We should not follow that model. There are better models out there, and taking a closer look at Singapore, Denmark or Finland we could learn something that is important about knowledge-based development. That is a lesson we can learn and it would benefit a whole lot of other things like the problems discussed in this Symposium.

My third question asks how committed are the communities to these problems? What is their understanding of the issues? Have they got some mental models which are not helpful and can we change those, how can we engage with them?

Slide 3



I was struck recently by the book *Paradise Saved*[1], which is a premature title unfortunately, but a lovely vision. It is a story of more than 350 community initiated eco-sanctuaries that have been established around New Zealand by local groups; it is amazing how this really has taken off in the last decade. People are aware of some of the high profile projects like the Maungatautari Sanctuary but there are so many others and it is such a popular thing for people and communities to do. When talking with these people, they feel so positive about their achievements; putting up a fence, running a trap line, bringing a whole lot of birds back into the community.

But thinking about the slightly different issue of biosecurity, it is the other way round: prevention of a bad thing happening, and the realisation of how important it is that the asset is not lost. So this question about communicating a clear vision about the risks that we run, building some mental awareness in the community, is really important.

Behavioural economics has important things to tell us about this. There is experimental evidence to show that people are much more concerned about losing something they already have, and much less concerned about getting something additional. In a sense, the huge enthusiasm for eco-sanctuaries is probably just the tip of an iceberg of enthusiasm in the community for protecting assets like lakes, for instance. We need to seriously consider the work that Mary de Winton presented to us today about myths held in the community. It is a big part of the challenge ahead: how to turn around the mental models held within our communities.

The members of the Land and Water Forum have pioneered and achieved respectability and a revival of collaborative problem solving methods in this country. At the national level, it is part of a wider movement, very strong in the United States, which might be called ‘place based community management’. Where the risks to a resource like a lake are recognised and the local community springs into action to protect it. There is a terrific

[1] Butler, D., Lindsay, T. and Hunt, J., 2014. *Paradise Saved: The Remarkable Story of New Zealand's Wildlife Sanctuaries and How They Are Stemming the Tide of Extinction,* Random House, NZ

amount to be gained by tapping the willingness of communities to be mobilised to do constructive things in the space. We now see a number of examples in New Zealand which tells us something about the possible potential.

I live in a little place on the coast not far from Nelson where there is a marine reserve; we have to deal with people who come into it and grab the abundant fish. If they come in a boat, DOC's hotline gets plenty of calls from people with binoculars identifying the boat. If they start fishing off the shore, locals talk to them and tell them, 'Look you can't fish here this is a marine reserve'.

There is a strong community sense which could also work in the Rotorua area for people arriving with a boat with weed hanging off it. If weed was a threat in the area where I live, the community would be down there stopping people launching boats and looking closely at their trailers. This community engagement is something to foster a lot more.

I was working a year ago with a community group in the Mackenzie Basin and there was an important issue which needed outside funding to solve it. A member of the group was the operator of the local ski field and he said, 'I'm going to set the ball rolling on this by giving all my customers an opportunity to make a donation towards the Save the Mackenzie Fund. We can get the private sector mobilised to put money into this and attract some co-funding from the Department of Conservation.' It is now gathering momentum and shows there are opportunities to tap into community groups as well.

We still face the fact that new weeds are going into lakes and wallabies are spreading. There is a long way to go in building up the community awareness, tapping sources of funding and building the contribution which the community can make to address these problems. That is a key way forward. The Bay of Plenty Regional Council are currently writing their 10 Year Plan and new Pest Management Plan. The Rotorua District Council and Department of Conversation could contribute and perhaps fund some facilitators to work with communities or co-fund initiatives which communities themselves want to start.

I come back to the reality that we are in an era in which there are so many threats: water quality decline, climate change, invasive species. We are at a stage in history where every environmental asset that we have in this country needs a community group alongside to look after it. We need to take that challenge seriously, empower those community groups, give them the knowhow and guidance they need and help them go forward.

THE ROLE OF A WEED MANAGEMENT AGENCY – A SMART APPROACH TO DELIVERING INNOVATIVE BIOSECURITY SERVICES

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Dave has been the Senior Portfolio Manager (Biosecurity) at Land Information New Zealand (LINZ) since 2012, moving into this position from a policy role at LINZ, which also had a biosecurity component. Dave has spent his career in a variety of technical and management roles at LINZ and its predecessor departments, specialising in the geospatial areas of topographic mapping and hydrographic charting, which LINZ took over from the Navy in 1996.

ABSTRACT
Over the past year, Land Information New Zealand (LINZ) has taken a new approach to biosecurity as a result of significant external factors and a new, organisation-wide 10 year vision. We have reviewed our biosecurity aims and goals, and re-examined the tools and processes that determine our ability to fulfil these overarching outcomes and objectives.

Our new thinking about biosecurity has been informed by what we call SMART procurement, and this approach has encouraged innovation, ensured a better focus on outcomes, and laid the foundations for a truly strategic partnership with our suppliers. This presentation will outline our SMART philosophy, and offer some thoughts on its benefits over traditional models of biosecurity management, focusing in particular on our aquatic weed control work.

TRANSCRIPT
Thank you for the introduction, I should point out that I am not a practitioner. I picked up the biosecurity portfolio about 6 years ago and found it fascinating. Through that time I have been involved with new legislation with the Biosecurity Act and an opportunity came up to cross the fence into operations and I have been in this position for the last 2½ years.

I would also like to applaud the two previous speakers who were brilliant. I was concerned initially that what I will talk about may have cross over, but thankfully not. I echo and reinforce what they talked about. I will take a different tact and talk about the significant transformation within LINZ over the last 12-24 months; a snapshot looking at the past, the present and future direction of LINZ biosecurity. In my area we hope to take more of a leadership role. We have introduced a new business model which will hopefully provoke some thinking amongst the agencies here that can be applied to your type of work.

The Role of a Weed Management Agency
I would like to begin with a bit of context and look at the big picture**. (Slide 1)** We all play a part in enhancing or maintaining those biodiversity values that we hold so dear, unique New Zealand values which enhance our environment for recreation, economic purposes, cultural identity and of course the health of the environment. When I first came into the job I wanted to see where LINZ biosecurity saw itself at the time, its position and looking forward. How did LINZ want to position itself in the future?

Slide 1

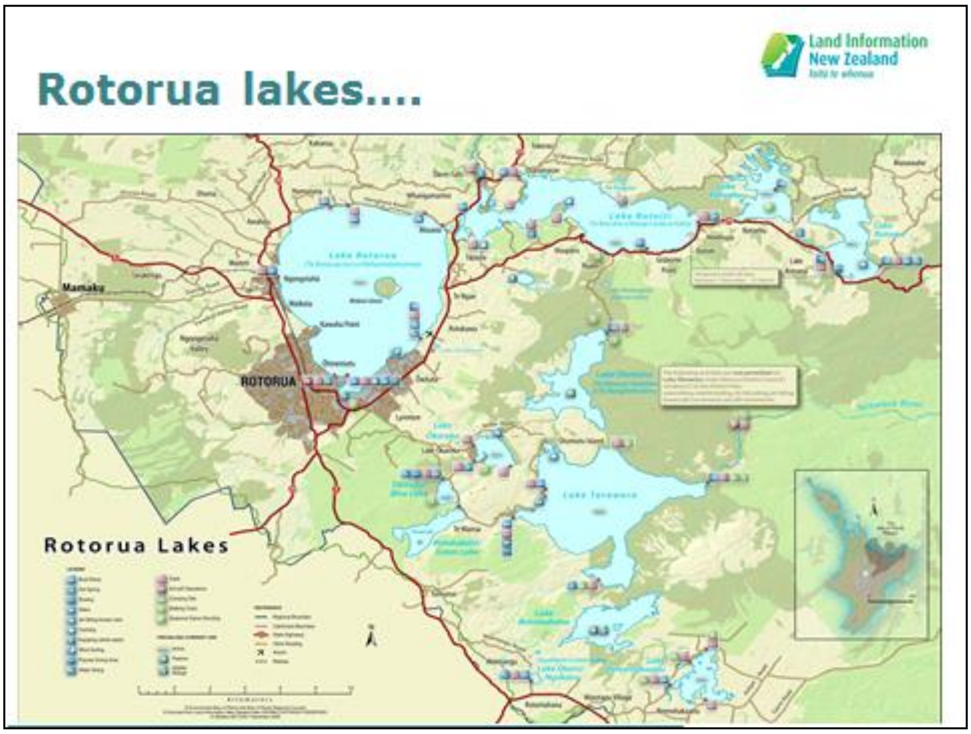
LINZ's Role as a Weed Management Agency

On behalf of the Crown governed by the Land Act 1948, LINZ manages roughly 8% of New Zealand land which equates to about 3 million hectares. This includes some of the iconic high country pastoral leased farms and a number of iconic lakes, most of which are in the South Island, such Lakes Pukaki, Benmore, Whakatipu and Wanaka. **(Slide 2)**

