
BEST PRACTICE TOOLBOX FOR WHOLE OF LAKE WEED STRATEGIES

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

TRANSCRIPT

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

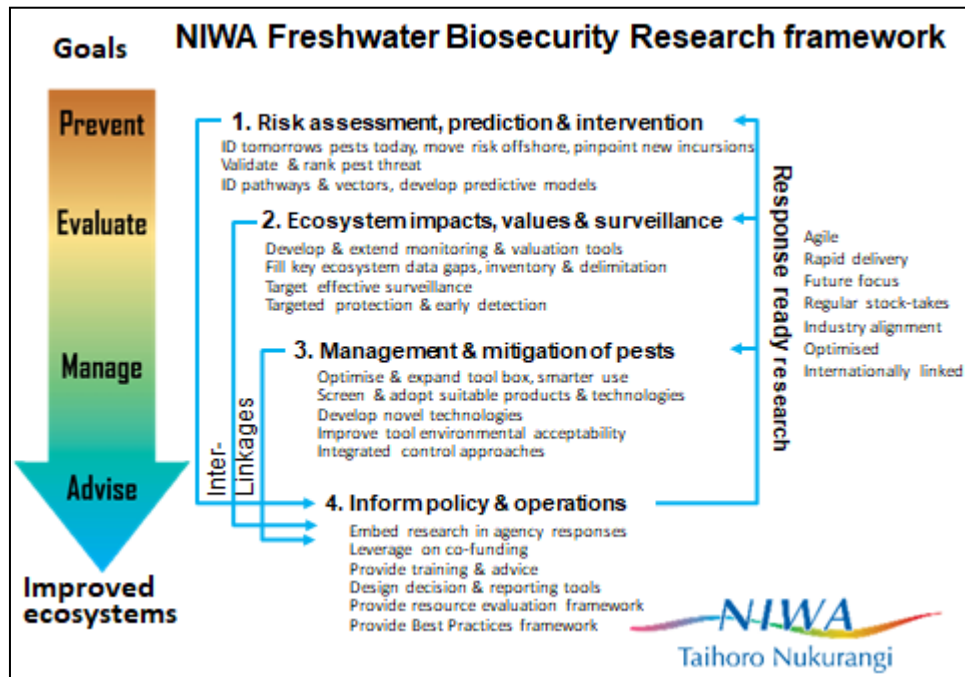
By the end of those two years we will have three tools:

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

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

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

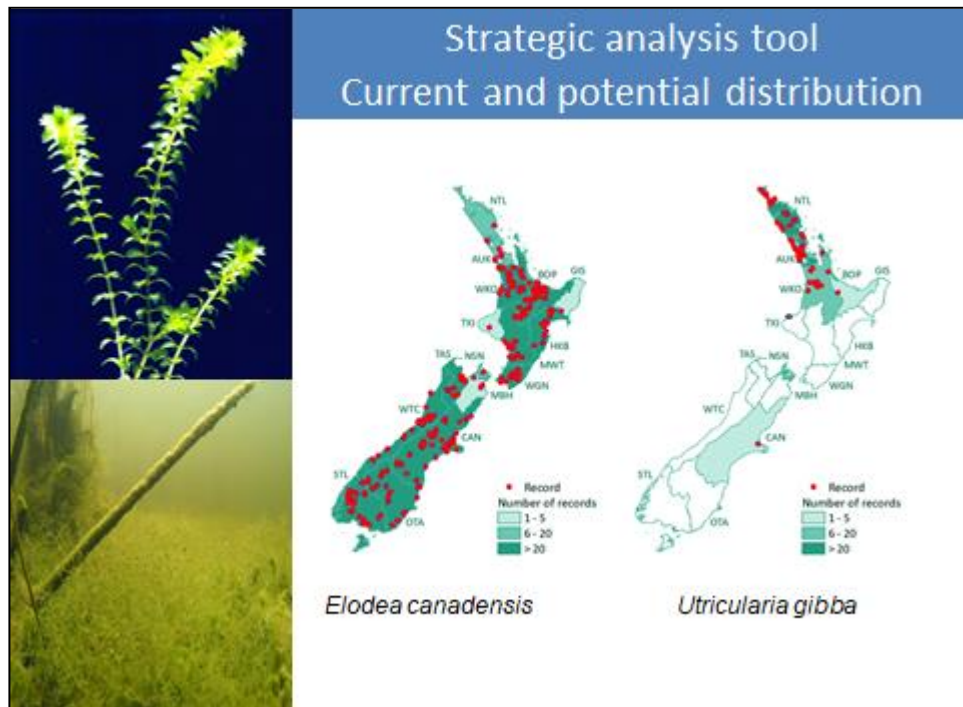
Our research programme covers three areas of research from prevention strategies through to management strategies, risk assessment prediction and intervention. We look



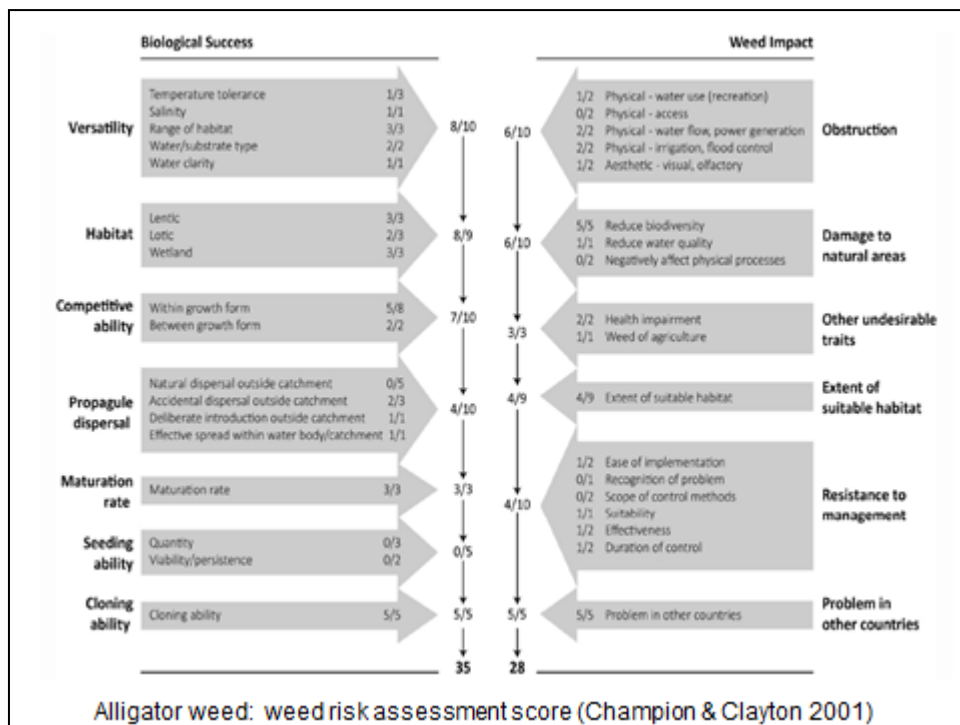
at species either already in the country or yet to be introduced to New Zealand, what risk they pose and the pathways by which they could be introduced and spread. We predict what systems are likely to be impacted, those of highest value, and how to target effective surveillance enabling water body protection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

The Strategic Analysis Tool

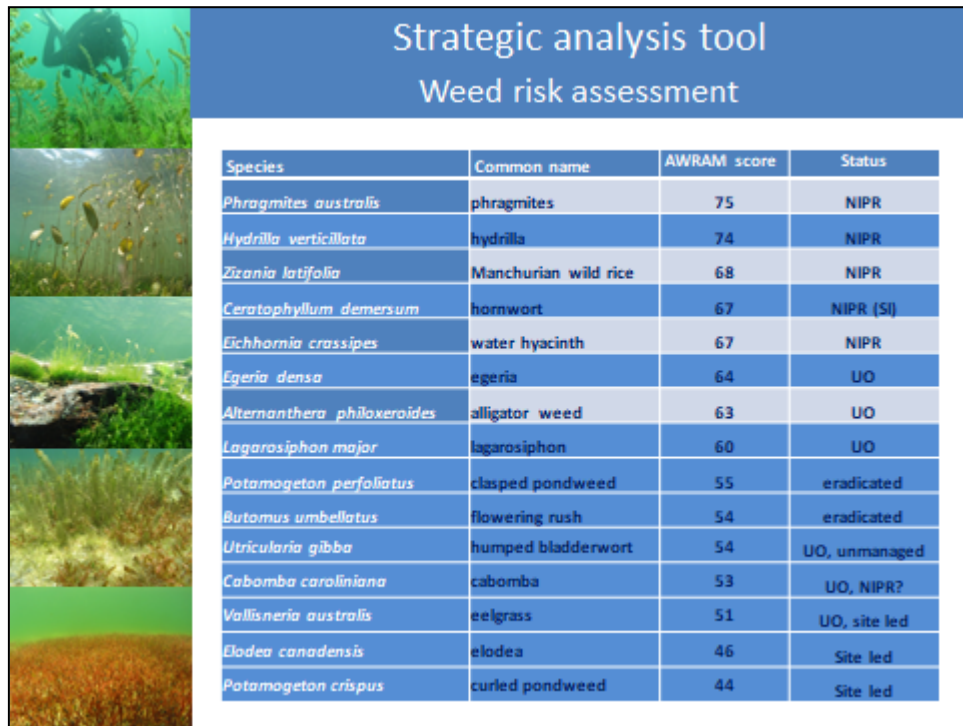
This first best-practice tool is for strategic analysis, providing the rationale for aquatic weed control by evaluating the desired outcomes from management. There are several components - what are the problem species or potential problem species, where they are found now, where they could spread and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



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



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



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

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

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



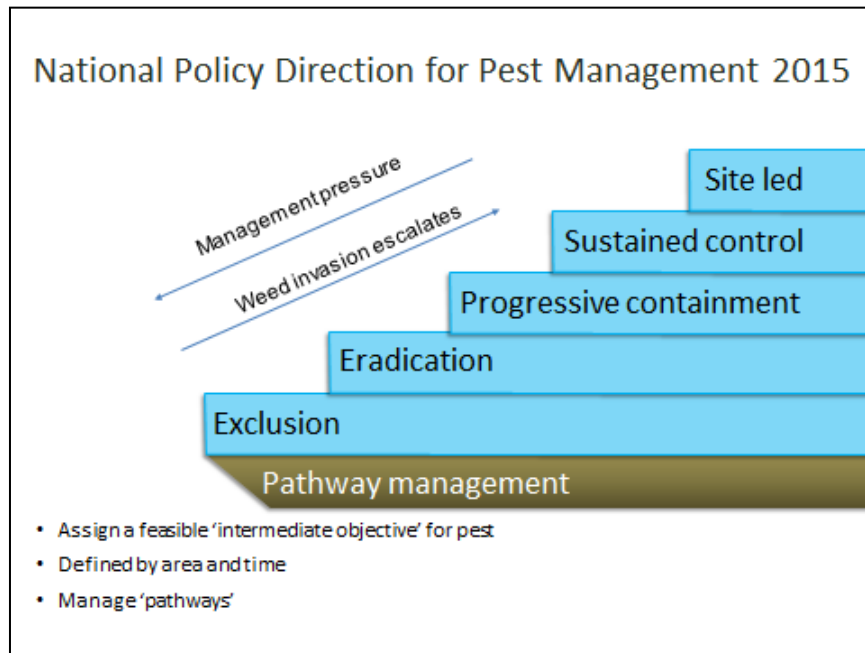
There are up and coming weeds. This is *Cabomba caroliniana* with a Koi carp (*Cyprinus carpio*), a photo from Paremuka in Henderson. This is the first field sign of this weed in New Zealand. In Australia, it is a weed of national significance but it has been in the aquarium trade in New Zealand for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

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



MPI provides some common language in the National Policy for Pest Management 2015. There are four immediate outcomes in a set of conceptual steps on a management pathway which could go up or down depending on the pest's status or the goal of management and their ability to amend strategies. The scale of the strategy application maybe a contained water body, or a site within a water body, or even on a catchment scale. Firstly exclusion - no new pests coming into the region. Next is early detection and these new pests going into an eradication programme. Progressive

containment is similar to eradication, working towards that aim but over a longer time period. Sustained control is about amenity control and site-led management is protecting special areas from the impact of weed species.



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

Strategic analysis tool
Current management of aquatic weeds

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

The Incursion Detection Tool

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

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

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



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



Decontamination - Check, Clean, Dry is a message everyone should be aware of. It came from the Didymo campaign. Last month Tracey Burton did a project funded by MPI to see if those protocols hold for other aquatic pests including lake snow, pond snail and our

three worst weeds. They were all treated in all of the recommendations that are on the MPI website. The only treatment that effectively killed all of these plants was using water that you can actually get out of your immersion heater at home, which has to be 55 degrees and more, and that was absolute control of all of the species tested.

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



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

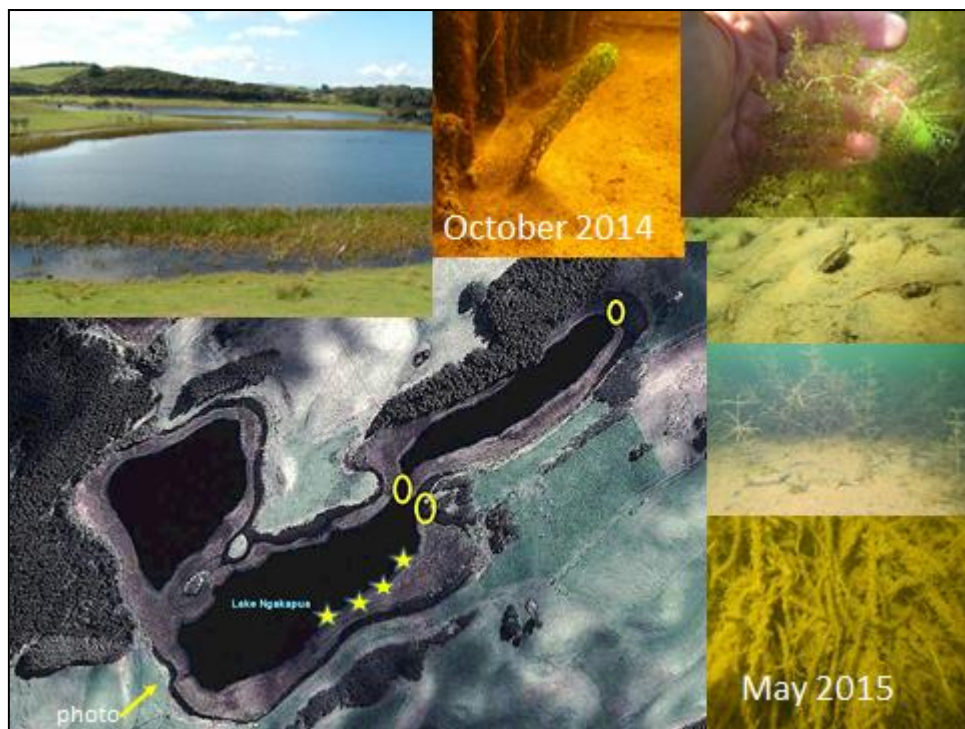


There were 6 trial sites, 12 divers and the detection targets were totara tree branches. This photo shows a totara branch looking very much like another aquatic weed.

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



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



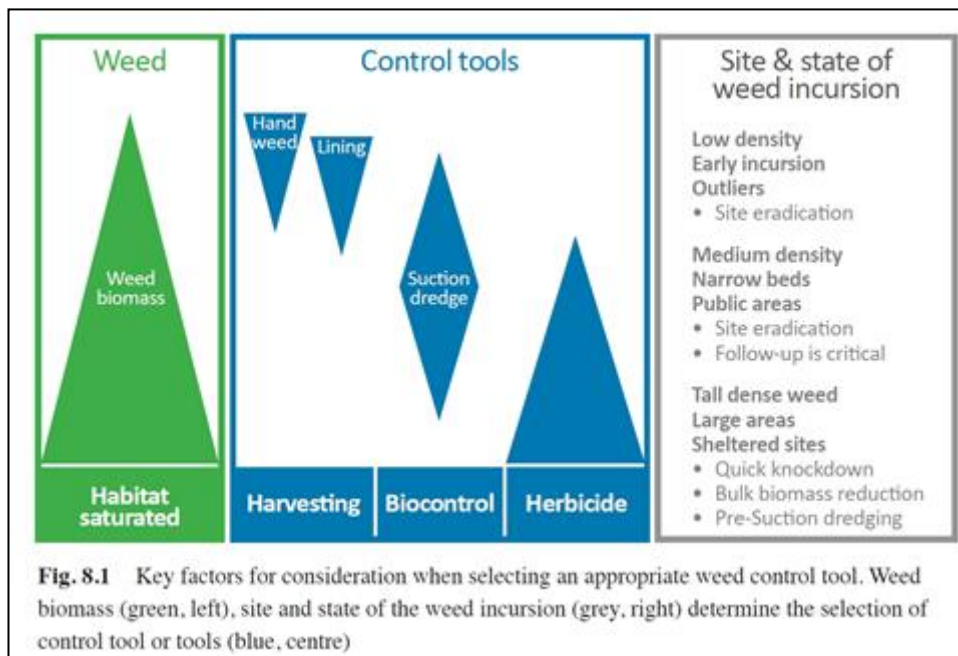
The Aquatic Weed Control Tool

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

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

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

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

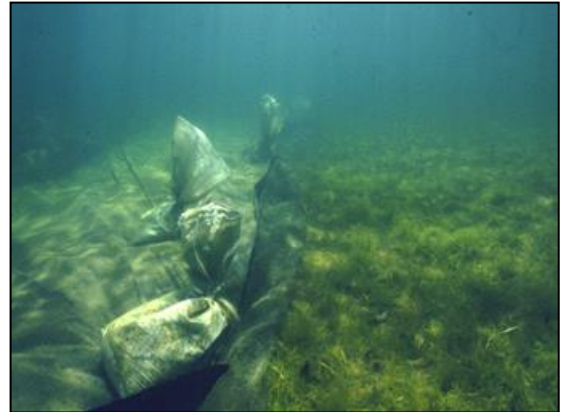


Control tools

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



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



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




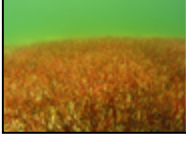
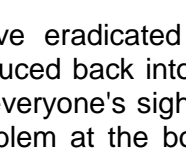
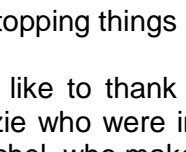
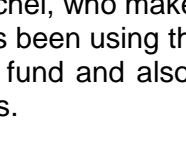
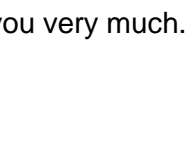
Hessian matting - Boffa Miskell have been trialling the technique that Deborah Hofstra talked about. There is a cost saving by laying big areas of hessian matting compared to suction dredging.



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

Harvester - in one of the Waikato River hydro lakes.



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

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

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

Thank you very much.

CHEMICAL CONTROL OF LAKE WEEDS

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

TRANSCRIPT

Kia ora

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



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



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

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

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



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

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

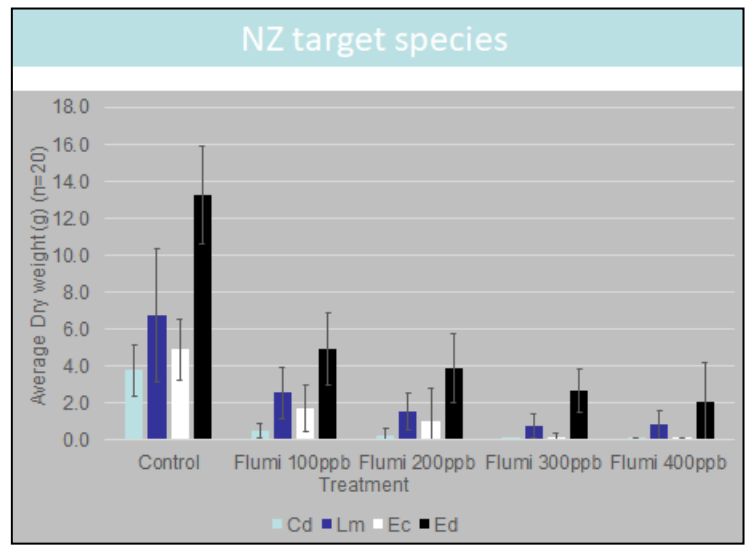
Products approved by EPA for aquatic use in the USA include:

- Contact herbicides*
 - Flumioxazin
 - Carfentrazone
- Systemic – ALS inhibitors*
 - Penoxsulam
 - Imazamox
 - Bispyribac-sodium

Efficacy trials are also underway by SePRO

- Procellacor

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



Diquat

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

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

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

30 L per ha diquat no allowance for depth

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

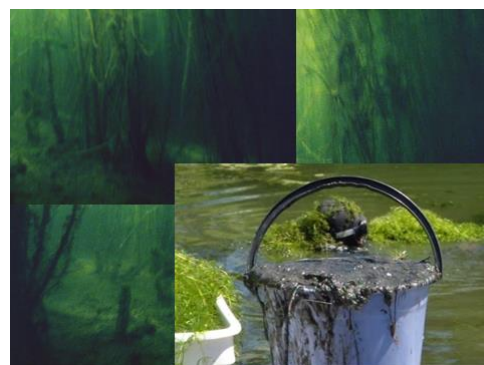
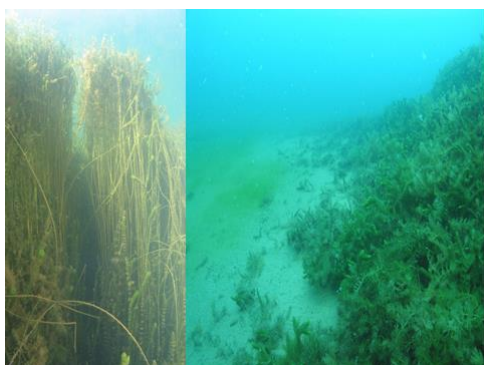
The herbicidal rate for diquat is one part per million and if applied at 30 litres per hectare, that rate treats only 0.3m depth of water. When treating a 3 metre tall weed bed, it is difficult to get a herbicidal dose as the application rate is about one ninth of the dose rate required.



For example, in the Otumutu Lagoon at Lake Tarawera, despite it being treated annually, the weed beds are surface reaching and obstruct boats leaving the boat ramp. Periodically the weed washes up on shore, stinky and decaying.



Just below the surface are 3 metre tall weed beds that displace the native vegetation. Underneath the weed beds is an environment without light, often with little oxygen and the sediments are highly organic, forming a soft sludge due to the continual addition of rotting vegetation from above. You can feel the pre-hornwort, more consolidated, soil horizon below. This sludge is an inhospitable habitat to most benthic fauna.



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

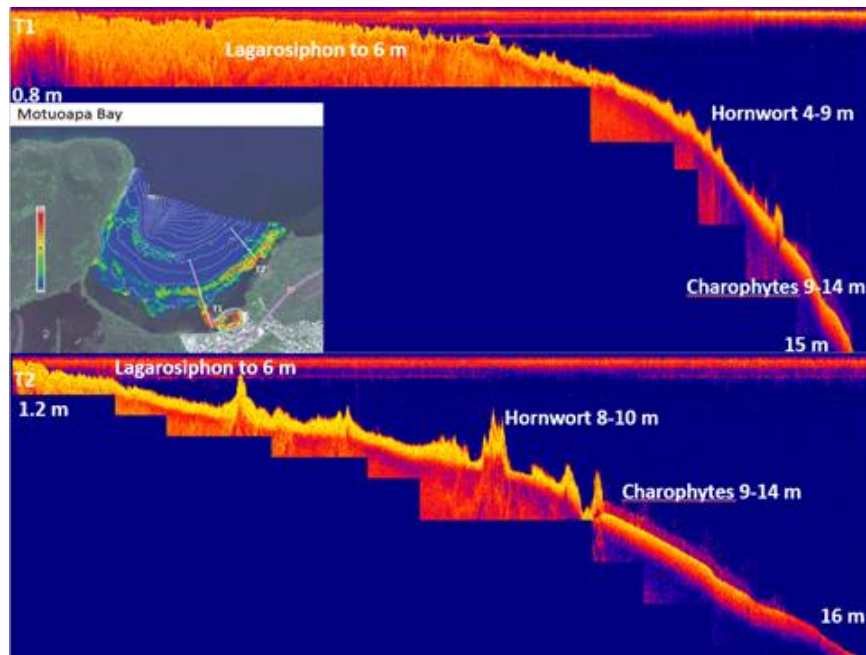


To illustrate that, on the left, we show the result of adding an aqueous formulation to water, it sits on top. We have added dye to highlight that. But if you add it with a gel you increase the density and sinkage rate, thus reducing drift and dispersion and ensuring that it gets down to the weeds.

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



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



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

Endothall

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

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

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

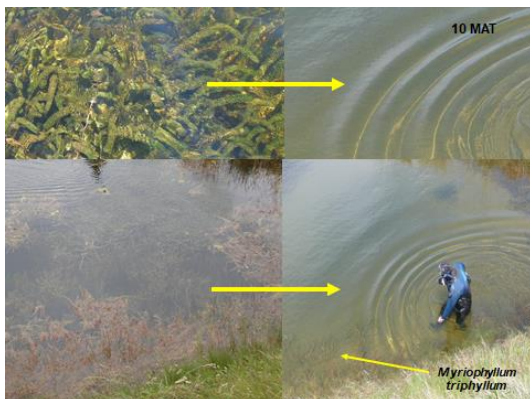
Although relatively new, our endothall label is already out of date. There has been so much more research submitted to USEPA because it is now their number one herbicide. In the United States researchers have a senior scientist

working very closely with USEPA to ensure they are fully informed and they had sufficient funding to get a re-assessment. The areas treated in the United States are very large and there is a very big market for making it economically viable for industry to fund it.

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



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



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

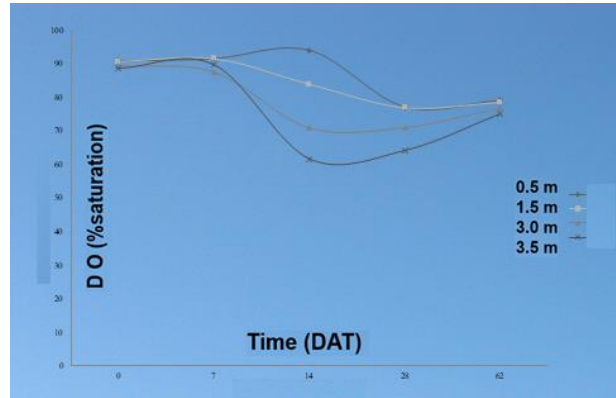
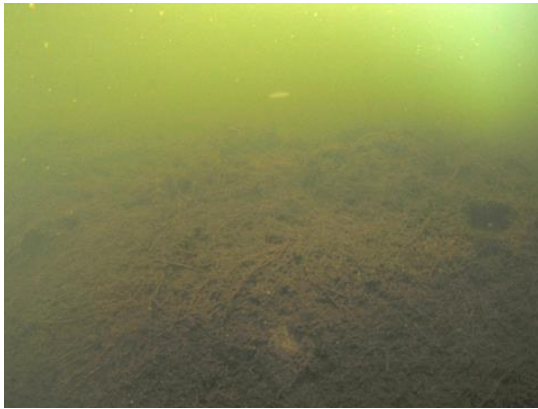
This is another good news story. Lake Ngakapua in Northland is 5-6 hectares and had scattered patches of lagarosiphon along its length. Northland Regional Council treated only 0.25 ha of the lake and in one treatment they eradicated the lagarosiphon. Lake Phoebe, Pouto (1 hectare) also had only one treatment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



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

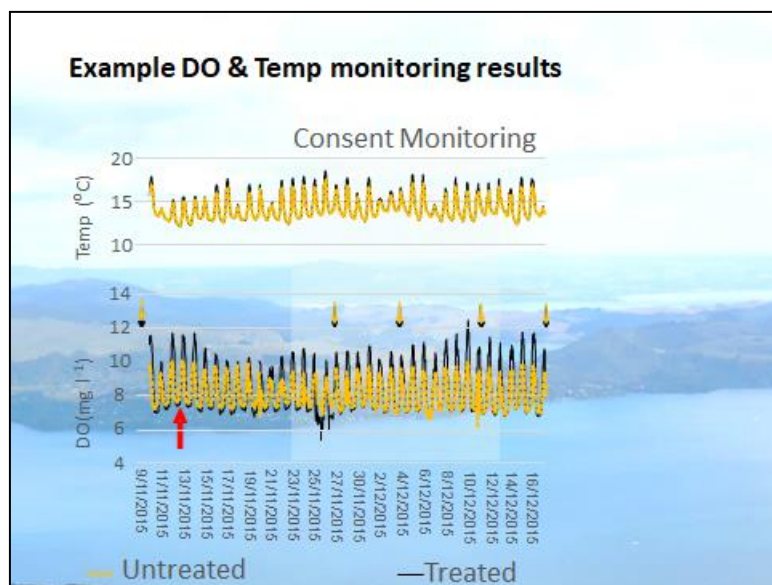
Substance	Oral LD50 (mg/kg)	Use	Real life comparisons
Cyanide	1	Feratox for possum	About 7 tsp could kill a 70 kg adult
Strychnine	2	Omega bait 0.5%	About 5 tsp could kill a 70 kg adult
Nicotine	1-50	Cigarette (1-20 mg)	58 cigarettes or less may kill a 70 kg adult
Parathion	6-50	Insecticide	0.8 L could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

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



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

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



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

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



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

Future Directions

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

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

I just want to acknowledge the following:-

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

QUESTIONS

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

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

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

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

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

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

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

John Gifford, Chair: That was with diquat, which is only giving you a chemical control of the top of the plant and the endothall that Rohan was talking about is an eradication

option. It kills the roots of the plant of lagarosiphon and hornwort so there is a difference. Not all of these things act in the same way.

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

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

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

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

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

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

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

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

a huge amount of money, \$800 million, and they have put a lot of science into research. Surely we are entitled to piggyback off their work and costs as an efficient approach to our approval processes.

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

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

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

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

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

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

Tipene Marr: How big was Benmore?

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

Warren Webber, LWQS: This is not a question. It is more a comment. I am looking forward to the trialling on larger water bodies. We have seen all afternoon that weed exists in the littoral zone of the lake. We do not have to treat the whole lake, in fact nothing deeper than 15 metres. We only have to treat the side of the lake. I am looking

forward to the application of endothall on large water bodies and see the proof of the pudding. I commend you for the work you are doing. Thank you

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

ANNUAL MAYORAL SPEAKER FORUM : SUSTAINABILITY

Facilitated by Warren Webber, LWQS

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

Mayor Steve Chadwick

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

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

It is my pleasure to introduce our speakers tonight:

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

Rod Oram has 40 years' experience as an international business journalist working for various publications in Europe and North America including the Financial Times of London. He is a valuable commentator on the state of the environment in New Zealand, contributing regularly to Nine to Noon on RNZ,

Newsroom.co.nz and the Larry Williams programme on Newstalk ZB. Rod is also a frequent public speaker on business, economics, innovation, creativity and entrepreneurship, in both NZ and global contexts. For more than a decade, Rod has helped fast-growing New Zealand companies through his involvement with the ICEHOUSE, the entrepreneurship centre at the University of Auckland's Business School.

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

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

Sir Rob Fenwick: This is an area that Rod has a lot of expertise. The whole environmental effort rests with local government and leadership of mayors like you, Steve. Currently there is a lot of discussion about the responsibilities of central government but most environmental problems impacting our daily lives are the responsibilities of local government. It is excellent that you and your Council get behind these issues.

The old carrot and stick argument comes to the fore whenever we think about change without regulation. In particular, the question is about the correct use of land with minimal impact on the environment. With no regulation there has to be the threat of regulation in the background and an incentive for change. The most obvious one in the farming community is changing markets. Farmers have only recently had to come to terms with significant emissions and nitrate loading issues, changing their thinking very quickly. There are huge capital issues around changing farming activities.

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

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

Rod Oram: I would like to build on what Rob has just said. There will always be a need for a solid framework of rules and regulations. However, we also need to

remind ourselves that technology, business economics and societal values move faster, at an accelerating rate, than we can keep up with regulations. Regulations lag the real leaders in the field.

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

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

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

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

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

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

Question, Warren Webber, LWQS: In the Rotorua area you will be aware that we have been first off the block in trying to allocate nutrient rights and reduce leaching

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

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

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

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

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

The second part of inspiring young people is to connect schools with communities. That was done really well by the Bay of Plenty Environment Council a few years ago by holding a Youth Environment Forum, bringing younger students together in

workshops about the environment. It is all about connecting schools and environmental leaders to talk about the same things and ensure we all go in the same direction. If we have those two things it will inspire young people to step up and take the mantle as the next generation.

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

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

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

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

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

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

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

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

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

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

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

Your particular question relates to three species that are not in the first suite of targets and I noticed that you did not call them predators. Pigs can very quickly destroy a kiwi nest and are ferocious predators and very destructive. We need to be careful that this whole conservation movement is not an anti-hunting group because that has polarised communities. I was a hunter when younger and it is an important part of community life being able to hunt for pigs and deer. But there are

some parts of New Zealand where they are very damaging and we have to get rid of them, in other places they are tolerable. It is a region by region process. The best wallaby is a dead wallaby anywhere. They are so destructive of the understory. In the context of 1080 we must be careful not to have a campaign against hunting. We need to look at it on a case by case basis.

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

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

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

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

Rod Oram: I would like to put one other really big issue on the table because this steers my thinking on direction for New Zealand's future as a food producer. The global impact of food production on the total ecosystem is severe. It is the second

largest source of greenhouse gases and there are all the problems of land use change and thus degradation of land and water. So global food production is a total mess. We need to get to where food production has zero environmental impact in 30 years' time, and even better would be when ecosystems are restoring.

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

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

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

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

The other national science challenge is biological heritage, specifically looking at biosecurity issues in the country. Again the Vision Maturanga aspect is hugely important and the value that indigenous people place on the flora and fauna that

has been part of their ecosystem for so long is fundamental to understanding where it goes to the future.

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

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

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

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

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

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

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

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

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

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

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

John Green, LWQS: I am very interested in this conversation, particularly Prof Hamilton's question which I do not feel you answered. Going back to the experience we had here in Rotorua in 2000 – 2003 it was the politicians saying there was no way to fix the lakes once they were in algal bloom. They did not worry too much about dairy farming, the environment would be fine. Ultimately Lake Rotoiti sorted us out in 2002/2003 with an algae bloom across the whole lake. Dogs were dying, people swimming were itchy, and the water was green and foamy. We had the local ratepayers AGM at the Ngati Pikiao Rugby League Club and 900 very irate, aggressive Rotoiti people turned up. No longer could the

councils turn their backs on the Rotorua Lakes. I have been involved through the 15 year community journey with programmes of \$235 million to sort out the lakes. Prof Hamilton was very instrumental in ensuring that everything was backed by science and the learning continues all the time. Working together, the Rotorua community has focussed on the real issues that count. Perhaps Lake Ellesmere never had such a proactive community around it?

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

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

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

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

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

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

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

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

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

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

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

Eamon Walsh: That is a huge issue. One of the main reasons is because they are not educated about the political landscape. Schools are now tackling the issue

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

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

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

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

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

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

Mayor Steve Chadwick: It has to come from outside the political domain, but democracy is the tool we use, its imperfect, it is not a popularity contest and it is hard. Fellow community board members and councillors would say we hardly

inspire the right people to engage in politics, either at a local or national level. It is more and more difficult with media scrutiny and one has to be really brave to stick to lofty ideas, which come from outside.

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

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

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

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

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

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

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

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

has gone into the dairy industry, mostly to on-farm not downstream issues. We have continued to underinvest in that downstream activity.

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

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

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

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

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

Session 5 : THE EIGHT LAKES OF TARAWERA

SESSION CHAIR – Don Atkinson, LakesWater Quality Society

PREDATOR FREE NEW ZEALAND BY 2050 – BENEFITS FOR THE LAKES

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

TRANSCRIPT

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

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

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

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

Included in my accountabilities is responsibility to coordinate the Department's response to the Predator Free 2050 initiative. That means for the work streams under our operational delivery arm, our partnerships group, and also under our communications team, I hold accountability to build the DOC component. This initiative is led across New Zealand. It is not an initiative led exclusively by the Department and I am charged with building the DOC component in association with the Predator Free 2050 Ltd company of

which the Government is a shareholder with the Predator Free Trust, the Bio Heritage National Science Challenge led by Andrea Byrom as Director, and then key stakeholders, obviously key among them Iwi and also the NEXT Foundation.

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



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

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

Predator Free 2025 goals: measuring progress

- 1 Extra 1 million hectares of land controlled through PF2050 projects
- 2 Scientific breakthrough capable of eradicating one of these predators: possums, rats, stoats
- 3 Areas of more than 20,000 hectares protected without fences
- 4 Remove introduced predators from all offshore island nature reserves

The graphic includes a photograph of a stoat in a grassy field, with one stoat in the foreground holding a small bird in its mouth and another stoat visible in the background.

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


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

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

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

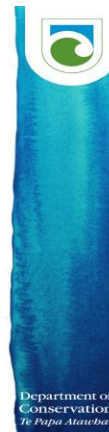
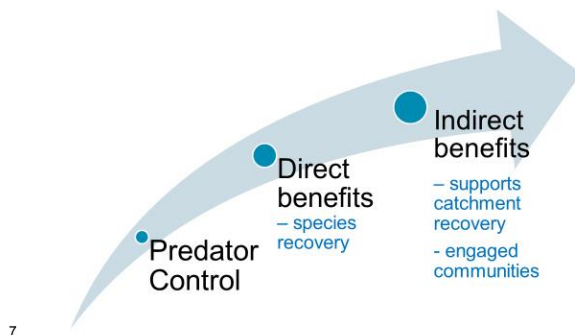
Predator Free Rangers

- Point of contact between DOC and community
- Advice on how to do predator control
- Access to DOC knowledge and rangers
- Support communities to be successful in becoming predator free



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

Predator free – what about the lakes?



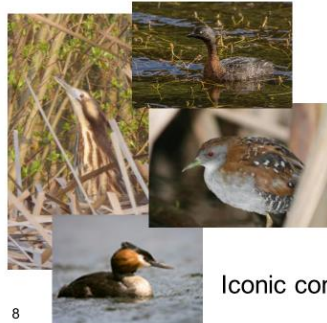
Striving for the predator free goal means not only more predator control, or perhaps the development of new tools to deal with predators, but it also means a better alignment of existing efforts and a chance to leverage off each other's work to maximise the collective impact of the predator control work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

benefits for our lakes and waterways.

The most obvious primary benefit is the recovery of bird life. We all know that predators are a major threat to native bird species, in forests and those that utilise lake ecosystems.

Australasian Bittern, Scoop, NZ Dab chick and Australasian Crested Grebes are species that are iconic components of our lake biodiversity and highly vulnerable to predation. They often nest on the edges of lakes and on adjoining wetlands and are susceptible to all the usual predators including, obviously, rats.

Recovery of birdlife



- Australasian Bittern
- Crakes
- NZ Dabchick
- Australasian Crested Grebe
- *and many other species*

Iconic components of lake biodiversity

8



Recovery of other fauna



- Kākahi/mussels
- Kōura/crayfish
- Freshwater fish

9



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

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

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

Indirect Benefits

- Engaged communities
- PF suburbs



11



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

Fresh water is a big driver in DOC's collaborative landscape approach and the way we look at whole of



10

Catchment recovery

- Indirect benefits – native vegetation recovery
- Combined with strategic approach to control other species

A principle that we have identified internally to inform our predator free landscape scale investment is alignment with other programmes of work. We have used the MFE vulnerable catchment work as a guide to inform that.

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

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

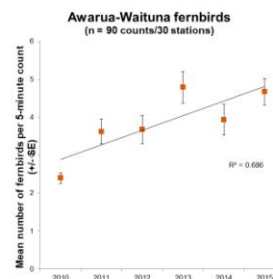
The opportunity exists to lever off this new and active community to bring them into projects supporting catchment recovery. What has occurred to us at DOC over the past few months is that rather than being a conservation initiative with community benefits, Predator Free is a community initiative which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

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



12

Can we make a difference?



Freshwater Stretch Goal



- Increased freshwater restoration– from the mountains to the sea
- Vulnerable catchments - in partnership with iwi, councils and others
- Supporting local & national initiatives
- (e.g. Freshwater Improvement Fund projects)

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

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



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

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

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

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

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

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

Kia ora - thank you very much.

LAKE TARAWERA – LAKE TARAWERA RESTORATION PLAN

Chris Ingle

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

TRANSCRIPT

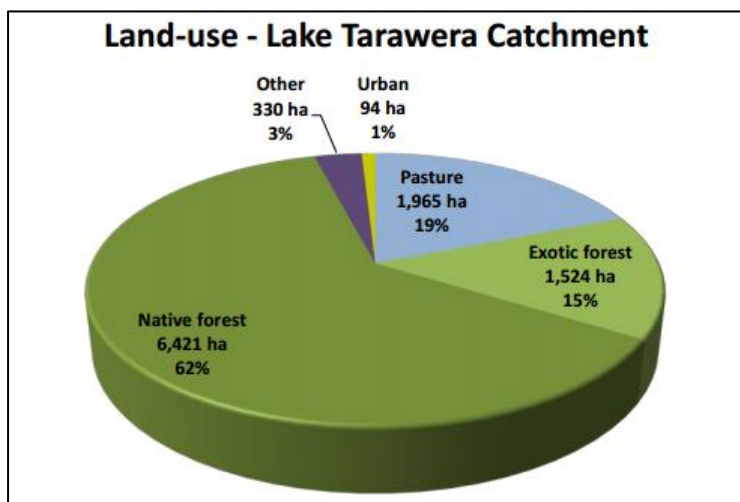
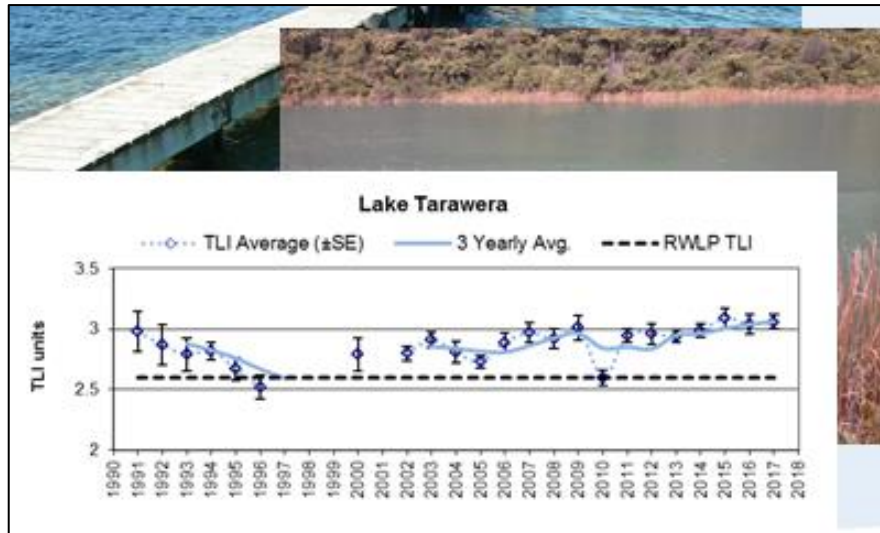
I would like to start by acknowledging the elected members from the Regional Council and the District Council who are here. The work we do together is quite complex and we still have a long way to go to improve lake water quality. I would also particularly like to acknowledge the Lakes Water Quality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

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

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

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

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



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

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

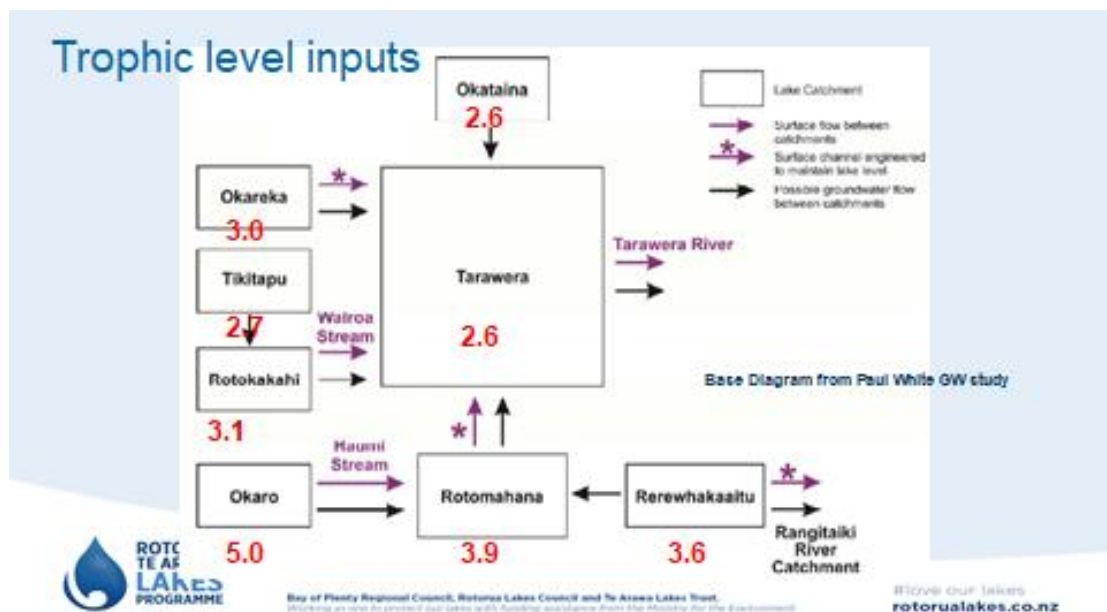
Andy Bruere and I have another problem which has been dominating our time in recent weeks and that is elevated lake levels. After the wet winter, Lake Okareka in particular is at unprecedented high levels and properties around it are at risk of flooding.

We are trying very hard to manage that lake level. There is no natural surface water flow from Okareka to Lake Tarawera. We installed a pipeline and started pumping the water down but it is only going down a couple of millimetres a day. With rainfall events like we had last night it is filling it up faster than we can pump out.

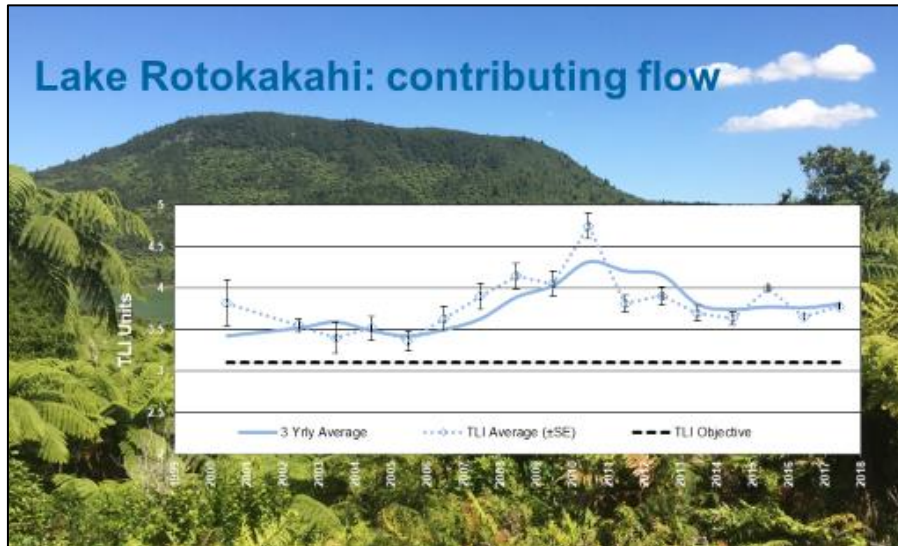
Load	Q (Woods) $m^3 s^{-1}$	Q (adj) $m^3 s^{-1}$	N load ty^{-1}	P load ty^{-1}
Tarawera catchment			66.87	4.47
Geothermal		0.4	6.30	5.00
Buried village septic		n/a	0.18	0.02
Okareka	0.49	0.49	3.40	0.11
Rotokakahi	0.5	0.5	3.50	0.19
Tikitapu	0.08	0.04	0.25	0.01
Rotomahana	2.62	1.31	9.10	1.27
Okataina	2.58	1.29	5.25	0.32
Total		4.03	94.85	11.37

This table, which a subsequent presenter will comment on in more detail, but it highlights the phosphate load into the lake. Geothermal inputs are something we cannot do anything to manage. Natural geothermal flows are estimated to bring in almost half the phosphorus and whatever we do, that quantum is always going to come into that lake. We need to be aware of that.

This is a slide from Paul White and his ground water study. The purple is surface flow and the black is possible ground water flows. I do not want to go into detail, I will let Paul do that, but the red figures show the TLI targets for each lake. We need to understand how the water quality target for Lake Tarawera will be achieved in the context of the land use within the contributing lakes and their catchment land uses. The first step is the development of a conceptual model bringing together all known catchment information.



At Lake Tarawera we are aiming towards TLI 2.6 and it is currently over 3. There is a mixture of other TLIs there; for example 2.6 for Okataina. You will notice that the lakes at the bottom are generally a little higher in their TLIs because of the nature of the lakes, whereas Okataina, Okareka, and Tikitapu are around the same as Lake Tarawera. It will be interesting to see in the next phase of study and research how those interactions impact Lake Tarawera as the bottom catchment lake, and whether Tarawera can actually achieve a reduction in TLI, when some of the contributory lakes have higher target TLIs. The progress we make on the outer lakes will affect the speed at which we can achieve improvements for Lake Tarawera. There are still many unknowns.



Lake Rotokakahi produces one of the contributing flows. I have picked on a couple of lakes because we have interesting information. This is the TLI graph and again the dotted line at the bottom is the target and the blue line is tracking the actual TLI – clearly we are not there yet and there are a number of fluctuations. We suspect that in the centre of that graph forest harvesting may have contributed to higher TLI levels at the time. There is work to do at Rotokakahi. We have started on an Action Plan but it is not yet complete.



Lake Okaro on the other hand, a farming catchment, has met its TLI target for 4 years, a good news story. Although looking at this year’s data I have some concern because it has risen a bit showing that we are not in a consistent downward trend. The light blue line is the 3 year rolling average, to remove the confusion of different seasons and climatic variability. I suspect the very wet winter this year will affect nutrient levels in the lakes, by using the 3 year rolling average we see the longer term trends rather than the noise.

In Lake Okaro a contributing factor to achieving the TLI has been alum dosing. Positive land use change has been going on at the same time, and it is not clear which has had the greatest impact on the TLI. It has not been practical to have a control trial in place to

test the steady state against an intervention. We have instead tried to put all actions in place as quickly as possible to improve the lake. Until we stop using alum we do not know whether the land use change, will result in long-term improvements in water quality.

Key outcomes from research:

Completed groundwater study → flow paths

Nutrient budgets complete → reduction targets

...To confirm with lake model

N limited lake → need to reduce P

High geothermal inputs of P



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These are key outcomes from the groundwater research that has been completed, which Paul White will expand upon. Lake models, nutrient budgets and targets will be required to determine the relative need to reduce phosphate and/or nitrogen. These discussions were played out in the Plan Change 10 hearings held recently for Lake Rotorua. Lake Tarawera has high geothermal inputs of phosphate that will be difficult to mitigate.

Tarawera Restoration Plan

1200 kg P reduction No increase in N



Key Actions:

- Sewage Reticulation ✓
- Environmental Farm plans ✓
- Land use rule (process commenced) ✓
- Build GW model ✓
- Cultural health assessment ✓
- Investigate geothermal inputs ✓
- Update community ✓

Te Arawa Lakes Trust



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So, to the nub of my presentation, a summary of the actions on the Tarawera Restoration Plan. We have a bull's eye target, but we are not quite there yet. The key actions include sewerage reticulation, which has been boosted by a recent \$6.5 million funding announcement from the Environment Minister. Rotorua Lakes Council is leading that work.

Chris Sutton is helping us with the environmental farm plans project and he is speaking later. They are well under way now in the wider catchment. Work started at Rerewhakaaitu in the early days has now spread out to the whole of the Tarawera catchment. Farmers will be working on that over the next few months; we have given it a tick because it has commenced, but I note that as with most of these targets, it is not yet completed.

The land use rule is an important action that the Regional Council will lead. The Regional Council recently agreed to bring this project forward as the next NPS Freshwater project off the ranks, so that's about to get under way. The actual plan change has not been drafted yet and consultation on that will happen soon.

The Ground Water model I have mentioned several times and that is complete.

The Cultural Health Assessment is also a very important part and Te Arawa will take the lead on that. There is a strategic partnership in place between the Te Arawa Lakes Trust, the Rotorua Lakes Council, Ministry for the Environment and the Regional Council which I assist with and that partnership approach works well.

An important part of the action plan is to investigate the phosphate coming into Lake Tarawera and what can be done to address that. The community will be kept updated as


Next steps

- Lake Model to confirm targets (1D)
- Consider need for 3 D model to understand spatial variation in WQ
- Coordinate development of Tarawera catchment conceptual model

Based on what we know

Identify knowledge gaps

Potential to link the catchments?

 ROTORUA
TE ARAWA
LAKES
PROGRAMME

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part of this process, connecting people and bringing innovation in through forums like this one today.

So what are the next steps? We are working on a lake model to confirm our targets. A 3D model is needed to embrace scientific innovation coming in from the Water Quality TAG and elsewhere. We need this to better understand spatial variation in water quality.

We are also considering the development of a conceptual model for the lakes that feed into Lake Tarawera. We need to understand how it all works at a fairly basic level, identify those links between lake catchments and identify any glaring knowledge gaps.

Thank you.

GROUNDWATER STUDY – THE EIGHT LAKES CATCHMENT

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Paul is a Senior Scientist in groundwater resources at GNS Science and has worked for 37 years in New Zealand groundwater hydrology with current research including: 3D models of geology, groundwater flow and groundwater use, that are developed to inform regional council water allocation policy decisions; land use, groundwater quality and lake water quality; and the economic drivers of groundwater use.

TRANSCRIPT

Thank you very much. This talk is on behalf of my colleagues in GNS Science - Mike Toewes, Conny Tschritter and others, and my colleagues in Bay of Plenty Regional Council - Janine Barber and previously Dougal Gordon.

I would like to quickly romp over some of the science we have done since 2002 in the Greater Tarawera catchment, focusing on results. I hope to give people a flavour of what we think is going on in each of the 8 lakes in the catchment:-

- The greater Tarawera catchment
- Purpose of Tarawera project
- Overview of scientific results
 - drilling and some early results
 - geological model
 - catchment hydrology of the 8 lakes
 - groundwater flow
 - nitrogen generation and discharge to lakes and streams
- How results are being used

The following slide is the greater Tarawera catchment which includes 8 lakes. Tarawera topographically is at the bottom and rainfall will gradually make its way down to Tarawera from its surrounding area.

What areas are we talking about in the greater Tarawera catchment? Rerewhakaaitu and Earthquake Flat have been the subject of debate within our team and the Regional Council as to where water goes on the margins. Earthquake Flat is included in the Waikato Region and we have included it also because there is evidence that water does flow from this area towards the Tarawera catchment and to the Ōkaro catchment.

We have a situation similar to the Rotorua catchment where part of the Lake Rotorua catchment is in the Waikato region. The Bay of Plenty Regional Council and Waikato Regional Council seem to be working well together in having consistent planning rules around the Waikato part of the Rotorua catchment and possibly the same will happen here.

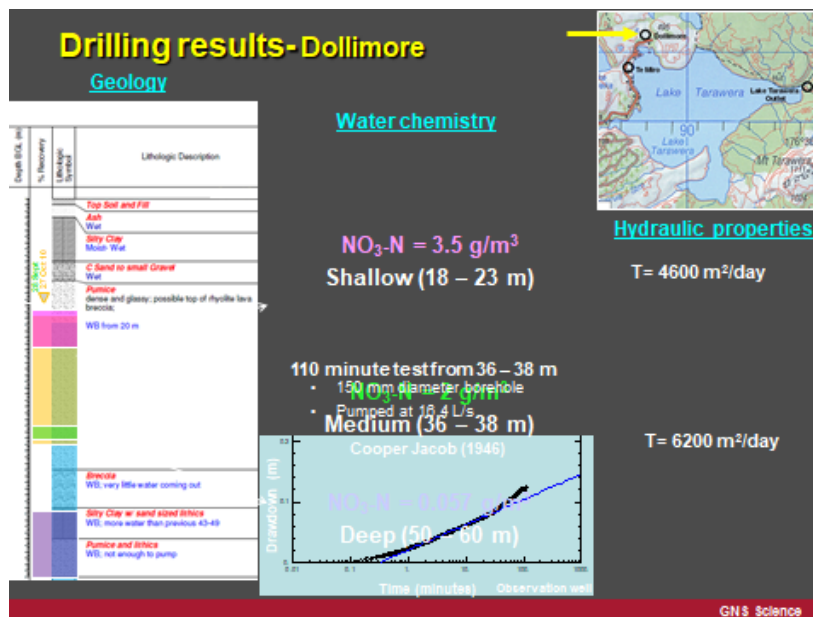
The greater Tarawera catchment

- Eight lakes and their catchments
- Groundwater is a significant unknown
- Purposes of project:
 - 1) Characterise the groundwater and surface water of the lakes and their catchments
 - 2) Develop models and data sets re water flows, land use and other science projects



GN S Science

In 2011 we started the Tarawera Project, a drilling programme, as very little was known about the groundwater system of the area. It is important to understand the groundwater systems to these lakes and I will give a lake by lake potted summary in a few minutes.



The purpose of drilling is to understand the geology, what sort of rocks are down there and the properties in relation to water flow. We drilled three wells, the first being on the Dollimore property in 2011/2012. On the left of the slide is a geological log which is produced by a drilling and shows the most common sediment type which is pumice sand.

We do pump tests, pumping the well, the water level goes down in the well and we can analyse for the hydraulic properties of the rocks in terms of water flow. We came up with numbers, called transmissivity. These numbers are about ten times the numbers in the Rotorua catchment. The implication is that groundwater flows faster in the Tarawera catchment than it does in the Rotorua catchment.

Groundwater chemistry. We sampled for all the nutrients and various other bits and bobs from shallow, medium and deep depths. The results in nitrate nitrogen were:-

- 3.5 g/m³ in the shallow zones, 18 to 23 metres
- 2 g/m³ in the moderate depths, 36 to 38 metres
- Less than 0.1 g/m³ in the deep

It is very common in groundwater systems to see a decrease of nitrate concentrations in groundwater. Is this number of concern? Yes, it clearly indicates the impact of human activities. That could either be septic tanks or farmland behind the Dollimore well.

Streams flowing into Lake Elsmere typically have a median nitrate concentration of about 3 ppm so this would definitely cause impacts on the nitrogen loading to the lake. In comparison, from a study we did around Lake Rerewhakaaitu in 2002, nitrate concentrations in groundwater around Lake Rerewhakaaitu are up to about 8 ppm and that reflects the intensive use around this lake.

From the geology we found that pumice and ash are the most common lithology, aquifers are mostly unconfined, and confining layers are uncommon. This showed that there is little impediment to groundwater flow and that nitrogen from land use can generally reach lakes. In some of New Zealand's groundwater systems there are denitrifying layers but it seems that these do not occur in the Tarawera catchment and that is because the eruptive products are quite recent.

The hydraulic properties show that the permeability values (K values) range from 14 to 3100 m/day which is typical for volcanic sand and gravels, and they are greater than in the Rotorua catchment. The implications are that nitrogen will respond to land use change and that response may be faster than Lake Rotorua as I mentioned before.

Water chemistry and nitrate nitrogen concentrations in shallow groundwater are higher than deeper groundwater. Sewerage removal should reduce the nitrogen load into the lake. The control of agricultural land uses is important to the regulation of nitrogen loading to the lake.

Lake Tarawera: implications of drilling results (3)

Water chemistry

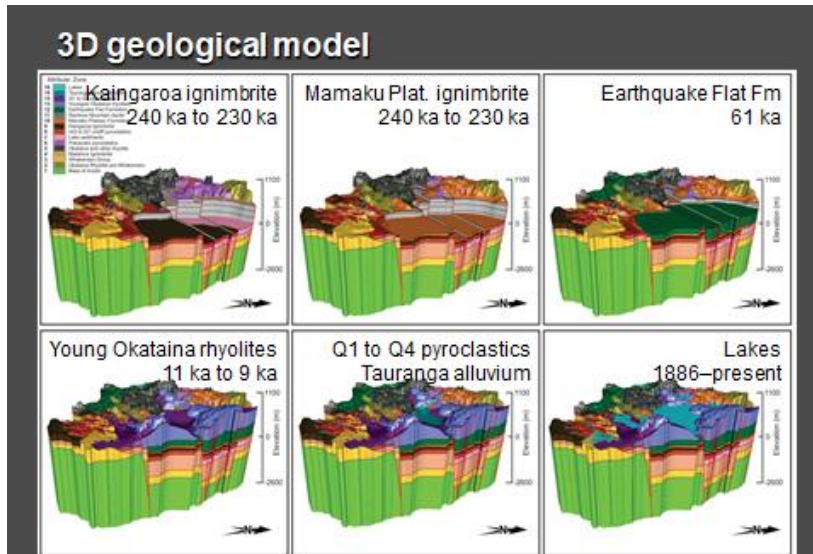
- NO₃-N concentrations in shallow groundwater are higher than deeper groundwater (except for lake outlet) indicating effects of land use
- HIGH NO₃-N at Dollimore site indicate effects from agricultural land use
- LOW NO₃-N at the lake outlet site are reflective of native bush surroundings

↓

- Sewage removal should reduce N loading to the lake
- Control of agricultural land use is important to regulation of N loading to the lake

Groundwater can be dated using isotopic methods. We measured the groundwater age to be about 10 to 40 years. For Rotorua the age is about 40 to 180 years. That is consistent

with the idea that groundwater is flowing faster in Tarawera than in Rotorua and means that it will respond faster to an increase in nitrate loading from the land and that reductions in taking out nitrate from the catchment will improve lake water quality over shorter timescales.



This 3D geological model represents the layers in the ground from the Kaingaroa plateau deposited from the Reporoa area 240,000 years ago to now. All these layers have different properties. Our drilling programme tries to understand the relevant properties of the key layers in relation to groundwater flow.



Above is a potted summary of some of the lakes, starting off at Lake Rerewhakaaitu. Work we did in 2002 with Dougal Gordon indicated that this lake was perched which answered an issue in terms of the management of that lake. I estimate that this catchment is probably the most intensively farmed in New Zealand. There is a lot of pasture, mostly dairy, and yet the lake is not as poor quality as you would expect if all the nutrients leaked into the lake. It looks like groundwater in the catchment is generally below lake level, which means the lake is perched. So the nitrate from land use seeps down into the ground travels in the directions of the Rangitaiki and Rotohama catchments, and mostly not into Lake Rerewhakaaitu.

I have spent a lot of time trying to figure out where it does go but it looks like nitrate flow in the groundwater is split between going towards Rangitaiki one way and towards Rotomahana the other way. It is a bit tricky to figure out where the boundary is.



Above is Ōkaro and Rotomahana. The purple streams are permanently flowing and there is one flowing into Ōkaro and the Haumi Stream flows down to Rotomahana. The red colours are geothermal and there is geothermal activity around the lake. The black lines are engineered channels with one going out of Rotomahana. There is another permanent stream on the eastern side which is probably recharged with flow from the Rerewhakaaitu catchment. Ōkaro itself possibly gets groundwater from the Earthquake Flat area.



Above is Rotokakahi and Blue Lake. Neither of these lakes have inflowing streams. Therefore rainfall on the catchment all travels into the groundwater system. Generally, 50% of rainfall goes into groundwater. Rainfall in this area may be 1.5 metres, or something like that, per year, that means 700 mm a year goes into the groundwater system. That is a lot of water, aggregated for catchments.

This is Ōkareka which has no permanently inflowing streams and the lake outlet is an engineered structure.

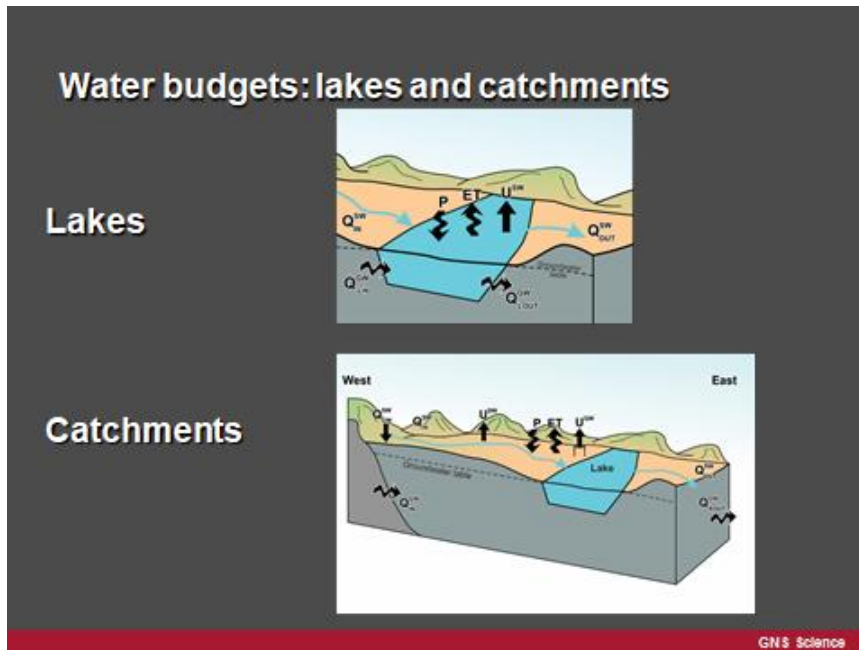


Ōkataina has a couple of little streams in the west and some sign of geothermal activity in the east.



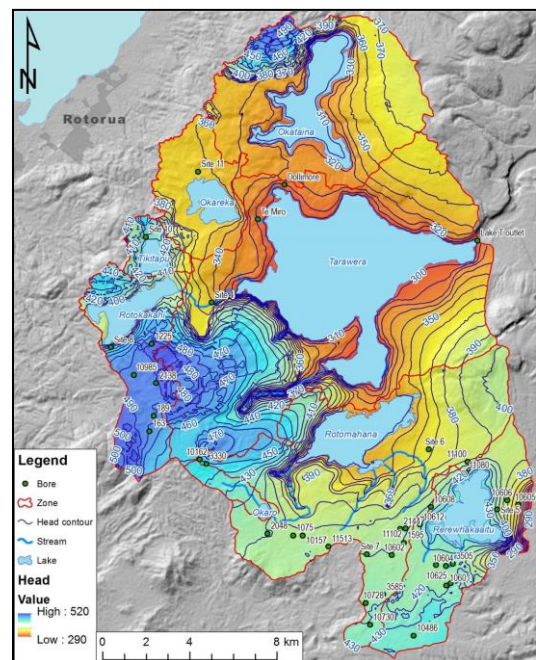
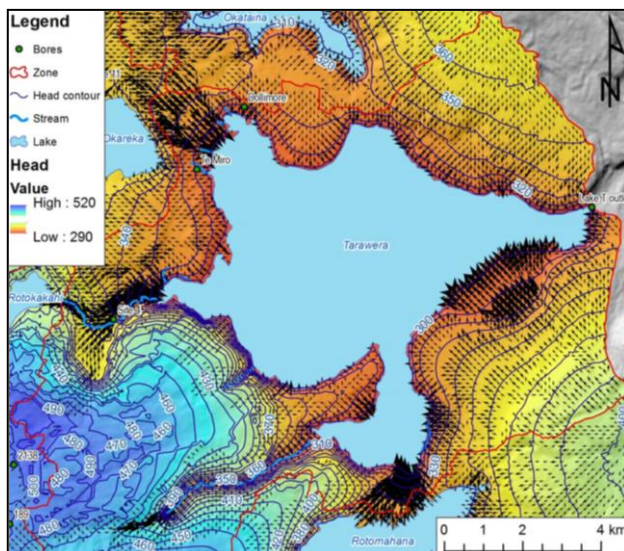
Tarawera is the most complex catchment. There are lots of springs around the lake shore, but not everywhere. For example, few springs are observed between the outlet and opposite Moura Point.

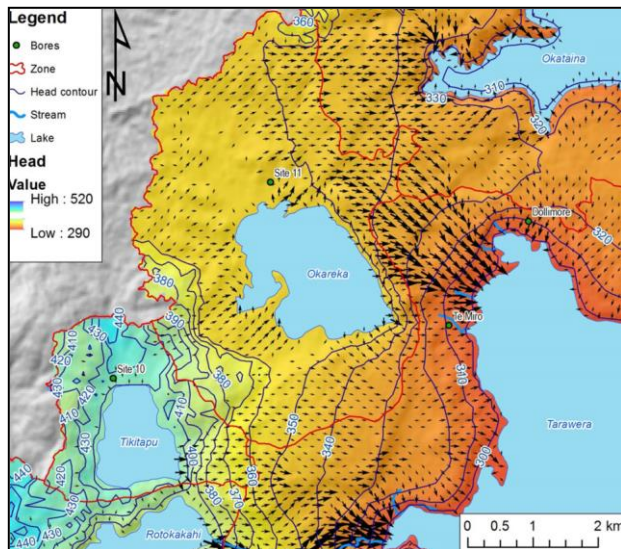




We did water budgets of the lakes to understand the inflows and outflows of each individual lake and the catchments. It is a bit tricky to figure out. One of the first things we did was to estimate properties of groundwater flows for setting up a groundwater flow model.

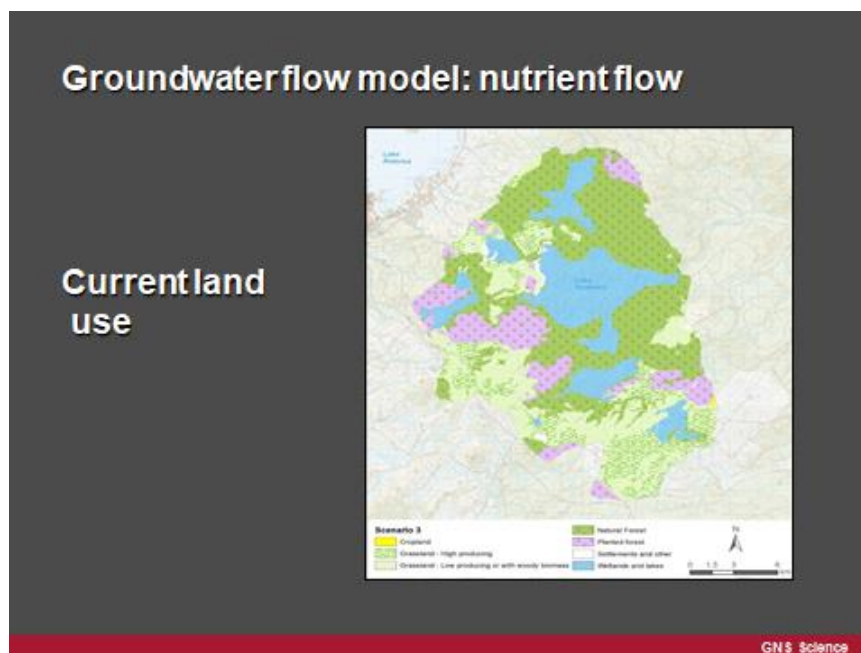
The next three slides are groundwater flow models. These contours are elevations of the water table. Like any contour map the groundwater table can be represented as an elevation map and we can figure out where the water is going. We can also understand how groundwater interacts with surface water, e.g. the spring-fed stream that crosses Spencer Road takes groundwater from the area between Tarawera and Okareka.





The Dollimore well is on the right slightly above centre of the slide

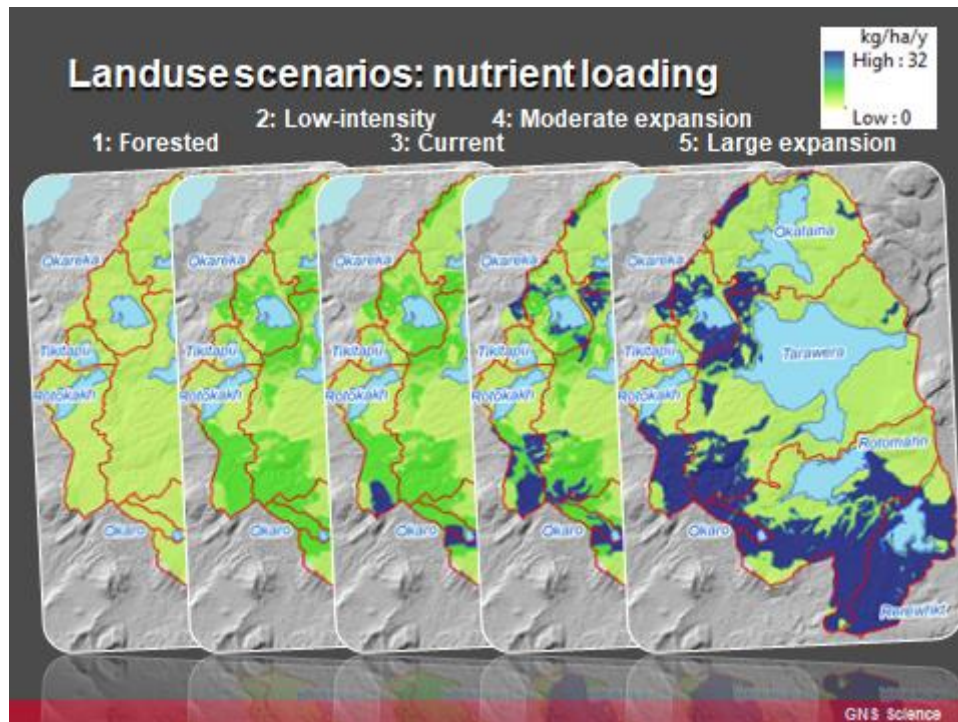
The computer can work out flow directions. You cannot quite see these details but these are all little arrows. The little arrows are then interpreted to figure out where groundwater is flowing to. The Dollimore well had quite high nitrates in the shallow part of the well. My interpretation of the cause of those would be land use in the area of the craters between Tarawera and Okareka. The arrows are swinging around and then coming down to the lake, so water would be recharged from back up this area. These maps are really important because they make the link between land parcels (and land use in the parcels) and receiving water bodies. We want to know, for instance, if groundwater is flowing directly to the lake or it is flowing to a spring fed stream and then to the lake.



With Alastair McCormack of the Bay of Plenty Regional Council (above) we looked at land use and nutrient flows, particularly nitrogen. The map from Landcare Land Resource Inventory (LRI) data set indicates native forest, exotic forest and pasture in different colours. We looked at what nitrogen could be generated from these land parcels and what the springs and lakes would receive. We looked at current land use, pre-development, pre-human, and a scenario of the likely future intensification. That is not

dairy cows everywhere as it is infeasible to think of dairy cows on top of Tarawera. But what if the existing pasture areas were intensified a bit more?

The next slide is actually 5 different scenarios showing the nutrient loading maps translating land use into nutrient loading. Different land uses have different loadings, forest has less than sheep and beef, and others have less than dairy which has less than market gardens for instance. They show a whole lot of zones that we defined around the lake catchments and the green colour goes into blue as the land use becomes more intensified. From forested land use on the left to the current one on the right showing a large expansion in the intensification of farming in the whole catchment.



Following on from that in the slide underneath we looked at nitrogen loading from streams and lakes to understand whether streams are spring fed. In other words are they impacted by land use, particularly nitrogen, or are they not? For the Wairua Stream flowing into Lake Tarawera (Scenario 1, pre-development) we think about 3 tonnes a year was going into there. For Wairua Stream, (Scenario 3, current land use) it has about 5 tonnes of nitrogen per year flowing into the stream with groundwater. Scenario 5 (the most intensified land use) has this discharge increasing to 10 tonnes of nitrogen per year. Therefore, we would have to predict there would be significant water quality effects with such an increase.

Nutrient loadings calculated for many streams and all lakes, e.g.,

Surface water body	Nitrogen loading (tonnes N/year)				
	Land-use scenario				
	1	2	3	4	5
Wairua Stream	3	5	5	5	10
Lake Tarawera	73	105	125	151	211
Lake Okareka	1	2	2	3	4

GNS Science

The Lake Tarawera Scenario 1 (i.e. all forested) about 70 tonnes a year is going into the lake. Nitrogen discharge with Scenario 3 (i.e. current land use) is about 125 tonnes a year, but at its most intensified land use Scenario 5 is about 211 tonnes a year.

In comparison, Lake Rerewhakaaitu shows a very small increase in nitrogen loading from groundwater between Scenario 3 and Scenario 5. This is because the lake is mostly perched.

Chris McBride takes numbers like these and the flows that we calculate and estimates water quality impacts of land use intensification with his lake water quality models.

There are a few more uses as well. We have been looking at the potential effects of land use intensification on spring fed streams. There is a paper on Lake Rerewhakaaitu in the final stages of completion with a student of David Hamilton's and myself. Other lake models are progressing; Chris McBride is going to talk about these models next.

Thank you.