Slide 2

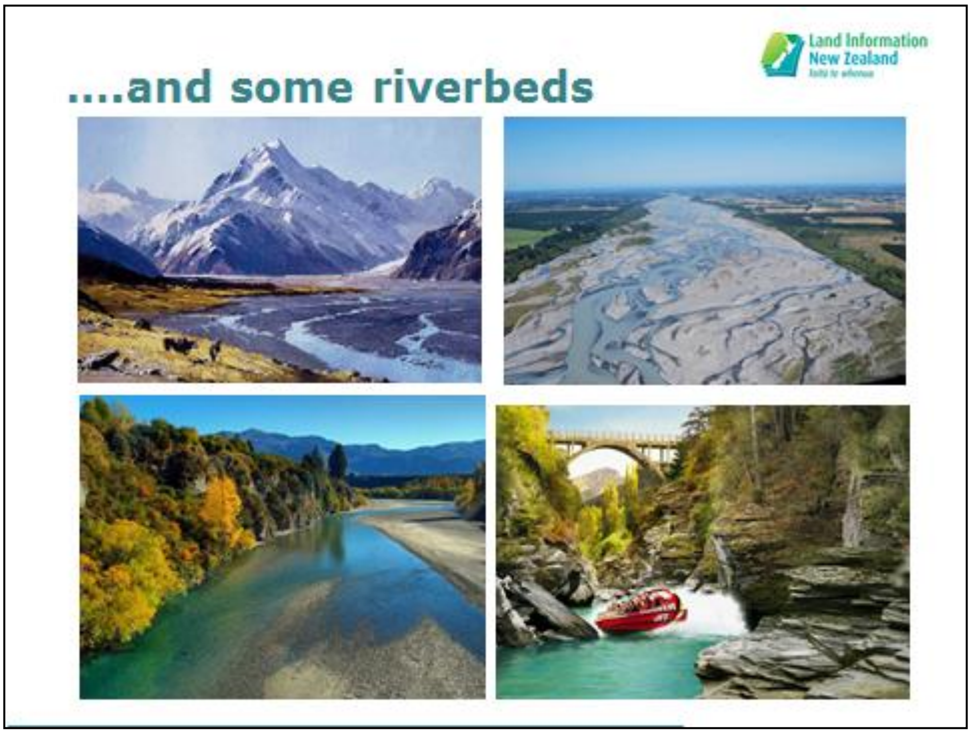
We have a special role with the Rotorua Lakes since the Te Arawa settlement in 2006. **(Slide 3)** We co-manage these lakes and I will describe that later on.

Slide 3



We manage some of the rivers shown in **Slide 4.** Top left is part of the Tasman River with Mount Cook in the background, Waimakariri on the top right and the Shotover.

Slide 4



LINZ’s Biosecurity Programme
Among LINZ’s management activities is its biosecurity programme. We have an annual appropriation of about $1.5 million, which is ring fenced, and together with partner contributions it is about $2 million a year we spend, half of which goes on aquatic weed control. That leaves another million dollars to spread, and the big ticket items are wilding pines which is very topical at the moment and our old favourite gorse and broom and to a lesser degree rabbits. **(Slide 5)**

Slide 5

We prioritise funding at two levels:

- Compliance or acting as a responsible land owner
  - Relevant standards and legislation
  - Compliance with Regional pest management strategies
  - Act as a responsible land owner and good neighbour
- At a site level
  - Site value + risk of spread + cost benefit
- Types of programmes
  - Eradication/exclusion
  - Progressive containment
  - Sustained containment

We need to be compliant and work under the Biosecurity Act and other relevant legislation. We also work closely with the Regional Pest Management Strategies to ensure there is compliance, but just as importantly LINZ consider ourselves a responsible land owner and good neighbour. There will be more about this good neighbourliness when the new legislation comes in shortly, but that is another story.

At a lower level we look regionally and establish plans on the principles behind site value, the risk of spread and the cost benefit. That is how we would approach a programme and that then translates to the type of programme to employ. Some examples are eradiation and exclusion, such as at Lake Whakatipu which is considered weed free at this stage so

we would just undertake a monitoring programme. If we find the occasional weed then it is removed.

A good example of progressive containment is in Lake Wanaka where we are completing a 10 year strategy plan and it has worked very well. NIWA are reviewing that plan for another 10 years. We have progressively rolled that weed back and it is almost near the Wanaka township. Anything north of the containment line is now classed at eradication or exclusion and suction-dredged or hand-picked.

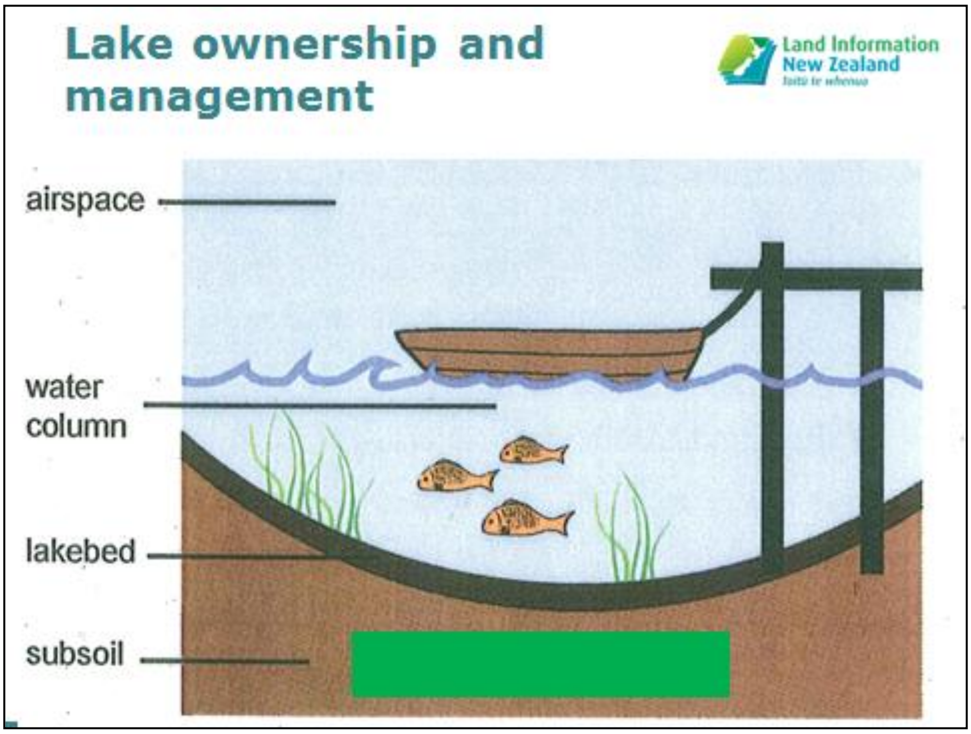
We cannot say the same for Lake Dunstan at the other end of the Clutha River which flows out of Wanaka and into Dunstan. There we are obliged to undertake a sustained control and concentrate on the high value which is all we can do because it is not going to go away until the problem upstream is fixed. There is an additional site led programme, we have one or two but they are just sites.

How We Operate
Up until recently LINZ has used a traditional outsource and contract model. In 2009 we contracted Boffa Miskell that is an environmental consultancy company based in Christchurch with offices in Wellington, Tauranga and Auckland. They are my operational arm and consult and develop together the annual work programmes, run the contracts use sub-contractors, do post-control audits, etc.

Let's talk about lakes. We use traditional herbicide control methods, diquat and endothall. It comes down to what is most appropriate and cost effective, diver-based control, weed harvesting or weed cordons. We would consider alternative biocontrol methods such as the use of grass carp, provided they were ultimately viable.

Lake Ownership and Management

Slide 6



Ownership or management of lakes is complicated and it took a while to get my head around it. For Crown owned lakes LINZ owns the stratum which consists of the subsoil, the lake bed, the space where the water is and the air**. (Slide 6)** But of course there are other organisations and interested parties involved that make up the successful achievement of our business requirements and goals. **(Slice 7)**

Slide 7

For instance the Regional Council has an interest in the water column and the District Council has an interest in the structures around it. DOC looks after margin strips and biodiversity values, Fish and Game for the fish and game. The difference with the Rotorua Lakes is that from 2006 the lake bed and subsoil was handed to Te Arawa and we retained the stratum for above the lake bed to the air, and the weeds, but the rest stays the same.