MODELLING THE EIGHT LAKES OF TARAWERA

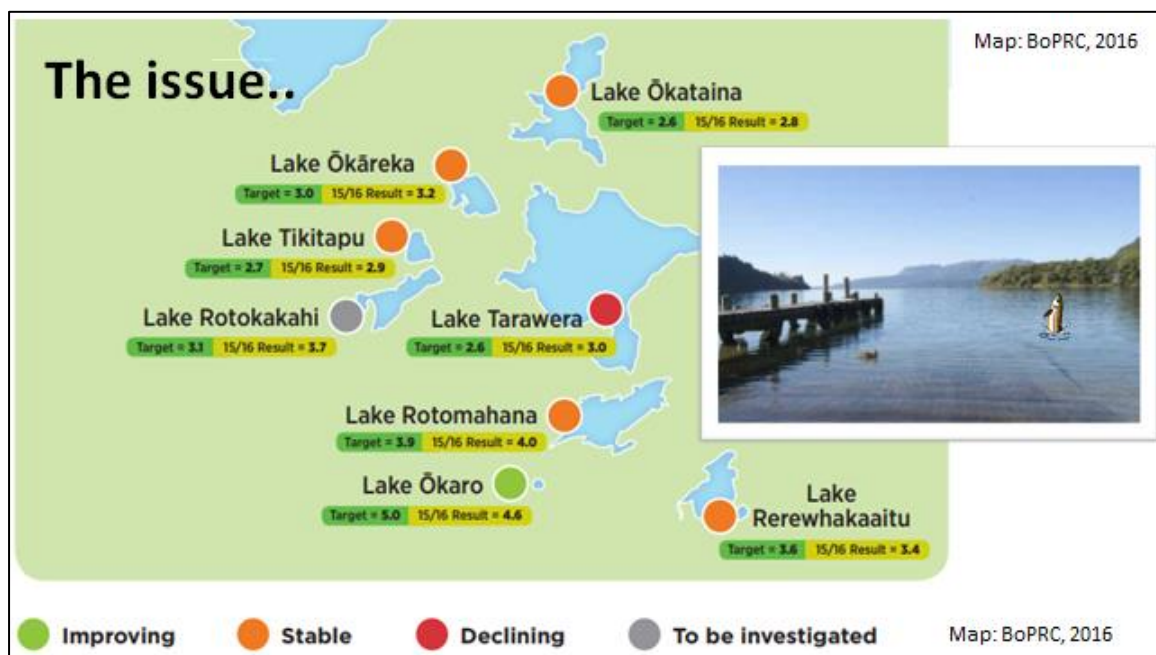
Chris McBride
University of Waikato
cmcbride@waikato.ac.nz

Chris began working on the Rotorua Te Arawa Lakes in 2003, studying food webs using stable isotopes. He has worked for Waikato University's Lakes Chair since 2005, developing and installing lake monitoring buoys, and undertaking lake modelling and nutrient budget studies.

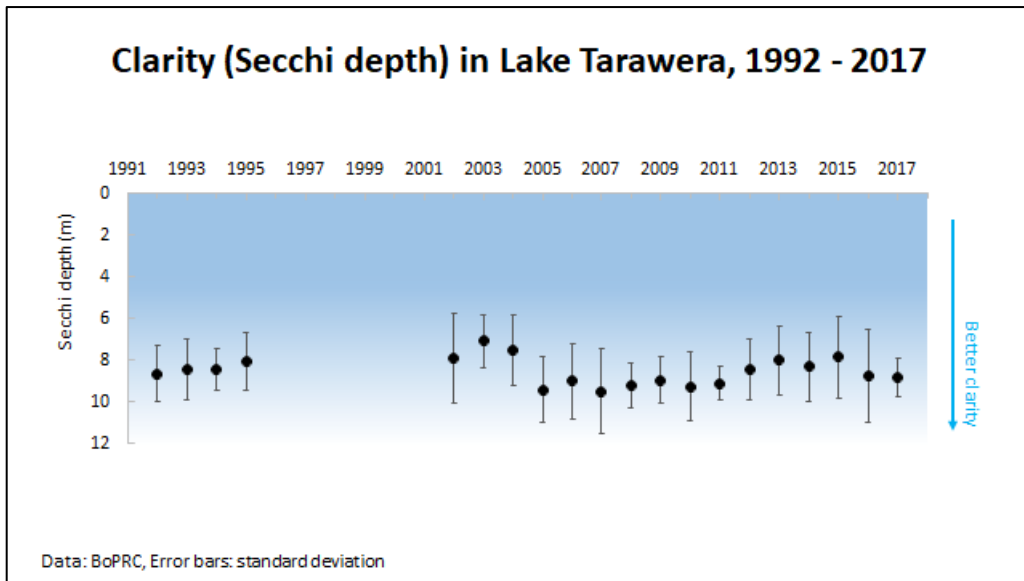
TRANSCRIPT

Thanks for a very generous introduction, and to the LakesWater Quality Society again for organising another fantastic symposium and for giving me an opportunity to present here.

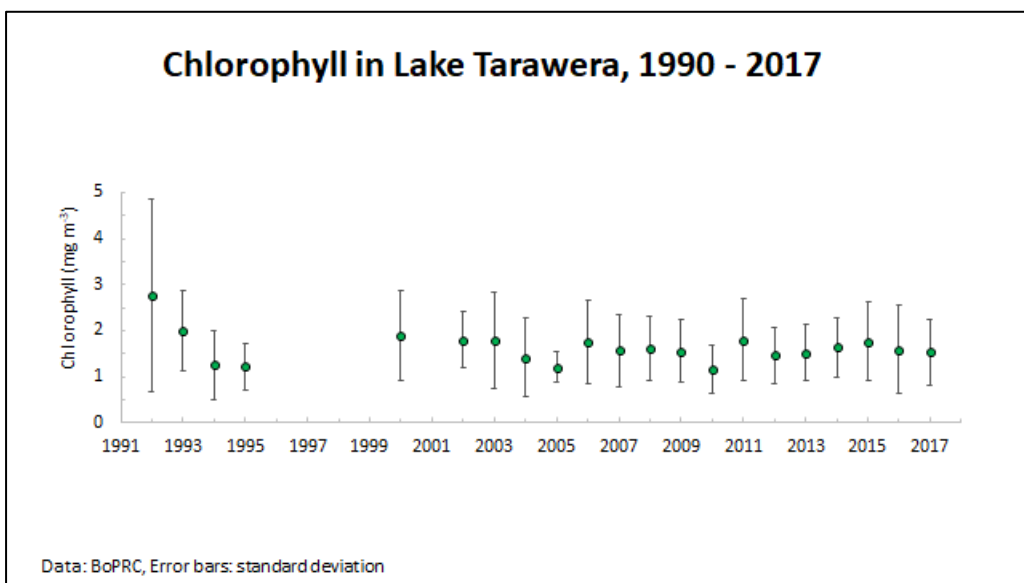
The work I am presenting today is on behalf of myself and the Waikato University team and also my collaborator Jonathon Abell, who is a former student of David's with our group. I am presently working towards a PhD, and some of this work will feed into that. Paul White has given a nice lead in to this talk and we will be leaning heavily on his great work. The project is to model water quality in Lake Tarawera and its response to climate and nutrient loading in particular. Obviously, modelling Lake Tarawera requires conceptualising and understanding the broader hydrological system, so that is a big part of this project too.



We are all well aware that Lake Tarawera can be a picture postcard perfect sort of environment, but in the most recent publicly available Lakes Water Quality Report it does stand out as a red dot on the map representing a declining TLI. That it does stand out as a red dot lake perhaps reflects the great work and success that we have had in some of the other lakes across the programme. Nevertheless that red dot is a little alarming and it is worth taking a deeper dive into some of the data behind that point on the map.

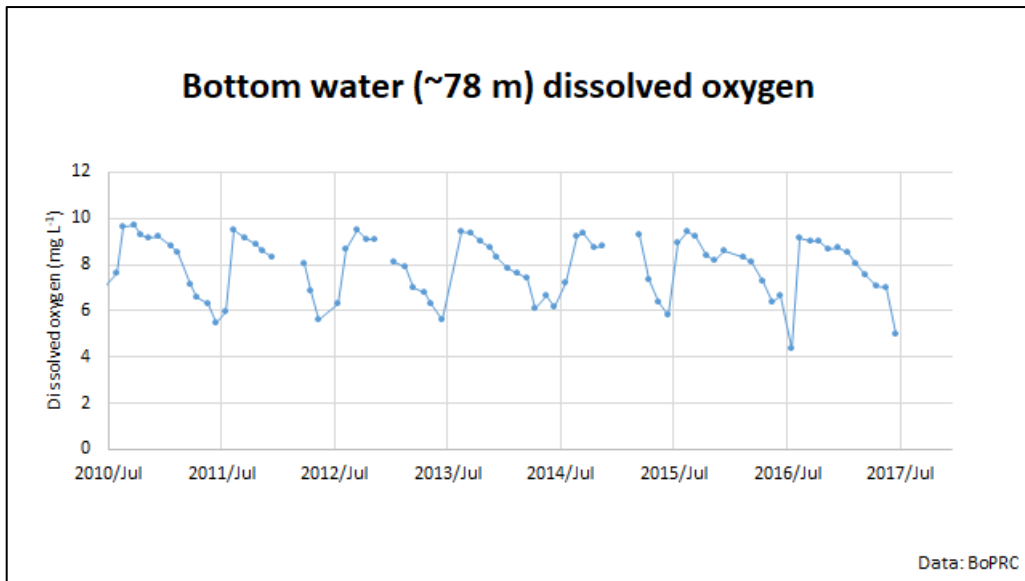


To follow on from the approach David took yesterday for the northern lakes in the region, we will look at the chlorophyll concentration and Secchi depth (which is indicative of water clarity). This is the long-term data set for Tarawera with values further down representing a deeper Secchi depth measurement, and better water clarity. There is certainly nothing too dramatic over recent years in any decline in annual average water clarity in the lake.



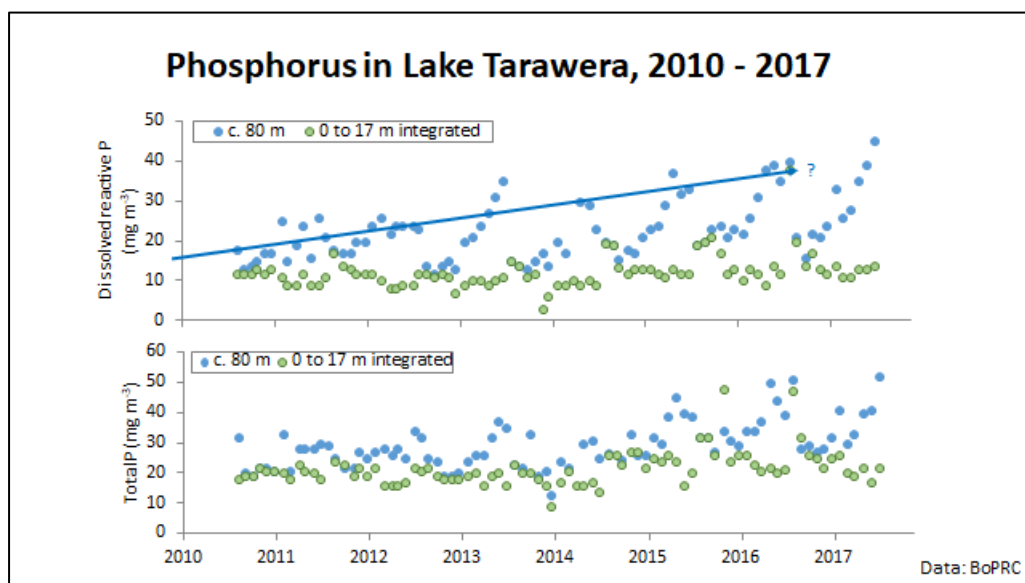
Likewise for chlorophyll, no dramatic rise over the recent decade or so in annual average values for the lake. So no dramatic changes, despite periodic anecdotal observations of blooms at the Hot Water Beach end, and also some green water coming in from Rotokakahi at times around the Landing.

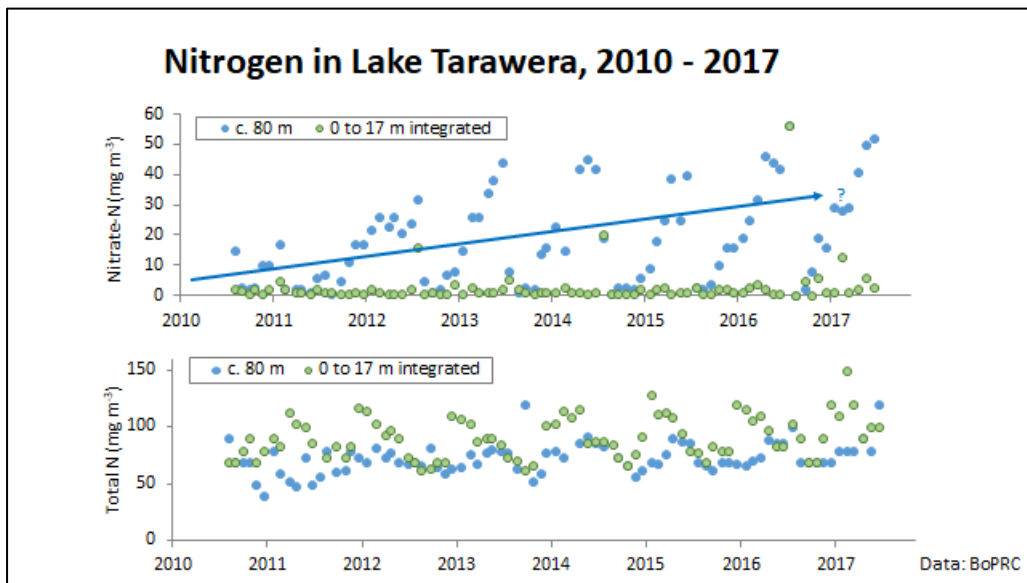
Again, in a similar plot to what David showed, (next page) bottom water dissolved oxygen in the lake looks fairly stable over the last 7 or so years, although maybe one month we did see some unprecedented low concentrations in bottom waters. When we get low oxygen concentrations in the bottom waters of stratified lakes, as David explained yesterday, that can lead to internal loading via release of nutrients that are stored within the sediments.



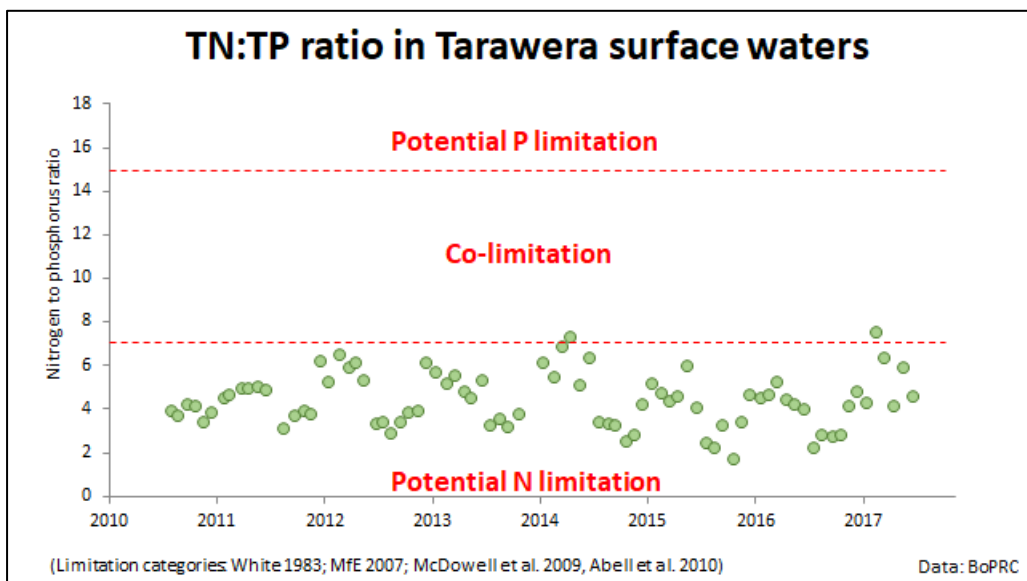
Below is the phosphorus data, dissolved phosphorus in the top panel and total phosphorus in the bottom panel, with blue dots representing bottom water concentrations over a 7 year period, and green dots representing surface waters. What we might be able to infer (with very non-scientific style regression lines), is some indication of an increase in bottom water concentrations over that last 7 year period, which is obviously cause for concern. Lakes can get into an internal feedback cycle with bottom sediments supplying nutrients to the water column, creating more organic matter growth and subsequent decay, then more deposition to bottom sediments. That kind of self-reinforcement is a critical aspect for managing and monitoring lakes.

There is a very similar pattern for nitrogen, (next page) with dissolved nitrogen on the top, nitrate and total nitrogen on the bottom, and an indication of an increase in bottom water N concentration and bottom sediment nutrient release. More research is needed to better understand these processes in Tarawera.



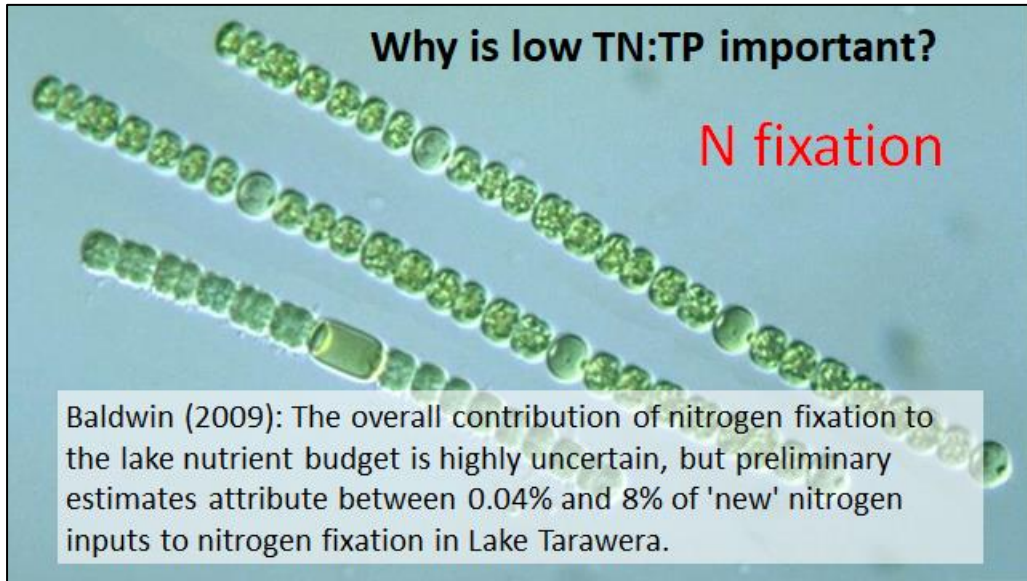


We can also look below at nitrogen and phosphorus levels in relative terms - as the nitrogen to phosphorous ratio. Chris Ingle mentioned how important this discussion has been in the Plan Change 10 process for Lake Rotorua, in terms of which is the most limiting nutrient for phytoplankton growth or algal production in the water of the lake. In the case of Lake Tarawera it is a unique and interesting system in that most of these values sit comfortably within the zone of what we would call 'potential nitrogen limitation'. Nitrogen is likely to be a stronger limitation on algal production than is phosphorus.



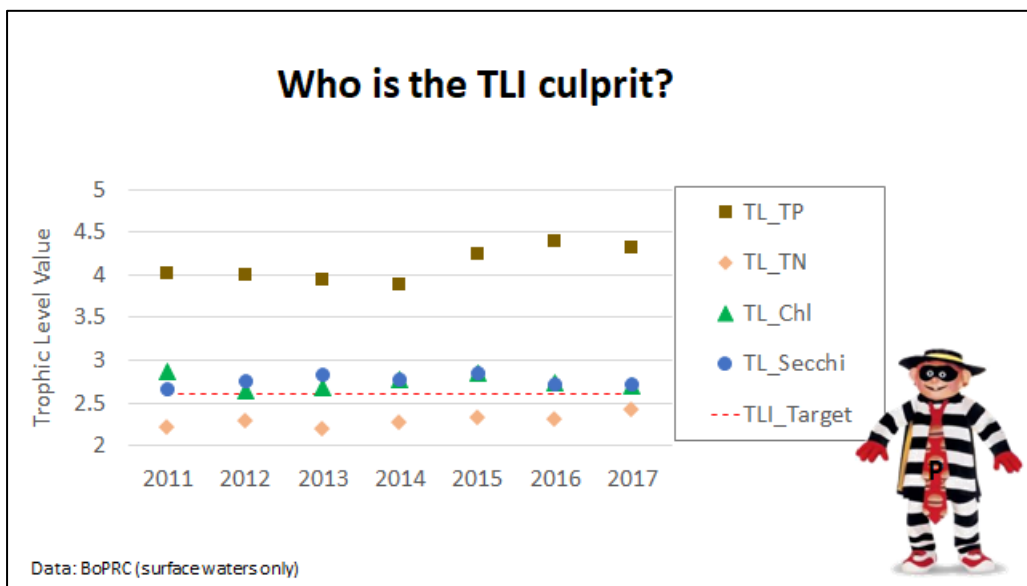
Why is that important? When we have a low N to P ratio this can favour the production of cyanobacteria due to the ability of some cyanobacterial taxa to fix atmospheric nitrogen. Those familiar with Lake Tarawera can be surprised by relatively dense flocks of cyanobacteria in the water column, when at other times the lake is very clear.

Amanda Baldwin, for her PhD research, studied nitrogen fixation in the lake between 2007 and 2009 and estimated that fixation might account for somewhere between almost nil and 8% of new nitrogen inputs to Lake Tarawera. Further to that we might expect that if



phosphorus inputs were to increase faster than nitrogen inputs then fixation may become a more substantial component of nitrogen input to the system, in a relative sense.

Taking all the four components that we have looked at - chlorophyll, nitrogen, phosphorus and Secchi depth or clarity, in the context of the TLI, we can plot these all on the same scale. The N to P ratio jumps out in this plot as something really quite interesting in that three of those TLI variables sit at or around the TLI target for the lake, but it is phosphorus that is most affecting the actual TLI for the lake.



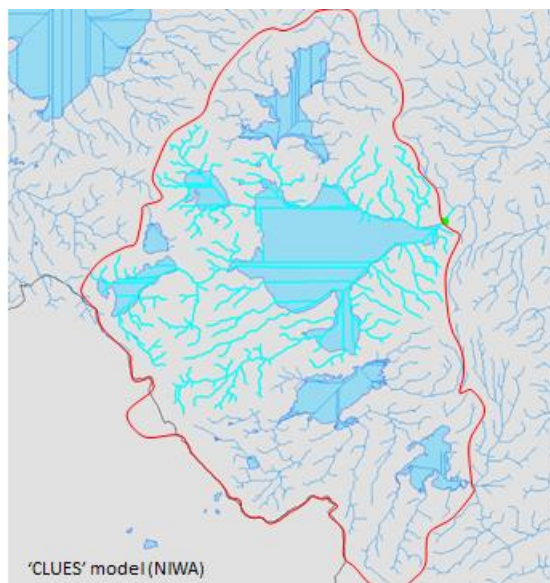
From this it might be tempting to think we only need to manage phosphorus. However, something really important to note is that, because of the oversupply of P, if we add any N to the system, we are likely to get a corresponding increase in chlorophyll and a reduction in clarity. So it becomes doubly important to manage both sources – this is now reflected in the Lake Tarawera Restoration Plan as a reduction in phosphorous in conjunction with nil increase in nitrogen.

Now that we have the context of broad water quality issues in Lake Tarawera, we can move onto the actual modelling project. The aims are multi-faceted. In the process of establishing these models we work to understand the system, the inputs, the hydrology and the nutrient loads. The aims of the project are:-

- Review and synthesise available budget information
- Configure a 1-dimensional computer model of Lake Tarawera, the DYRESM–CAEDYM model
- Validate the model using lake water quality data
- Simulate broad nutrient loading scenarios to understand how lake water quality responds to changes to nutrient loads (e.g., Δ P and N loads by 5%, 10%, 20%, etc.)

An intended outcome of this work is to identify sustainable nutrient load targets that will lead to, or achieve, the TLI target for the lake.

Tarawera..
..it's complicated



The modelling of lake water quality necessitates understanding and conceptualising the system. Paul White has done a fantastic job of this already, but I will reiterate that, as it is complicated. We have a number of lakes in the Tarawera system, some with surface water connections, which are shown by the connected blue lines in this CLUES model (NIWA), and some which have groundwater connections only.

I am the third person to use the next slide, a great diagram that Paul White put together and we are all using it. It shows the connected lakes and the way that surface water and ground water connections flow between them.

Conceptualising the system

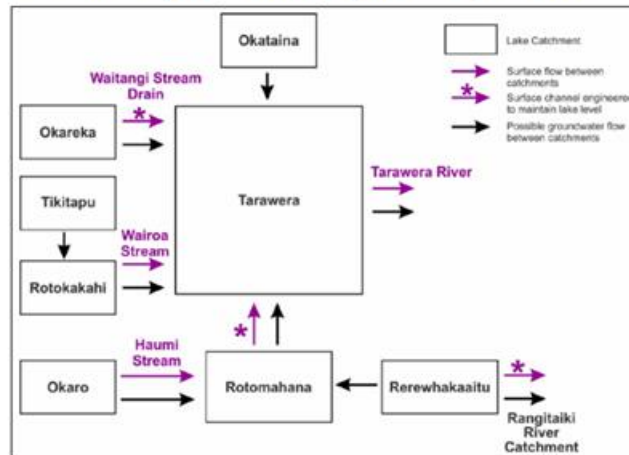
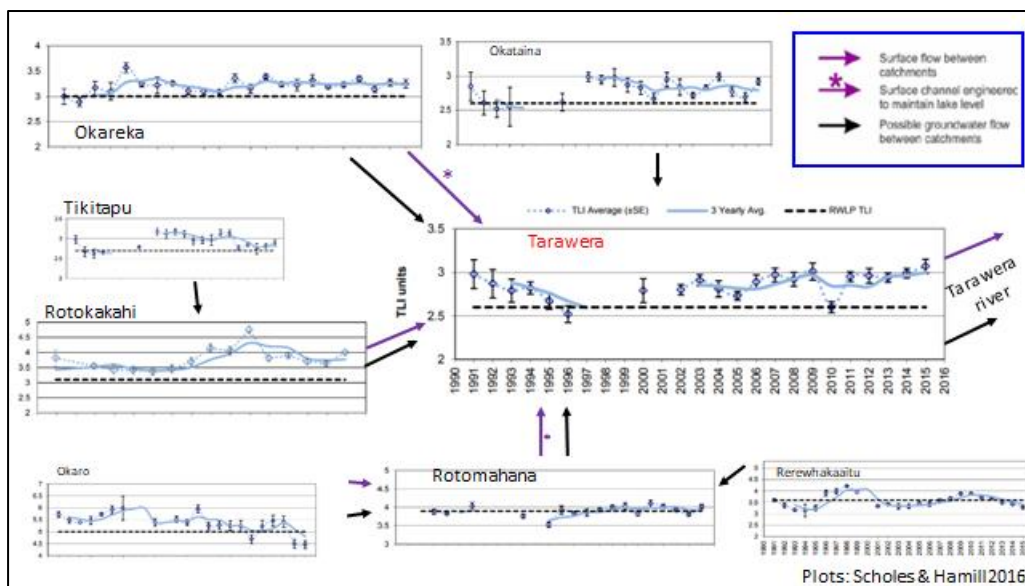


Figure 3.3 Water budgets schematic for the greater Lake Tarawera catchments.

White et al, 2016

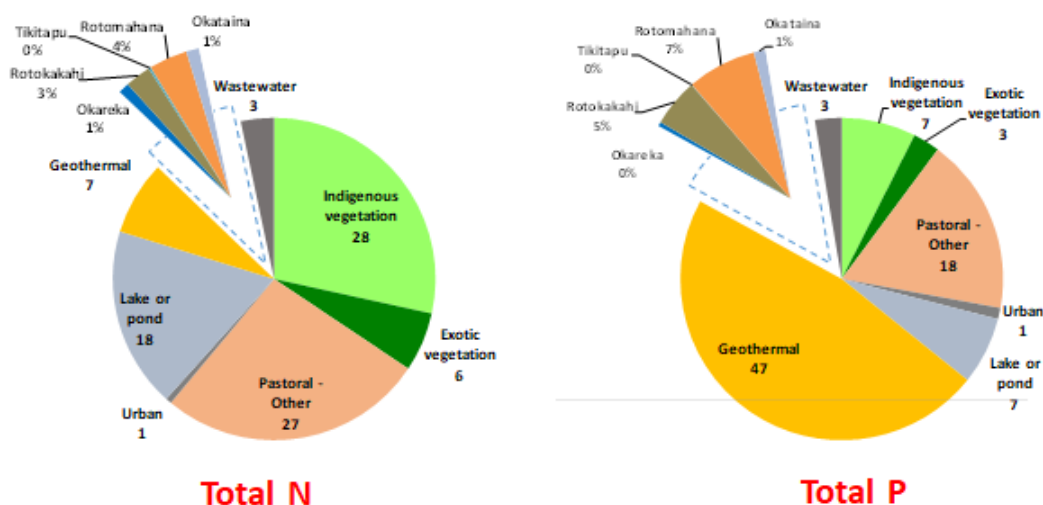
Expanding on that concept, I have replaced the boxes with TLI plots from each of those lake systems so we can see where gains might be made for Tarawera through approaching or achieving TLI targets in the other lakes. Looking at this plot it is tempting to say, 'Oh well, we can manage Tarawera just by hitting our targets in the other lakes', but unfortunately life is never quite that simple.



Plots: Scholes & Hamill 2016

The pie charts on the next page show the nitrogen and phosphorus budget for the greater Tarawera catchment, including the smaller lakes. The zoomed out wedge of the chart represents inputs from other lakes, and is a relatively small contribution of both N and P to the system as a whole. Following on from Chris Ingle's comments, the geothermal load of phosphorus to Tarawera is potentially massive, but it is also worth noting that the yellow wedge is subject to a very high degree of uncertainty. I will touch on that again later. Nutrient budgets like those pie charts are a rather blunt instrument for managing the lakes. What we aim to do with this project is something a little more sophisticated.

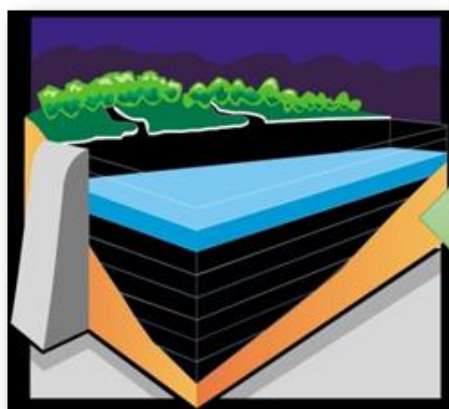
Sources to Tarawera



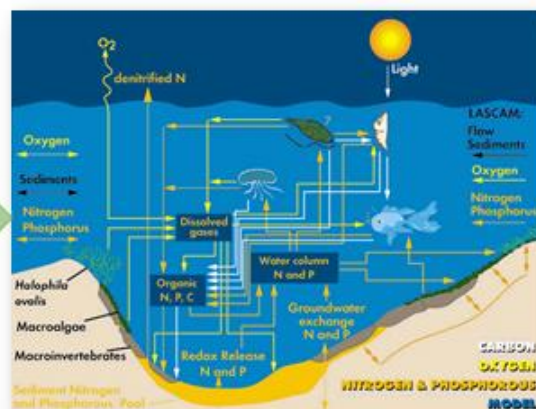
These are the DYRESM–CAEDYM models coupling the hydrodynamics of water movement with the biogeochemical (nutrient and biological) cycles in the water column. These diagrams can be simplified to show how the model accounts for all the various inputs - surface water, groundwater, climate, atmospheric deposition, phytoplankton growth and internal nutrient loading. The model represents all those processes to provide a best informed estimate of the water quality response to external forcing.

Coupled hydrodynamic and ecological models

DYRESM - Dynamic Reservoir Simulation Model

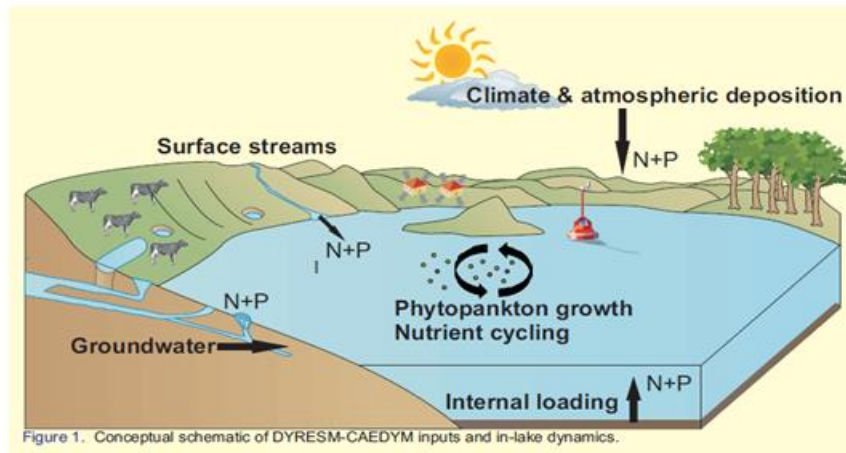


CAEDYM - Computational Aquatic Ecosystem Dynamics Model

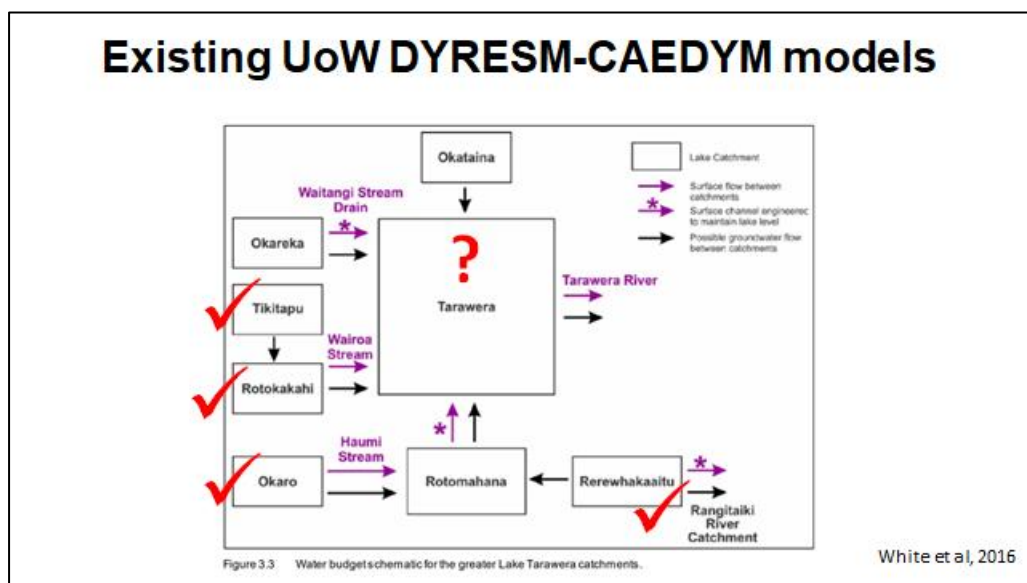


We have used the DYRESM–CAEDYM model (on the next page) across the Rotorua Lakes. For the greater Tarawera catchment we have models already established and published for Lakes Tikitapu, Rotokakahi, Ōkaro and Rerewhakaaitu. It is probably time to model the greater Tarawera catchment, the grandfather model of them all.

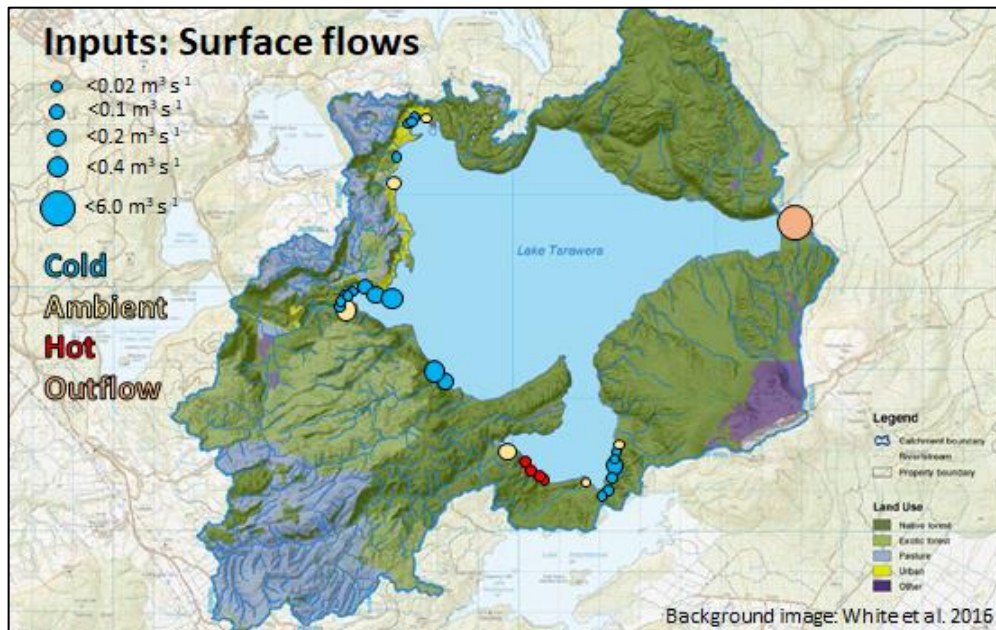
The model: DYRESM-CAEDYM



These models, with their multiple inputs, are data hungry. They provide a useful opportunity to aggregate all the data and knowledge that has been collected across this greater lake catchment into one tool, and use it to project water quality.

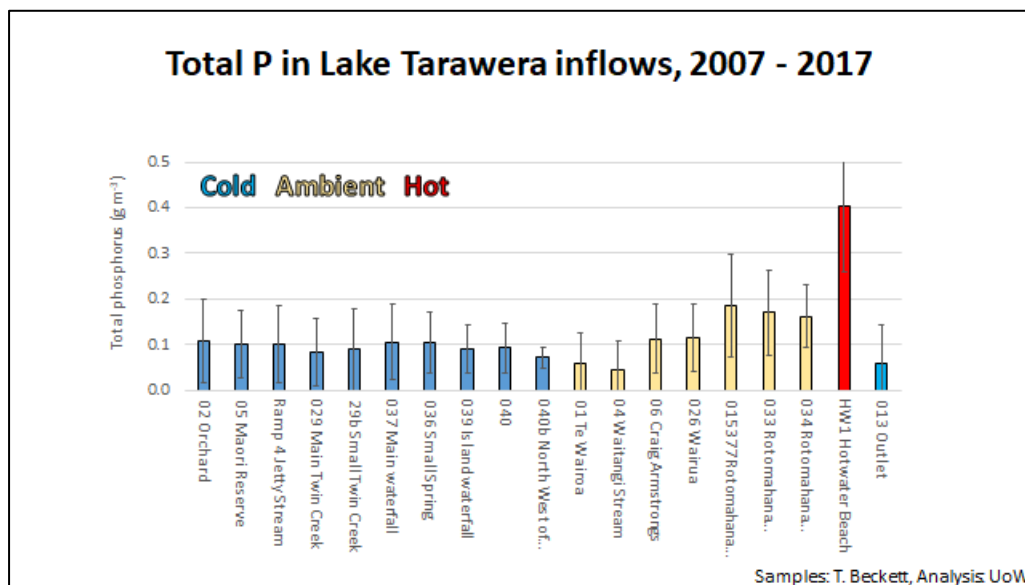


One of the primary inputs or data types we need is obviously water discharge and water quality inputs from the catchment. This is Matt Hamilton, a former student with us, who did some of the original nutrient budget work back in the mid-2000s. Since Matt's work we have been very fortunate to have the commitment of Terry Beckett, and some students as well, who have helped him to monitor the various inputs to the lake, quarterly since about 2007.