Success Relies on Working with Others
There has been a lot of talk over the last couple of days of collaboration and the need for team work and I can only reinforce that going forward. Success relies on working with others and I treat this on two levels. On a national scale it is very important LINZ and most of you here work with MPI and other Crown agencies like DOC in the overarching policy and governance roles.

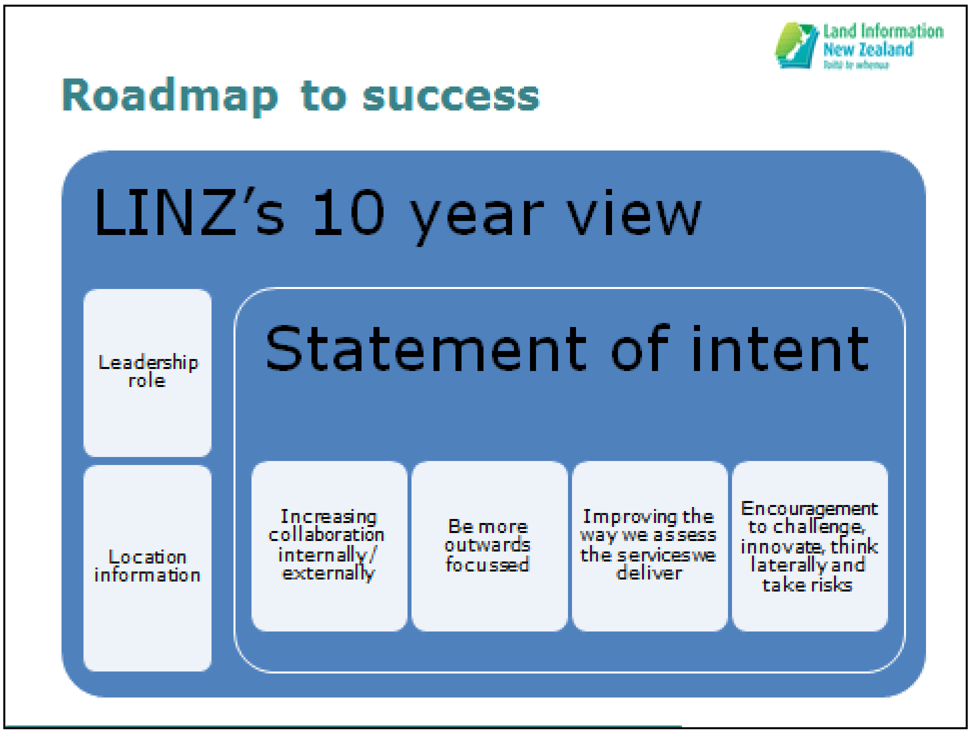
At a regional level we can establish relationships or partnerships to achieve our business goals. Lake Benmore, for example, there is a partnership with Meridian Energy. They have their own drivers for hydro-electricity and we have ours, but jointly fund an annual programme and have a strategy going forward. In Rotorua we have the Aquatic Pest Co-ordinating Group (Aptag) which consists of LINZ, Regional Council, District Council, Te Arawa, Fish and Game and DOC and together there is joint funding, the bulk is for weed management, mostly LINZ but Bay of Plenty do contribute.

Wanaka is probably the most successful lake we have with all the same stakeholders as well as the Guardians of the Lake which is like a Trust. But the plan that we have in place

there has been a real success story. If we could adopt that type of model going forward here it would be great, because the success over the last 10 years has been so noticeable.

Future Role of LINZ as a Weed Management Agency

Slide 8



In mid-2013 LINZ and the whole system went through a huge transition. **(Slide 8)** Within LINZ a new chief executive brought fresh ideas and a 10 year vision called 'The Power of Where' which is a powerful value proposition. This vision promotes leadership, the first key word. LINZ's Statement of Intent also contains 4 clear messages:

- to promote collaboration
- to be more outwards focussed
- to effectively improve our services
- to challenge ourselves to be innovative and take risks

Historically, reasons for not doing things rather than reasons for doing things existed, but we have changed that paradigm to challenge ourselves and go forward and 'just do it'.

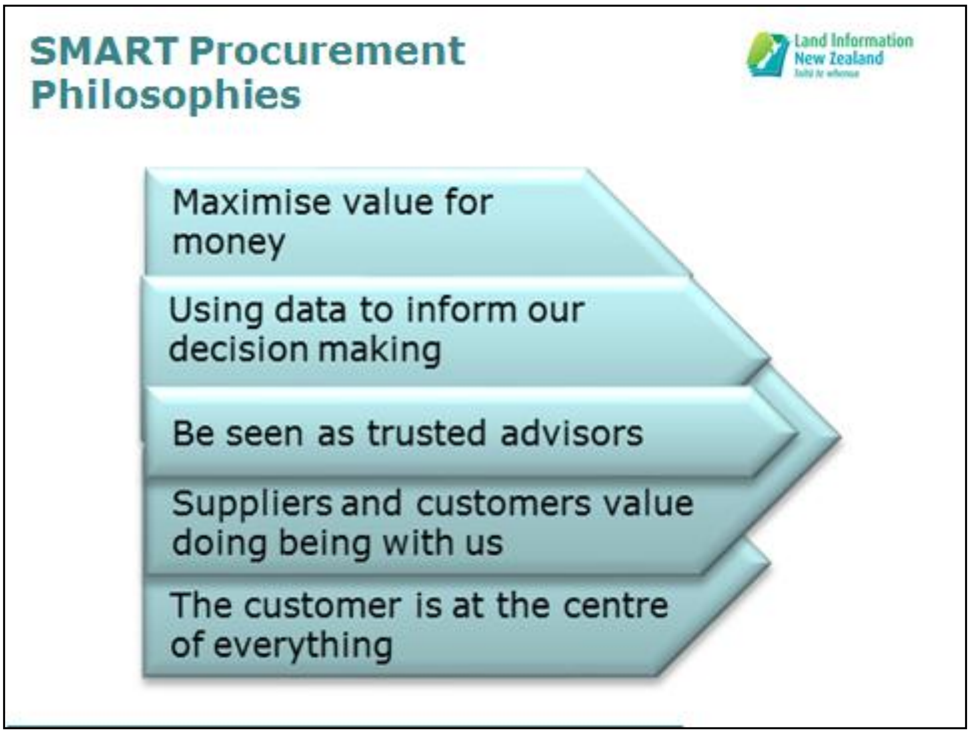
At that same time the contract with Boffa Miskell was about to expire. For the previous five years they had performed very well, establishing relationships with our stakeholders and maintaining them extraordinarily well. There were also external things happening as we came out of a recession. There was a zero budget and we had to do the best we could with what we had which was not much. Importantly there were changes to legislation based around a complete review of the biosecurity system undertaken by MPI which started around 2009 and is still rolling out. It is huge culminating with the national plan of action which has effectively replaced the biosecurity strategy of 2003.

There were some extenuating factors in terms of a supplier and a direction for LINZ biosecurity going forward. Taking all these things into consideration, internal factors and our new direction for LINZ plus the externalities, we came up with three key drivers:

- It had to be outcome focussed to think longer term, more sustainable and do the best we can with what we have and aligning with stakeholders
- It was about legislation and compliance to protect LINZ's interest
- To provide a better public service and value for money, common sense to be smarter.

LINZ has adopted SMART procurement philosophies. **(Slide 9)** SMART is an acronym used in many ways, I am not sure what SMART stands for in this case but these are the principles behind our SMART philosophy. What I have learnt over the last 12 months is that things that I previously thought not possible can be done and very easily.

Slide 9



On 1 July 2014 LINZ entered a 10 year strategic partnership with Boffa Miskell that was the first of its kind, certainly for LINZ and Boffa, and probably the first of the kind across government because it is a true partnership. MBIE are treating this partnership as a case study and there is interest in this particular model going forward. It is a true partnership. What was a 62 page very prescriptive contract is now 2 pages and suits the outcomes that we want. Previously, like most contracts, it was so prescribed that you tell the contractor how to do their jobs. In this case you know there are controls in place like health and safety, which fulfils that prescription.

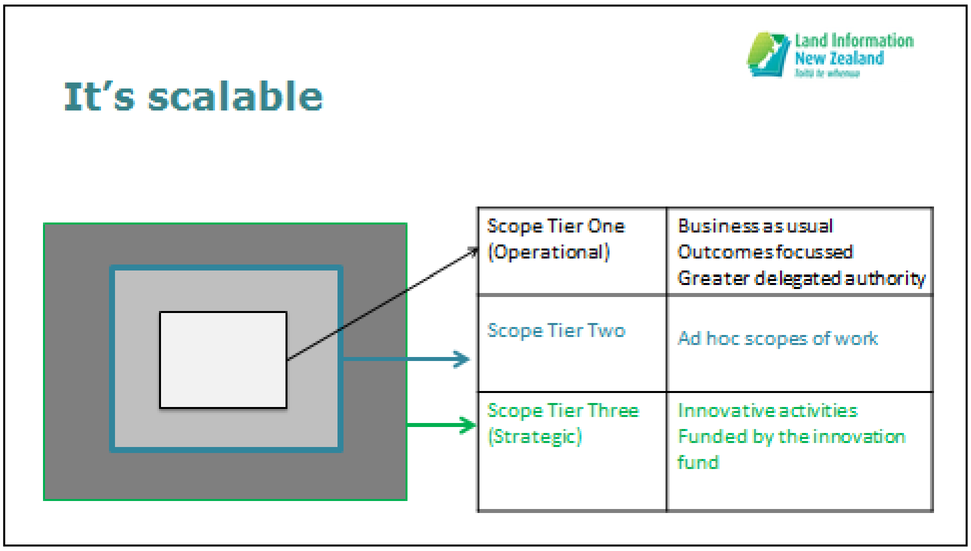
Both parties are working towards a mutual goal striving for mutual gain:

- vested in each other's business
- committed to learning from each other
- measures consider how successful the partnership is, not how well the work is done
- innovation underpins our purpose

In a similar vein we have an MOU between the two agencies and have established a governance board, and it's important to note the individual make-up of that Board. On the LINZ side there are three, myself as the business owner, a representative from Policy to ensure that we are not pushing too far outside our remit and to make us aware of relevant legislation and strategies that might be appropriate for the partnership going forward. The third is the Procurement Manager who understands the business and provides an effective procurement system and process.

This business model is future proof. It promotes collaboration and ensures alignment with our stakeholder's outcomes and objectives. It shares technology with our stakeholders and also resources and information. In terms of measuring our success, we have a list of no more than five or six key success indicators (KSIs) such as partnership effectiveness and relationship health. We measure the performance of the partnership as opposed to the performance of the services. The KSIs are based around risk, such as preserving the reputation of both chief executives and the minister, operational health and safety, and success factors around the delivery of strategies and programmes. These are measured annually and have targets. There is a matrix on the health of the partnership, where we started from and where we want to be and individuals mark off where we are. Where we are not measuring up we can identify those areas and take remedial action.

Slide 10



This model is also scalable and **Slide 10** shows the makeup of the partnership. Tier 1 is business as usual, our core business, the annual programme and the expert advice, relationship management, everything to do with our key goals. Tier 2 promotes ourselves as a centre of expertise to provide advice and pick up biosecurity work where it seems beneficial or more effective for us to do so, whether that is from another business group within LINZ or an external stakeholder. An example could be that if down the track LINZ would pick up the properties in the red zone area of Christchurch. Currently it would be a Tier 2 that would come with a resource and eventually it might come to Tier 1 as business as usual.

Tier 3 is the exciting fun part. We have established an innovation fund where both parties put in a significant amount annually, capped at $60,000 at the moment, for more effective and efficient business functions. Now we have an innovation register, a log, where the board consider ideas. The fund is for innovative tools and investment in research education or if a programme is failing somewhere we have the capability to pump it back

into a programme. There is growing capability in the sector. We can think outside the square and come up with these innovative ideas on how and where to succeed.

The first purchase has been a drone and this has taken on a life of its own with the amount of interest not only by colleagues and other business groups, but external parties. We talked to MPI, the Police and everyone is talking about drones. We have purchased it for our own business requirements for surveillance or monitoring areas that we cannot access currently or with the use of a helicopter. A helicopter costs $2,000 an hour, this just needs someone to drive it.

LINZ is the national mapping agency and home to a lot of public spatial information, which is made available - but can it be made available in a more accessible form. There are a couple of tools here which have wider applications using and sharing location information. We have recently introduced a new service called LINZMaps which is not available externally but will be shortly. It is a visualisation tool, web based and takes information largely the same layers as on LDS and puts it in a web view and we can add as many new layers as you like.

A prime purpose of this service is when we do work with our stakeholders - you external stakeholders - so we are all looking at the same information. We can take layers from you and collectively make informed decisions. One project I am involved in is the National Wilding Pines Strategy and LINZ is leading that with mapping and monitoring which is quite an exciting venture.

In summary it is all about collaboration and working together. We can make some improvements. Guy Salmon certainly mentioned a couple of opportunities going forward but without that cooperation we will not succeed. Cooperation and collaboration lead to more effective, more efficient decision making and more efficient processes. Partnerships such as the formal type we have adopted can only be of benefit where we are aligned and share the same vision, objectives and business requirements, become a centre of expertise, and last but not least to apply innovation which can really be fun!.

Everything leads back to the first slide where we all contribute equally to the bigger picture, New Zealand lakes and maintaining those values, thank you very much.

RESPONSIBILITIES AND FUNDING – CONSENTING PATHWAYS AND OPTIONS

Angus McKenzie (MNZPI, MRTPI)
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Angus is a Senior Planner with over 15 years of consultancy and local government experience. He is an accomplished resource management practitioner and has provided environmental management advice to a wide variety of private, local government and central government clients. Angus has significant experience in the development and implementation of biosecurity programmes and projects. His diverse skill set has seen them involved in a range of collaborative biosecurity projects to navigate legislative frameworks to improve the efficiency, including a national business case for simplifying the regulation of aerial 1080, a national permit for aquatic pest plant control and comprehensive consents for biosecurity programmes.

ABSTRACT
This presentation will outline the regulatory framework for biosecurity programmes within the Rotorua Lakes and explore a range of potential options for tackling the framework, drawing on my experiences with collaborative comprehensive consenting and national policy tools. Examples to be discussed will include:

- National aquatic weed consent. A multi-agency reassessment that has expanded the aquatic weed toolkit under HSNO and provided efficiencies through reducing administration costs.

- Comprehensive consenting in the Waikato region. Programme level consents for the Waikato Regional Council, their effectiveness, outcomes and relevance to the Rotorua Lakes context.

These examples showcase a range of alternative responses to regulatory requirements that have resulted in positive outcomes for the agencies involved and could provide a framework for the Rotorua Lakes programmes.

TRANSCRIPT
Kia ora koutou and thank you for the opportunity to speak, it is a real privilege with all the expertise that we have here today. I have seen some detailed presentations and great high level stuff, notably Guy Salmon's presentation just now which was very interesting. I am also interested in finding out more about the partnership approach that LINZ is taking. That is a great initiative and represents forward thinking regarding where we might take biosecurity.

I have also enjoyed the number of heritage buildings that we have been in at this Symposium. I have a bit of a heritage bent and think that back wall that we look at might be the exterior of an old building. This convention centre is a great example of what can be achieved and the Blue Baths last night is a wonderful example of the heritage we have in this country.

I am a planner by background sadly, but I am proud of that and in the last 5 years have become involved in the biosecurity area and I am very passionate about it. I am sure this passion is shared within this room. It is an area where we can collectively make some of

the biggest environmental gains for this generation and those to come. I applaud the work of those people who do it on a day to day basis at grassroots level. It is a challenging and at times very uncertain field. It is also an area of extensive scope for those a bit younger than me and notably in the cross over between planning and biosecurity.