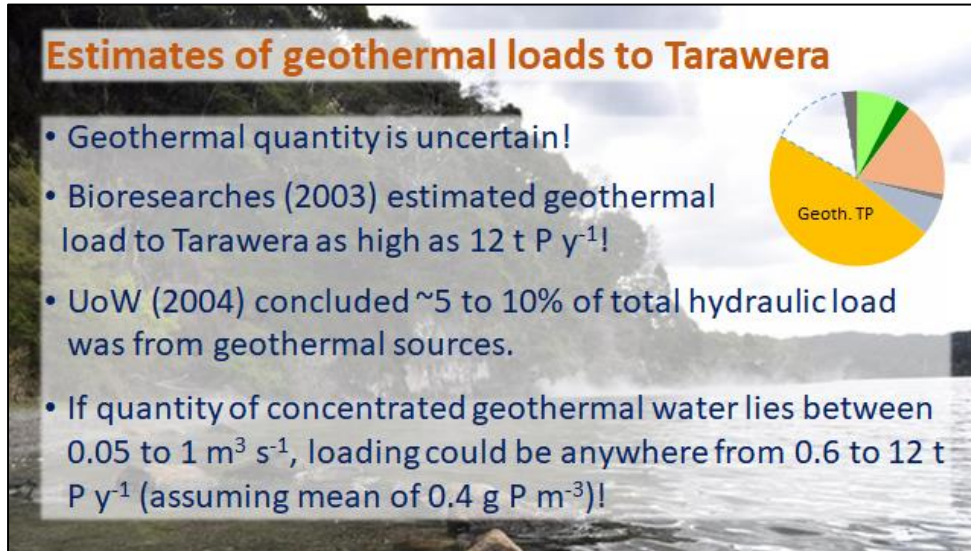


The dots on this chart represent categories of surface flow. The size reflects flow rate at those point sources and the colour indicates the type of flow. Blue is cold water, yellow is ambient temperature, basically surface streams, and red is hot geothermal loads which we will come back to later.

Terry has done a fantastic job of collecting samples for analysis at Waikato. From this we can calculate the long-term average nutrient concentrations for each lake input. This graph is for phosphorus; cold and ambient concentrations have moderate P concentrations. Ambient flows are a little higher, perhaps representing surface flows around some of the more intensively used land areas, but the one that sticks out is the very high P value in geothermal water, and this is the reason for the really large yellow wedge on the pie chart.

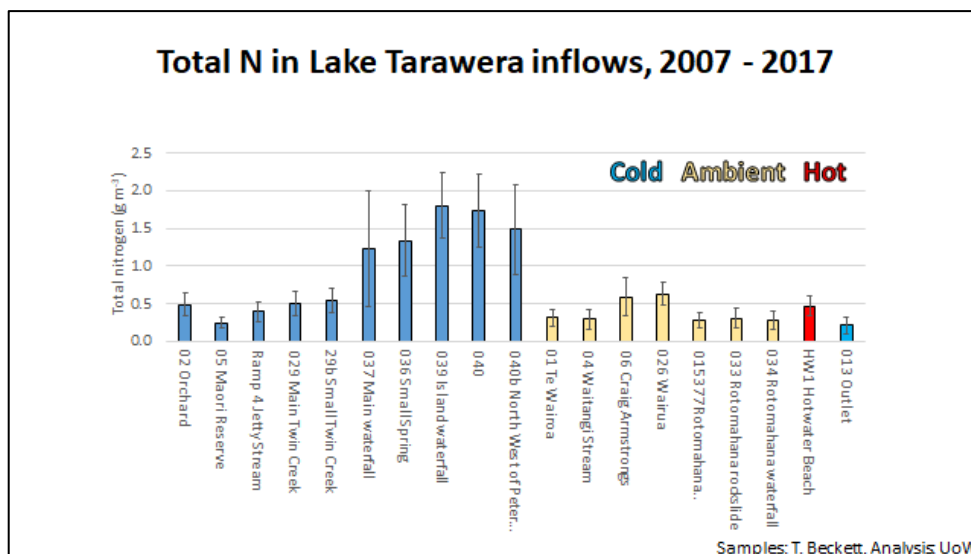


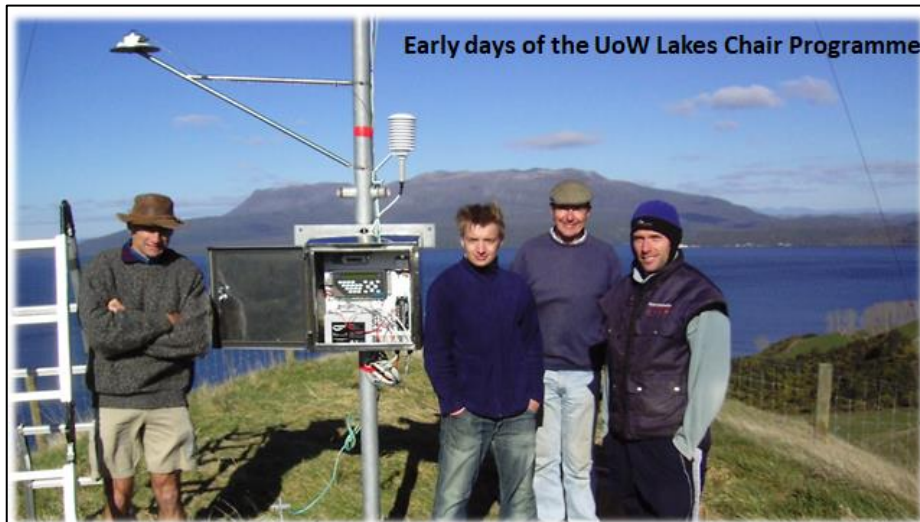
That wedge is subject to quite a lot of uncertainty. Although we have a good handle on what the concentration of that water is around the Hot Water Beach area, the actual volume is a lot harder to estimate because many of those inputs are diffuse and subsurface. Historical research in 2003 estimated the geothermal load might be as high as 12 tonnes of phosphorus, so that would be more than twice all the other P inputs combined.



A more recent study by Waikato University estimated that 5% to 10% of the total hydraulic load to the lake could be from geothermal sources. The 5 tonnes P estimate shown by the yellow wedge on the pie chart is based on a 5% geothermal water contribution, equal to slightly less than half a cubic metre of geothermal flow into the lake. This is one area in which we will do more work to tighten up our estimates of the volume of geothermal water going into the lake itself.

Switching back to Terry’s monitoring data on inputs, looking this time at nitrogen, it is almost the reverse of P; there are quite high N inputs from some of the surface streams and springs. That follows logically from what Paul White described with the shallow ground water being N enriched up to approximately 3.5 milligrams per litre (grams per cubic metre).

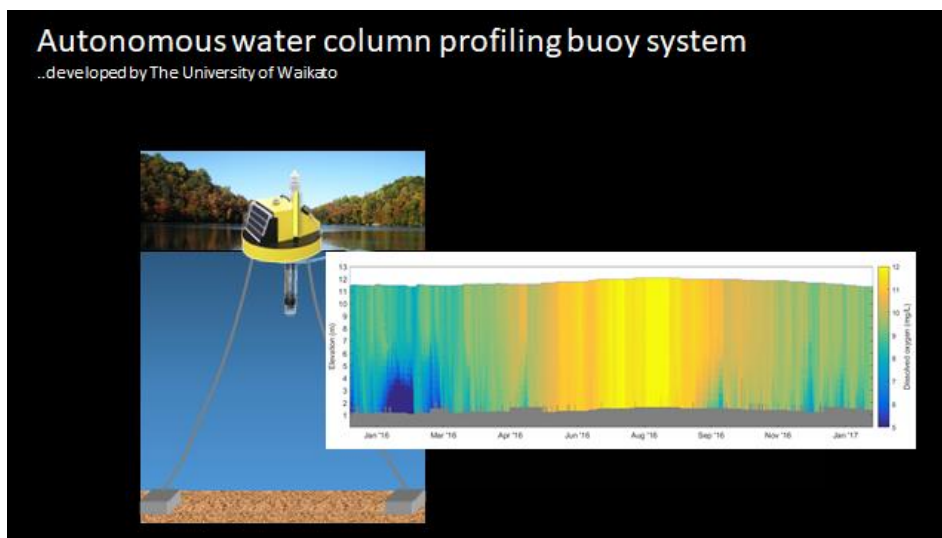




We have a nice handle on the water quality inputs in water quality of inflows to the lake. Another data type that we feed into the model is climate data. In the early days of the programme David Packman kindly donated a small space on the top of a hill on his farm where we could set up a weather station overlooking the lake. This has given us a good record of climate quite near to the lake for the last 10 years or so. You can see the Danish and British guys look pretty comfortable, but the kiwis are more rugged up. It was a pretty cold afternoon despite the sunshine!

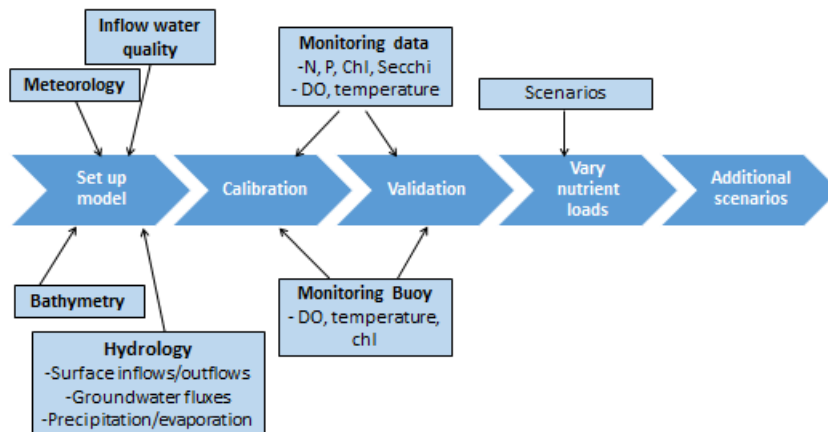
Additionally we have high frequency lake monitoring buoys, which I have been quite involved with. These also have a climate station and right on the lake we have weather data as well as near real time water quality information at 15 minute intervals with occasional gaps. The Tarawera monitoring buoy has proved something of a problem child due to the depth and exposed nature of the site.

Over the last few years we have been developing these water column profiling buoys which use an automated winch to raise and lower a sensor package up and down through the water column. The advantage of this is that we can measure variables like oxygen, pH, chlorophyll fluorescence or water turbidity throughout the water column, rather than



just at one or two depths that we would be restricted to by a traditional buoy with fixed sensors. With this buoy we can generate nice plots and get a much better feel for the vertical dynamics in the system. That will be very beneficial for the future, particularly the 1D modelling, that we undertake. The data is from a year of uninterrupted recording from the prototype profiler buoy, which was deployed at Lake Rerewhakaaitu. Periods of oxygen loss from the bottom waters are evident in this plot. This is the type of data we will be generating for Lake Tarawera going forward.

Lake modelling process



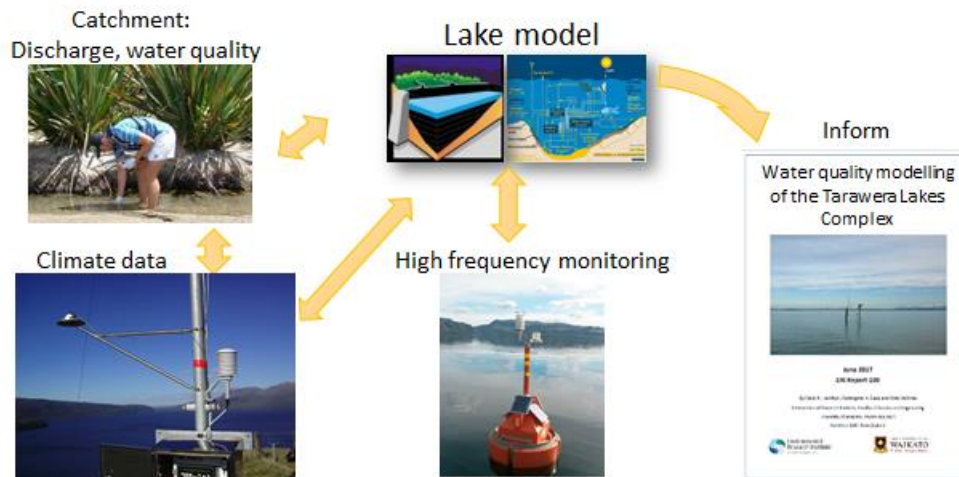
This flowchart shows the process for the modelling project. There are no results at this stage but we will set up the model with the inputs that we have just considered. We then calibrate the model using the monitoring data that we summarised in the first five slides to optimise model performance and check that it reproduces the observations accurately. Then we will validate the performance of that model with an independent time series or separate time period of the monitoring data, so that we can have confidence in the model's projections. That will allow us to run scenarios, perhaps in two stages; firstly, some broad scenarios with broad assumptions, then more detailed, based for example, on Paul's White's modelling.

MODEL 'SCENARIOS'

- **Multiple simple nutrient load scenarios to identify sustainable nutrient loads that will achieve the TLI target:**
 - e.g. 5, 10, 20% reduction in N and/or P?
- **Additional scenarios, e.g.;**
 - What if all tributary lakes met their TLI target?
 - Intercept geothermal loads?
- **The lake model will provide a tool that could be integrated with future catchment modelling to understand how changes in individual sub-catchments will affect Lake Tarawera.**

Those model scenarios will have multiple simple nutrient load scenarios to try and identify sustainable loads that might achieve the TLI target. That might mean starting off by looking at 5%, 10%, 20% reductions for example in N and/or P to the lake. We could then use the model to run additional or more specific scenarios like, for example, what is the water quality outcome for Lake Tarawera if the TLI changed only in the tributary lakes. Or what if we were able to somehow intercept 20% of the geothermal P load, or similar.

Lake modelling to support lake management



As a longer term vision, the lake model might provide a tool that could be integrated into future catchment modelling, such as Paul White has completed with his MODFLOW groundwater study. This would help understand how changes in more specific parts of the greater catchment might impact the water quality at Tarawera.

The net result of that is we are bringing together the whole picture of monitoring and modelling, and using these tools to inform both the community and the process of management and implementation for the restoration plan.

In conclusion, Lake Tarawera water quality does currently exceed its TLI target and the TLI has increased over the period of 2000 to 2016, although there was a similarly high TLI observed in the early 1990s to mid-1990s. That is not to say that is where the water quality should be, because obviously water quality measurements in the lake only started relatively recently.

Nitrogen, chlorophyll and Secchi depth are roughly in line with the TLI target. However, phosphorus is a great deal higher and results in a low N to P ratio, which is a specific issue for consideration in Tarawera.

The hydrology of the lake is very complex and that presents a challenge for lake managers, but we do have this project under way to integrate the work that has come before, and try to identify sustainable nutrient loads to the lake. Our aim is that the model will prove to be a tool that can be integrated with other undertakings and other modelling endeavours, be they surface water catchment modelling, groundwater modelling, or other information from the greater catchment.

With that I will say thank you and acknowledge all the people below. You have been a great help towards getting this project going.

Paul White (GNS)
UoW Aquatic Team
David Hamilton (Griffith University)
Joseph Butterworth (JFB Environmental)
Paul Scholes, Alastair MacCormick (BoPRC)
Terry Beckett, David and Robyn Packman, and the Lake Tarawera Ratepayers
Association

Thank you

QUESTIONS

Don Atkinson, LWQS: Chris, there is an enormous amount of work being done and absolutely fundamental going forward with solutions to the catchment. Is it now fully funded and when will it be completed?

Chris McBride: It is fully funded. I believe we are going forward with the 1D modelling project now.

Don Atkinson: The modelling project that is indeed funded and under way.

Chris McBride: I think probably it should be perhaps three months away.

Don Atkinson: That is very encouraging.

John Green, LWQS: A question for our pest man but he has gone. I was going to say that having run a ten acre property on Lake Rotoiti the pests are unbelievable. The key is to get care groups throughout New Zealand focussing on targeting those particular pests. We killed thousands of rats and possums over our time and we still could not get on top of them. It is a challenge.

Going back to Chris and Paul, I really enjoyed your presentations because you have shown us how complex the Tarawera lakes system is. What I find interesting is that Tarawera looks like it is the main problem and it is not so much those outside lakes. Their TLIs are slightly higher than the central lake but what impact does the volcanic mountain have? You do not appear to have focussed on that at all. Does the mountain have some input of phosphorus that has not been measured or identified? I am so pleased with the work you are doing and keep it going because it is clearly a very complex system. Thank you.

Chris McBride: What impact does the mountain have? If it explodes again there will be a pretty big impact I would imagine. It has definitely had a big impact in the past as you can see from a sediment core. When we constructed the nutrient budgets in the pie charts that I presented, they are based on broad export rate coefficients that we assume for different land types and based on whatever published literature we can find for losses from that type of land cover. It is accounted for in the nutrient budgets but probably there has not been too much detail yet so maybe it is something we could focus more attention on.

Gary Rushworth, Hawkes Bay Regional Council: A question for Chris. You mentioned briefly the core. The model did not seem to include a lot about nutrient legacy. I have been working on Lake Tutira and we collected cores to understand internal cycling of nutrients. Is that part of the model?

Chris McBride: Yes. The diagram I presented was very much a simplification of what was represented. There are hundreds, maybe thousands of processes represented and it does not explicitly include release of nutrients from sediments and sediment legacies but it is part of the model.

Gary Rushworth: How would you rank its importance? Obviously it will vary from lake to lake. Is it something that New Zealand Scientists need to understand more about? How does it rank in terms of knowledge gap?

Chris McBride: Absolutely, particularly the impacted lakes and those that stratify. The internal loading is a really important source of nutrients to the water column, as much or even more so, than external sources. It definitely needs to be considered in any system that is impacted or may be impacted.

John La Roche, LWQS: My question is related to alum dosing in Lake Ōkaro but equally in Lake Rotorua. The mechanism of alum dosing is that the aluminium sulphate forms a flock with the turbidity in the water that then settles out. It is certainly removing phosphorus and nitrogen by tying them up in the turbidity, but that flock forms a blanket right across the base of the lake that would not deteriorate very quickly. Are you investigating what happens from alum dosing on the floor of the lake and what is the long term effect of having a blanket of inert aluminium sulphate or aluminium hydroxide across the floor of the lake?

Chris McBride: I could comment quickly and then defer to Max Gibbs who is the expert on this. As part of the Lakes' Programme, we have ongoing studies taking sediment cores and monitoring aluminium concentrations in the sediments of both Lake Rotoehu and Lake Rotorua. We have just completed a follow-up study to that.

In terms of accumulation in the sediments there is some aluminium sulphate detectable mainly around the points of insertion of those dosed inflows but it is not dramatic. There may be some subsidiary effects in the long term accumulation preventing further release of alum into the water column. If the dosing were to be stopped, over time that layer would be buried in deeper sediments as organic matter settles onto the lake floor.

Max, have you anything to add or correct or anything else?

Max Gibbs: It is pretty much what you said. The idea of alum capping is that it resets the sediments, forms a very thin blanket, perhaps a couple of millimetres at the most, and that sequesters everything out of the water column at the time that it was applied. It also stops anything coming up from the sediments below. The lake is then reset, no phosphorus in it. Whatever happens from the catchment will cover it.

Overseas these layers get buried deeper and deeper into the lake and that legacy material is held within the sediments rather than recycling. The alum process gives a chance to reset the lake and gets the lake water quality improving, which we see in Lake Okaro.

Andy Bruere, BOPRC: I have a question for Chris. You talked about the uncertainty of our estimates of the phosphorus input from geothermal. Do you think there is a possibility that those geothermal inputs might be changing and increasing? That is something that we have not experienced before.

Chris McBride: It is certainly possible. It is outside my domain, and probably Paul White would be much better placed to respond. It is something we definitely need to look into as part of the study assessing what the geothermal quantity might be. Part of that picture is how it might be changing through time, which is especially important because it is such a large fraction of the inputs to the lake. We need to understand that if we make changes in Tarawera and the other lakes, how might that affect natural variation of phosphorus inputs from geothermal sources.

Max Gibbs: John Green raised a very important point about the influence of the mountain. In Lake Taupo we know that there is a hydrothermal vent at the bottom of the lake which

was discovered by GNS. We have been monitoring it since about 1975. We can pick up the chemistry difference from this vent. We know that it couples with eruptions in Mt Ruapehu and the southern mountains and with large earthquakes across the system. Has anybody looked to see whether there is an equivalent vent at the bottom of Lake Tarawera rather than just at Hot Water Beach?

Chris McBride: Perhaps we should. Perhaps another way we could look at this is following up on Matt Hamilton's mid-2000 study that I mentioned, using sodium as a tracer for potential geothermal inputs. Maybe we need to do a follow up study on that as well.

Fred Stevens, Rotorua Lakes Community Board: I have been living at Tarawera for over 30 years now. We have never been able to get a straight answer to, 'Did we have a Tarawera Action Plan?' Several years ago it was demoted to a Tarawera Restoration Plan. My understanding is that an action plan has more statutory weight. The reason we were told it was put back to a restoration plan was because they are waiting for more data. From what Chris McBride said it sounds as though works are being undertaken at the moment. I just want to ask Chris Ingle when are we likely to get the Tarawera Restoration Plan put back to a Tarawera Action Plan?

Andy Bruere, BOPRC: Thanks Fred. First of all, the reason it was called a restoration plan was because when the nutrient budget work was undertaken there were no identified sources of nutrient, particularly phosphorus, which we could reduce to meet the reduction target required to make a sustainable land use change around the lake. So they decided to call it a restoration plan. We will convert that to an action plan when we have identified nutrient sources and actions that will definitely meet those targets. In terms of timing it is reliant on this modelling work and on the farm environment plan work and then on the work that Chris McBride talked about with conceptual modelling.

Giving you a timeframe is probably a bit like a politician's promises at the moment, it is likely to be broken. I would prefer to say we will work through that work and see what information we have to achieve those reductions. It is a watch this space, sorry.

Fred Stevens: It still does not answer my question but thank you.

Chris McBride: You mentioned statutory weight, but I do not think either of them has any statutory weight. The name of the action plan or whatever we call it is semantics really. What you are looking for that has statutory weight is the Regional Plan and the Regional Policy Statement. We have just made a decision to start that Regional Policy Statement process of identifying outcomes for water quality in these lake catchments which is coming up quite soon. We have to get Council go ahead on a few things and sort a few more but once we have changes to the Regional Plan that will have effect on land use in the catchments.

Bob Armstrong, Gisborne Point, Rotoiti: As a long standing member of the LWQS, I am intrigued not only with the information that has been gathered but also the method of gathering it, particularly the three wells, which we saw drilled around the shores of Tarawera. Two of the wells were on an area where inlet water would obviously be coming in, but I noted with interest that the third well appeared to be at the outlet. Could I ask why that was chosen and if so what valuable information was received from that particular well?

Paul White: That well was sited for two purposes. The first one was a water budget purpose trying to understand the inflows and outflows of Tarawera. It has been observed

that the surface flow at the bridge by the camp ground is about 3 cubic metres a second less than the flow below the falls, so downstream that river gains a substantial amount of water.

The first question was where is that water coming from, could it be coming from the lake? David Hamilton and I supervised a Masters student maybe ten years ago, Nicolas Gillon. He did an interesting project with options of inflows and outflows to and from Tarawera. Our best guess was about 2 cubic metres a second was missing in the water budget, so it looked as though the increase of flow at Tarawera Falls came from the lake somehow. So we sited the well there to intercept geology that was capable of transmitting about 2 to 3 cubic metres a second from the lake. That is important to the lake model because there is 2 to 3 cubic metres a second that we need to make the whole budget work and we had to see where it was going.

We drilled a couple of wells, one about 90 metres deep and the other about 80 metres, and intersected the same geological material, fractionated rhyolite, which is at the Tarawera Falls. It had sufficient hydraulic properties to be able to provide 2 to 3 cubic metres a second. There was some other work done but I think the problem is more or less solved. That flow is probably coming from the lake bed somewhere.

The second purpose of having the well there was to have it in a pristine catchment. The other wells on the western side were purposely drilled in the town to see what impacts of land use in the catchment behind the wells were having on the shallow and deep ground waters. That was demonstrated by the Dollimore well that I showed the results from. A relatively pristine catchment showed that the nitrate concentrations are much lower, consistent with native forests.

Session 6 : THE EIGHT LAKES OF TARAWERA

SESSION CHAIR - Warren Webber, LakesWater Quality Society

I would like to begin this session by acknowledging the huge amount of work that Ian McLean has put into this Society. He was the Chair of the Society from 1999 when it changed its name from the Lakeweed Control Society to the LakesWater Quality Society when it recognised the issues were much wider than just weed. He drove the founding principle for these symposia which was the need to bring evidence based science to the water quality problem. We must not deal with folk lore and anecdote. If we are going to solve this, we need good evidence based information. I just want to thank you for that, Ian. Thank you.

Ian McLean

Thank you, Warren. Warren and I are the only two members of the original committee who are still on this committee. There are others here who made a big contribution early on, including Nick and Elizabeth Miller and Mary Stanton who has been supportive throughout the years. It started almost accidentally and has had great support from a lot of people and been a wonderful team effort, well worth doing. Thank you very much for your kind words.

THE CULTURAL PERSPECTIVE: LAKEWEED AND PEST ANIMALS

Nicki Douglas

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Nicki Douglas is the Environmental Manager for the Te Arawa Lakes Trust. Her focus is to ensure that Te Arawa values are known and provided for in decision making as well as active participation by Te Arawa whanau, hapu and iwi. Nicki has spent the past 15 years working for the Department of Conservation in a variety of operational and strategic management roles.

TRANSCRIPT

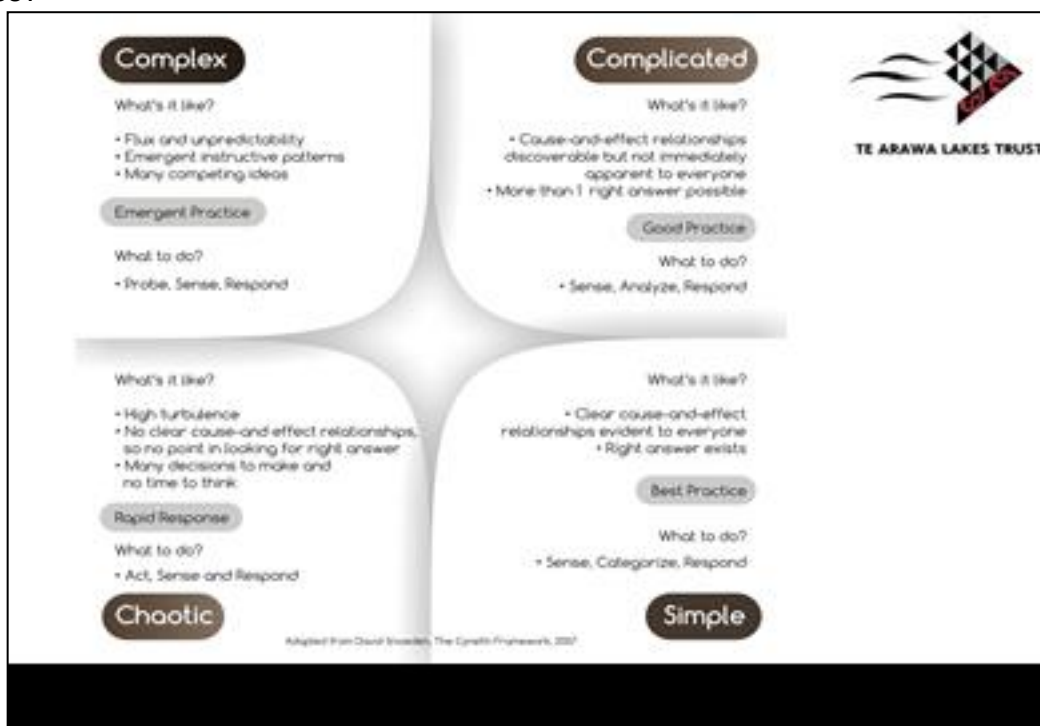
Kia ora, tena tatou

I have been with the Department of Conservation for about 15 years now and worked in Rotorua for 11 of those 15 years in various roles. I was lucky enough to be the Operations Manager for Lake Tarawera so I have a very strong association from a practitioner perspective. Practitioner is probably the key word for me. Most of my korero today will be based on experience and practice in working with communities and that is my area of expertise. I will talk about collective impact. It does say that I am talking about lake weeds and pests and I will mention them at least twice.

What is collective impact? It is a cool model developed by John Kania and Mark Kramer in the United States and describes groups of people coming together for a common cause, sorting a common agenda or goal and then putting things in place to achieve it. That well describes what we are doing here around these lakes. I want a wider discussion about some of the elements of collective impact that we might address in a different way. As a practitioner I often look for improvements from frameworks and then apply those in our work.

I want to acknowledge Ken Raureti. He was going to run this session today and asked me to step in for him, so it will be a different kind of conversation, but I will give you some insights into the cultural perspective. I also want to acknowledge Sir Toby Curtis, the Chair of the Te Arawa Lakes Trust, for being here this morning, Ken Kennedy for his mihi whakatau and Cr Tipene Marr, Rangitihī Tuhourangi. I speak about his papakainga so I want to acknowledge all of you in the room today. Kia ora.

Let's talk about complexity. The symposium theme is complex lakes and system restoration. This slide is the Cynefin Framework which is a decision making critical thinking model that helps us make decisions about where we might put our time, effort, and resources into issues that we deal with. What is the problem to solve? Is it a simple problem? Is it a complicated problem? Is it a complex problem or are we in complete chaos?



During this symposium I have heard a lot about science and evidence based decision making which is phenomenal. What we thought complex ten years ago when the Lakes Programme was set in place has changed. The strategy was developed and we moved from complex into complicated because of all the work being done. In saying that though, dealing with those problems, together with urgency and in the social, cultural, and economic environment, it brings us back into the complex.

Looking at the complexity, we have to be agile. It is an emergent space learning as we go, trying something, and if it fails we try again. We have to recognise that sometimes that is okay. When we can solve a problem quickly we should do that effectively. That is how I think about complexity. What type of problem am I trying to solve?

What is the role of Maturanga Maori and of Te Arawa to actively fulfil their role as kaitiaki in the collective impact model? Kaitiakitangi is a form of collective impact and Te Arawa see themselves as an integral part of the system of nature and people, as part of us, and we describe that in the context of 'Mauri'. The life force that exists in any living object also exists in us and we give and take mauri to each other.

The cause and effect of kaitiakitanga and mauri in the collective impact model is if I take something, I replace it. It must be protected for future generations. Mavis Mullins is Business Leader of the Year and talks about decisions made today must be right for our mokopuna in the future. It is about those ahead of me, and asking permission from our creator to take things, and that creator is within the context of our cultural framework.

Every single hapu, whanau and Iwi member sees themselves as part of their system and acts within the bounds of that tikanga, (culture) and therefore as a collective make a significant difference in a positive way to the environment by living by that tikanga, by those cultural practices. Individuals, groups, and collectives all have an impact on our environment.

The Lake Tarawera network is made up of 8 lakes and I thought we should show you them. This is Rotomahana.





These are the five conditions of collective impact:

The common agenda

From a cultural perspective the outcome, or the common agenda, that we ask for in the Lakes Restoration Programme can be expressed in our own whakataua.

*Te ma o te wai e rite ana kia kite nga tapuwae a te koura
The footsteps of the koura can be seen because the water is so clean*

That is a goal and if we attributed that to our broader goals of water quality and having clean lakes, those two things line up. It is about the common agenda expressed in a cultural framework.

Shared measurement

For collective impact to work we need to collect data from everybody who is involved, and that is happening. But what is the data missing from the cultural framework that can inform and give indicators towards those outcomes?

Te Arawa Lakes Trust has gone through a refreshed strategic planning process and developed a set of indicators that are meaningful to our people. An indicator would be that mauri is restored, the water is clean. Another indicator would be the abundance of kōura and other taonga fisheries that we collect for our cultural practices.

How do we measure our ability to move closer to those things? Can we have measurements in the programme that reflect Te Arawa values and demonstrate to Te Arawa whanau, hapu, and Iwi that we are moving closer to that goal?

Mutually reinforcing activities

Collective impact means that the goal is the centre and everybody's contribution matters as long as it contributes to the goal and that can be demonstrated and have a measurable difference. The centre is the goal and everybody being valued and seeing their role. For

Te Arawa what are the things associated with this Lakes Programme work that make a real difference to our outcome and the values we attribute to these taonga.

Continuous communication

It is clear to me just how much institutional knowledge and information is being shared among the parties in this programme. To get a collective impact model working well, those parties that are the coordinators must spend a lot of time together. Something that needs to be done better in the Te Arawa Lakes Trust role is to communicate with those undertaking active Kaitiaki roles.

What am I doing on the ground and how is it making a difference to the goal? How do we tell that story and communicate with the wider public? It is important to keep the flow of information between those who are active and those keeping the goal going so they know what their contribution is, how it might need to shift, how their measurements demonstrate the impact they are making and how they might change what they are doing to make a better difference. We probably do continuous communication well from the centre but doing more outside may need some attention.

Backbone support

This is about having an organisation, and the Lakes Programme is well supported by agencies that play a crucial role. It is about connecting to the wider network.

Tarawera and the Lakes Programme is a good example of a collective impact model. I seek the presence of Te Arawa values in that model and some improvement around how we could address that model and put our hands up to be party to that.

I want to congratulate the Rerewhakaaitu Farmers' Collective for their work around the Rerewhakaaitu Action Plan. When I left Rotorua in 2013 conversations had been going on for a couple of years. Coming back to see the commitment and dedication of that Collective is fantastic. Kia ora.

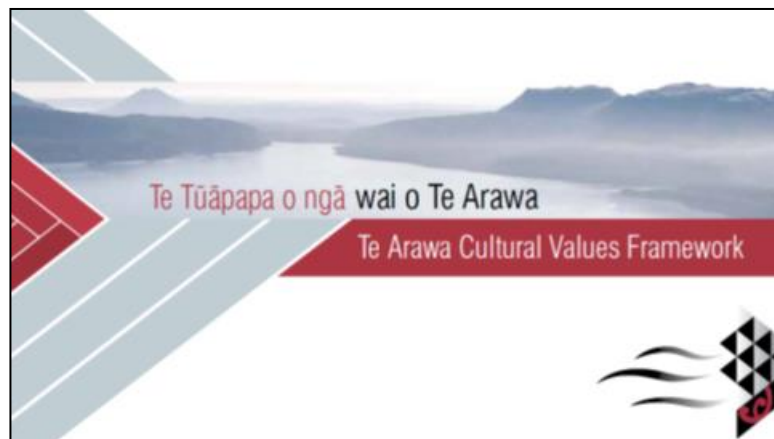


I was heavily involved with the Ruawahia 2B pine removal operation on Mount Tarawera which Ken would have talked about as he holds that project close to his heart. He talks about it being mana maunga mana tangata, bringing back the restoration of that maunga into its natural state being a representation of the return of their people to that maunga.



The terrestrial efforts, community pest control efforts, the conversations that our whanau at Okataina and Rotoiti have about pest control. We all know the pest control issues and the damage to the understorey. Possums, wallabies, deer, rats, mice and stoats, browsers at every level of the ecosystem, that forest needs some serious attention. I was inspired by our Rotoiti whanau taking on that challenge and having that conversation amongst themselves and with their people.

Aquatic pests. I went to an amazing workshop run by Shane Grayling and Lindsay Chadderton was there. I learnt so much. The last thing I want to see is catfish near the complex Tarawera system, what damage they could do. Ian Kusabs mentioned yesterday that kōura do not like Tarawera, they like other lakes. I want to ensure that while we are protecting the values in the other lakes, and if we can improve them, they will make a significant difference in Tarawera.



How does a cultural values framework work with collective impact? What is it?

It starts with water - wai, and is about the relationship of water coming from our gods. We call it waiariki. The tears of Ranginui come to Papatuenuku. Kingi, Sir Toby's poem, was not translated yesterday but he said in his tauparapara that we express our relationship with water through our activities. How it makes us feel, how clean we feel, our spiritual response to water, the way it feels on our skin and then how clean the water is itself.

Wairua is the spiritual connection the way we think about our relationship with the water, the species that live in it and what this means to us, that we eat them and that we also feed them by protecting them so we ensure that we only take them at certain times of the

year. We use cultural practices to keep the numbers in manageable lots and then Waiata. How do we actively express our role in those lakes? By restoring wetlands by doing our stream restoration. Those are the footprints of our people that made their way to the lakes using those streams and those pathways. For us it is about how would we express that?



Iwi management plans for the environment play a key role because they are somewhere to go. We can all look at them and see the values of those people in those places. It brings to life the stories and the attributes of the people associated with that place into the public domain and gives us some clues about how we might work with those people who hold that place so dearly to get the solution that we might be looking for.

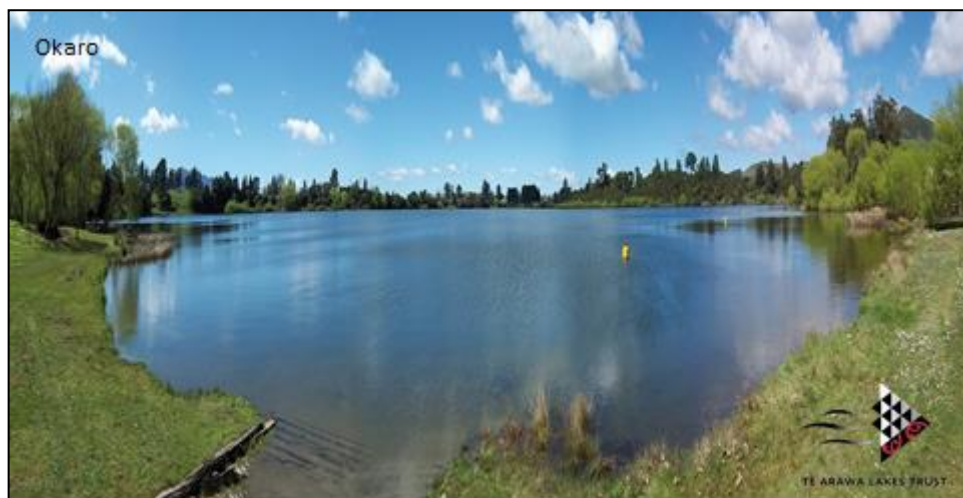
Capacity building - We have seen a lot of research. I had a conversation with Ian Kusabs yesterday evening about research that we might drive from the Te Arawa Lakes Trust perspective in terms of Maturanga Maori. I have been at the Trust for 4 months and have met ten graduates; science bachelors, masters or PhDs, who are Te Arawa living in Rotorua. That is a massive opportunity for us in tapping into their expertise and giving them the opportunity to flourish here in Rotorua. They can offer this programme something that may not have been done before, or in a new way.

Value Te Ao Maori is another principle of this framework. It is about managing the whole system, taking an holistic view. We talk about social, cultural, environmental and economic well beings. The approach that Maori take is to look at all those well beings and address them through their role as Kaitiaki, managing the whole system, land to lake, stream to sea and connecting them up.