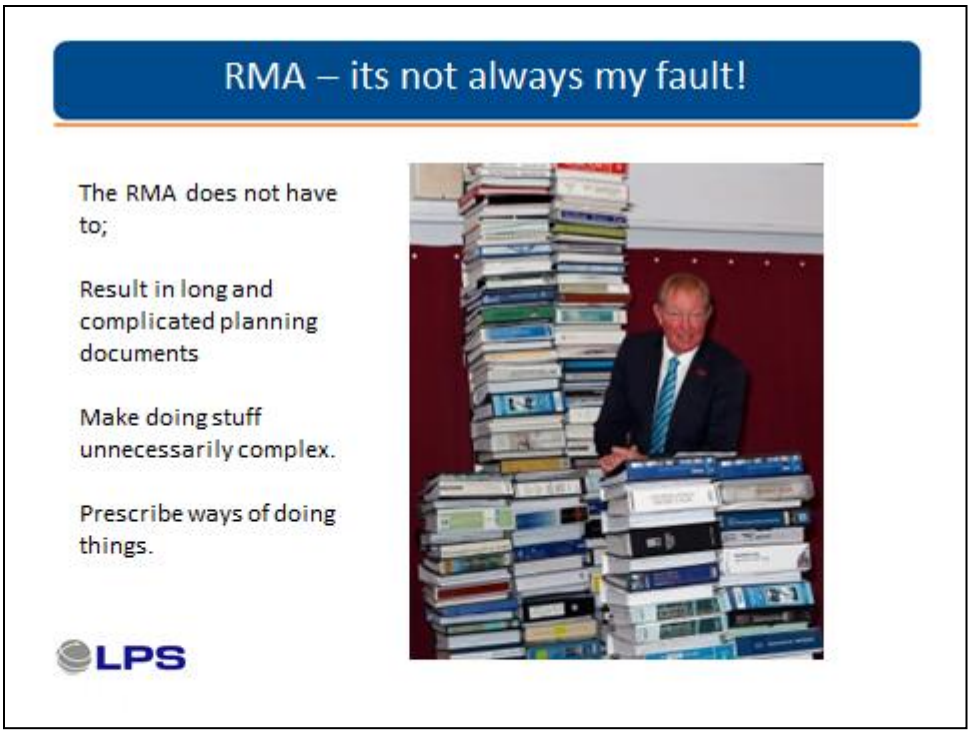
I want to cover my views on how the planning world is implementing that wonderful piece of legislation called the RMA, and how we are going in respect of biosecurity. I will look at some of the key drivers to improve the implementation around the RMA. I do not profess to know in detail the planning context for the Rotorua Lakes but I will talk briefly on where I consider some of the consenting hurdles lie. There have been some interesting questions around this issue during the Symposium. I would also like to take you through a couple of consenting example in the Waikato Region that we have worked on as a possible tool to apply here. I will touch on some work that we did nationally with NIWA, and particularly Paul Champion, to expand the biosecurity toolkit and make more tools available. I will conclude with the benefits and explore some of the downsides of these approaches and the potential applicability to the Lakes' Programme.

Before I start I want to touch on a theme that has come through for me, and I know this amazing community group has done so much work in the last 15 years to get to this point. As the Hollies once wrote, 'The road is long and with many a winding turn'.

The road is long,
With many winding turns,
That leads us to who knows where,
Who knows where.

So we have to keep at it and this has resonated with me at this symposium. We need to carry on and we need strong leadership, we do not want to end up where England ended recently. AB de Villiers showed some good leadership, and Mr McCullum, and we do not want to end up on the Boeing 747 bound for Heathrow. So let's keep going.

Slide 1



I do want to acknowledge Hon Dr Smith. I thought his address yesterday was excellent and I am pleased he is the Minister in that portfolio with the background and experience and a really good grasp of regional issues, which I have not seen before in that portfolio before. **(Slide 1)** There are some major issues on the district side of planning and particularly in relating to housing. I am not sure that the wholesale changes to the RMA are the way to go, but I do agree it needs some tweaking. I was interested to hear the Minister's thinking about better co-ordination of funding with the regional planning as that is a need I have come across as well. We would love to see further work to co-ordinate and focus funding.

The RMA is just a tool, it does not result in long complicated planning documents, it does not make doing stuff unnecessarily complex. At a recent planning conference, a clause one of the planners from Northland highlighted was that you do not actually have to have any rules in regional or district plans, you can rely on policies and objectives. There is a lot of focus and angst around rules in planning but the RMA does not encumber this on planning, it is just the way it is being implemented at the moment. The RMA is not overly prescriptive; it has in fact a large amount of flexibility. In my view a lot of issues are created by a lack of quality implementation and are the reason planning is a dirty word.

There are some key drivers that have been around for the last 5 years for improving that implementation, increased need for co-governance and structures that you are well aware of in this community. Government is always calling for better integration between land use and infrastructure planning, not inundating our roads with commercial and housing developments and making sure we look across legislation more and the juncture of the RMA and Biosecurity Act is an example of this.

A number of cross boundary jurisdiction issues have also been touched on at this symposium as well as good partnerships happening with the Waikato Regional Council, the Bay of Plenty Regional Council, LINZ and DOC and other partners.

A tight fiscal environment still exists within the Government realm and in my view this will continue into the future. We must look for efficiencies and try to squeeze more from less. There are perceived barriers to service delivery so making our RMA more straightforward would deliver to communities what we have signed up for under our pest management strategies and various other plans.

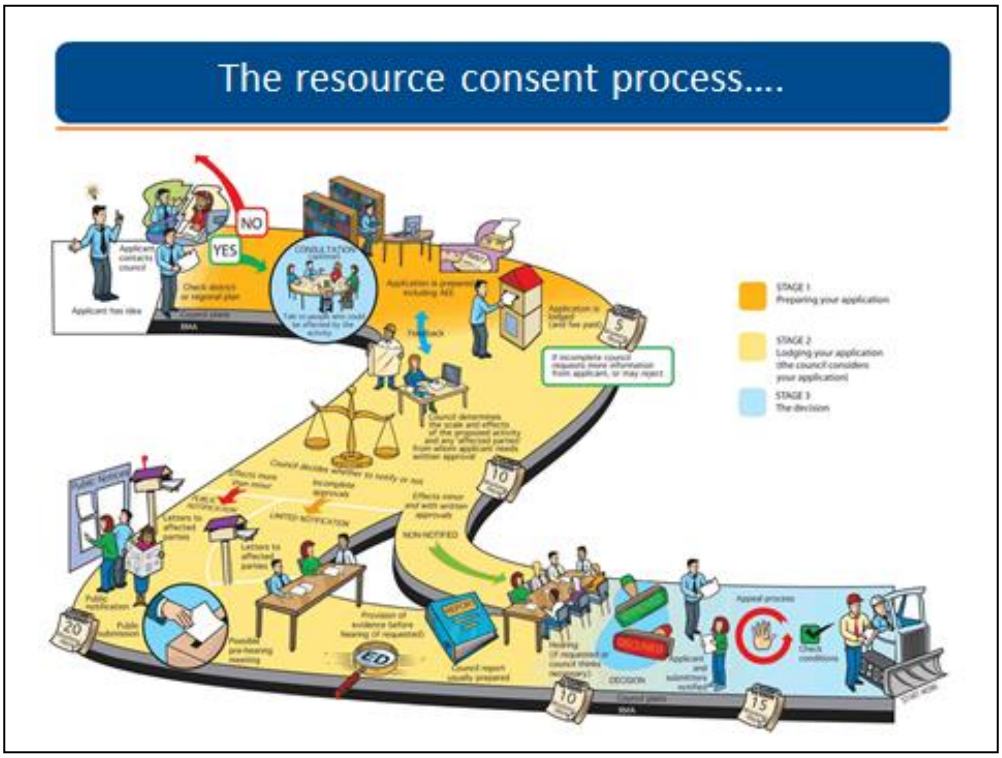
In terms of integration in the biosecurity space, the National Plan of Action talks about:

- better and more effective tools.
- developing, maintaining and registering physical controls and monitoring tools
- best practice guidelines for use
- provision of accessible info to Iwi, industry and public, strengthening collaboration

Moving now to the consenting requirements for the Lakes. In most regions animal pest and weed control programmes require two types of permit - one is on the RMA side and generally on the Hazardous Substances and New Organisms Act (HSNO) as well. The Bay of Plenty Regional Plan requires consents for aquatic weed work and consents for aerial toxic agent operations as well. EPA permissions are also required, although they are at times already in place, and I will touch on that later.

Slide 2 sets out the Resource Consent process. I have counted 25 steps. It snakes and ladders and can go any which way. My view at a programme level is – why therefore would you want to do it over and over and over again, operation by operation? Why would you want to focus on one particular herbicide for one particular site? If the context is appropriate, and that is critical, do it once, do it right, and look at a comprehensive approach to consenting.

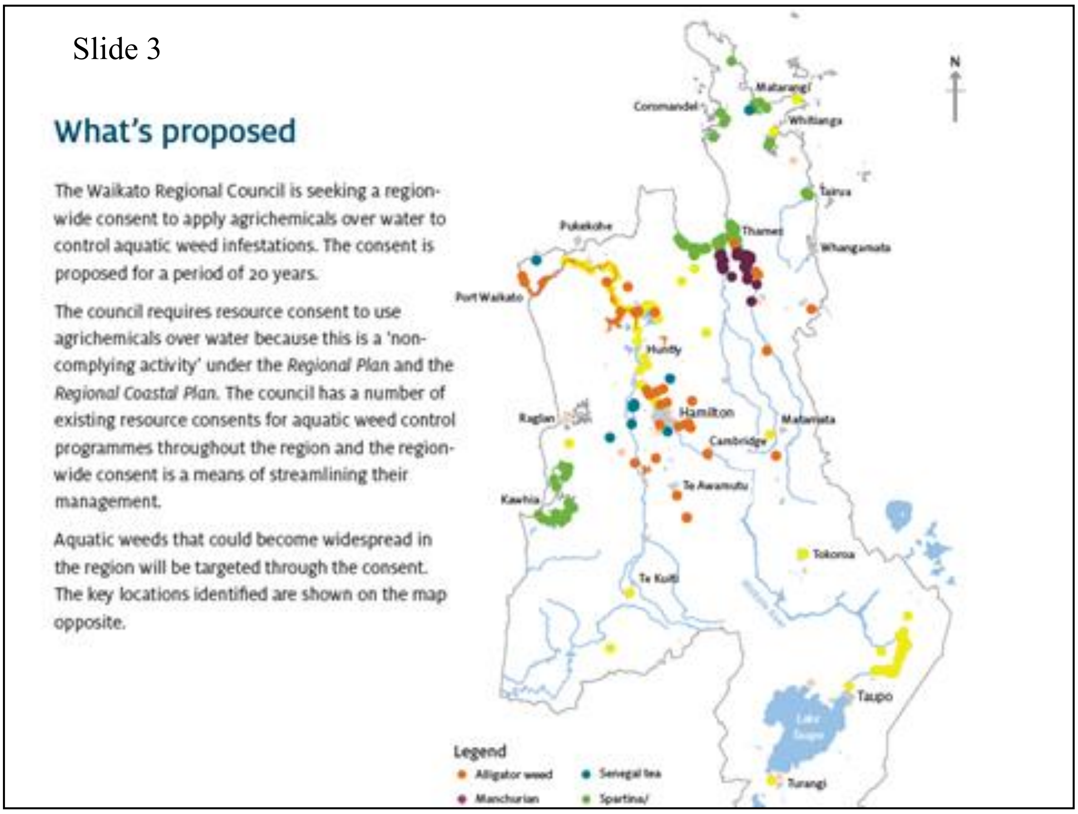
Slide 2



What are comprehensive resource consents? They generally cover a wide geographic area. They can go region wide or district wide. They can be programme level and generally on a wide geographic area for a long term. The RMA allows regional consents to be granted for a 35 year period and these consents can incorporate multiple activities, for example weed management activities alongside animal control activities. You need to think about these consents at a programme level.

I should acknowledge Wendy Mead who was a great driver for the Waikato Region wide consent that worked on all the RPMS priority aquatic weeds there. Consent was required for application of herbicide over water under the Regional Plan. The objective was a 'single long term comprehensive consent for aquatic weed control in the Waikato Region'. It was a multi-party application. MPI were applicants together with the Department of Conservation and the Waikato Regional Council. This shows that you can bring applicants together within a consent, even diverse groups with different drivers.

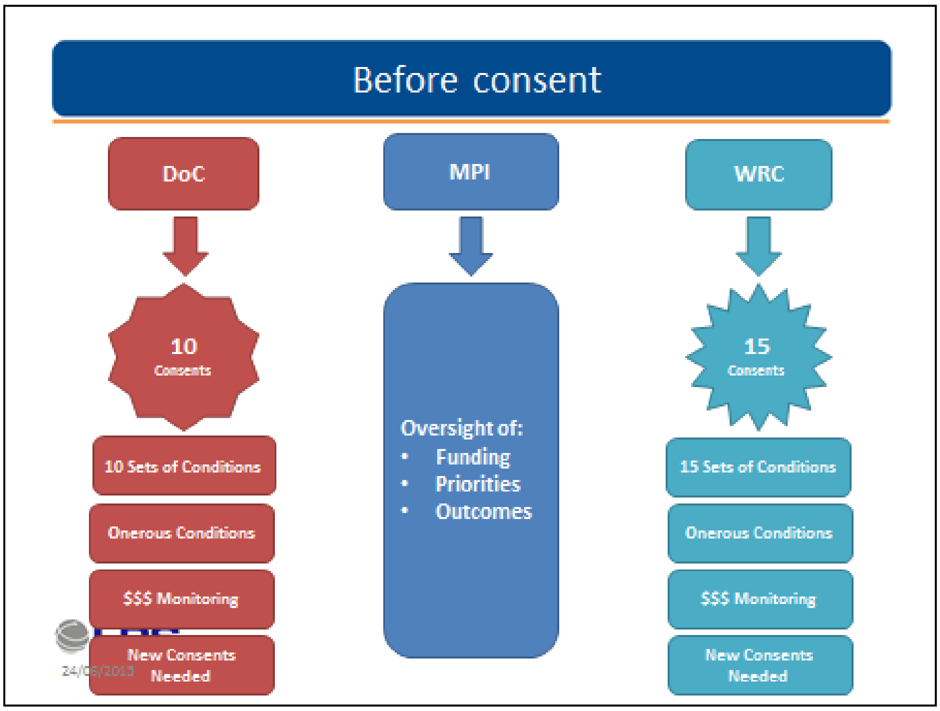
Slide 3 is an extract from a piece of consultation and gives a picture of how we communicated. Conceptually it is difficult to get one's head around, but we showed the history of the control in the Waikato for the last 10 years. It is not everywhere, there are sites we manage and it is a dynamic thing so we need flexibility within the tool. Conceptually it can be done.



Slide 3

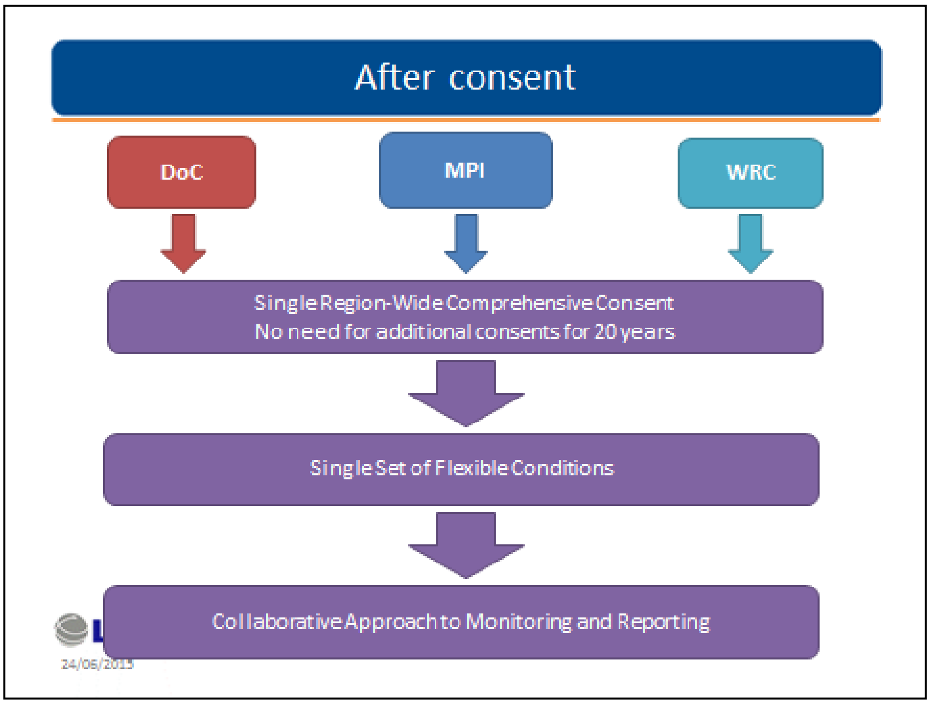
Before the consent there were three agencies operating under different consent frameworks. DOC had around 10 separate consents, meaning 10 sets of conditions to comply with, 10 lots of monitoring, and more money spent on monitoring. **(Slide 4)** MPI had the oversight role in this case. WRC had around 15 to 20 consents, with all the sets of conditions and monitoring requirements and an ongoing need to get consent on a site by site basis.

Slide 4



After the comprehensive consultation there was one consent for a 20 year period for the whole region with a single set of flexible conditions. **(Slide 5)** You may not agree with that Wendy, but from a planning perspective it was a pretty good deal. There has also been a collaborative approach to monitoring and reporting thereafter and this has led to roll out of national monitoring programme.