A quick summary

- How close are we to a collective impact for Tarawera?
- Acknowledging the level of complexity and taking stock of what is complex?
- Are the outcomes expressing everyone's values and aspirations?
- Are there other ways we could express those outcomes?
- How are we measuring success?
- What story do we tell about this?
- Is it making a difference for whanau?
- How is each party making a contribution to the bigger picture?
- How are the parties connecting for effectiveness and wider benefit?
- Who is taking care of things?



He pena pena he roki roki he rakai whenua
To save to manage we will all be wealthy.

Kia ora



THE IMPACT OF 1080 ON AQUATIC ECOLOGY

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Alastair Suren is a freshwater ecologist working for the Bay of Plenty Regional Council in Whakatāne. Prior to this, he worked at NIWA Christchurch where he was involved with a wide range of research and commercial work looking at flow-biota interactions, the impacts of urbanisation on streams, and wetland ecology. While at NIWA he also led research examining the effects of 1080 on freshwater ecosystems, and on the fate of 1080 in catchments.

TRANSCRIPT

Kia ora everyone. I was at NIWA in Christchurch before coming north to the Bay of Plenty Regional Council. I became involved with the following studies as a result of what could best be described as a low-key assessment of a 1080 drop on the West Coast with the West Coast Regional Council. Following this low key assessment, I approached the Animal Health Board to conduct some more robust studies to answer the very important question, 'What effect does 1080 have on aquatic ecosystems?' I eventually did five studies while at NIWA, which were all funded by the Animal Health Board, and it is these studies that I will now discuss.

These studies essentially build on previous work, and answered questions such as:

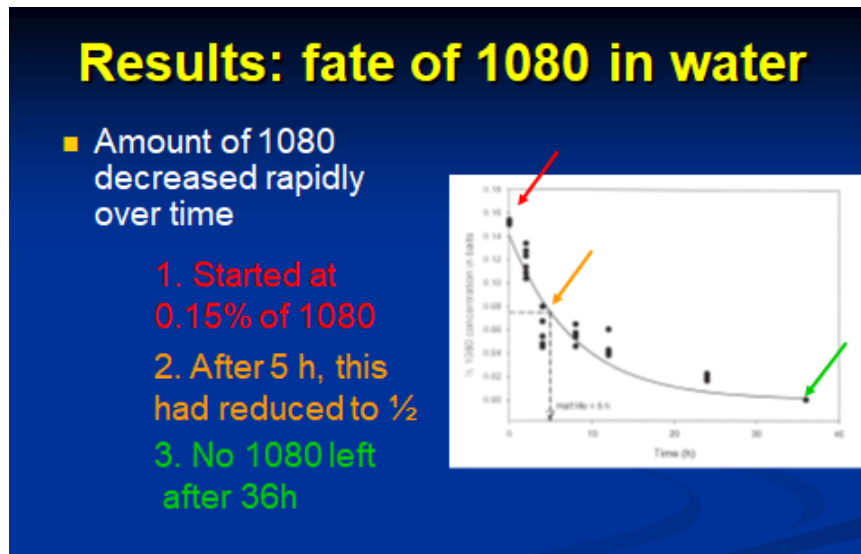
- What happens when 1080 baits land in streams?
- What effect does 1080 have on stream life (fish and stream insects)?
- What effect does 1080 have on kōura?
- What is the fate of 1080 under rainfall – do streams become contaminated?
- Does 1080 enter soil and groundwater?

Within New Zealand, 1080 is the only pesticide allowed to be applied aerially. However helicopters simply cannot avoid flying over streams during these aerial operations. Although some regional councils implement buffers around their bigger rivers, most of the smaller ones have no such buffers, and it is these small streams that baits can, and do, land in. For example, the slide here shows a small stream in the Lewis Pass area with a 1080 bait in it.

The question is, then what happens to these baits? I wanted to see how quickly 1080 leaches from baits once they have landed in a stream. At NIWA, we do a lot of work with flow and ecology. We had a flow tank which could circulate water at 20 cm per second around the tank. This velocity is typical of an average mountain stream. I placed baits in the flow tank and measured the 1080 levels over time at 1 hour, 2



hours, 4 hours, 8 hours and 12 hours to find out how much 1080 was in the baits. From this I could easily calculate the time it takes for 1080 to leach out of the baits.



The graph shows that overall the amount of 1080 in the baits decreased very rapidly over time. You can see time is shown on the X axis - 10 hours, 20 hours, 30 hours and on the Y-axis is the 1080 concentration. We express the amount of 1080 in a bait as percentage weight of 10u0 per weight of bait. We start off at 0.15% weight of 1080 per weight of bait. As you can see after 5 hours that decreased to half the concentration, and after 30 hours there was no 1080 left. You can see the rapid exponential decay and then it tapers out over time.

Once it leaves the baits, with all this water flowing past, the 1080 chemical is diluted to extremely small quantities, often below detection, and is simply washed away. It is probably the only time I would be happy to say, 'dilution is the solution to pollution'. We also know that because 1080 is a natural product, it is broken down by bacteria, although this rate of decomposition is slower in colder waters such as in the South Island.

Most Regional Councils and the Health Department require operators to monitor water quality after a drop for signs of 1080 contamination. The Ministry of Health has set guidelines to ensure that no 1080 contamination of drinking water supplies exceeds 2 parts per billion for safe drinking.

Landcare Research lab tests have shown no significant or prolonged contamination of surface waters with 1080 after drops, and they analysed over 2,400 samples. This is an impressive result, especially when considering that we can detect 1080 to a degree of 0.1 parts per billion.

To give you an idea as to how sensitive the test is to detect 1080, let me explain what 1 part per billion is. Imagine 1 gram of something put into a single 10-tonne dump truck. Then imagine that you have another 99 more 10-tonne dump trucks driving past. Thus 1 gram amongst those 100 10-tonne trucks is 1 part per billion. But we can detect 1080 down to 0.1 parts per billion: that is 1/10th this amount. So, if we cannot detect 1080 in water at concentrations of 0.1 parts per billion, it raises the philosophical question that if we cannot detect it, is it still there? Obviously I do not have the answer to that question because everyone's philosophies are different, but the point I am trying to make is that the

tests for 1080 are incredibly sensitive, and yet the vast majority of results have returned an absence of detectable 1080 from water sampling.

Once I had shown that 1080 leaches from baits relatively quickly, and that it is often diluted to below our ability to detect it, I then had to answer my second question, 'What was the effect of 1080 on stream life?' I examined the effect of 1080 on fish and invertebrates in five streams near Greymouth that flowed into the Grey River near Red Jack's Creek. These streams had very small discharge as I wanted to minimise dilution. They were generally no more than 1-2 metres wide, and mostly quite shallow. Their average discharge was less than 100 litres per second, which represents very small streams where dilution would be minimal.

I wanted to simulate a worst case scenario of a lot of baits landing in a small area. As part of earlier work characterising the degree to which streams become contaminated with 1080 baits, I walked up a number of streams in operational zones where 1080 was being applied aerially. The most number of baits I counted up a 100m section of stream was 8, so I put in ten times that in one location in the small streams I used for this experiment. This was to ensure that I was creating a big loading to see if that worst case scenario could affect fish and invertebrates.

I monitored fish and invertebrates survival above and below the baits. The fish species targeted were longfin tuna, upland bullies and koaro. I put these fish in separate cages, at 2 sites above the baits, and 2 sites at increasing distances below the baits. I then looked at survival 1 and 4 days after the introduction of the 1080 baits. I did not run the experiment for more than 4 days because there would be no 1080 left in either the bait or the water by then. I was thus only interested in short term acute effects. I also collected water samples to measure how much 1080 was in each stream after I added the baits, and to confirm that all the 1080 had disappeared by day 4.

I only assessed the effect of 1080 leaching from baits, and not of animals consuming baits. Some people might think that is a big weakness to the study, but I did this because all our native fish are predators, and would not eat cereal bait. Fish are visual feeders and feed on things floating in the water column or at the surface of the water, or moving along the streambed. They will swim by a bait and simply ignore it. This behaviour is why Landcare Research had to force feed tuna 1080 bait in a study they did to assess whether tuna were affected by 1080.

Most invertebrates would also not consume baits. They are so small that they could not consume a whole pallet. Although an individual animal might crawl onto a bait, only those invertebrates such as caddisflies or stoneflies that have mouthparts to allow them to actively 'shred' and bite into decaying leaf litter would ingest parts of a 1080 bait. Furthermore, any consumption would only be by those animals that directly encounter a bait, and I was looking at the effect of 1080 leaching from baits on the entire community that would be potentially exposed to the 1080.

Did 1080 affect the invertebrate community below where I introduced it? From my water sampling, 1080 concentrations were found at only very low concentrations, about 0.2 parts per billion, which lasted for only a short period of time. After 24 hours, no more 1080 was detected. This result again emphasised that dilution is really important in reducing the effects of 1080.

The invertebrate community was dominated by caddisflies, midges, mayflies and stoneflies. We found absolutely no effects to biotic metrics that we calculated that

described aspects of the invertebrate community. Although we found a slight significant difference with one metric above and below the 1080, I regarded this small difference as not ecologically significant. It must be emphasised that there is a large difference between statistical significance and ecological difference. For example, if we record the temperature on one day at 23 degrees, and on another day at 21 degrees, that is statistically different. However, would we really feel that difference, and would it affect us?

There is a big difference between statistical differences and ecological differences. The subtle statistical difference in only one of the many metrics that was used to describe the invertebrate community was not regarded as ecologically meaningful. All the other metrics displayed no consistent differences above and below the 1080 baits, as would be expected if the 1080 leaching from the baits was killing invertebrates. Because of this, I could confidently say that we did not observe any adverse effect of 1080 on the invertebrate community – even at the very high doses that we exposed these animals to.

We also recorded no fish mortality, suggesting that fish are tolerant to dissolved 1080. The USEPA have done some work on toxicity of 1080 to fish, and regard it as ‘practically non-toxic’ to the fish they used, one of which was fingerling rainbow trout. This lack of toxicity simply reflects the different metabolism animals have. Thus, dogs are very sensitive to 1080, whereas fish and other cold blooded animals are very, very tolerant, simply because their physiology is different.

From these results, I concluded that 1080 leaching from submerged baits had no detectable biological effects on fish or invertebrates. This reflected mainly the huge effect of dilution and also the fact that these animals are naturally tolerant to 1080.

What about kōura? Kōura are big enough to consume 1080 baits, and if they do, what are the implications? Will they die? So I did a study to look at that.



This study was run in a stream simulator at NIWA Christchurch, with water flowing through a pool and riffle area. I added kōura, invertebrates and leaf litter for food and left them alone in the simulator for about a week to acclimatise. I placed 10 kōura in the riffles and 10 kōura in the pool, each in separate cages. After 1 week, I placed a single pellet in each cage at dusk, because kōura come out to feed at night. Again, I wanted to simulate a worst case scenario of a pellet landing in an area where a kōura would encounter it in a very short time – to minimise the time that 1080 could leach from the bait.

I also did not give any bait to another 8 kōura placed in the flow tank. These animals acted as control to see if they could absorb 1080 through their gills or their exo-skeleton. I then monitored the behaviour of all kōura over time and measured their tissue for signs of 1080 after 1, 2, 4 and 8 days. After those times I randomly selected replicate kōura, euthanized them, analysed the viscera (or guts), the stomach and the muscles for signs of 1080. I always collected water samples as well.

What did I find? The highest 1080 concentration was only 1.1 part per billion, despite putting 20 baits in the simulator with a discharge of only 5 litres a second. Again this low concentration highlights the importance of dilution. I also found that kōura consumed the

baits. Indeed, one individual ate almost half the bait, which I thought was quite interesting, but no mortality was observed, and their behaviour seemed unchanged. I did not interview them because I can't, but they looked and behaved perfectly okay!

What is important to note is that over 1, 2, 4 and 8 days the 1080 concentration in the koura viscera and muscles decreased, suggesting that kōura metabolised and excreted the ingested 1080. This is a well-documented physiological response of many animals which consume sub-lethal doses of 1080: they metabolise and excrete it. I was happy with these results as they confirmed the results of other studies of 1080 on other animals, in terms of the ability of animals to consume sub-lethal doses of 1080 and metabolise it.

I also found no 1080 in the control animals. That strongly suggests that 1080 contamination of koura flesh can only arise by direct consumption, and not by animals sitting in water where baits may have landed. This result also suggests that 1080 cannot enter via the gills or the exco-skeleton.

The conclusion from the koura study showed that they are unlikely to become contaminated due to their small home range, the presence of other food which they might prefer to eat and the rapid leaching rate of 1080.

Some people are also concerned about what happens after a drop of 1080 and it rains. Does the 1080 leach out and contaminate streams? This led me to my fourth study, which was done in a small sub-catchment that was excluded from a larger aerial drop done by the Animal Health Board a few weeks prior. It was not until heavy rain was forecast that 1080 was aurally applied to this small sub-catchment.

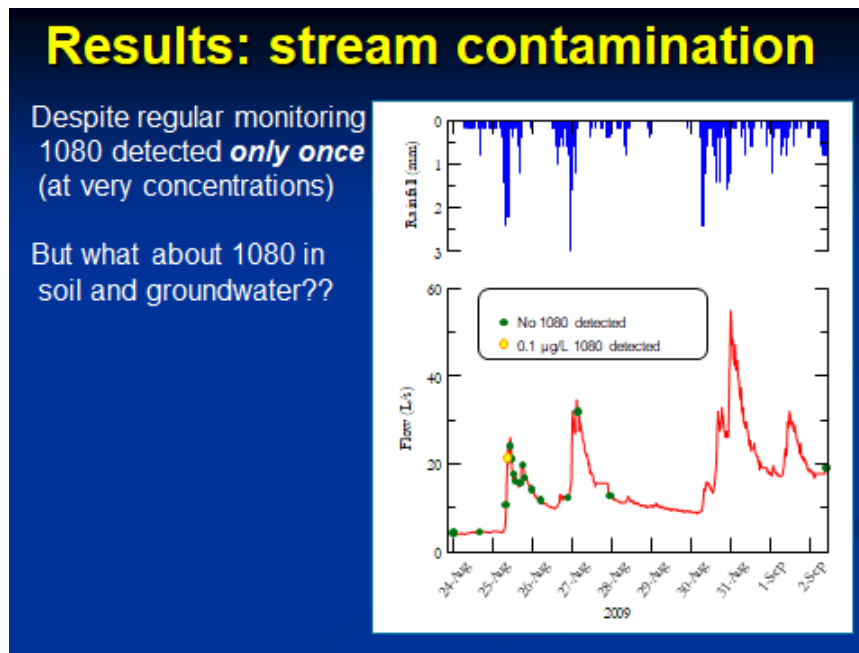
I did this work with a hydrologist at NIWA Christchurch, and we were examining the chances of 1080 contaminating surface water if 1080 was applied immediately before rain. Because the majority of the area had been subject to an aerial 1080 application a few weeks prior to our experiment, we assumed that few (if any) baits in the sub-catchment would be consumed. 1080 was aurally dropped 1 day prior to forecast rain, and we monitored a small stream, every hour for 12 hours after the start of the rain to see if we could detect 1080 in the stream. We continued the monitoring at increasing lengths of time for up to 9 days after the rainfall event. We had lots of coffee during this time as well!

These photos show the very steep country, well forested with black and mountain beech. You can also see the size of the very small stream, which was only about 5 litres a second



at base flow. Again this was done as we wanted to minimise dilution, and give us the best chance of picking up a 1080 signal.

What did we find? This graph shows the date the 1080 was dropped, at that second dot. We also collected a water sample prior to the drop to show an absence of 1080 prior to the drop. The rainfall is shown on the Y axis, and when it rained the stream flow increased. The one yellow dot on the graph is the only time where 1080 was detected, at 0.1 parts per billion. Every other sample we collected was below this detection level. I am not saying that there was no 1080 in the water, but I am saying that we simply could not detect it, even at 0.1 parts per billion. That is the limit of detection.



So, despite this very intensive monitoring during a rainfall event we detected 1080 in stream water only once, and at a very low concentration.

Finally, what about soil and groundwater, do they become contaminated? This question led us to the last study that looked at the fate of 1080 when it leaches from a bait in the catchment. Where does it go? Does it move into the soil and groundwater and eventually end up in the stream? To help answer this question we had 4 goals:

- to quantify the 1080 transport in overland flow
- to understand 1080 movement into the soil
- to examine whether 1080 enters groundwater
- to monitor 1080 concentrations in stream water

We wanted to quantify the importance of all these different pathways of 1080 and look at how long 1080 stays in the environment. We designed a somewhat ridiculous study whereby we placed 2 kgs of 1080 bait into a small area (0.4m²) of hill slope. This huge amount was applied to such a small area simply to allow us to detect the 1080, and thus determine where it goes. Remember, we were interested in assessing the movement of 1080 from baits, into the soil water, the groundwater, and the stream water; not how realistic that movement was. For some context, aerial applications normally apply 1080 at about 2.5 kilograms per hectare, so the application rate we used was 50,000 times more than operators are allowed to apply. We then did lots of monitoring of water flowing across

the soil or entering the soil, groundwater or stream. We applied the baits just prior to forecasted heavy rainfall, and collected samples throughout the rainfall period.

We ringfenced an experimental area by driving metal sheets into a slope up a steep sided valley about 25-27 metres away from a small stream which was about 3-4 metres wide. We caught any runoff from this area by collecting all the surface runoff at the base of the experimental area. We also deployed lysimeters, these big suction tubes, into the soil to sample soil water. We used a vacuum to pull the water from the soil into the tubes, and we took samples. We also installed a groundwater bore at the base of the experimental area near where we collected the stream water samples. The photos show the locations where we monitored the runoff, soil water, groundwater, and stream water. You can see that the forest floor was a mixture of fir, grasses and a few ferns. It was about 50% vegetated, 50% bare. The picture also shows the lysimeter as we take a water sample out.



Again we were lucky with the rain, and drank lots of coffee. A total of 75 mls of rain fell over a few days, equivalent to a 1 in 5 year rainfall event. Stream discharge increased and groundwater levels rose, because of the rain falling into the catchment and soaking into the soil water to enter the groundwater. We collected 95 samples during our coffee drinking experiment, but we only analysed 56 because the analysis of 1080 is very expensive. We deliberately chose those 56 samples to have the highest probability of containing 1080. These samples were all collected in the first 8 - 12 hours. Our thinking was that if we found 1080 in these samples, then we would return and process the other samples to see how long the contamination lasted for.

We found little, if any, overland flow, despite the hill slope being quite steep. More than 99% of the rainfall infiltrated into the soil water, which we were quite surprised at. We found no 1080 in the groundwater, or in the overland flow and stream samples, despite using that huge amount of 1080. The only 1080 we did find was in 7 soil water samples, of which 4 were right at our limit of detection of 0.1 part per billion.

The highest concentration we detected was 1.4 part per billion, and this was found in a shallow soil water sample 10 hours after the rainfall started. To put this concentration into context, the Ministry of Health safe limit for drinking water is 2 parts of 1080 per billion, so

we could have drunk that soil water and have been fine. After 4 days, the concentrations in the soil water had decreased even more, down to 0.3 ppb and 0.1 ppb in the shallow and deep lysimeters respectively. This simply reflected the fact that it had now stopped raining, and that water was slowly seeping through the soil, and becoming more diluted as it worked its way downhill.

To summarise these results, only minute amounts of 1080 were detected in the soil water, none in the groundwater, overland flow or stream water. This was despite the huge amount that we applied to a small area at the head of our experimental area. This result again demonstrates the huge role of dilution during rain. However 1080 was detected in soil water following leaching from baits, but only at very, low concentrations.

From these results, we concluded that surface water and shallow groundwater can become contaminated, but under a realistic scenario it is negligible.

To summarise:

- 1080 rapidly leaches from bait and is diluted to extremely low concentrations
- Leached 1080 has no demonstrable effect on fish and aquatic invertebrates
- Koura can consume 1080 and metabolise it without harm
- Aerial applications will result in only minute quantities of 1080 leaching into surface water
- Any 1080 entering soil and groundwater becomes extremely diluted – often below detection

The relevance for lake restoration efforts is quite simple, in my mind anyway. Land based applications to remove pest species are unlikely to have any adverse effects on lake ecology or water quality and finally it is highly unlikely there would be any adverse effects at all on kōura.

1080 AND THE FIGHT TO SAVE NEW ZEALAND'S WILDLIFE

Dave Hansford

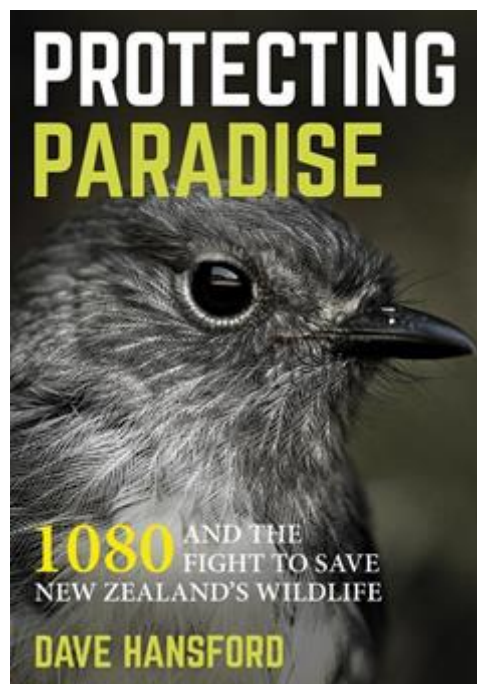
Investigative Journalist and Photographer
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Dave Hansford is an award-winning writer and photographer based in Nelson, specialising in science and environment issues. He spent 14 years as a press photographer before turning to freelance writing in 2002. He has worked as a science reporter for National Geographic News, and environment writer and columnist on The Listener.

TRANSCRIPT

Thank you for inviting me to come and speak today. I would also like to acknowledge a debt of gratitude to Alastair Suren, not only for that perfect primer to my talk but also for the fact that I cut and pasted nearly all of that into my book.

I grinned when I saw the title of the symposium was 'Troublemakers'. I am here because I wrote 'Protecting Paradise' and in it I looked at the science around 1080. I explored some of the popular myths and fallacies around 1080, those intractable fallacies that do not go away. I was so intrigued that much to my editor's concern I decided to find out why they are so intractable. Believe me that is a rabbit hole and I am going to take you as far down it as I can in 20 minutes.



- *Many poisons imbibed in parts per trillion by pregnant mothers are known to have disastrous effects on the off-spring. 1080 is one of these poisons.*
- *'From Dr Scanlon's report to the ERMA review in 2010 we learn of clusters of miscarriages, stillbirths and congenital malformations to the children of pregnant women following aerial 1080 drops. I remember the Featherstone (sic) outbreak. There was no warning.'*

This was a copy of a letter I received from a newspaper editor on the Coromandel recently. There has been a rash of these. It continues:-

- *'If you live in Manaia for example, there is no way to prevent the streams being poisoned. All you can do is take your own precautions for yourself and for your growing children.'*

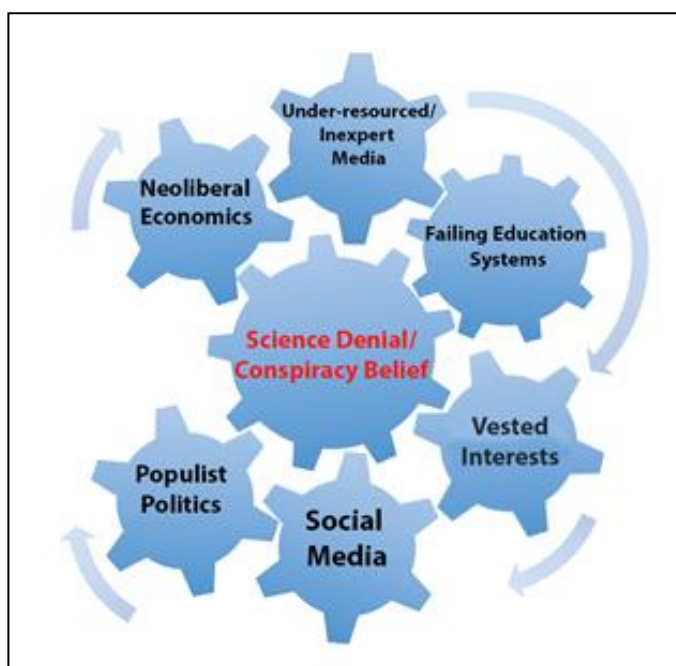
- *'To avoid dust stay many kilometers away from the area on the days baits are dropping. To avoid drinking poisoned water bring water in from outside the area for at least a year after the drop.'*

A newspaper editor sent this missive to me and said, 'Look I am trying to figure out whether I should publish this. Can you provide some comment on it?' So I duly did and I will return to that in a moment. I would like to point out, this was just written last week but it could have been written in 1980. It could have been written in 1990.

This stuff will not go away, even when Alastair has so clearly demonstrated that so much of it is unfounded. I do not know about you but I am keen to know why it will not go away. I have been thinking more about the phenomenon which people increasingly refer to as the rising tide of science denial and ante intellectualism where somebody's beliefs and opinions are recorded the same value as evidence based science. Even worse they are portrayed that way in media and most certainly on Facebook.

I will take you through some of the socio-political and economic drivers that I have concluded are helping to pour petrol on this fire of science denial and conspiracy belief. There is growing evidence that the two phenomena are very strongly linked and I will hopefully provide you with some evidence for that as we go through.

There are those two drivers that I came up with and I would be very interested to hear from others if you have some more. My favourite topic is neoliberal economics. The contention is that our present systems of governance and the way that we now harness and use wealth have contributed to the growing inequity in society and that is self-evident. You see so many figures. The growing privatisation of what was formerly the province of the state; all those core government services - health, welfare, education and infrastructure - are disappearing. The regions are feeling the brunt of this dogma most painfully. It does not help when media start running stories like this.



Westpac closures reflect bigger trend affecting small town New Zealand

JOHN ANTHONY

Last updated 07:49, August 24 2016



If the Westpac branch in Fairlie closes, the town will be left without a bank.

I want to give you my observation. When I looked at the hotspots of resistance or anti-1080 sentiment around the country there was a very clear demarcation between the attitudes of urban dwellers and those of rural dwellers. That is indisputable. So when we look at the real hotbeds of 1080 activism, the West Coast, Golden Bay and Coromandel – those happen to be the provinces that have been worst affected by what we refer to as ‘Rogernomics,’ the increasing privatisation of formerly state-run assets, neoliberal economics.

Newshub.

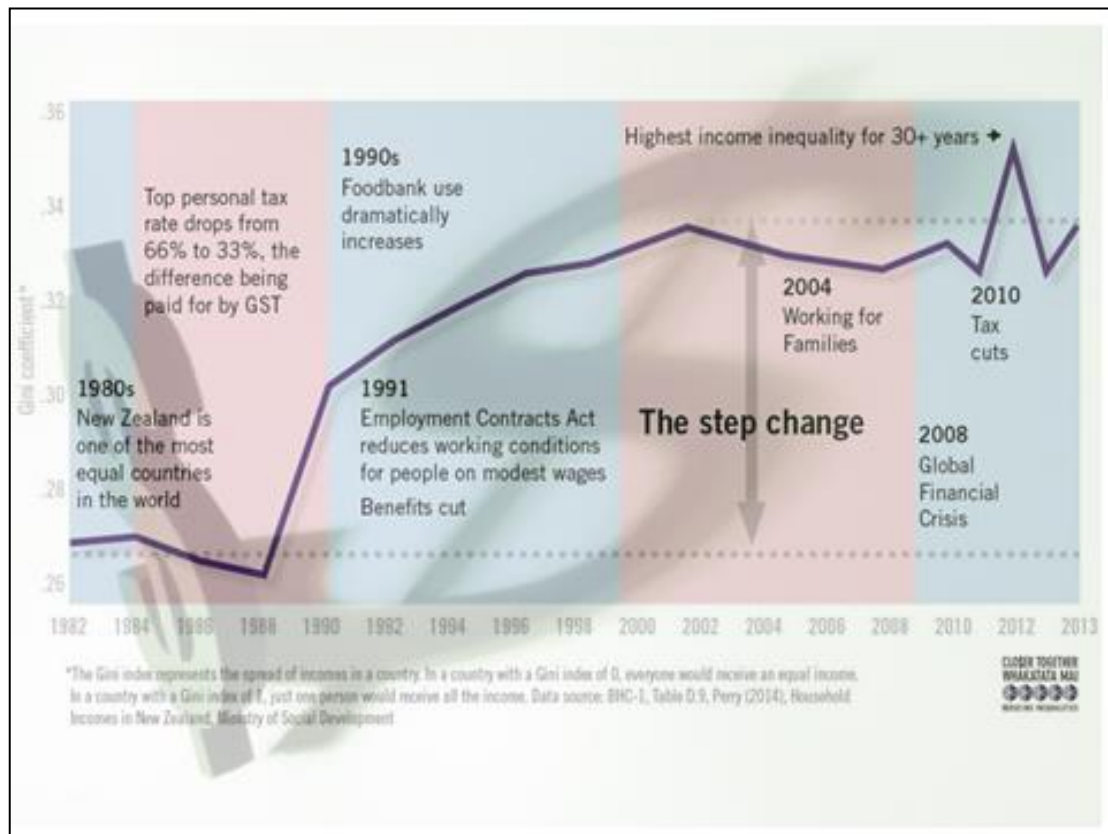
8 March 2017

HOME NEW ZEALAND WORLD POLITICS SPORT

Are NZ's small towns doomed?

28/02/2017 | By Scott Palmer





This is that step change I was talking about, the inequality. Ask yourself, ‘How could this not have a social impact? How could it not leave people feeling like the system has let them down? How is it not working for them?’ Would it be unreasonable to assume that it engenders distrust in the State, in the Government and of course in all its manifestations, all its agents, people, you and me? They seem to think I am part of the conspiracy, in the media.

This is where a lot of the growing sentiment comes from. If you have a quiet night, hold your nose and go onto Facebook and look at some of the anti-1080 Facebook pages and this is a recurring theme throughout. More than half the time 1080 takes a back seat and everybody is complaining about the ‘damn Government’. Like I say, we really should not be surprised by this.



“Fucken DOC make me so angry I could scream. I seriously hate DOC & the government so much it hurts.”

1080 Eyewitness, Facebook, 9 September 2015



This was a great study. If you are interested I urge you to look up the Leaders' Report from 2013, it was a very wide reaching study and spoke to public servants all over the OECD and makes for fascinating reading.

I talked earlier on about the purported link between conspiracy belief and science denial. Out there in the science community the jury is still out but a number of very important studies have come back with a conclusive link. I will leave that one over to you and you can make up your own minds.

Going back to people, in the absence of information, if you like, people feel like they can understand or trust. They create their own explanation for the things they see surrounding them. I am old enough to have read and relished Alvin Toffler's book, 'The Future Shock'. In it he contends that the rate and extent of change in the future will be so great that it will inevitably leave large sectors of society behind. I suggest to you these are just contentions, I am not a scientist, I am just a journo, but we may well be seeing that happening. People are now coming up with their own explanations for things that they either cannot understand, will not understand or simply do not trust.



"[T]o our knowledge, our results are the first to provide empirical evidence for the correlation between a general construct of conspiracist ideation and the general tendency to reject well-founded science."

Lewandowsky S, Gignac GE, Oberauer K (2013) The Role of Conspiracist Ideation and Worldviews in Predicting Rejection of Science. *PLoS ONE* 8(10): e75637

This is a very popular theme. In a great deal of cases there is the notion that a lifestyle is under attack, that birthrights are being stolen. That is a broad and pervasive sentiment and, as I say, of course particularly strong in the rural sector. This happened last week in a very small town but residents again expressed the same old concerns about their water supply, they were going to be poisoned and there would be effects on the unborn. You can tick them off on your fingers nowadays.

I put this slide in by way of throwing a wicked question out to you. Every time we provide an alternative water supply during 1080 drops, we reinforce the belief. I do not understand the sensitivities that local authorities face when they have to deal with these things, but it is quite a vexed issue.



"...the government is hiding the truth and misleading our people..."

1080 Eyewitness, Facebook, 16 February 2017

Council to supply temporary water supply

FRANCES FERGUSON
Last updated 13:25, August 24 2017



Ohura resident Denis Smith is disappointed the Ruapehu District Council isn't doing enough to protect the water supply.

An alternative water supply is being arranged for residents of the small Central North Island town of Ohura after concerns over a 1080 poison drop in the town water supply catchment area.

If you want to know just how far this stuff can go I have put this in for a bit of fun. Most of you have got it already but the plot is quite a pervasive theme on anti-1080 Facebook pages. There is a belief out there that the Government owns the technology to trigger earthquakes at will. What happened to Kaikoura was the Government trying to clear it out to make way for Statoil so that they could get their hands on the oil and gas.

'A lot of streams flow from that area (Kaikoura). It is almost as though the (1080) drop was orchestrated so survivors of the pre-planned quake or those on off grid blocks could be poisoned from meat or water.

Clean out the population to make a free for all for big oil or mining companies. The scam worked well for Christchurch. The dynamic duo of Key and Brownlee have their nose in the trough again.'

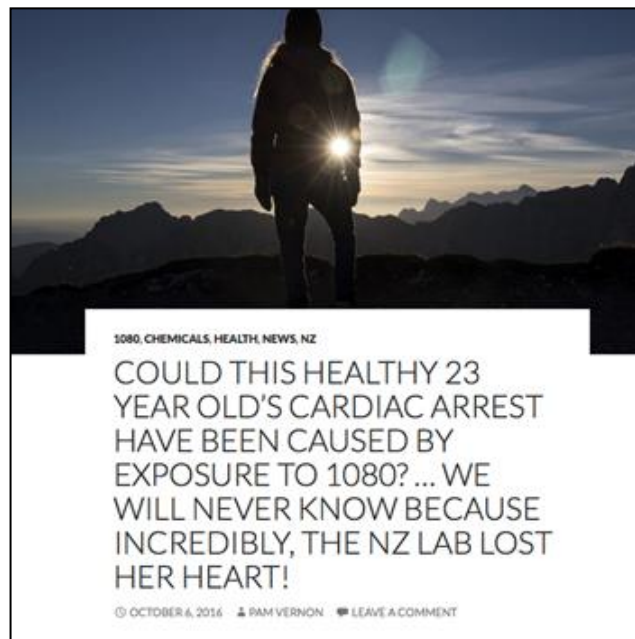
1080 Eyewitness, Facebook, 16 November 2016

Getting back to 1080, and it is quite a long bow, I could not find a 1080 drop around Kaikoura anyway, which let the theory down, but the Government is using 1080 to mop up the survivors from the earthquakes.



You cannot help but laugh at this but I am here to suggest that maybe we should stop laughing. The big contention is that we urgently need a programme of psychosocial research to help us understand what the hell is going on out there in certain sectors of New Zealand society, because it is very important.

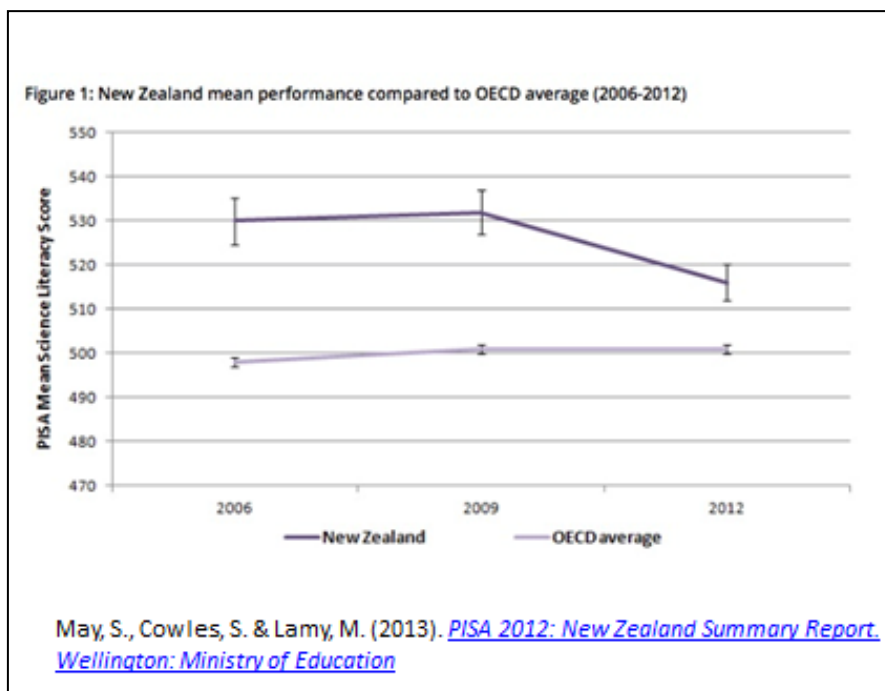
Nicki Douglas talked about collective impact and the five principles, what we need to start prosecuting broad scale public policy and respond to all major environmental challenges that face us. Lord knows there are enough of them. They have to be informed by sound evidence based science. How do we do that if a growing proportion of the populace refuses to accept that science? It behoves us to start understanding this and that is my whole point. These things are always framed as a question. I do not need to tell you that there is absolutely no basis to any of these things.



'This Government is forcing us to urbanise and be reliant on what their trade and supply offer. That's a conspiracy theory!!! But it is the only logical reason that I can come up with for what they are recklessly doing!'

1080 Eyewitness, Facebook, 16 February 2017

This leads me on to the second driver. We talked about the impact of fundamental capitalism on society and how it has left people disaffected. I want to briefly talk about our levels of scientific education. Historically we have not done too badly, hovering around the OECD average. Sir Peter Gluckman and many others have drawn the Government's attention to this inexorable slide, particularly at primary school levels. Maori and Pacifica students are struggling with Western concepts that come often couched in terms for which their own languages have no equivalent. So children are significantly disadvantaged right from the start. I wrote a story about this in 2012 and spoke to primary school teachers, many of whom had the same thing to say. They lack confidence teaching science these days and do not feel well supported. Health and Safety means they cannot do the old experiments in the lab with the Bunsen burners. It is very hard to win good practical moments with science any more.



'... In my view, school science education in New Zealand is not in terrible shape ... but unfortunately we have a long tail of underachievement and we need to be thinking now about the challenges that are emerging.'

Chief Science Advisor Sir Peter Gluckman, 2011

The media is another cog in that wheel of science denial and conspiracy belief and a subject near and dear to my heart:

'... much of the media still tend to prefer controversies. We have seen how such a situation leads to the promotion of false debate when there is in fact, largely scientific consensus.'

The Office of the Prime Minister's Science Advisory Committee, *Scientists, the Media and Society: Where Are We Now?* 26 July 2013

This is not new. We know that the media have a love affair with conflict and 1080 in particular. When I started talking about 1080 - feel free to insert 'vaccination programmes', 'fluoridation', 'contrails', 'climate change', 'folic acid' - all of these things are gifts for media. We have a responsibility to report science based issues much better than we do.

I deliberately say 'We'. This is my favourite example. These two characters, Clyde and Steve Graf, are both committed anti-1080 activists. This story went to print in the Christchurch Press saying that Steve claimed that DOC had killed 12,000 native birds in one single 1080 drop.

I interviewed him and said, 'What was the basis for this?'
He said, 'Oh well, we found 9 birds there in the snow, and then we extrapolated.'



That was a question that the Press journalist did not ask, and failed to point out that it was an unbelievably hard winter storm and birds tend to die in storms. By the way, 5 of those are blackbirds, so they do not count. The 4 natives were sent away and none of them

was found with so much as a trace of 1080 in them but the damage was done. The story was out and people read it and they thought, 'My God, 12,000 birds!' It is easy to see how bad reporting only helps to feed science denial. **Beware fake news.**



Populist politicians are another cog in the wheel, although this one may have fallen off already. Not very long ago the prospect of banning 1080 was a promise that New Zealand First made. They now deny that and I keep sending them screen shots of their own press releases to remind them that they did.

A New Zealand First politician Richard Prosser toured with Clyde Graf and Kathy White and a number of others around those very regions that we talked about with some appalling anti-science. I sat in on one in Takaka. Fortunately only 13 people showed up but he said some truly egregious things about 1080 and ecology in general. Nothing is challenged so I include this political aspect because it is another coercive force in helping to legitimise bad junk science as an opportunistic motive force.

It gets quite militant at times and this is why it matters and another reason why we should stop laughing and take things seriously because anything that can happen already has.





What are the ramifications of science denial and conspiracy belief for blue sky projects? The immediate example that springs to mind is Predator Free 2050. I come from Nelson where we witnessed the most appalling spectacle of a small group of committed anti-1080 activists being able to capture a community group in Nelson by legally challenging the Brook Waimarama

Fence Sanctuary proposed aerial drop of poison. They have done an excellent job of doing real harm to that community project. The bill for the Sanctuary is now close to \$100,000 and it has gone to the High Court, having already been to the Appeal Court. They lodged an injunction, which was finally thrown out yesterday, but there is still an appeal and they talk of going to the Supreme Court.

There is a very real cost in practical terms to science denial, and particularly organised science denial. In my view, if we are going to achieve Predator Free 2050, we need a couple of game changes. One of them is almost certainly gene editing, a massive opportunity. It also carries some risks, but we must be able to make decisions on those 5 platforms and one of them must be evidence based science. We need to know what we are up against.

This is another cost and we see more of this now. I outlined a chronology of measles outbreaks in Auckland in my book. They were all in very recent history and none should have happened.



'We are at the most dangerous moment in the development of humanity ... Right now we only have one planet, and we need to work together to protect it.

'To do that, we need to break down, not build up, barriers within and between nations. If we are to stand a chance of doing that, the world's leaders need to acknowledge that they have failed and are failing the many.

'With resources increasingly concentrated in the hands of a few, we are going to have to learn to share far more than at present.'

Stephen Hawking, The Guardian, December 2016

I will leave you with Steven Hawking. At this point somebody usually puts a hand up and says, 'What do we do about it?' That is where I struggle because this science denial has been putting down hard roots for more than 60 years. We need an epic socio-political game changer to start turning it around.

If we start attending to those cogs around that central wheel we need a system of governance that re-empowers people, makes people feel like they count, and their decisions and choices will have an outcome. They need a grand vision. We made the mistake with climate change of getting bogged down on articles of science and facts. Facts on their own do not win arguments. Narratives do. Trump proved that. He had no facts going into that electoral campaign and look where he is now. We have got to learn from that.

When we talk about Predator Free 2050 we must not start off by saying, 'Listen, gene editing will be perfectly safe.' We talk about flocks of kaka. We talk about the fact that tieke are already nesting in people's backyards now in Te Aro in Wellington. People must feel they want to subscribe because every study that has been done only reinforces the suspicion that if you try to counteract somebody's belief with facts, all they do is double down. You attack them, because their beliefs are their identity and you are also attacking their tribe and affiliation, which, it turns out, is way more important than evidence or facts or reality. We need to get a better handle on these social dynamics and understand what motivates people, what frightens people, why they choose to invest all of this in belief rather than critical thought. We need to find a way to turn it around and I suggest to you we could start making society a little bit fairer.

Recently Maggie Barry gave a speech and said, 'In terms of the anti-1080 naysayers, we are just going to have to leave them behind.' I would suggest to you that a lot of those people are naysayers because they have already been left behind.

Thank you.

CASE STUDY – HUNUA 1080 PROJECT

Mace Ward and Rachel Kelleher
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Mace Ward is General Manager Parks, Sports and Recreation, Auckland Council. The Parks Sport and Recreation department of Auckland Council is responsible for 4000 parks (45,000 hectares), 42 pools and leisure centres, sport and recreation management, and the administration of co-governed land, including the Tupuna Maunga. The department seeks to inspire Aucklanders to be more active, connect to nature, provide outstanding park destinations, conserve natural and cultural heritage and increase Auckland's Maori identity.

TRANSCRIPT

Kia ora mai tatou

Thank you very much for the welcome. You will notice that there is more than one of us. I am very pleased to have one of the real people who led the case study that we will talk about. Rachel Kelleher is the Manager of our Regional Parks in Auckland, all 27 regional parks across 40,000 hectares with 6 million visitors. The Hunua Ranges (Kohukohunui) regional parkland is what this case study focuses on.

I want to start by acknowledging Dave Hansford who is a hard act to follow. Mayor Goff's vision for Auckland is to be a world class city and the contribution of parks and open spaces and the intrinsic natural and cultural values of parks and open spaces are integral to that vision. It is not all about infrastructure. It is about people and how they feel about their environment and community, a different sort of prose than Dave talked about. Rudyard Kipling said when he came to Auckland in 1891, 'Last loneliest, loveliest, exquisite and apart.' He was talking about Auckland but he could have been talking about anywhere in New Zealand. He described Auckland as 'a very beautiful city, perhaps the most beautiful I have ever seen'.

We had a problem. We had some troublemakers, rats and possum numbers in the Hunua Ranges parkland, an area that is significant ecologically and provides 65% of Auckland's water supply. It is our largest contiguous area of indigenous forest in Auckland with a significant connection to Tikapa Moana, the Hauraki Gulf. How were we going to deal with that? We had a long term programme in place but needed a game changer.

We will talk today about the history, how we took the problem to our elected members, our partners, Iwi and our community. We needed to share our vision and what we were going to do with our community. It was not necessarily about the science. We knew the science. We knew the problem and we knew how to deal with it. There were some options in how to deal with it but we needed to work with the community and to think about the narrative of what was talked about this morning, mokopuna. What was our legacy going to be? Were we happy to see the Hunua Ranges decline to a point where it was an unhealthy environment feeding and nurturing Auckland? Lastly we will talk about measuring success, celebrating those successes together with the community and continue talking to them.

Without further ado I will hand over to Rachel and we will share some of this presentation.

Rachel Kelleher

Picking up on a comment of Dave Hansford, one thing that we did right from the outset when planning this operation was not to talk about it as a pest control operation. We talked about it being a programme to create a ‘healthy Hunua’, very much focussing our discussions around the outcomes and what we were trying to achieve as opposed to focussing on the methods and the way we were going to get there.

Hunua Ranges / Kohukohunui

- 17,000 ha Regional Park
- 4 Reservoirs – 65% of Auckland’s potable water
- Approx. 300k visitors annually



Very briefly, the Hunua Ranges is the dark green dot down there at the very bottom part of the Auckland region on the east coast, a 17,000 hectare regional park. What made this particular operation quite bold from a political perspective was that it contained four reservoirs that supply 65% of Auckland’s drinking water. So a decision to use aerial 1080 in a catchment like this is one that has some controversy and requires a really good conversation. There are approximately 300,000 visitors annually undertaking a whole range of activities, mountain biking, walking and tramping. I found out through the operational planning that we have a small bore musket group and a whole range of other things as well as hunting.

History of pest control

- Started in 1994 with “Rod and Rachel”
- 1080 applied in 1994 and then not repeated
- Trap and bait stations



The Hunua Ranges are a fantastic forest ecosystem, in fact a whole range of different ecosystems – coastal, forest, wetlands right up to cloud forest in some of the higher altitudinal areas. There is also our only naturally remaining population of kokako in the mainland Auckland region. The pest control work started with a programme back in 1994. It began with Rod and Rachel, not me, a different Rachel. There were some ornithological surveys carried out in 1994 looking at the kokako and they found a significant decrease in the numbers of birds present.

That prompted a census; a survey exercise to determine that there were five breeding pairs still persisting in the range. They thought that was not great but better than nothing. They instituted a ring of steel around those breeding pairs, setting up a trap infrastructure and waited with bated breath to see how pest control using 1080 would help the breeding of those pairs. It did not go too well as they did not successfully breed. That prompted looking at why and they found that of the low numbers there were four male/male pairs and only Rod and Rachel were a female and male pair.





That began a real journey of recovery. A lot of pest control has gone into bringing that population back from the brink to now. It is looking like it is going to achieve, even exceed its projected targets for population recovery. We have had to do a bit of work bringing in new genetics and but that is one of our success stories.

Pest control is largely trap and bait stations. There is an intensively managed area of about 1,700 hectares where we focus on protecting kokako. Outside of that 1,700 hectares, across the broader park, we have an annual programme of pest control focussed on hotspots but never covering the whole range. It has been a moving pattern of pest control using ground based methods.

The catalyst for change was our extremely high rodent and possum densities. We do a lot of monitoring in the Hunua Ranges to inform our management, particularly around the kokako. We had a mast year which people may be aware of as a result of DOC's Battle for the Birds Programme that got a lot of media attention. It was prompted from mast year events that happen in the South Island but similar things happened in the North Island as well.

The catalyst for change

- Extremely high rodent and possum densities
- Mast year
- Current methods no longer effectively reducing pests
- Desire to reduce reliance on brodifacoum



The current methods were no longer effectively reducing pests in our intensively managed area. We were struggling using methods that had been quite successful up to then to get our pest densities down. This was not surprising because when using anything for a long time there is resilience or resistance from the pests being targeted with those methods. We were also interested in looking at reducing the reliance on brodifacoum which is a commonly used pest control toxin. It is readily available, publicly accessible, but known to have impacts in terms of aggregation through the food chain.

Mace Ward

Process for Change: My job was to provide the leadership to talk to our elected members, iwi and our partners about this real need for change. We did some stakeholder surveys, canvassing our community to find what their interest was. We were able to tell the science story with comprehensive monitoring and technical review from others. We undertook a planning assessment of what we needed to do and ran a workshop with technical experts to share the knowledge with our community and partners including Iwi. Finally it went to the Regional Strategy and Policy committee in October 2014 for them to make a decision on the change of methodology, in a room that was quite hostile which was quite uncomfortable at times, but well worth seeing through. It was about telling the narrative of what we wanted to achieve - a healthy Hunua with kokako, reintroducing kiwi after 50 years, which we did achieve this year.

Why we chose 1080? Because 1080 effectively kills the target species we were after on this occasion – possums, rates and stoats. It was applied with minimal disturbance and impact to the natural environment. Unlike other parts of Auckland, the Hunua Ranges are kauri dieback free. For us to do that with a trapping network, which was an important discussion with Iwi in particular, we would have had to cut hundreds of kilometres of tracks, over 600,000 traps, to effectively do the same work. The adverse effects on species of non-target wildlife are known to be outweighed by the benefits of controlling the pests. We had to keep our eye on the prize and the risk to human health and community was minor and managed through strict national guidelines and requirements particularly in the context of the operational area being a water supply catchment. The design of our programme took that into account as well. It was cost effective at the landscape scale of over 20,000 hectares for the same price as partial control. Not only were we able to treat our land, we were able to include 4,000 hectares of other land around the parkland and that was quite important.


Key Partners:

- *Water Care Services.* Their objective is to provide clean, healthy water supply to Aucklanders. The water that comes from the Hunua Ranges does not have a lot of treatment, unlike the water from the Waikato River, and it is gravity fed into Auckland.
- *Department of Conservation.* We treated their adjoining land and private land
- *Waikato Regional Council.* Two thirds of the park, around 8,000 hectares, is in the jurisdiction of Waikato
- *Manawhenua.* Kohukohunui is a significant site. There was significant discussion with seven Iwi and tell the story about what we wanted to achieve. The environment was key and they weighed up the choice of rats or kokako and returning the kiwi to the Hunua Ranges and they chose the latter of returning those treasures and using 1080.

Manawhenua Engagement. In Auckland, like some other regions around the country, we have 19 Iwi and 7 have Manawhenua or Kaitiaki status in the Hunua Ranges. Engagement was really important and had to be open and honest and we needed to

listen. At times we left Iwi alone in the room to make their own decisions. Hui, workshops, site visits with elected members, building trust and confidence and the support given was for kokako in favour of rats.

Iwi	Organisation
Ngāti Paoa Iwi Trust	Ngāti Paoa Iwi Trust
Ngāi Tai Ki Tāmaki	Ngāi Tai Ki Tāmaki Tribal Trust
Ngāti Tamaoho	Ngāti Tamaoho Trust
Ngāti Whanaunga	Ngāti Whanaunga Incorporated Environment Unit
Ngāti Maru Rūnanga	Ngāti Maru Rūnanga Incorporated
Ngāti Te Ata Waiohua	Te Ara Rangatu o Te Iwi o Ngāti Te Ata Waiohua
Tainui – Waikato	Waikato Tainui Te Kauhanganui



On the morning that we had the first drop, a number of Iwi were up there at dawn with us and they said, ‘Last time we were here we were probably chasing each other around with taiaha.’ But I have nothing to prove that that was the case.

We developed a cultural awa monitoring plan and since then we have been doing a lot of work to develop a Te Mahere Hononga Māori – Māori Relations Plan, to strengthen the relationship in the Hunua Ranges.

This was guided by two objectives:

- a) To sustain the mauri (life force) of taonga within regional parks in ways which enable the significant place of tangata whenua to be acknowledged and their role as kaitiaki recognised.
- b) To contribute to the hauora (long-term wellbeing) of tangata whenua, by providing for relationships and activities which enable the intergenerational transfer of tangata whenua knowledge and practices.

We also have an operational plan for track clearing and water sampling. We took the opportunity to develop a Kaitiaki cadet programme, involving people from Manawhenua and part of the success of the project.

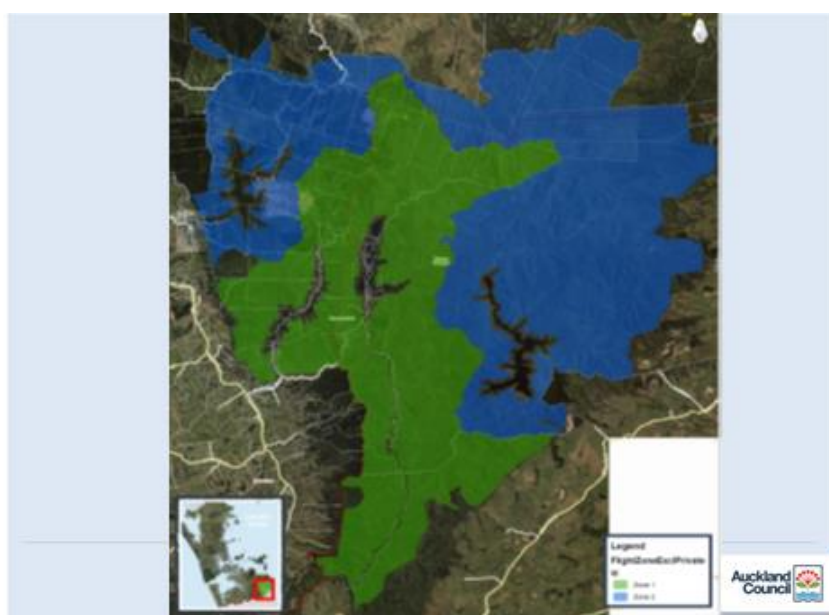
Rachel Kelleher

The Operational Programme. We did a huge amount of work to get the message out. We had a website that received over 5000 dedicated views, press ads, fact sheets, paid advertorials, interpretive signs, and warning signs. At one stage I counted how many pieces of dedicated communication we had, and it was over 23 with landowners adjoining the operation specifically that mention the risk to dogs. We did a lot of work with our adjoining communities and the wider Auckland public.



The operational area was 21,500 hectares and included Council park land, DOC and private land. We ended up developing an operational programme that, in a large part, managed perception of risk rather than actual risk. Listening to Dave Hansford and Alastair Suren's comments, there is a question as to the extent to which we should manage perceptions. However, given that this was the first aerial operation we had undertaken in 20 years, we felt that it was prudent to do a robust operation that would give us good information to present back to the community for future conversations.

There were two treatment blocks and that enabled us to isolate the water supply in one treated block while we work in the area that was being treated. It allowed that water supply isolation. We used pre-feed of 1.5 kilos per hectare; the toxic sowing rate is 2.5 kilos. We had a range of measures to manage risk including exclusion zones, setbacks around the reservoirs, a water monitoring programme, track clearance of forestry roads and amenity areas and infrastructure checks like rooftops, water disconnection and reconnection. Regional parks have a lot of infrastructure.



This map gives you an idea of what the operational area looked like. There were two operational blocks from a practitioner perspective, probably not ideal for flying a helicopter around that kind of shape but it was to enable the isolation of the reservoirs pairing up the smaller and the larger reservoirs with each other so that we did not have two small out and two large together.



The photo shows what one of those reservoirs looks like in part of that catchment. The operation was undertaken in two parts and these shots came from the actual operation to give you an idea of what is involved.

The operation

30 July
Pre-feed of block one with non-toxic cereal baits.

21 August
1080 applied to block one and pre-feed of block two.

14 September
1080 applied to block two.

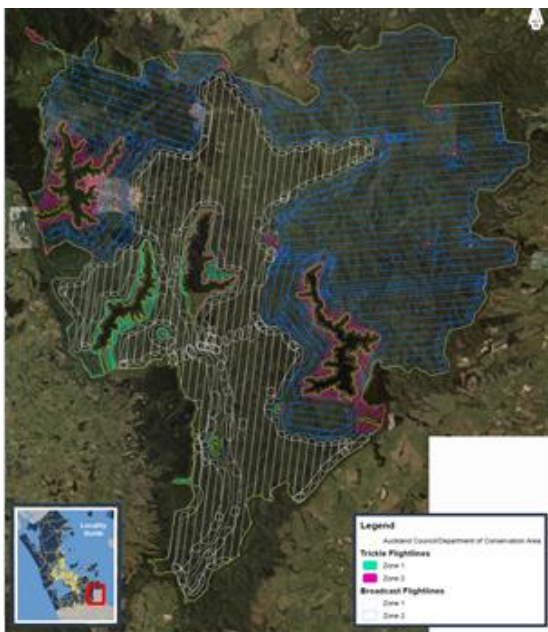
21 September
Parkland reopens.



This was the Blessing of our first bait application and the photo on the top right was taken from a viewing platform that we have overlooking one of the reservoirs that I showed you.



In our flying sites we had a couple of different helicopters working with two different buckets. One was a trickle bucket which trickles bait out in a very precise way and used to apply bait around the margins of the reservoirs and the perimeter of the operational area. The green buckets was used as a broadcast way of infilling that operational zone.



This is a print out of the operation showing how accurately the information is captured about where bait has gone. The broadcast bands are much wider in white and blue and the trickle lines are in purple and green around the reservoirs and the perimeter of the operational area.

We captured that information in live time down at the operational loading site. As a helicopter came in we would download the track log information. We knew at that point in time exactly where they had been, whether there were any issues with where the helicopter had applied bait and also good information about how to base our track clearance programme and when staff could start to move into the site to collect water samples.



One of the biggest challenges we had was the track clearance programme. From a public health perspective the largest concern our Medical Officer of Health had was about exposure of young children to bait on track. We had an extensive track clearance programme with multiple staff going out. On one day we had up to 70 staff out on site clearing tracks. We also had assistance from our neighbouring Waikato Council, which we were very pleased to have, volunteers and members of the Manawhenua came and helped as well.



These are examples of what we saw out on the day. There were also a lot of animals out the next day showing signs of lethargy having consumed the bait. The fact that we saw so many possums out the next day was testimony that there were a lot of possums out there. I have done a lot of these operations and you do not usually see heaps of animals out the next day but we did in this instance. Searching for bait the next day was like looking for a needle in the haystack, but once you get your eye in they are quite obvious, particularly in open track environments.



Water monitoring. We had four reservoirs of about 500 hectares in size. We also developed a programme of monitoring across 14 streams and rivers of variable size, some quite small to those much wider. A criticism of water sampling programmes is that often samples are collected around a 24 hour timeframe. Those who have concerns about these types of operations say that is not soon enough to detect 1080 if it is present. I am not sure what the benefit would be. If you get to 24 hours not detecting 1080 then you are not detecting it! So we did collect samples right from 4 hours after the operation through to 4 weeks. We did have one heavy rainfall event after our first operation and that constituted a whole new testing regime.

Over 300 samples were collected. It was the largest sampling programme that has ever been carried out for any single 1080 operation and not a single detection of 1080 from any of those 300 samples.

Post control pest monitoring results

Result Target	Treatment Block	Result	Monitoring line details
Less than 5% Residual Trap Catch (possums) for treatment area	Block One	0.25% ((-0.04% - 0.54%) +/- 0.29%)	40 monitoring lines 400 traps 1200 trap nights
Less than 5% Residual Trap Catch (possums) for treatment area	Block Two	1.00% ((0.45% - 1.55%) +/- 0.55%)	50 monitoring lines 500 traps 1500 trap nights
Less than 5% Tracking Tunnel Index (rats) in Kokako Management Areas (KMA and Piggots)	Traversed both blocks	0%	10 monitoring lines 100 tracking tunnels
Significant reduction in Tracking Tunnel Index (rats) across wider treatment area (pre-operational result 91.6%)	Both Blocks	1.03%	29 monitoring lines 290 tracking tunnels

These are our results. We did extremely well achieving well below our targets for all the pests we focused on. Possums and rats were both below 5%.



We did an extensive programme of breakdown monitoring, monitoring both carcass and bait breakdown in real time to inform the reopening of the park for dogs in particular. We were able to say with confidence that there was no risk posed to dogs at the time that we declared the site free of any issue. When we lifted the caution period it was based on practical information rather than theoretical information. This gives you an idea of what that looks like.



We had a range of different outcome monitoring - kokako nesting success, general forest bird monitoring, vegetation photo points, Hochstetter's frog and the long-tailed bats. The six pairs of kokako are monitored annually. In 2014, before the operation, no eggs hatched and adult birds were predated. In the 2015 and most recent 2016 breeding season we have had 13 chicks of each of the six monitored pairs which is the best output that we have had.

The challenges - Park closures, vandalism, protests by a small dedicated group of about six people, one confirmed dog death that happened despite those 20 plus pieces of communication, offers of emetics and also free muzzles that staff were available to help fit, which were declined in that instance. We also had graffiti around the place but all in all a fairly minor impact.

A few facts and figures

- *8: the number of signs/barriers ignored by one trumper the day after bait application. We closed the park and had a whole range of different ways of closing it. This person decided it was a good time to go for a tramp because it would be nice and quiet and he felt like a bit of solitude and knew he would not meet anyone on the day. He had gone past eight different barriers to get where we found him.*
- *5: the number of dogs caught by staff inside the operational area unaccompanied by owners, Lucky for those dogs, staff were able to catch them and they were safely moved outside the operation. But in all instances the owners knew the operation was happening, thought their dogs were secure but they were not.*
- *>1100km: covered by track clearance teams across a number of days.*
- *0: the number of rats and mice detected following three successive monitoring periods of our kokako management area after the operation. We got over six months of no detection of rats, mice and possums in that area.*
- *1: the first nest and fledged chick outside the intensively managed areas*
- *5390: dedicated website views*



Thank you.

THE NUTRIENT IMPACTS OF FORESTRY

Peter Beets

Scion

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Peter Beets has worked as a research scientist at the New Zealand Forest Research Institute since 1974. He has research interests in:

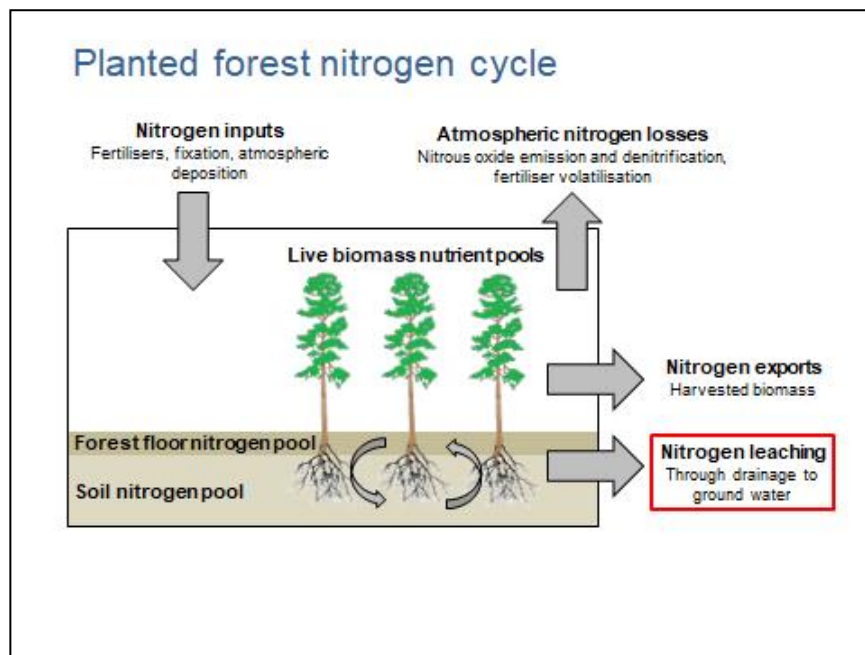
- *Measurement and modelling of carbon stocks and changes in planted and natural forest*
- *Modelling stand productivity, water-use, and nutrient cycling in *Pinus radiata**

TRANSCRIPT

Good afternoon ladies and gentlemen. Kia ora

I have had a long history in forestry and it started early as I was raised in a little place called Kaitawa at Waikaremoana. I roamed in the bush when I was a little kid and I have not lost the enthusiasm for trees and forest.

I have been working on New Zealand's Land Use and Carbon Analysis System (LUCAS) for the Ministry for the Environment to quantify carbon stocks and changes for planted and natural forests. I originally started at Scion when it was called the Forest Research Institute working on tree nutrition. It is relevant for me to discuss this topic now because after we put the carbon models together I was able to come back to tree nutrition. I was amazed to find the papers we published years ago were still in journals and not incorporated into models that we could use for tree nutrition. I suggested to the managers that it was time for me to put away administrative things and managing projects and focus on reading all those publications, not just from Scion, but other agencies too and put them into models. We are making progress.



A model is just a representation but to understand what happens in a planted forest you have to remember that they are very dynamic. The title was 'Forestry Impacts', which means a management component. We know that trees are planted, they grow, they accumulate biomass and nutrients that cycle around and you can see that in the flow diagram. There are nitrogen inputs coming from the atmosphere and nitrogen taken up from the soil, which accumulate in live biomass and dead matter in the forest as it grows. Some nitrogen can be exported in harvested logs but how much of that nitrogen in the forest ecosystem can leach?

There have been reviews of factors that influence forest nutrient cycling and leaching losses and what the forestry impacts are. Davis (2014), and Baillie and Neary (2015) showed that land use history is one of the important things to consider when looking at forestry's impact. It may be different from what you might expect but the fertility of the site is key. When trees are limited in terms of nutrition they take up nitrogen very efficiently. You do not expect nitrogen to leach out of a forest plantation that is short of nitrogen.

**LU history - unimproved shrubland with C/N = 24:
N & P loss to ground water are minimal**


Knight and Will (1977), Warsnop and Will (1980) - lysimeter drainage water quality, Kaingaroa Forest, Pumice soil

Parameter (loss kg/ha/year)	Age 1-3 years after harvesting	Age 6-12 years	Age 14 years (2 nd year after fertiliser applied)
NO ₃ - N	4.8	0.0	0.006
NH ₄ - N	0.0	0.0	0.005
PO ₄ - P	0.096	0.007	0.0

Rainfall averaged 1500mm
Drainage occurred Sept/Oct each year, and commonly in June-Oct

200kg/ha of ¹⁵N enriched urea applied Feb. 1975 (13 year trees)

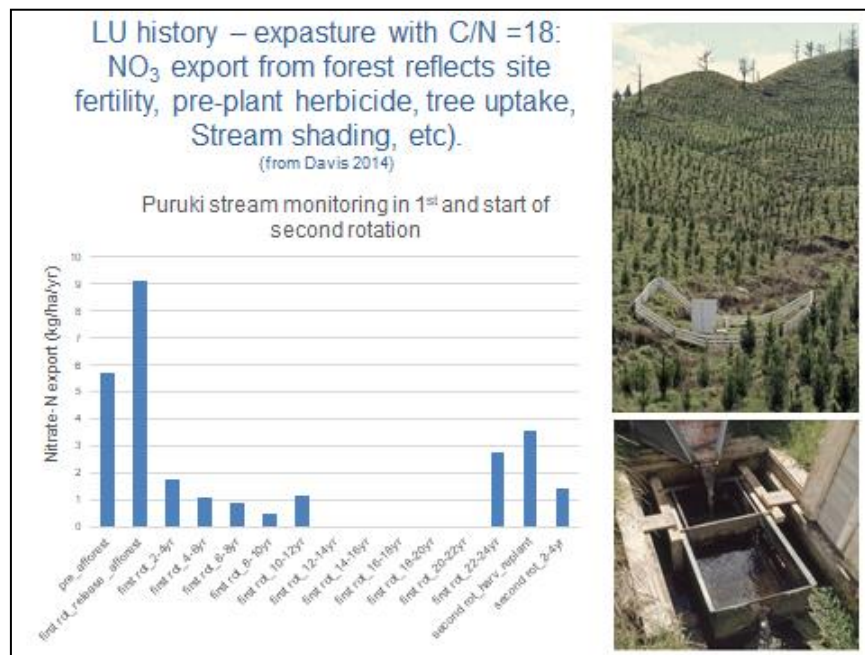
- Monitored for 3 years: virtually no N leached to groundwater
- NH₄ - soil elevated in week 1 (maximum in week 4)
- NO₃ - surface soil elevated in week 2 (persisted for 3 years)
- Week 2: 90% of N recovered in forest floor/soil to 30cm
- Week 4: 80% of N in floor/soil, and 50% after 3 years
- Timing and method of application minimized losses
- Trees accumulated 100kg fertiliser N/ha - demand > supply



The Kaingaroa Forest is an example of a forest not overly rich with nitrogen. It has had a history of shrubland (not a farming history) so nitrogen availability is quite low. A lysimeter study that collected water draining from the soil under the forest showed that zero nitrogen leached from this forest once the tree canopy had fully developed. The tree demand for nitrogen is too high at that stage to allow nitrogen to escape. This lysimeter study also showed that even after nitrogen fertiliser was applied to the soil to improve tree growth, hardly any nitrogen leached from the soil. For nitrogen to leach there has to be water draining from the soil. The fertiliser was deliberately applied in summer (February), when trees use lots of water, and soil moisture storage capacity was sufficient at that time to prevent drainage from occurring. So even though there was nitrogen as nitrate in the soil surface, it did not leach. Nitrogen moved deeper down in the soil profile but we also know how deep roots are. The rapidly growing trees had sufficient time to take up this nitrogen.

When tree growth is interrupted following a harvesting operation suddenly there is a completely different ecosystem. New trees are planted but their nutrient requirements are initially very low and nitrogen levels in the soil water increase. All sorts of weeds grow back rapidly, using some of this nitrogen, and there is spraying to control weeds. Tree evapotranspiration is low because there are hardly any leaves on the young pine trees in the first few years. Evapotranspiration is the amount of water the pine forest is using. Drainage therefore increases following harvesting and more water moves down through the soil beyond the reach of tree roots. The newly planted trees do not take up all of the available nitrogen so some nitrogen leaches at that stage.

A very fertile site is quite a different story. Does the supply of nutrients exceed the requirements of trees? If it does that excess nitrogen is not used and will leach under the type of soils that we have.



Here we see a little data series of stream nitrate exports when a fertilised pasture catchment is converted to pine forest. These are called land use history catchments. The Puruki experimental catchment was set up as part of the international hydrological decade. There were several catchments in this 1960s study, and this site has been monitored almost continuously since that time. Where the young pine trees are growing used to be pasture. There is an adjacent catchment left as pasture. There is also a native forest catchment there so it is a very interesting study.

There were lots of agencies that worked here including NIWA and scientists at the Water Quality Centre. A lot of data was collected. Interestingly in those days researchers seemed to be partitioned in what they were allowed to do. The Water Quality guys worked on streams and measured the quality of the water. We were forestry people and our focus was on measuring the forest. It is curious now because, as we have heard over the last few days, what goes on in the land determines what is going to happen in the water. One wonders why the separation. The good thing about this study was that it was an interdisciplinary interagency programme and allowed us to talk to each other and find out what was happening. As the data was collected there was plenty of discussion going on.

The graph shows that stream water nitrate levels vary markedly over time. The series begins pre-afforestation when the catchment was still in pasture, continues after tree planting, and ends after harvesting and replanting of the catchment. The area was sprayed prior to planting the trees, to release them from competition, and there is an obvious pulse of nitrate in stream water at that time. You all remember what happened at Hubbard Brook¹ don't you? If you keep on spraying, a lot of the nutrients will leach out. Then the trees grow quickly and there is a rapid reduction in the nitrate in stream water. Unfortunately there was a gap in the record. Water Quality monitoring commenced again just before the trees were harvested, when it was apparent that nitrate nitrogen in stream water had slowly increased as the trees became mature. This time series indicates that forestry has different effects at different times in the rotation. It is not just 'here is a forest effect and there is a pasture effect'. In a managed forest, tree requirements for nitrogen change over a rotation. Nitrate nitrogen that is not being taken up leaches from the soil and drains into the stream.

When the harvesting operation occurred, this tree age-related pattern repeats itself. Interesting pattern isn't it? To understand it, in the next few slides we will look at the nitrogen cycle in a managed forest more closely, but before doing this, one more piece of research is helpful to consider.

LU history – ex-pasture with C/N =18:
Soil water versus stream export (1984 with 11yr old pine) of
N, P, and ratios for pasture versus pine
(from Cooper and Thomsen 1988)

Land use	Parameter	Soil loss (in springs) kg/ha	Stream loss (catchment baseflow) (kg/ha)	Stream loss (catchment total flow) (kg/ha)
Purutaka pasture	NO ₃ – N	8.1	0.29	1.19
	DKN	0.15	0.72	2.62
	Total N		1.15	11.95
	DRP	0.13	0.037	0.37
	Total P		0.122	1.67
	TN/TP	63.5	9.4	7.2
Puruki pine forest	NO ₃ – N	1.23	0.4	0.55
	DKN	0.43	0.19	0.52
	Total N		0.63	1.31
	DRP	0.07	0.017	0.038
	Total P		0.038	0.095
	TN/TP	23.7	16.6	13.8

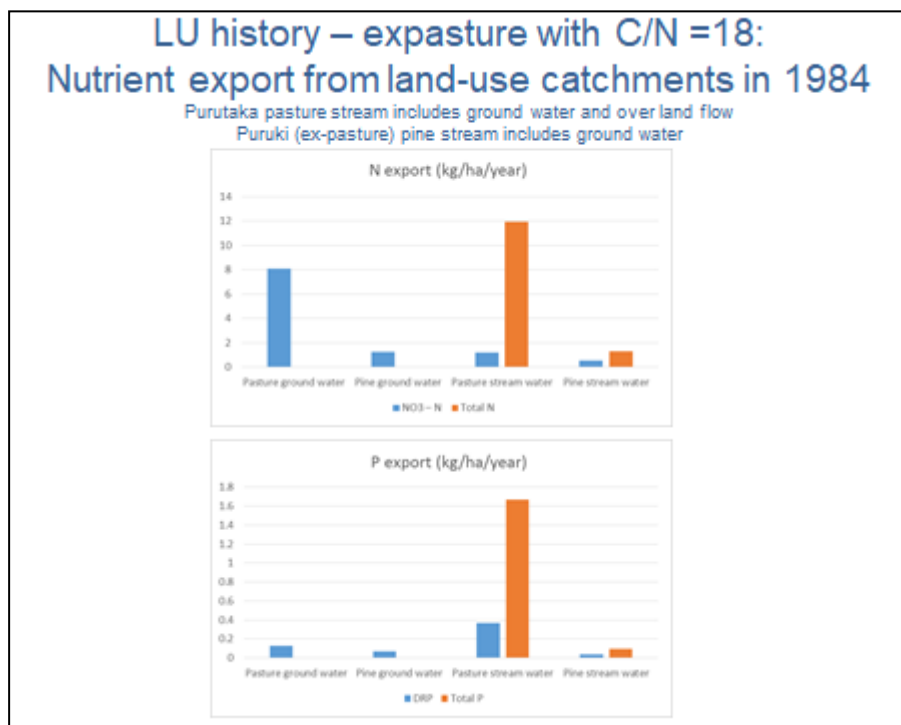
¹ <https://hubbardbrook.org/> At the 8,000-acre Hubbard Brook Experimental Forest in New Hampshire, long-term studies of air, water, soils, plants, and animals have produced major discoveries about human and natural disturbances to the forested landscape of the northeastern United States. In a collaborative research project spanning nearly six decades, scientists have discovered the existence and origins of acid rain; unlocked the mysteries of lead, salt, and nitrogen pollution in streams and lakes; and charted the rise and fall of bird populations because of climate change and other threats. Research findings at Hubbard Brook provide the raw material for education and policy-outreach programs that deliver authentic data to students, policymakers, and members of the public who care deeply about our natural world. Hubbard Brook is much more than an ecological field station in New Hampshire—it represents a new paradigm of 'ecosystem thinking' that has changed the way we understand how nature works.

The previous slide is the work that Bryce Cooper and colleagues did showing soil (ground) water versus stream water export of nitrogen and phosphorus at Puruki. The trees were 11 years old at the time they did this study which showed that ground water draining from a pine forest catchment (that used to be pasture) contained much less nitrate than ground water draining from an adjacent pasture catchment. Why is that? The modelling work that comes next shows that 11 year old pine require a large amount of nitrogen, most of which comes from the soil. In the stream is a different story. In fact ground water and stream water monitoring tell different stories. What is it they are telling? As water trickles down the stream channel changes can occur in the form of nitrogen.