Slide 5

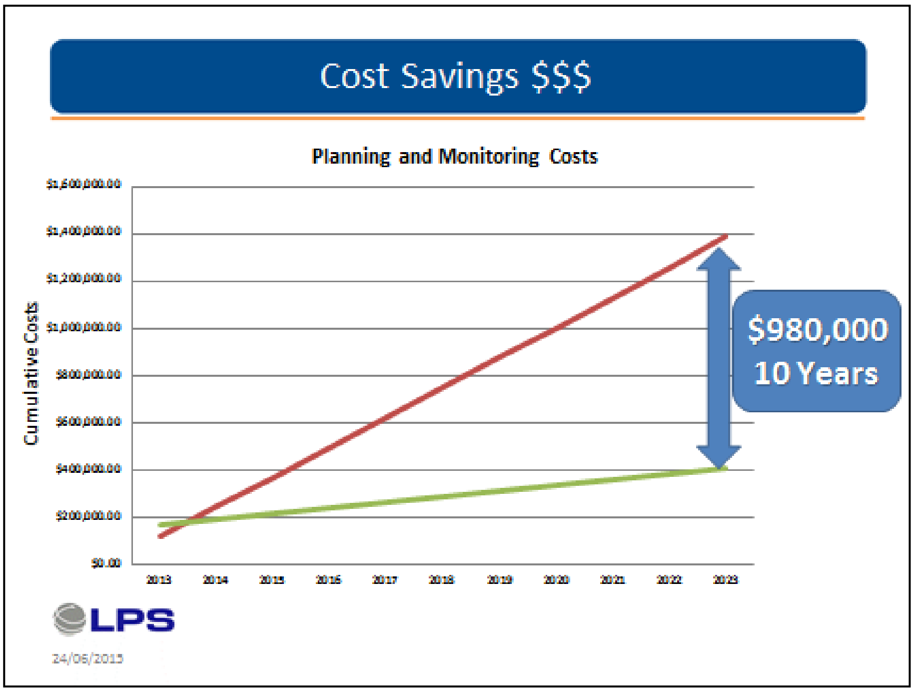


There were a number of benefits to this approach. We were able to access the extensive consultation networks of these applicants. DOC and WRC have a long history of good consultation in the Waikato. It provided a forum for those parties to come together and talk about their shared operations and what they were doing. We were able to use technical

information efficiently as well, using NIWA for that single assessment of environmental effects. The process benefits meant that the joint applicants rather than the submitters in the process addressed the issues up front not during the process to resolve issues within that process.

Slide 6 shows the cost savings for another comprehensive consent investigation we have undertaken for the New Zealand Transport Agency. NZTA hold around 450 consents in the Waikato. We looked at some rationalisation around that by reducing to about 8 to 10 consents. There were quite considerable cost savings if we can.

Slide 6



What are the downsides to a comprehensive approach? The biggest risk is that not all key stakeholders grasp the concept and/or get their head around the scale. Most notably this relates to the consent authority planner - you have to get that planner on board. It takes time and resource upfront to get everyone on that same page and generally you need more time, but the long term gain is what you are after. There is a need to develop robust and workable conditions for operations in the future that will balance of management environmental effects. Allow for that future input and review that gives the community some certainty if things change. Resource up front pre-application discussions, consult widely and get the strategy together before pursuing any of these pathways.

You have a great strategic story here that could be used for a similar approach. Why are we here, why do we need to spray, why are we even doing this? Put it in strategic terms and filter it down to the detail. Assume you are going to be notified and assume that you may go to the Environment Court. Clearly you need to allow time for that. Work up conditions and get them in early so that you can influence the process as well. 70%-80% of that effort is upfront before you get into the actual consent process.

We have also worked with NIWA on the National Aquatic Weed Permit through the Environmental Protection Agency. Paul Champion schooled me on the weeds in the photos below for a few years now, Alligator weed is on the left and the other picture is in Northland with its wonderful riparian margin of Manchurian wild rice. That entire green margin along the river is an invasive pest.

This national consent was a much more collaborative framework, 15 Regional Councils were involved alongside other parties such as DOC and MPI. The consent was about securing approval for the use of herbicides over water under HSNO. All 4 herbicides are critical tools in the management programmes alongside other methods.

The table below shows the plant species managed nationally. The process allowed a stocktake of this information which has led to more national monitoring and national

Pest Plant Species	Freshwater Presence	Marine Presence	Eradication Areas
Alligator Weed	Yes	No	Bay of Plenty, Horizons, Waikato
Californian Bulrush	Yes	Yes	Horizons
Fringed Water Lily	Yes	No	Nationally eradicated
Manchurian Wild Rice	Yes	No	NIPR species, eradication targeted at all sites outside Kaipara Containment Zone
Marshwort	Yes	No	Auckland, Waikato, Bay of Plenty, Nelson-Tasman, Canterbury
Monkey Musk	Yes	No	Northland
Phragmites	Yes	No	NIPR species, national eradication targeted
Purple Loosestrife	Yes	No	Northland, Auckland, Waikato, Bay of Plenty, Horizons, Greater Wellington, Nelson-Tasman, Canterbury, Southland
Saltwater Paspalum	Yes	Yes	Waikato
Sagittaria	Yes	No	Auckland, Waikato
Salvinia	Yes	No	NIPR species, national eradication targeted
Senegal Tea	Yes	No	Northland, Auckland, Waikato, Bay of Plenty, Taranaki, Horizons, Nelson-Tasman, Marlborough, Canterbury
Spartina	No	Yes	Northland, Auckland, Bay of Plenty, Waikato, Gisborne, Horizons, Nelson-Tasman, Marlborough, West Coast, Canterbury, Otago, Southland
Water Hyacinth	Yes	No	NIPR species, national eradication targeted
Water Poppy	Yes	No	Auckland, Bay of Plenty, Northland
Yellow Flag Iris	Yes	Yes	Northland, Waikato

approval subject to conditions. I viewed the project as a tool kit expansion, previously we did not have the appropriate approvals for those herbicides, but the permit opened access to the tool kit and introduced a couple tools more into the mix.

The costs were shared and cost savings were achieved by sharing the burden. When looking at biosecurity tool kit expansions a collaborative approach is vital, particularly in terms of tackling the EPA. At this point I would like to acknowledge the Regional Council biosecurity managers for taking the lead on this project. This is an excellent forum for tackling these more strategic national issues and the EPA were very supportive of this approach. The permit has since led to a national monitoring programme for aquatic weed management which we are working on with the EPA at the moment.

Where to from here for the Lakes? My observations from these two days, and I do not confess to know masses of detail, but I have been learning the whole time. It seems you have the structures in place, a good strategic story and solid governance structure to run a high level consent for the tools required in the programme. You have a programme history, have built community trust and relationships, but the tool kit is a little limited by the RMA.

There is potential for large scale animal pest control in the future and could definitely look at some integrated consenting arrangement around that. This would provide a vehicle and opportunity to integrate across the two programmes of water quality and the aquatic weed management programme. Tackle it strategically and look at a joint consent and policy approach.

Thank you very much.

QUESTIONS

Craig Morley, Waiariki Institute: My question is regarding the citizen science. I find there is a dilution of work as a result of this? In other words we are not getting graduates employed. I saw a newspaper article in the Herald on Monday with a whole class from Massey University with Honours Degrees in Environmental Planning and Environmental Management; none of whom have jobs. Now the issue that I have with citizen science is - are we diluting prospects for these guys to get jobs and funding because it is going into citizen science for agencies?

Tracey Burton, NIWA: Yes, that is a really good question. I do not think we are. The type of science, observations and data that people collect, is not a double up. We ask for extra information that we would not usually employ to collect anyway because that funding is simply not there and they are not on the front line. We are not taking other people's jobs but those people would be prime candidates to tackle awareness programmes should funding become available. I did not mention with citizen science before that it is not a silver bullet. A good citizen science programme takes a lot of planning and plenty of involvement. These people need to be given the knowledge, training and ongoing support so it is not something you can up and walk away. An expert must be involved and of course that comes at a cost. I do not believe that we would take anyone's jobs.

David Hamilton, Waikato University: I have a question for Guy in relation to your evaluation of councils. You identified funding as an issue to uptake for science. From my personal experience working with councils and also presenting to councillors, to what extent is the backing of councillors and their staff a factor in funding that uptake of science.

Guy Salmon, Ecologic Foundation: Yes that is a real issue and there are a lot of issues around the governance of councils which I could talk about for some time. Since regional councils were established in 1989 their performance has been quite disappointing and patchy. Nowhere do you see that more dramatically than in the water quality area where the regional councils' jurisdiction was established about the beginning of the dairy boom and we had huge expansion of intensive land use impacting on water quality. Nothing was done in almost all the regions during the 25 year period that followed. In a series of interviews and studies of regional councils I tried to understand why that happened and it is partly in the composition of the councils as they are elected.

There are two sectors of the community that are perhaps a little further advanced in their concern and awareness of environmental issues and the sort of people who are members of environmental groups like Forest and Bird or Fish and Game, recreational groups on the one hand and on the other Iwi. When you look at the membership of regional councils those two are quite under represented compared to the population basis or in the national parliament. It has to do with the system by which councillors in every region are elected, except the Bay of Plenty. The composition of the councils tends to have an over-representation of primary sector interests compared to the rest of the community. That is not entirely surprising because the decisions the councils make have a large concentrated impact on the primary sector. For urban people perhaps they do not feel quite as passionate about following what councils are up to. In Environment Canterbury for example over the last 25 years they have handed out water permits valued around $5 billion but most people are not aware of that, They think it is just a bit of administrative paperwork being done and there are some quite strong incentives for some sections of the community to pay more attention to the regional council elections than others do.

This was an issue discussed at the Land and Water Forum and while there was no support for changing from elective regional councils there was a strong feeling that there ought to be. The regional councillors themselves ought to be supplemented by some appointed representatives who would reflect the interests of Iwi and environmental interests and provide what might be called a governance component to the council. In other words bring to the table people whose focus is on looking at what the statute says, what is supposed to be done and make sure it is done. Not the continual drift around which is unfortunately so often the pattern.

I am afraid that is a longer answer than I should have given but I wanted to say that I believe the governance of regional councils is a big issue. The Land and Water Forum has recommended some changes but so far nothing has happened and unless it does we cannot expect a higher level of performance.

Dale Williams, BOPRC: Guy in your presentation you commented on the lack of risk assessments. You will be pleased to know that Bruce Warberton from Landcare Research has just been contracted to carry out a risk assessment of both the Dama wallabies and the Bennetts wallabies to look at what the potential implications are if we do nothing about preventing the further spread of those species.

Te Taru White, Pukahukiwi Kaokaoroa Inc.: Kia ora, a question to David Mole. I applaud the notion of collaboration and cooperation because as a land owner it is increasingly frustrating to look back at all the bureaucracies, energy and resources that have been soaked up in that space when looking for delivery at the coal face. It is tough when funding is restricted and everything else. I saw the new framework for LINZ and the comments you made and thought I have probably seen some of those words 10 years ago. I wonder what is going to be different to make this happen instead of being in silo - really cooperating and collaborating together.

David Mole, LINZ: The short answer is watch this space and I will deliver on my word. This partnership is not just me, we have it with another agency and have invested in each other's business and really believe in this. I dare say it does come down to individuals but by and large this is a new direction. Before, LINZ was under the radar and decisions were based on 'not to do things' as opposed to 'doing things'. We are now front footing this, being proactive and want to be leaders in the space. It comes down to personal aspiration and seeing tangible achievements.

Warren Webber, LWQS: David, as a community member I have observed what has happened with the weed spraying programme, particularly around the Lake Rotoiti area. My impression has been that it is grossly underfunded, under resourced and we struggle to get the work done that as a community we see is required. When I saw your funding slide earlier with $2 million per annum, of which only half goes to aquatic weed control, it struck me as being a huge underfunded proposition. Would you like to comment on that?

David Mole, LINZ: I agree. I would like to defend the programme that we do have in the Rotorua Lakes. I think it is effective but going back to that prioritisation and the types of programmes we employ, effectively for these lakes we employ a sustained containment programme. We could make improvements and we talked about strategy. Once again it comes down to collaboration and firmer partnerships. There are ways of becoming beneficiaries of more funding. Money is tight and there is no question about that and I concede that in order to get new funding there has to be a problem. It is more reactive than proactive. But things can be done and I certainly see opportunities. From what I have heard over the last couple of hours, and the report from yesterday, there are opportunities

in Rotorua to press things this way and perhaps get more definitive plans in place. A business case, if you like, for the lakes going forward which would attract new funding.

Nick Miller, LWQS: I would like to commend Tracey on her advocacy of what she called citizen science. We all need to remember that there are a lot of very famous scientists who were really citizen scientists, or amateur scientists, such as Newton, Darwin and numerous other illustrious people. There is no way they could they have been called professional scientists. I am sure amongst the membership of the LWQS and at this symposium where we have the professional scientists I suspect there are a good few amateur or citizen scientists as well. For many decades one of the world's leading scientific periodicals produced a column every month called 'The Amateur Scientist'. No longer produced alas which may reflect current views.

CLOSING COMMENTS

I have to say that this has been one of our best symposiums. The quality of delivery and ideas and the way you as presenters put your case with excellent slides demonstrates the depth of thought that went into the issues that have been widely traversed. I must compliment you on the clear delivery of scientific messages to the community by keeping the message relatively simple. ‘Keep it simple stupid’ for the layman. I have the same issue in board reporting. If you can get the message across simply it is amazing how you get the community engaged.

So I congratulate all the speakers and will not go through each one individually in giving a summary. We have a wonderful science community here and our society is there to promote and encourage your work and convince the politicians wherever we can that more money needs to go into science to achieve the challenges of the future.

We will put all presentations and comments from this symposium into a proceedings. We have found these to be invaluable and the hard copy in demand. They capture all those messages which would otherwise be forgotten and it will be an excellent reference on lake weed and wallabies for all stakeholders. If you want one, contact Ann. It is a big challenge for her now because she is going to take the information off the tapes and get it to book format, which takes about 3 months, but we feel it is well worth it.

I cannot go away without making a few observations. Yesterday it was clear to us that we need to have lake plans for each lake for invasive species. We have done nutrient plans for the lakes and were able to get the community and politicians engaged and that is why we have been successful as a community as we have had science behind us the whole way. It is clear that is the model that Central Government and Nick Smith all like to see. So if we are going to get anything done we need to put it into a plan actively worked through will all stakeholders including the scientists, socialise the plan, hear what the community’s goals are, make sure we have the science, decide what action is required and who is responsible and obviously the funding. That was a really important point brought home for me yesterday on dealing with our invasive weeds.

There is no question from what we have heard the last two days that we need to focus on funding. There is clearly not enough in the LINZ budget of $2million for all New Zealand for our invasive pests and weeds. So setting ourselves a plan and working altogether to achieve the outcomes that we want though a business case to the councils and central government is our challenge.

Another big message that came though is that our tool box is lacking. Endothall obviously was one which was talked about as a success story with hornwort and had an impressive record. Are we as stakeholders working together to get the appropriate consents for spraying invasive weeds?

Another key point was that exotic weeds can grow in any water quality conditions; they are not a function of good or bad water quality. It was a very solid message that Mary gave us enabling us to separate them in our minds. Two further messages were to keep invasive species out so we do not have to deal with them at all. But when they do come into lakes or waterways move on them fast and deal to them, rather than wait and see.

We learned today that forests are very complex. I enjoyed the Okataina papers and presentations; it has made it a lot more complex subject than what I thought before I came

this morning unfortunately. There are many factors that influence a forest, we understand that. We have not done any studies measuring the effects of browsing animals on water quality. I presume at some stage that will be looked at.

There is no question that sediment comes from bank erosion, landslides and storms yet exclusion plots did show that wallabies and deer do have an effect. Lake Okataina has shown signs of increasing phosphorus in recent years and a pristine lake at risk. There is no question that we should be get more action around and in that lake. Following the precautionary principles it is dangerous to simply do nothing, we need research urgently.

We heard about practical ways to reduce wallaby populations and at moderate cost. But we need to deal with the other pests, possums and rats, as well as they are all part of the cycle. The urgency and concern for wallabies is that they are very close to the main ranges and have a forest path up to the Coromandel.

We can all play our part as front line workers in keeping out alien invaders. The use of apps gives a far greater opportunity to get the community involved and modern technology allows us to take photographs to identify invasive species just by pointing your cell phone and it will come back and tell you there is a problem and we need to act. I do think that many in our community do not have a strong environmental view on the threats to the environment and the use of apps may well be an opportunity.

Perhaps every environmental asset needs a community group to take care of it. The Minister said that environmental reporting is coming around the corner. LWQS has always believed that we should have environmental reporting. By measuring the environmental impacts it would highlight the problems in the environment to the community.

Thank you speakers for giving us those messages, and many others, which will be recorded in the proceedings for posterity. Thank you for your attendance and all the time that you put into your speeches. For the chairs, thank you very much for giving your personal time and effort to conduct the meetings. I thought they all went very well; we stayed by and large within time and it was a very efficient meeting. For my committee, Ian, Don, Warren, Jim, Marcel and Ann, thank you for your support and all the meetings we had in planning. It takes an enormous amount of time in planning these symposia but it is very much appreciated.

Thank you Hilary, Diane, Ann and Brian for your support as ‘go to’ people to make each session run smoothly. Just a note for those speakers who seek reimbursement of expenses or costs, talk to Marcel before you leave and get his address to send your costs to him.

Thank you John Madsen very much for coming to New Zealand and sharing your thoughts. I know you had to get permission from the US Government to come. I hope you have a very good weekend fishing with Rohan on Lake Tarawera, but I can tell you Lake Rotoiti has much bigger fish, but anyway you prove us wrong. On Monday you are going to see the Bay of Plenty Regional Council and then we will take you to see Chris Battershill, Bay of Plenty Regional Council Chair in Coastal Science, based in Tauranga. I am told there is a very heavy weather event coming through so it may be that we will drive you up to Auckland so that the US Government cannot accuse us of trying to kidnap you.

John Green
Chair, LakesWater Quality Society