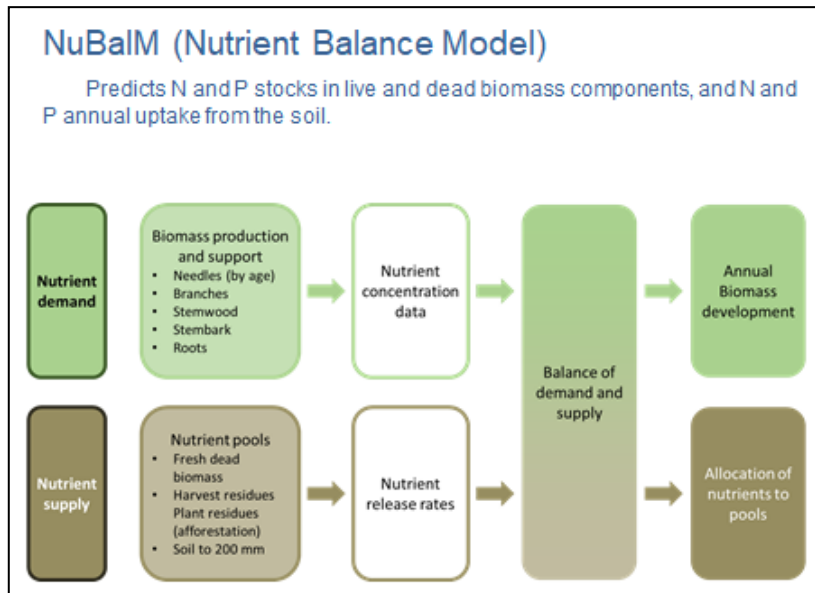
The relatively high levels of nitrate in ground water draining this pasture catchment were markedly reduced after entering the stream. That is the in-stream processing where vegetation growing in the stream channel takes up nitrate and stores it as organic matter before it even reaches the weir where measurements of nutrient exports are made. Organic forms of nitrogen from the vegetation growing in the stream channel are still exported, but this occurs mostly during storm events, which explains why the total nitrogen export from the pasture stream is high.

It is a similar story for dissolved phosphorus in ground water. However, total phosphorus export increases markedly from the pasture catchment when overland flow transports additional P, presumably from animal waste, during intense or prolonged storm events, which was not evident in the pine catchment.

Unlike the pasture catchment, forest cover largely shades out vegetation that would otherwise grow in the stream channel, and in-stream processing of the nitrate in ground water that enters the stream does not occur. Therefore the export of both nitrate and total nitrogen from the pine catchment is low, as is the export of total phosphorus.



This slide shows a nutrient balance model (NuBaIM) which has been developed for radiata pine to help explain and predict what goes on as a forest grows. We have biomass, the representation of different parts of a tree and nutrient concentrations which are needed to estimate N and P uptake from the soil. There is also dead material accumulating and decaying on the forest floor, which cycles nutrients including N and P back to the trees.



To get that kind of data you have to pull trees apart, age the needles, look at the different components such as the branches, stems and root, to work out how much requirement there is for nitrogen as a forest grows. Samples are divided into different components and analysed to look at their nutrient concentrations.

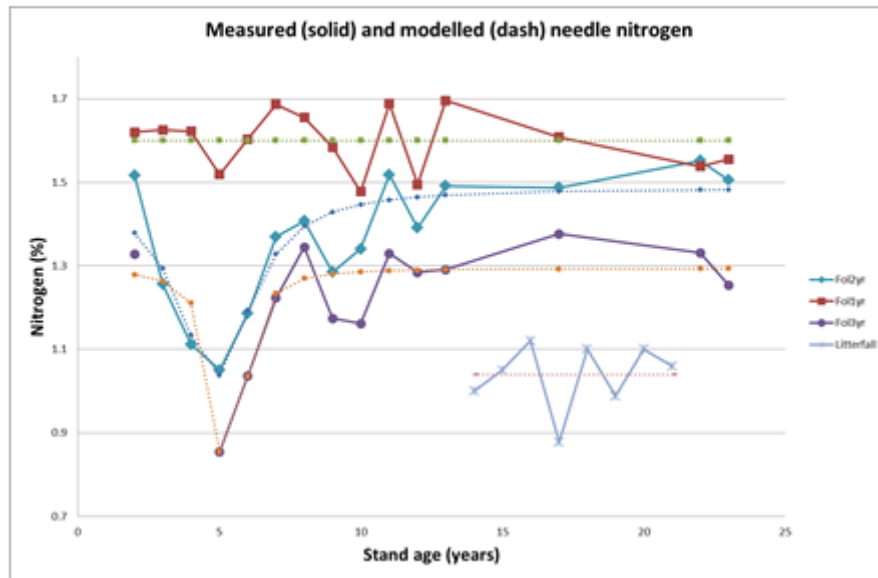
Live biomass component dry matter (DM) measurement

- Needles by age, branches, stems.
- Samples analysed in laboratory - Nitrogen, Phosphorus, etc.
- Biomass measurements and sample analysis undertaken periodically (age effects).

The photograph shows several researchers in a forest setting. They are gathered around a yellow tarp on the ground, which is covered with cut branches and needles. One researcher is kneeling and using a tool to measure a sample. Other researchers are standing nearby, some holding buckets. The background shows a dense forest of trees.

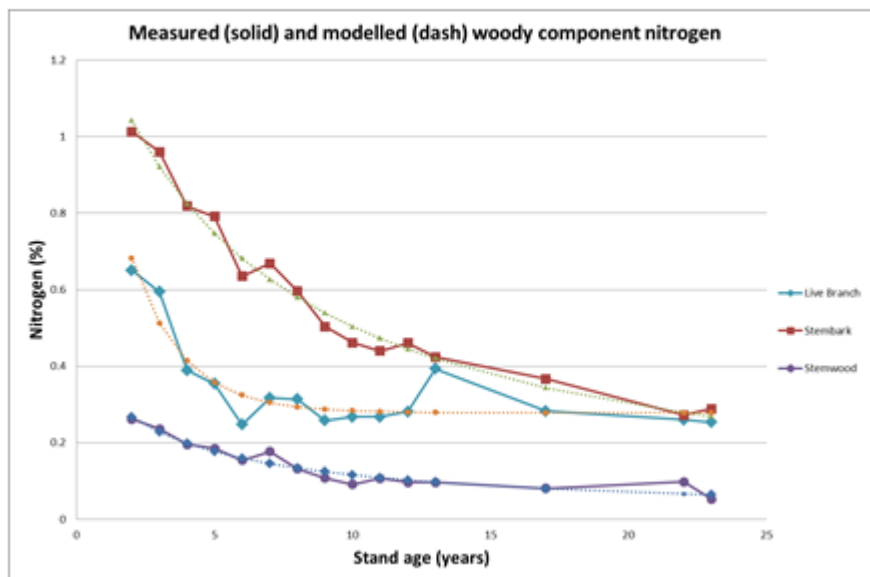
The new and old needle growth was measured and there is a big drop in concentrations between the two ages of needles when the trees are 5 years old but not later on. That is interesting. The litter fall comes when trees let older needles fall.

Needle component N%: Puruki expasture site



We also looked at how much the stem wood, stem bark and branches take up by tracking the concentrations in these components. Going back to the same forest year after year and re-measuring another sample of trees gave us data for modelling nutrient uptake.

Stem & branch component N%: Puruki expasture site




The next slide shows the forest floor litter layer formed from the needle fall measurements in un-thinned and thinned pine stands. The most interesting information is the average value of 0.5, which states that the rate at which needles in the forest floor turned over nitrogen is half the rate at which the carbon turned over. In other words, the litter is rotting

away but the nitrogen is retained for twice as long. That has implications on the graphs that follow.

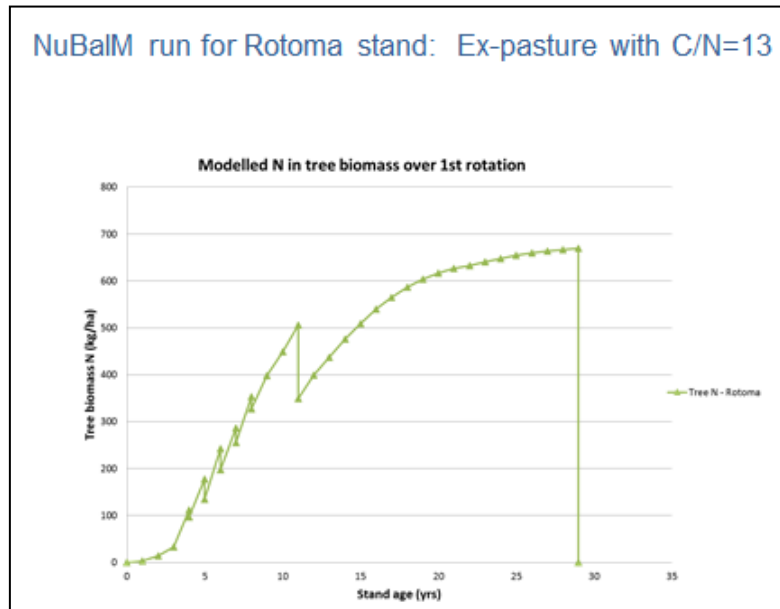
Litter N%: Puruki expasture site

Puruki Subcatchment	Forest floor (LFH) pool at age 22 years (excl. dead branch)			Average annual needle fall from age 14 – 21 years			Turnover rate		
	DM (t/ha)	N (kg/ha)	N (%)	DM (t/ha/yr)	N (kg/ha/yr)	N (%)	DM	N	Ratio N:DM
Plant 2200 sph, unthinned	35.9	762	2.12	6.33	70.8	1.12	0.18	0.093	0.53
Planted 2200, thin to 676 sph	23.5	509	2.17	5.15	53.4	1.04	0.22	0.105	0.48
Average									0.50

- Needlefall measured continuously (1987-1994).
- Forest floor measured in 1995 (to determine turnover rate).
- Nitrogen turnover rate expressed relative to dry matter turnover rate.



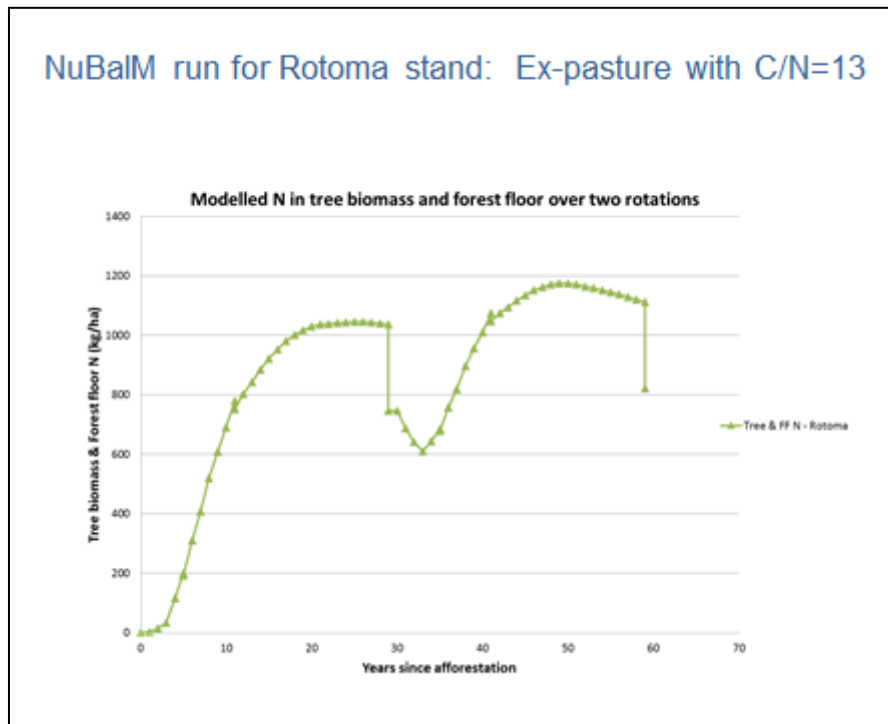
This shows the result of modelling nitrogen in live tree biomass in a first rotation stand at Rotoma. The tree biomass takes up over 600 kilos per hectare by the time the trees are about 30 years old. Pruning and thinning operations at Rotoma cause the periodic drops in nitrogen (saw tooth effect), which are followed by recovery of N in the tree biomass



This shows the total nitrogen (live biomass plus forest floor) in a first rotation stand (climbing to just over 1000kg/ha) followed by the second rotation (about 1100kg/ha). At harvest there is a decrease in nitrogen (nitrogen in harvested logs is removed off-site and harvest residues decay) and then nitrogen climbs back up again as the second rotation trees grow. With the subsequent regrowth of trees nitrogen accumulates to over 1,000

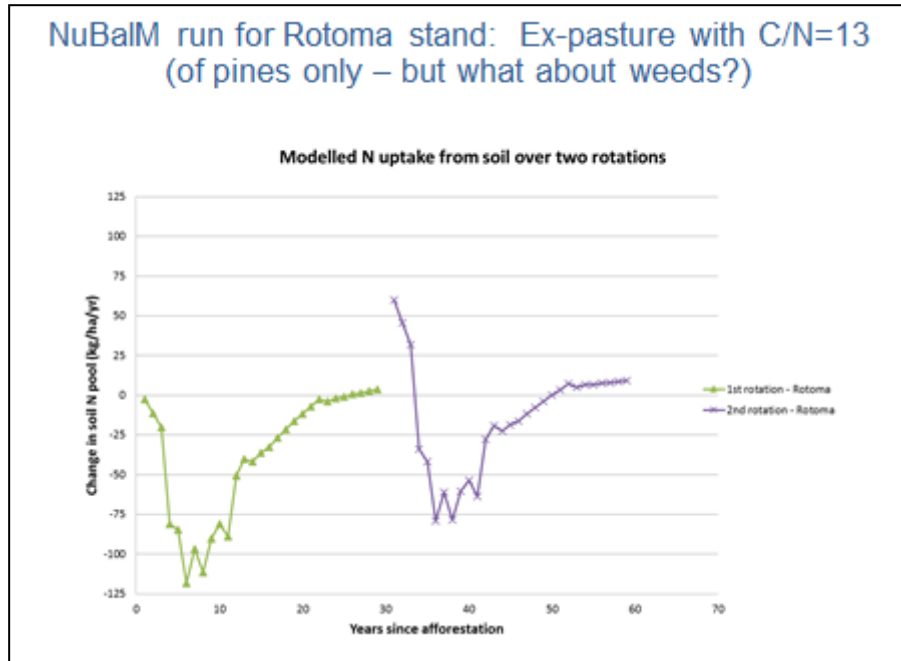
kilos per hectare after 50 years. All that nitrogen comes from the soil, except a little bit from atmospheric inputs.

You would have seen harvest residues at a harvested site - they provide the nitrogen for the second rotation. The sudden drop at about year 30 results from removing the nitrogen as logs. The first rotation tree crop does most of the work of pulling nitrogen directly out of the soil and the second rotation relies a lot on recycling of nitrogen in harvest residues. This information has interesting implications in the longer term if the intention is to continue to draw down excess levels of soil nitrogen to reduce nutrient leaching.



This slide gives an idea of turning the nitrogen accumulation graph (the previous slide) into the annual nitrogen demand from the soil. The slide does not show the stock of nitrogen in the soil, but the change in stock (negative values mean the soil nitrogen stock decreases by the amount shown). So, how much is the forest needing out of this soil each year? At around about age 5 or 6 (1st rotation) the soil must supply about 100kg per hectare per year. That is a lot of nitrogen. You will then notice that, from age 10 – 20 years the annual nitrogen requirement from the soil gradually decreases (slowly becomes less negative). That is because nitrogen is increasingly being cycled through the litter fall and cycling through the forest floor.

The annual demands on the soil eventually decline right away as the trees get older and rely increasingly on nutrient cycling. This nitrogen uptake pattern repeats itself in the 2nd rotation. However the demands on the soil are not as great now because the decaying harvest residues left on site provide nitrogen. In fact, the positive values at the start of the second rotation indicate that the amount of nitrogen released from decaying residues exceeds the annual requirements of the newly planted trees. Some of this nitrogen will be taken up by weeds and the rest will leach if soil water drainage is occurring.



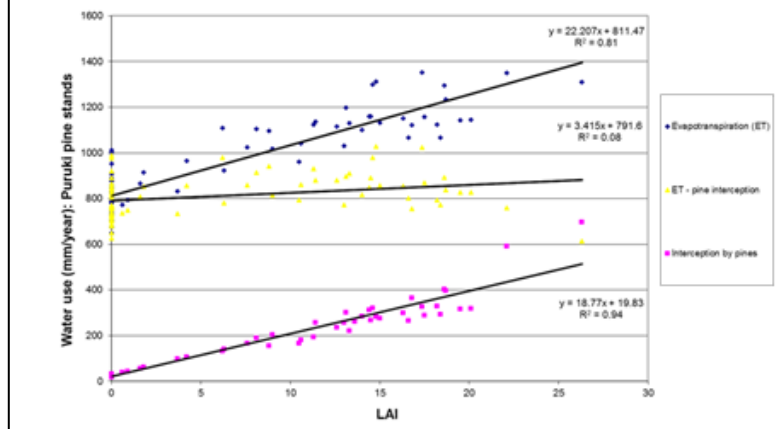
To test the model, we used the NuBaIM Water Balance Module at Lake Rotoma to see what is expected to happen. Rotoma had pine plantations recently harvested right near the lake. Working with the Bay of Plenty Regional Council, using lysimeters, we wanted to know how much nitrate nitrogen was in the surface soil water both prior to and after harvesting. The intention is to look at nitrogen leaching to the lake.

To get nitrogen leaching there has to be nitrate in the surface as a measurement. We have got a measurement of 1.29 milligrams of nitrogen per litre from these lysimeters at 1 metre depth. Then you need to have water draining through the soil to take the nitrate out. There is plenty of water fluxing through the soil at Rotoma (drainage is 985mm/year) when there is that much rainfall. Nitrogen leaching, based on calculating the concentrations at that one metre depth, is 12.7 kg/ha/year. We have ground water bores installed at Rotoma to compare with loss estimates based on lysimeters. Lysimeters 1 metre from the soil surface do not allow for tree uptake below 1 metre depth.



This shows a road cutting to look at how far down tree roots go. There are masses of fine roots well below 1 metre depth. When measuring the concentration of nitrogen in the surface, it does not mean it is necessarily going to leach to the lake. There is plenty of opportunity for the deep rooted species to grab hold of nitrogen before the soil water moves below the root system.

ET and radiata pine interception losses, given the rainfall

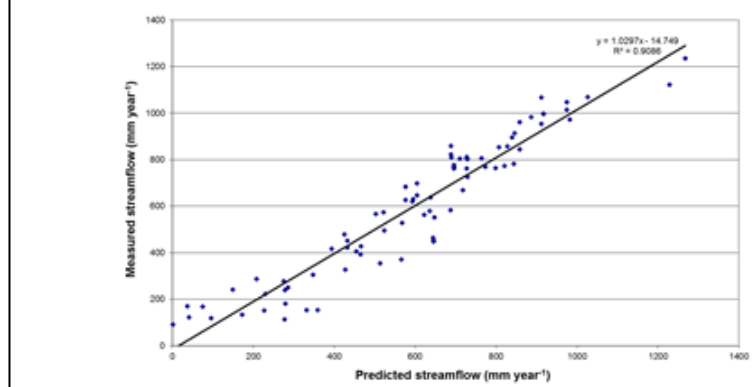


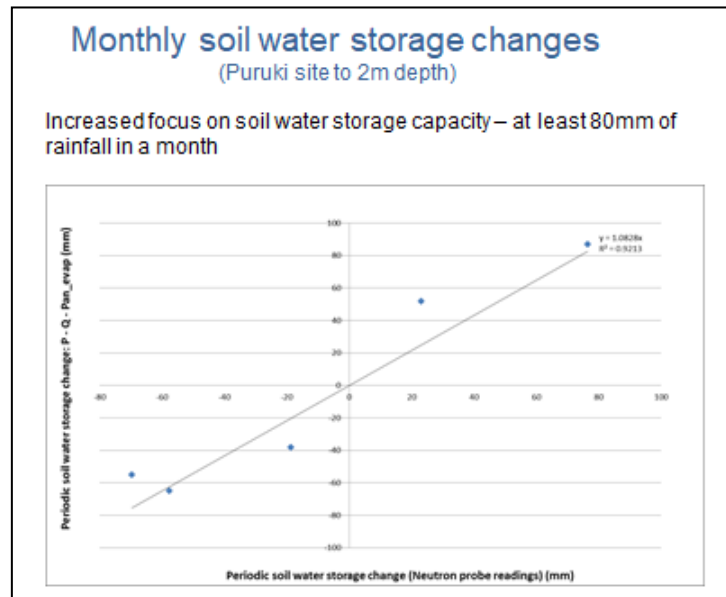
We can work out the drainage rates from a forest because we can calculate how much water is used by the forest from its leaf area (LAI). These three slides are based on the international hydrological decade study at Puruki. In this slide there are many layers of pine needles stacked on top of each other (that's the LAI = 20 when the tree canopy is closed) intercepting about 350 - 400 mm of rain. Intercepted rain evaporates before it reaches the ground. Evapo-transpiration (ET, is overall water use including interception loss) by forest is therefore higher than pasture because forest has higher interception losses. When there is 1600 mm of rainfall and the leaf area index of the pine forest is 20, evapo-transpiration is 1200 mm. Take that off rainfall and there is drainage (or streamflow) of 400 mm.

The slide below compares measured streamflow with the predicted drainage from the model. With 1600 mm of rainfall, drainage from the pasture will be about 800 mm, which is double that from a closed canopy pine forest. So that is why water use of forests is higher than farmland, which some people complain about. But it means that soils under forests are not as wet as those under pastures and can therefore accommodate more and larger storms.

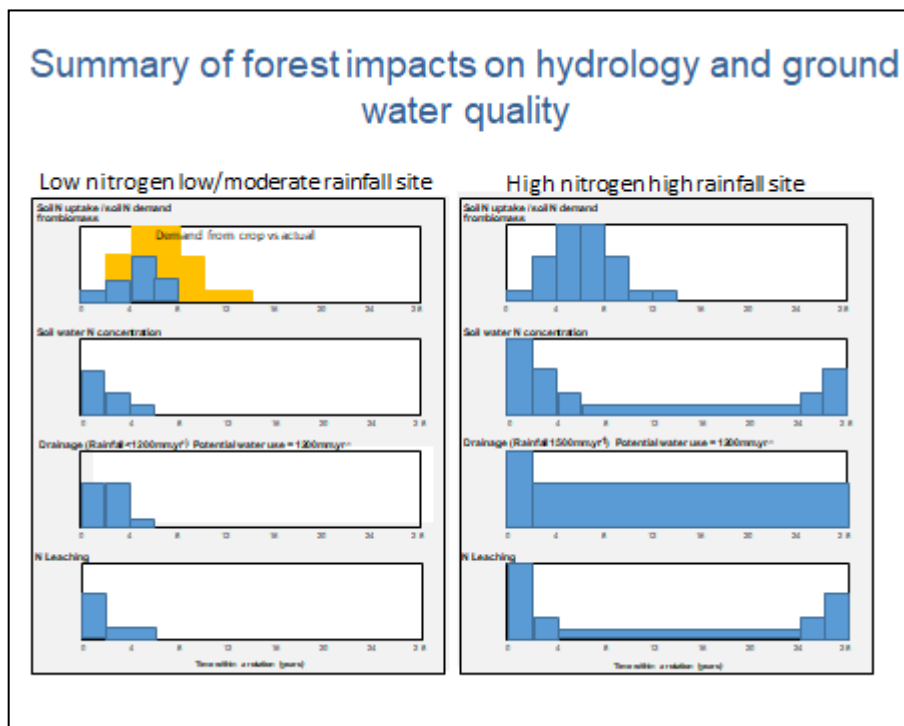
Annual streamflow

Puruki streamflow predicted as a function of modelled LAI and measured rainfall using NuBaIM





The above slide shows that soil water storage can vary by about ± 160 mm from one month to the next at Puruki. Depending on how wet it is, the soil content can absorb rainfall events of 80 mm or more without any drainage occurring. Those sorts of things have to be brought into the modelling to be able to predict nitrogen leaching.



The above diagram shows the main principles around nitrogen leaching that I want to summarise with respect to tree demand, soil nitrogen supply, and drainage.

Left panel: At a low nitrogen site, trees still demand a lot, they want to grow fast, they are pine trees growing but there is not enough nitrogen in the soil for them to take up. The nitrogen uptake is less than what they demand and cannot get. Can nitrogen leach then?

No. Of course early on there is hardly any leaf area and tree demands are still very small, so nitrogen supply from the soil exceeds the demand. That is when there is some leaching loss at low nitrogen sites - in very young stands after harvesting. Water comes in as rainfall, nitrogen is in the soil water and water comes through because there is not much leaf area on a young pine tree. That leads to nitrogen leaching.

Right panel: On a farm site planted with trees in an area with excess rainfall, leaching is quite different, the tree demand for nitrogen now being fully satisfied by that rich soil providing the nitrogen. There will always be some nitrogen left over in the soil water. This will drain away and some nitrogen leaching losses occur every year. The pattern of nitrogen leaching loss mirrors what we saw in the stream data on page 3 where a peak loss of nitrate (when the trees were small) is followed by a rapid decrease in leaching losses as the tree demands go up. There is a little climb later towards the end of the rotation, which the model predicts will happen because more demand is met through nitrogen cycling.

Sediment is probably the most difficult issue for forestry to deal with. Harvesting is the only time in the life of a stand where there will be more water coming off per hectare in drainage water than when there is pasture. For the rest of the time the trees will use more water than pasture. More water run-off means there is a greater potential for sediment loss.



This shows endeavours at Rotoma to trap sediment, considered to be needed in case the dry gully begins to flow. If we start planting more forests in lake catchments we need to consider sediment mitigation options. This issue has not been fully explored yet in terms of smaller wood lots with respect to the new National Environmental Standards. It will need to be looked at very closely, particularly around harvesting. Rotoma is one of those dreaded dry catchments that hopefully does not become a raging torrent

in downpours. I do not think it is a sensible to plant up farm stream gullies that will later be harvested. Where would you put in a forest? Trees do not need fertiliser on ex-pasture sites.

This summarises some of the benefits of having forest on farms to reduce leaching losses to ground water:-

Soil fertility

- Trees do not need to be fertilised
- N and P leaching losses diminish relative to pasture land use
- Forest demands on soil nutrient reserves are large in first rotation but small in the second rotation (with stem only harvesting)
- Research shows that soil nutrient depletion occurs using more intensive organic matter removal practice or intensive biomass harvesting (eg. for energy) – is this desirable?

-
- The challenge is to close the cycle - fertiliser inputs to farm could be reduced by cycling nutrients trapped by trees back to pasture
 - How? Tree species for silvo-pastoral systems (fodder). Litter raking (bedding)

Sediment issues

- Run-off increases when harvesting. Sediment transport control options need to be considered

In the old days they used to litter rake for bedding which was used under stock in their yards. Litter raking reduced forest productivity, until that practice was banned in some countries. It is an example to show that nutrients can be drawn down by removing and raking all the forest floor away, and accentuating the drawn down in areas where there is too much nutrient, which might be in zones where nutrients are trapped.

I talked about pine because we have lots of data but there are other tree species and silver pastoral systems that could be considered. Apples and all sorts of woody vegetation used to be grown with pastures. It was not all pure pasture but mixed up and the variety of species provided key nutrients. We bring in palm kernel for key nutrients. I do not know why. Why not grow other species to do that?

The NuBaIM model development research described in this presentation is funded by New Zealand Forest Owners through the levy. Every grower of a stand pays the levy when the trees are harvested. Research now is focussed on linking this modelling system to different types of soils around the country but it is mostly focussed around here at this stage.

FARMER PERSPECTIVE

Chris Sutton
Farmer, Rerewhakaaitu
crisanda@xtra.co.nz

Chris Sutton is no stranger to Rotorua's political and environmental scene. He has been involved in Project Rerewhakaaitu for over 10 years. He was also a member of the Land Use Futures Board, past Provincial President of Rotorua/Taupo Federated Farmers and National Vice Chairman of the Federated Farmers Dairy Section. Chris and Rosemary Sutton have farmed 105 hectares in Rerewhakaaitu for 23 years. Up until three years ago they were milking 260 cows, today they fatten heifers and steers. Chris and Rosemary are thoroughly enjoying the change in stock class within the new farm system.

TRANSCRIPT

When we did the biography and it was only 100 words, I gave it to my wife and said, 'Well there we are, 30 to 40 years gone'.

We are beef farmers now. We went to the Rerewhakaaitu area as dairy farmers and four years ago, on 23 September 2013, we sold the dairy cows and moved into a beef unit. We have been a beef unit ever since on 100 hectares. When we first got married, Rosemary was a nurse from Te Whaiti and we both decided to own a lifestyle block either at Kaharoa or Rerewhakaaitu and ended up buying at Rerewhakaaitu in a roundabout fashion.

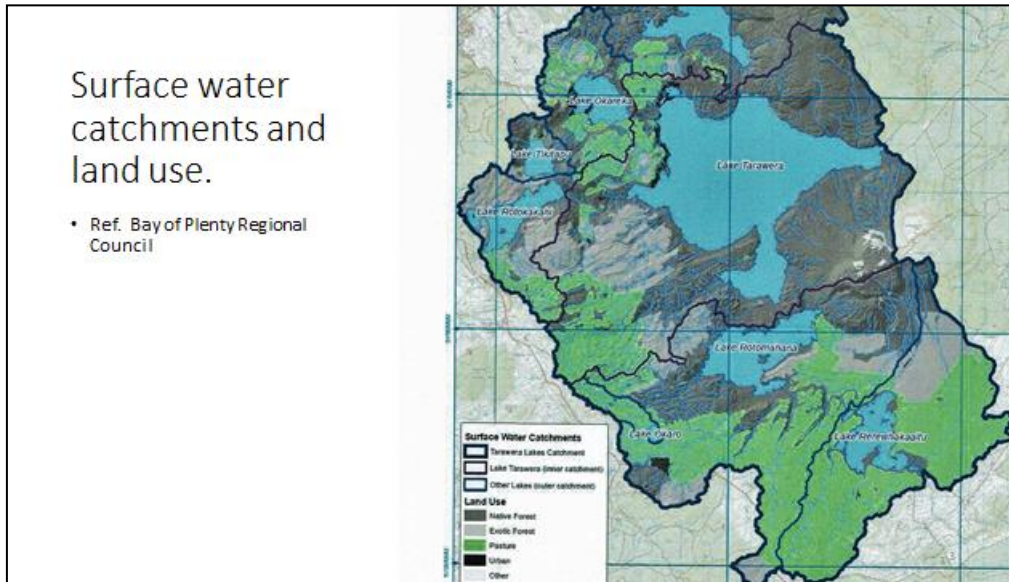
Thanks very much to those who have said good things about Project Rerewhakaaitu. I get embarrassed about it. I sit down and go, 'Well, what have we done, what did we do?' I find it a little hard to handle that compliment, sorry about that, but thanks very much anyway. It is good to know that (due to time constraints) there is no discussion afterwards.

So we get to Paul White. I am the only well in Rerewhakaaitu scoring 8 and we all know why. It has nothing to do with the farm. As you move towards Rotomahana and Tarawera, the wells get a little lower and in the end they are about 4 - 4.5 pmm. The work that we have done shows that if we measured some of the wells up in the forest, unbeknown to the forest owners, then went down through the catchment, we do have an input. There is a footprint and that is expected but it does not show an increase as you go towards Tarawera, where the water is supposed to go. So just remember that.

We need to acknowledge the staff and personnel of the following, without whom this would not be possible:-

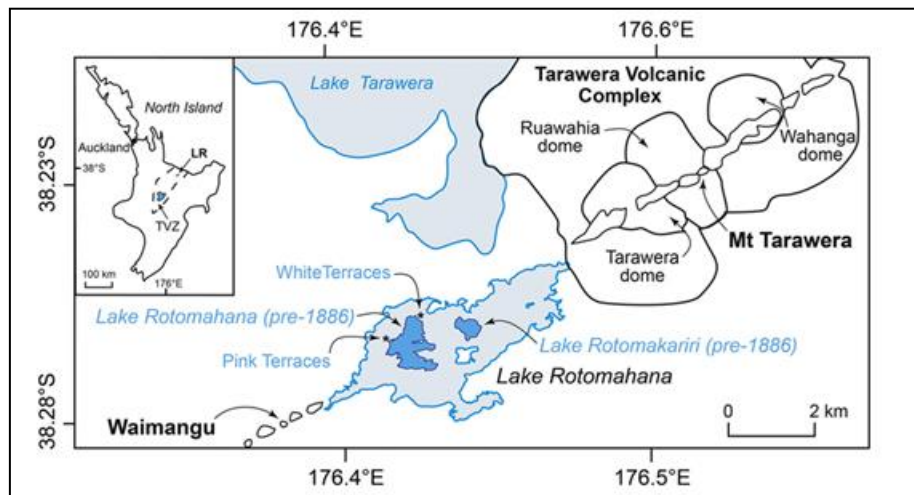
- AgResearch
- Fruition
- Dairy New Zealand
- Beef+Lamb New Zealand
- Bay of Plenty Regional Council
- Rotorua Te Arawa Lakes Strategy Group
- Blackman Spargo
- Fonterra
- Sustainable Farming Fund
- The farmers

Without them nothing would happen and I would not be standing here if it was not for AgResearch and Fruition. I went to a symposium in 2002 and met Mike O'Connor of AgResearch and Bob Parker from Fruition. After I got up and asked a couple of questions they came out to Rerewhakaaitu and from there the project grew. There is a 7-page summary of the project up until 2015 available outside for those interested. The entire group has helped us out over the many years. Fonterra is now involved and the Sustainable Farming Fund and farmers.



This shows the surface water catchments and land use of the area and I farm over on the bottom left in the Rerewhakaaitu catchment. Rerewhakaaitu 1A2B is a lot of land. They have just had it handed back after a 99-year lease, 'lease' being a polite word. Onuku is another big player. Both blocks have got 3 or 4 dairy farms and a large sheep and beef unit. The same with Onuku and Lake Okaro. The dairy farms stop just past Lake Okaro on the Okaro/Waimangu Road. They are predominantly dairy but not intensively dairying. (pointing to Rotomahana & Rerewhakaaitu lakes catchments). Several own quite a few farms. I only own one and not that rich.

From here on around it is sheep and beef and we have been asked to pick up Crater Lake Farm. They are not great players as far as high stocking rates go. There are some privately owned forest areas. There are also a couple of little private forests.



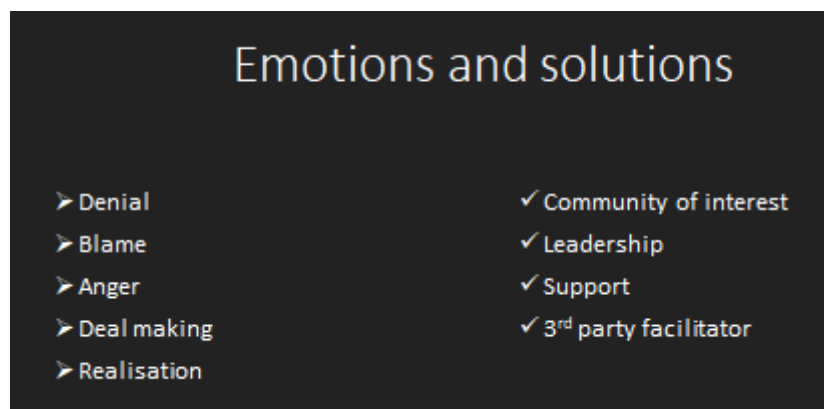
The above slide is another map showing the White Terraces and the two small lakes (Lake Rotomahana and Lake Rotomakariri) prior to 1886 and the Pink Terraces. There are steaming cliffs and it is quite active. We had Professor Hamilton out recently. He told us a year ago that between 60% to 70% of the phosphorus entering this lake is coming from geothermal. GNS rate this lake to be as volcanically active as White Island at idle. It is humming along and goes up and down. Andy Bruere tells me it breaks out into Tarawera every now and then and so do the hunters.

The average take home pay to the guides prior to the 1886 eruption was £10,000. The museum says it was £8,000 but a YouTube presentation in the Council Chambers by Te Arawa had it at £10,000 and I believe them.

If I understand correctly, the hotel was owned by local Iwi and Crays was the manager. Bainbridge Road is over our way and Mr Bainbridge was the gentleman killed in the hotel. The rocks that you see at the Buried Village came from Tarawera but did not land originally at the village but north of Lake Rerewhakaaitu. One of the members on our committee took 16 truckloads of rocks to the Buried Village. Do not believe everything you see in town especially if it is Rotovegas. It is a tourist town.

When you put something together in the community by social reengineering and say, 'Hey, you have got to stop doing what you are doing, you get denial. With the work and positions I have been given, one of which is on the Upper Waikato Catchment Committee, I have got to know staff there who have put together a similar project to what we have here in Rerewhakaaitu on the Whirinaki arm. It will be good to see that happen. We went out to Waiotahi the other day to sit with some farmers.

Back in 2002 we did not have the support that we have now. We turn up to meetings and people from DairyNZ, Fonterra and the Regional Council are all there to help. The hand has been extended and you have to take it up, and you do. But there is another hand and it has not got a carrot. We went through denial and blame. We blamed the forestry or we blamed the farmer next-door, the new guy, the big guy and all the rest of them. We went through all those things. There is the anger and sometimes you get them all back to front. You try and make a deal and then the realisation comes.



These are all the emotions you get with any sort of trauma that happens in a family. But the thing is, while you are trying to save the environment, the general population does not understand that Rosemary and I and the kids have put everything into the farm for the last 30 - 40 years and you want us to change.

Sure, we changed three or four years ago and are most probably the better for it, but that is what these farmers go through. When you go to the community as a staff member of one of the agencies that is what you are dealing with. The easiest way is to find the community of interest. We have that in Rerewhakaaitu. There was always interest in the mountain and the lake. We cleaned up the pines around the lake. Woodsman came from Woodsmen School and cleaned up the mountain. We all did it together as a community.

Leadership is a big thing. We started out with three of us - Mike, Bob and myself. We grew to a group of 5 or 6, then to 10 and now we have 15. We needed support and had AgResearch, the science support, and support from the Regional Council. It is good to have a third-party, a facilitator, which was like a filter. It stops the shit going both ways. At the beginning it was necessary but good staff on the Regional Council made a difference.

✓ We want to work with BOPRC.

✓ If we are part of the problem then we need to be part of the solution

✓ We believe that if farmers are fully involved in the process they will take ownership of the solution

Challenges

- "Take control of our destiny." B Bayfield.
- "Take ownership of the Project." W Murray.
- "Ensure that farmers understand the science so they can understand the solutions." M Barton
- "Hunt as a pack and get ahead of the wave." D Leeder
- "You have to be in the black to deal to the green," T Hamilton

6

This is what we believe in and we wanted to work with the Bay of Plenty Regional Council, so any submissions we have will always head with that. There is no way we are going to fight them. In 2002 I was Provincial President in Federated Farmers, and one thing I learned is that change happens, and change is going to come at you. It is what you make of that change, how you can get something out of that change, or it will run you over.

We believe if we are part of the problem we need to be part of the solution. We also believe that if farmers are fully involved in the process, they will take ownership of the solution. That is the big one. If you take us through and include us in how you arrived at that solution, you set the scientists in front of us, do the experiments; get the farmers to put the phosphorus socks in the streams, get the farmers to understand how it all works, then they will take ownership of it all. They will understand. It is their community and they want to stay there.

There were huge challenges put before us. Bill Bayfield, Chief Executive of the Bay of Plenty Regional Council before Mary Anne MacLeod, asked us to take control of our destiny. As a Deeded Lake, Lake Okaro had gone through an action plan process, which was advertised and everything else. But no one in that catchment submitted to that process and yet there were 13 submissions from outside submitters, everybody else telling those people in that catchment what to do. Bill Bayfield said get into making submissions and be involved.

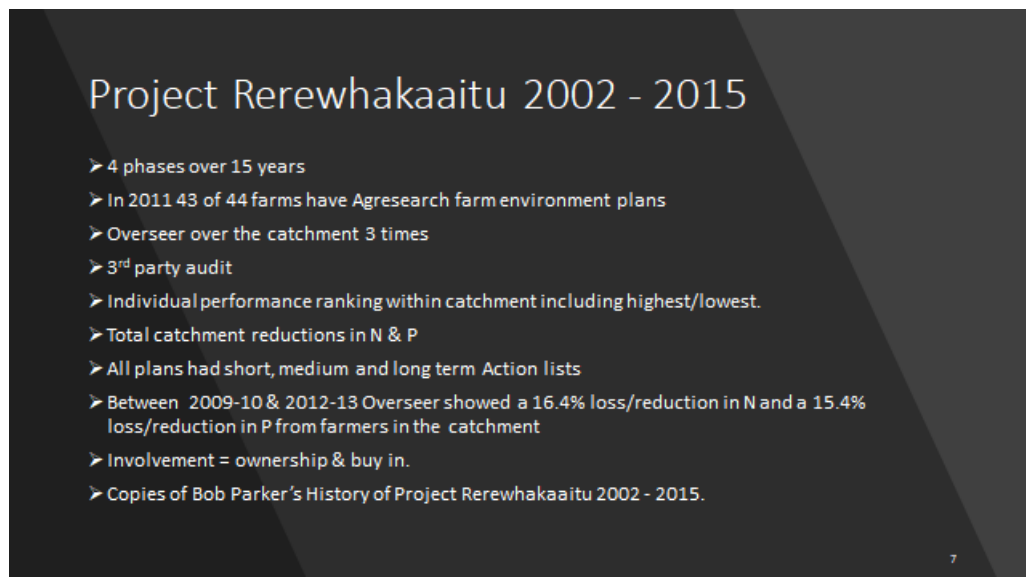
Warwick Murray asked us to take ownership of the project too. This was just after we had changed from dairying to beef, about 2014 and 2015. He wanted us to contribute to the action on the ground, which we were doing anyway. We wondered what Warwick was on about but, hey, that is okay.

Warwick was Chris Ingle's predecessor as was Paul Dell, so we have been through 3 of these guys. Warwick, I knew quite well because I spent 3 years with him on the Land Use Futures Board in Rotorua, which was good. We understood where he was coming from. We took ownership of the project by making it into an incorporated society and that moved us into understanding 'we were it'.

Mike Barton of Taupo Beef said to ensure that all farmers understood the science so that they could understand the solution. That is a big thing.

Doug Leeder, Chair of the Bay of Plenty Regional Council, said hunt as a pack. Doug goes through a lot with us about where we are heading, where we need to understand the rules and everything else that comes at us.

Trevor Hamilton, a farmer, said we have to be in the black to deal to the green. That was obvious.



Project Rerewhakaaitu, 2002 – 2015 had 4 phases. An important thing to look at is the 16.4% reduction in nitrogen and 15.4% reduction in phosphorus from the farmers in the catchment between 2009 and 2013. That is for the Council really, but it was good for the farmers to know. We get ranked and we have a third-party audit. Another big thing was that all plans had short, medium and long-term action lists. The farmers got a plan and understood what nitrogen and phosphorus is about. They worked to their plans, got involved and took ownership.

At the moment on our committee we have 15 members, both men and women, 2 from the Bay of Plenty Regional Council, 1 from Dairy NZ, 1 from Beef+Lamb NZ and Simon Park from Land Connect, who is implementing the land environment plans. It is quite a big meeting and easy to operate. It is my job to make sure they are up to date. It is very positive, they discuss and decide, constantly looking for solutions. There is an unwritten

policy of no secrets and we will get on to that later on. That has to be there. There is a strong relationship theme all the way through.

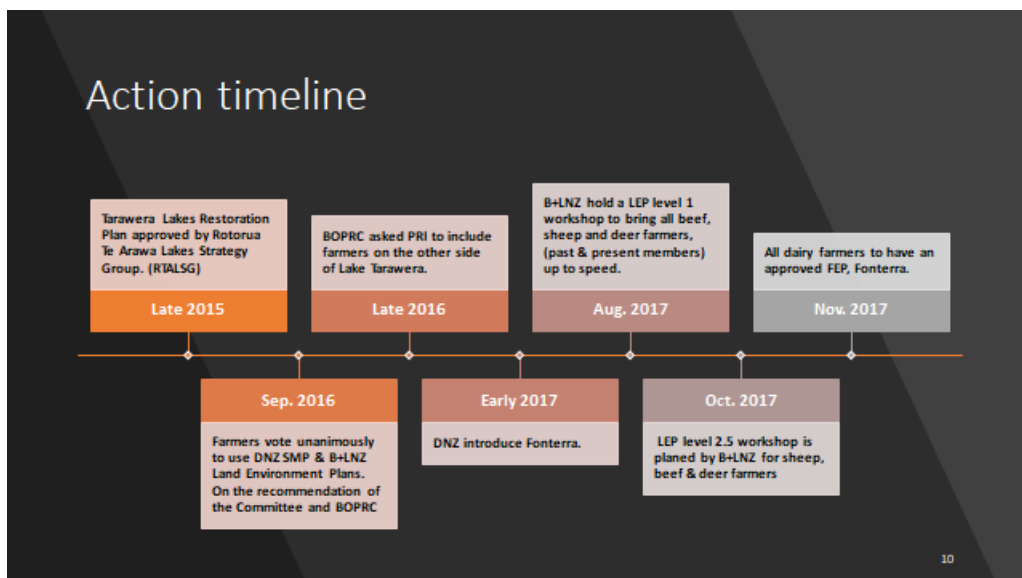
We have accountability being an incorporated society. You do not want to be on the Action and Unfinished Business List. I am usually on that and others are too, but Professor Hamilton got off that the other night with a presentation to the community.

Transparency and ownership is a given. We have 75% paid up members and everybody gets a newsletter. This tells us how many people are really in the game. At present 86% of farmers have farm environment plans either with AgResearch or Beef+Lamb NZ. We do meet the action plans at the moment, but we are going beyond that.

There are now new farm environment plans. We have 50 farmers in the catchments, 28 are dairy farmers, 22 are sheep, beef and deer farmers. Fonterra will do the action plans on all the dairy farms at their cost to the standards of the Regional Council. That was a big windfall and good for everybody. We look for nitrogen, phosphorus, E.coli, silt and bio-diversity. Phosphorus is the target problem, and as David Hamilton has told us time and time again, if P is the target, forestry is not the answer.

This plan recognises past improvements which came from the previous plans funded by farmers. We have not got handouts. I is our own money back there.

The data from Overseer is called amalgamated data which models the catchment and comes from the nutrient budget, part of the farm environment plan in Action 6. Once these plans are in place we will start discussing Action 5.



We have an action timeline. We tried earlier to get where we are now, but we slipped up. PC10 dragged us back down in there, but it allowed DairyNZ to bring Fonterra in. We were ready to do the DairyNZ 'sustainable milk platform' plan. When DairyNZ found out that Fonterra was trialling a farm environment plan, we managed to get them to fit their trial in this area. If it is successful here, there is a good chance that it may roll out even further. That is their news to break, not ours, so that is a win.

Summary of actions				
All actions included in the document including expected reductions and estimated costs are summarised in Table 5.				
Table 5 Summary of all actions				
Actions to reduce nutrients				
Action	Nitrogen reduction kg/year	Phosphorus reduction kg/year	Cost	Cost per kgN and kgP
Action 1 – Reticulate houses in the Lake Tarawera urban community and upgrade conventional septic tanks outside the future reticulation zone.	2,829	283	\$12,400,000 (+GST)	\$43,816 /kgP \$4,383 /kgN
Action 3 – Control nitrogen fixing pest plants in the Lake Tarawera Catchment.	230	n/a	\$181,000	\$700 /kgN
Actions with no reductions				
Action	Outcome		Cost	
Action 2 – All agricultural properties within the Lake Tarawera Inner Catchment to have environmental management plans.	Voluntary reductions in phosphorus from agricultural land in the inner catchment.		\$90,000 (Includes cost of consultant only. Does not include cost of any nutrient reduction actions)	
Action 4 – All agricultural properties within the Lake Tarawera Outer Catchment to have environmental management plans by 1 December 2020.	Voluntary reductions in phosphorus from agricultural land in the outer catchment.		\$120,000 (Includes cost of consultant only. Does not include cost of any nutrient reduction actions)	
Action 5 – Develop a rule to limit land-use changes that increase nutrients in the Tarawera System.	Cap on total nutrients in the catchment will safeguard the lake from increased nutrient loading.		Costs met by other Council work streams or projects.	
Action 6 – Build a model of the Lake Tarawera groundwater system.	Better understanding of the land-uses that contribute to water quality in Lake Tarawera.		Costs met by other Council work streams or projects.	
Action 7 – Carry out a Cultural Health Assessment of the Lake Tarawera Catchment.	Better understanding of the interrelationship between lake water quality and tangata whenua values.		\$50,000 (Includes cost of consultant only. Does not include cost of any nutrient reduction actions)	
Action 8 – Investigate geothermal inputs into Lake Tarawera.	Better understanding of the geothermal inputs into Lake Tarawera.		Costs met by other Council work streams or projects.	
Action 9 – Summarise science around minor nutrient sources.	Consolidated science around minor sources of nutrients in Lake Tarawera.		\$10,000	
Action 10 – Keep community informed (in Plain English) of science updates and reports when available.	Well informed and engaged community.		No cost	

We had a Summary of Actions and a Land Use Capability Workshop as well to understand land use classification. If you are into that, it is really good, and it was where we saw two regional councils work together on the day.

Chris Ingle talked about the action plan. Action 1 of reticulating houses is in place. While I have sat on the Tarawera Sewerage Steering Committee, that figure has gone to about \$18M.

Action 2 is in place with funding sought.

Action 3 has been done. Andy, tell me if I am wrong, as I understand the nitrogen fixing plants have been taken out.

Actions 2 and 4, which are plans on the inner and outer catchments, are in place and in process. There will be savings because Fonterra and Beef+Lamb will be picking up a fair bit of the bill plus everything else.

Action 5 - we have talked to Rebecca Burton. The outcome in Action 5 is a cap on total nutrients. I want to know that the cap is on my head, not on my shoulder nor on my waist, otherwise we will have a different discussion. A cap is a cap otherwise do not call it a cap. Then there is protection, if there is any change in land use that could come in and erode our work. We need to protect the work that we have done over the last 15 years. We do not want someone to upset the model. It threatens the science, it threatens the lake, it threatens everything. So, Action 5 will take place pretty soon.

Action 6 will work because it gets the data out of Actions 2 and 4 and will be under way as well.

Action 7 - I understand from Andy that a cultural assessment will take place.

Action 8 is a biggie and where Paul White will see out his days on geothermal investigations on that job.

Action 9 summarises the science and the minor nutrient sources at a cost of \$10,000.

Action 10 is keeping the community informed and at no cost. Some people say they know the cost of everything and the value of nothing. But if you get that wrong this all falls over and is so important. It is the only thing that is tripping us up at the moment but it will take place.

What does the future bring? Agriculture will continue to be processed by regional councils throughout New Zealand and give effect to the National Policy Statement on Freshwater Management. That is going to happen, no matter what, right throughout the country. Regional councils will process district councils to meet the said Policy Statement. That will happen, and they will go through denial, anger and frustration.

Regional councils will have to work with forestry owners to address the issue of logging and Class 6 land and other sensitive areas. I could take you for a drive to show land that does not look good. If I cannot crop Class 6 land, why would I be allowed to log it? It is one thing to plant trees; it is another thing to take them away. Forestry should work with agriculture, not oppose it, and land use should be complimentary, not competitive. New Zealand Inc. should consider land use capability, understand its capability classification and add a science component to fully utilise New Zealand's natural resources. Not all land is suitable for farming.

If we could throw everything up in the air and let it settle back down in its right place it would be good. To get them to move from one land use to another involves money. We are driven by nothing else. As I said, you have got to be in the black to get in the green.

Surveillance drones will be as common as electric cars. Chris Ingle tells his staff there had better not be a surveillance drone operating anywhere near here. If I had got wind of it the next thing it would be on the front page of the paper that we shot one down. But to be honest and fair, it is our money that is spent to survey what we are doing. Aeroplanes and helicopters are great, but drones are wonderful. You could come into the Rerewhakaaitu catchment, set up a programme on your laptop, sit back and let one go and it would check out all the ponds and everything else needed from the air. That would be wonderful.

Wind turbines are suitable at Kaharoa which is not the only place, but this is the way we are heading. Dams are yesterday's dinosaurs. That will be a discussion in the future as to how effective the hydro dams are, we will see more wind turbines around, in my opinion. I am allowed my own opinion even though I sit on all those boards and committees.

More science is needed around mitigation and less around litigation; because that is the way it happens at the moment. People look for blame and then it ends up in a fight and there is a lawyer involved. I would like to see more science because I constantly get calls from farmers looking for knowledge and scientists. Do not underestimate the influence scientists and farmers can have belly to belly in the field. We have had Professor Hamilton out several times and he was out there again the other night with 25 in the room. One farmer with 10 farms, not all in our catchment and some in the South Island, came up to me after the meeting and said that that meeting was the best presentation he had had. It is the ability to sit down with scientists, such as David, one to one with the farmer and a laptop and talk things through in a non-threatening way. At the end of the day if they can change something on their land, and it does not cost a lot of money and gets the desired

result, isn't that what we want? Go the other way with a hidden agenda, it just does not work.

Farmers have a huge bullshit detector. They can detect it straight away. I sat there the other night and I can tell by the body language. If they lean forward on their knees and put their heads down, it goes over the top and they do not want to listen. If they sit back, they are taking it in, and that is how it should be.

Hey, thanks very much.

Session 7 : RESPONSIBILITIES, VALUES AND FUNDING

SESSION CHAIR - Bill Cleghorn, Bay Trust

CLEAN LAKES – WHAT VALUE? WHAT COST?

Hannah Mueller

Kessels Ecology

hannah@kessels-ecology.co.nz

Hannah is an ecologist working at Kessels Ecology in Hamilton. Earlier this year, she finished her PhD at the University of Waikato, which focused on an assessment of ecosystem services of lakes. Her research analysed catchment and lake values, the impact of land use on water quality of the lake, and the context of lake restoration of the Rotorua Te Arawa Lakes. Her talk today focuses on the values associated with the ecosystem of Lake Rotorua and its catchment, the costs of restoration, and some ideas around getting the best value out of future management of the lakes.

TRANSCRIPT

Kia ora everyone and thank you so much for making it back to the last session of this wonderful symposium. Thank you so much to the LakesWater Quality Society for inviting me here to speak today. I am excited by the opportunity to share with you some of the findings of my PhD research that I finished earlier this year.



Before I dive into costs and values of Lake Rotorua and its catchment, take a moment to look at this beautiful lake and think about what values you personally associate with a lake. It is actually not Rotorua but Lake Rotoma.

In this very diverse audience there will be many different values that come to mind. A lake ecosystem is hard to value because there are a lot of complexities and things that I have not been able to address. This was a pilot study to explore the values that we can associate with ecosystems rather than being a comprehensive study.

I will talk about the lake itself and the ecosystem services as values that it provides, as well as looking at the potential costs associated with degradation of that ecosystem. Then I will look at catchment land use values and ecosystem services as values that are associated with the catchment. Lastly I will look at the opportunity costs that might be associated with looking at different land use change scenarios.



When we talk about values of ecosystems, people associate something like putting a barcode or dollar on nature but that is only half the story. My study looked at what alternative options we have in looking at the value of an ecosystem such as a lake, what means can we describe the values and how can we put that into a context of weighing up the cost of restoration? What might we gain from the restoration and the complex interaction between the lake and its catchment?

It is not purely about putting a dollar figure on an ecosystem, rather looking at values beyond traditional land pricing. How else can we derive value? There are a lot of values that I have not been able to address in the small scope of my study and a lot more that can and should be done in this sphere.

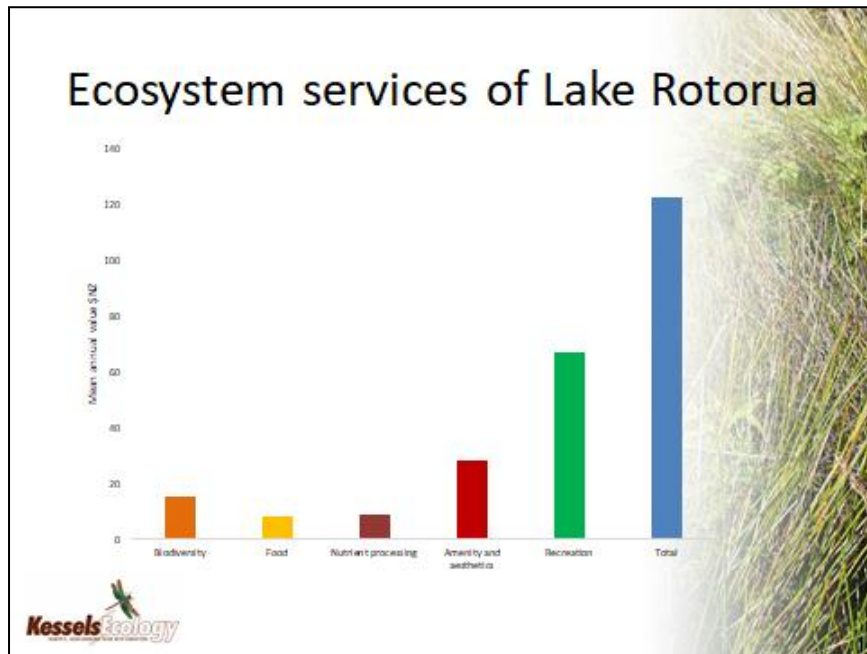
The main concept I used for my study was ecosystems services which are a tool developed to describe those services that are provided by a certain type of ecosystem that benefit humans, whether they be flood regulation or climate regulation or food provision. There are many kinds of services that humans benefit from. You will notice that by definition this concept is very human focussed and a human centric concept. It is all about what benefit we derive from this ecosystem?



My study also looked at different types of land use especially in the catchment of Lake Rotorua and I would like to point out that often when we look at land use we have a very one-sided perspective on how we value land use types. So often we only look at the productivity of the land and what money we might be able to get out of, say, productive uses of the land. But there are all kinds of other land use or land cover types as well that come with

their own different values, whether that is plantation forest, indigenous forest or wetlands or other areas. These types of land uses are also very valuable to consider when looking at the catchment and its interaction with the lake.

My case study was Lake Rotorua, one of the Rotorua Te Arawa Lakes. We are very familiar with it and in fact right next to it now. I studied both the ecosystem services of the lake and the catchment as well.



I identified 5 different ecosystem services. This is the bare minimum in terms of value and there are a lot that I have not accounted for but it does not hamper my outcome of concluding that this lake ecosystem has a very large value and even larger than I estimated.

The 5 ecosystem services were:

- biodiversity or habitat values
- food provision
- nutrient processing capacity of the lake as a value
- amenity and aesthetic values
- recreational values

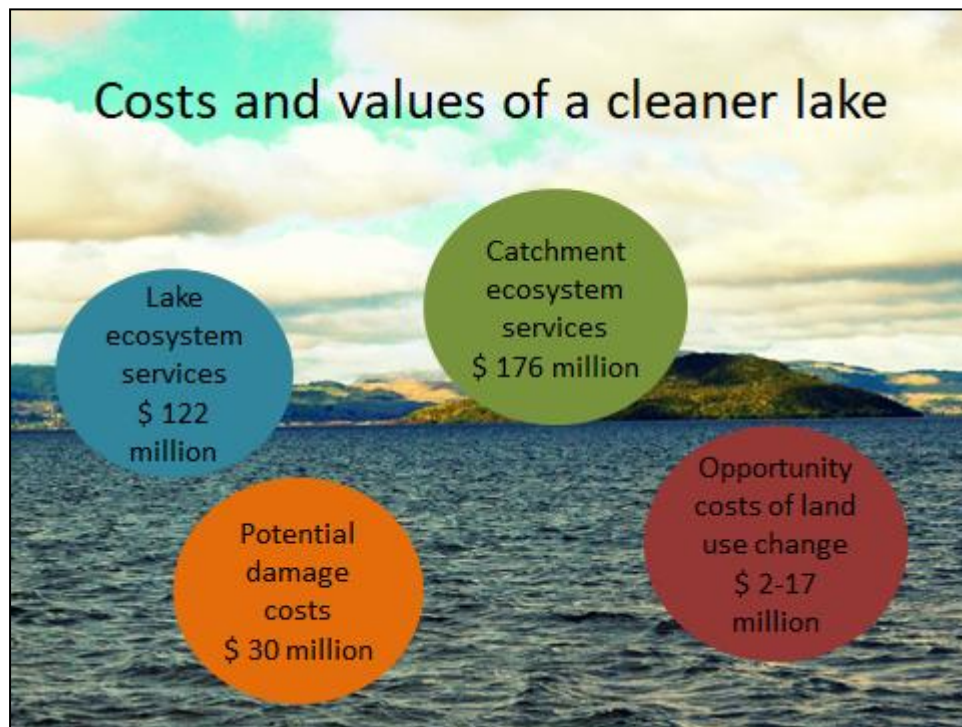
As an iconic lake, it is not surprising that the recreational values were the highest value, any type of recreational usage such as fishing, boating and visitors to the lake are very important for this ecosystem. The total value was an average of about \$122 million contributed by the ecosystem services of the lake every year. That is a fairly substantial contribution considering that we have not even looked at the wider management decisions at this stage.

As a second step I looked at the values we stand to lose if we allowed the ecosystem to degrade further from the state that it is now. I looked at a scenario predicted by a water quality model, indicated by the Trophic Level Index as a representation of the state of the ecosystem. I looked at the degradation of the current status of the TLI to 4.8 which is a slight degradation within the eutrophic range. Looking at the associated degradation of

Lastly, we want to know the costs associated with different scenarios of land use change. For example, moving away from dairying to a different type of land use, what are the costs associated with the loss of profit? The loss in profit from agricultural land use converting to other uses such as forests, depending on the scenario, was about \$5 to \$17 million per year and mitigation costs. These are the opportunity costs of lost opportunities and productivity of the land.

There were quite a few scenarios on different combinations of land use and mitigation on land which I do not have time to give here. **But if you are interested in the details it is neatly packaged and written up in my PhD thesis that is publicly available on the Waikato University website.**

An interesting finding that came from my studies was that this value is slightly lower when looking at ecosystem services value as well due to the fact that certain amounts of value are gained in the ecosystem services through a change in land use. We reduce the cost of loss and profit slightly by \$2 to \$13 million per year roughly. Putting that into context, the mitigation costs within the lake at this stage might have gone up a little now especially through alum dosing which is about \$1 million a year spent on maintaining the current water quality level on the lake.



This slide summarises the different costs and values of a cleaner lake. First of all the lake ecosystem services of the lake itself were about \$122 million and the potential damage costs of further degradation of the lake would be around \$30 million a year. In comparison the catchment ecosystem services provide about \$176 million a year and we could face the costs of between \$2 and \$17 million in opportunity costs playing through scenarios of land use change away from the more intensive land uses towards potential alternative options.

I am not going to do the maths because I do not think it is an equation done from a scientific point of view, but it definitely shows that it is worth spending money to incentivise

land use changes. In order to protect the lake, the Council is already proposing the intention to save money at the other end with a lake that is in a healthier state.

The Hon Dr Nick Smith said there must be pain on all sides including Council, land owners and ratepayers. He might have a point but I have to slightly disagree. That is a very negative way of phrasing it and not necessarily the way to go. It is not how to motivate people to bring about change. While I am not naive enough to believe there will be a win, win scenario in all kinds of different situations within the catchment, there are a lot of diverse options for profitable land use while also improving environmental outcomes.

Looking into the future, it is possible to come up with solutions where landowners can diversify and make a profit with a more limited impact on the environment, be it through a change in farming or a change in land use or a combination. We need positive motivation rather than further costs. In some cases, new land use types might be more profitable than further intensification. I am not expecting everyone to start mountain bike parks on their farms but it could be a good idea for some farmers, or a combination.

New regulation sets out funding for land use change and we need to future proof land use and find concrete options that work for all. How can we incentivise positive change toward different types of land use that can create profit in the end for the land owner and the wider region rather than punish a few farmers who struggle with the way their farm might impact the environment?

To conclude, it is definitely time to rethink how we look at the different ecosystems and how we look at land use and value it or look at alternative more holistic points of view. So many people have already come up with innovative ideas and new ways of dealing with the challenges that we face in water quality and the protection of these Rotorua Lakes. I am very optimistic. Listening to all the talks at this symposium, great things are going to happen in managing water quality and Rotorua is definitely ahead of the curve in New Zealand. We need a lot of positive motivation, good thoughts and great innovators working together. We need to plan in the long term. If you plan in the long term the opportunities are there to take up.

I would like to acknowledge the following:-

University of Waikato
LERNZ
Bay of Plenty Regional Council
National Institute for Water & Atmospheric Research
Fish & Game NZ
Funding: Ministry for Business, Innovation & Employment

Kia ora, thank you.

LAKE TARAWERA – THE COSTS OF P MITIGATION AND PEST CONTROL

Greg Corbett and John Paterson

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Greg Corbett

Greg is the Biosecurity Manager with the Bay of Plenty Regional Council. Originally from Auckland, he escaped as soon as he left school in 1983 to work for the old Hawkes Bay Pest Board chasing rabbits and possums. Over the following years pest and biosecurity work has taken him to the Wairarapa, Central Otago, Gisborne, Ruatoria and finally to the Bay of Plenty. Since arriving in the Bay Greg has held various positions from Pest Animal Officer, to Bovine TB Vector Manager to Land Resources Manager and now Biosecurity Manager. In his current role Greg has the pleasure of leading a broadly skilled and passionate team who are dealing with some fairly big challenges, such as lakeweed, catfish and wallabies. In his spare time he enjoys mountain-biking, fishing, hunting pheasants with a German pointer dog and tries to do at least one tramping/climbing/hunting trip to the southern alps each year.

John Paterson

John Paterson is a Sustainable Farming Advisor with BOPRC. Independently of Council, he also works as Project Manager for the 'Phosphorus Mitigation Project'. In his spare time he farms deer at Kaharoa, 20km north of Lake Rotorua.

TRANSCRIPT

Greg Corbett

Kia ora tatou

With a background in pest management, my only experience in phosphorus is mixing it with apple paste to poison rabbits a few years ago. Bringing John along to tag team with me brings a level of credibility to this presentation.

Firstly, we have been asked to talk about the costs of mitigating P in the Tarawera catchments. It is reasonably well understood that farming activities can lead to phosphorus loss if they are not managed properly. Recent studies have also shown the possible links between pests and phosphorus loss in forested catchments.

John and I will give this presentation in two parts. I will talk about pests and then John will move to farming. Neither of us will predict how much phosphorus could be managed nor comment on the cost-effectiveness of any actions. We simply attempt to provide ballpark figures for work that could reduce phosphorus losses to the lakes to some degree.

The basis for our talk is the Tarawera Lakes Restoration Plan, which Chris Ingle talked about this morning. He alluded to the fact that there is a target of reducing phosphorus by 1,200 kilos which is about 10% of the total 11.4 tonnes of phosphorus entering Lake Tarawera each year. The plan also wants to address all known sources of phosphorus and promote better management of agricultural land.

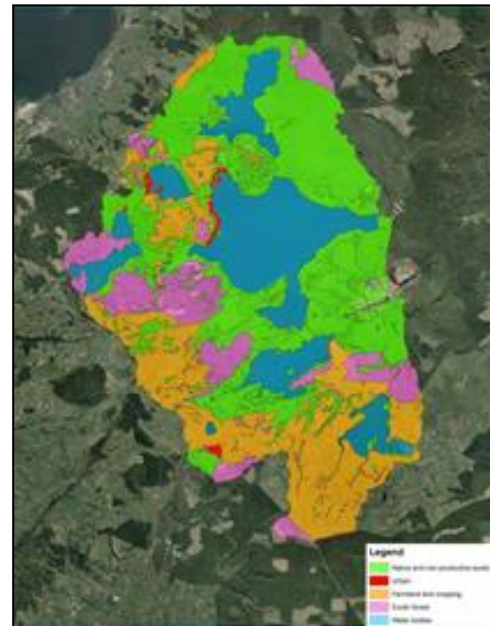
We have made some assumptions and included human-introduced animals as anthropogenic sources in this definition:

- Target P from anthropogenic sources
- Heavy rain leads to P in the lake
- On-going intensive pest control will restore forests and reduce P losses
- Community, stakeholders and funders will support long term work programmes
- The mitigations will not unduly compromise farm productivity
- Costs are indicative only and based on currently available methodologies

Tarawera Catchment Land Use: The green area shows native forest and scrub, the orange areas are farm land, the purple areas are exotic forests and the small patches of red are urban or industrial land:

Urban	196 ha	<1%
Farmland	9,033 ha	31%
Exotic forests	4,634 ha	16%
Native/Scrub	<u>15,521 ha</u>	53%
	29,384 ha	

Over 70% of these catchments are forested with less than a third being used for farming or urban uses.



Pest management: There is substantial pest habitat around the Tarawera Lakes:-

Exotic forests	4,634 ha
Native/scrub	<u>15,521 ha</u>
	20,155 ha

It is just over 20,000 hectares. We do not know whether we need to control pests in the whole area but it doesn't make good sense to only do parts. This will probably lead to increased costs and reduced effectiveness as we would end up with constant pest reinvasion.

Concerns were raised at a previous symposium about increasing P levels in the largely forested catchment of Ōkātina and were wallabies responsible? The University of Waikato investigated the drivers for changes in water quality over time. (Theo Kpodonu, PhD, 2016) Theo determined that erosion was a primary driver for lake productivity and also concluded that invasive mammals, together



with climate change are likely to increase sediment and nutrients entering the lake. Given this, there is a case for invasive mammals being considered for management in forested catchments.

So what do pests have to do with water quality? Firstly, if we look at a normal lowland forest, it is structured with a complex system of plants and shrubs in 4 general tiers. During rain events it acts like a sponge. Once water filters through all the leaf layers to reach the forest floor it begins to pool and flow but we have mosses and ferns and other ground covers there to filter that overland water flow.

What do pests have to do with water quality?

Un-modified forest

- Multi-tier structure
- Vegetation acts as a 'sponge' – soaking up rain
- Ground cover 'filters' any run-off

What do pests have to do with water quality?

Browsing mammals arrive

- Selectively browse palatable vegetation
- Different animals target different forest tiers
- Limit regeneration

Enter a few animals. Most of the browsing mammals in New Zealand selectively browse our forests taking out certain components of the forest and, as this slide demonstrates they target different tiers of the forest. Different pests will have different impacts on the forest.

What we are left with is a thinner forest. The forest structure is compromised and no longer absorbs as much moisture during rain events and allows water to pool and flow over the ground more quickly. There is less ground cover to filter those overland flows and more ability for that water to carry soil particles with it.

What do pests have to do with water quality?

What we are left with

- Modified forest structure
- Forest unable to absorb as much rain
- Increased run-off with limited 'filtering'



What does it look like in the bush?
 This is the wallaby enclosure at Dogger Bank in Okataina. Inside the fence on the right-hand side are seedlings, saplings and ground cover recovering. Outside the fence it is a very different story. Those seedlings and ground covers are conspicuous only by their absence.

What pests are we talking about? There will not be many who would defend these two critters. Possum impacts are well-documented; however the impacts of wallabies on native forests are less well-understood. We were lucky that the Forest Service set up a series of exclosures at Dogger Bank in 1984 and these provided us with some useful insights. When Wallace re-measured these plots in 1995 he concluded that wallabies were inhibiting kanuka forest regeneration.



Now for something a little more controversial. These may look like a couple of photos of deer to most people but the hunters out there will recognise red deer on the left, which are the most common deer in New Zealand and hunted for venison. The other one is a Sambar deer which are highly prized trophy animals of limited distribution through New Zealand but found around Rotomahana. The reason we should not ignore deer came from the exclosure plots as well. When the plots were re-measured in 2001 by Mathew Benes and 2007 by Stephen Hall, they both concluded that deer had a greater impact on the forest understory recruitment than wallabies.

The last animal I include in the photo is no less controversial. These pigs are bulldozers on four legs and we cannot ignore them. They do graze vegetation. Their habit of rooting up ground to hunt for invertebrates exposes soil, leaving it vulnerable to erosion.

As Cam Speedy said at the last symposium, 'There are many methods and approaches to control pests but there are no silver bullets.' Each method that is available has its advantages and disadvantages. How an operation of the scale we are talking about could be carried out can only be determined through genuine engagement and consultation with land owners, Iwi, adjoining communities and stakeholders.

Basic principles we need to consider:

- Must be effective, i.e. will achieve outcome
- Must be affordable for the long-term
- Must be socially acceptable and supported by the community and Iwi

I have not used the word 'cost' effective here as a criteria because there could be some methods that are cost effective but not affordable in the long term so I separated those two. This is about a long term programme of works which must be supported by the whole community.

To do this costing I made a few assumptions. We have not had the conversations with the community about what might be acceptable and how the control would be carried out. But since I don't know what will be acceptable to the community I have based it on a range of control options that meet the effectiveness and affordable criteria and have based my costing scenario on the first two - largely what is effective and what is affordable.

My scenario – the basis of costing

Method	% of habitat	Cost range	Frequency
Aerial 1080	75%	\$25 - \$30 per ha	3 years
Ground (includes community groups)	25%	\$12 - \$200 per ha	2 years
Ground hunting	75%	\$5 - \$10 per ha	3 years of knock down then every 2 year
Operational monitoring	100%	\$10K - \$20K	Annual
Outcome monitoring	75%	\$810K - \$349K	10 years
Planning, management	100%	5% - 10% of annual cost	Annual

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You will note that my costing is based on some form of aerial 1080 and includes some ground work and community work as well. We have several groups working in these catchments doing good work. I propose that we have very intensive ground hunting for pigs and deer and also that there is a significant monitoring component to this work. We need to understand the status of our pest populations from year to year to ensure control operations achieving the right results and are implemented when needed. We must also understand what the response from the forest is to those control operations.

Costs

	Year 1 (\$,000)	Annual (\$,000)	20 years (\$,000)
Planning, management	\$110	\$110	\$2,206
Aerial	\$401	\$140	\$2,804
Ground (includes community groups)	\$471	\$235	\$4,709
Ground hunting	\$113	\$62	\$1,238
Monitoring	\$306	\$59	\$1,175
Total	\$1,401	\$606	\$12,132

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Based on that assumption, and assuming that we have approval to implement the whole area in the first year, we would need about \$1.4M up front in the first year and then every year after that a cost of about \$600,000 a year. It is important to note that if we did end up with a programme that involved less aerial control the costs would climb substantially. For example, if we could only control half the area with aerial 1080, the remaining being done

on the ground, then the costs would climb out to 20 years by an additional \$4 million to \$6 million. It is important to note this work will not be a one-off operation. It would need to be implemented over at least 15 – 20 years before we know whether we are making any difference and assuming we were then carry on indefinitely.

I would like to conclude by repeating a few thoughts from speakers from the last LakesWater Quality Society Symposium (2015). Willy Shaw recognised the significant ecological threats that these animals pose but did wonder whether the erosion generated by them was significant when compared to storm-induced landslides and lakeshore erosions from fluctuating lake levels, and we are seeing a lot of that this year.

Rob Allen also talked on the status and drivers of change to New Zealand's forests and concluded by posing a few questions:

- Are undesirable changes to our forests reversible?
- Is it economically, socially and biologically feasible to reverse them?
- Do we have a robust evidence-base for our actions?

Who knows? These are still good questions when thinking about implementing a programme of work of the scale that would be needed and the costs involved.

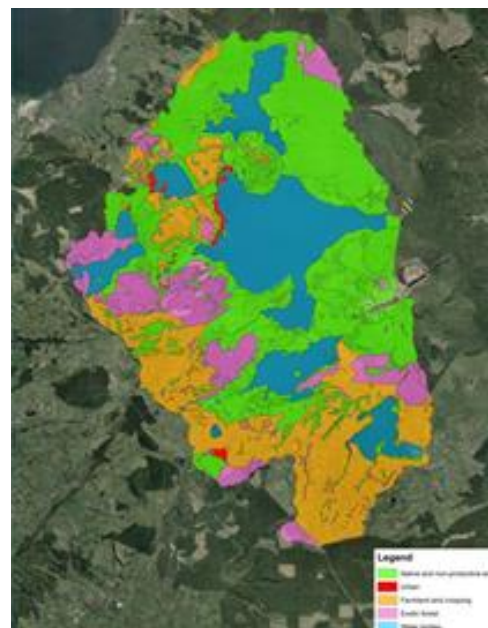
Thank you. I would like to hand over to John now.

John Paterson

My name is John and I am a P addict. My last fix was on Monday night between 8.00 and 9.00 pm. What am I talking about? Phosphorus. I had another as I sat down to dinner at 8.00 last night. Rain. Heavy rain. High intensity rain. That is going to be a repeating theme in my presentation.

I do have to take issue with Chris Sutton. I liaised with Chris for quite a few years and as a Council employee he has always had that line, 'No surprises, John', but his last slide showed that he had bought a wind farm or was going to convert a farm up in Kaharoa to a wind farm and that is a real surprise.

On-Farm Mitigations: Farmland area is shown in orange and is a total of 9,033 hectares, about 31% of the catchment. My presentation is about the cost efficiencies of some farm applied mitigations, not the total cost accountability of P mitigations on farms which is a subject worthy of a whole symposium on its own. P loss from the catchment is highly intermittent and only flows off the land during storm events.



We have some obvious opportunities to deal with P loss that we do not have with nitrogen loss. There are three themes:

- Prevent P mobilising in the first place, achieved largely through good management practices
- Intercept P in transit, like holding down the bolting horse and not as good as the first option
- Treating P loss at its destination with flocculants.

Preventing P mobilising: Phosphorus focussed research is continuing to deliver a growing list of good management practice options but these have to be owned by land managers - farmers, farm owners and farm managers. They have to be perceived as an asset and farmers be convinced they will work and be normalised into land management practices.

The very first step is for farmers to have a farmer-owned Environment Management System (EMS). We have seen really good initiatives on environment management systems in the Tarawera catchments. At the field day at Lake Ōkaro on Wednesday Megan Birchall told us about the environment management system that farmers had engaged in some years ago which was an early version of the Beef & Lamb LEP. Chris Sutton talked about the environment management systems being implemented in the Tarawera Lakes' catchment and that is also the industry LEP and originally the DairyNZ Sustainable Milk Plan.

Theme 1 - Prevent P mobilising cont.

Environment Management Systems (EMS) in NZ Agriculture

Leadership with Ag Industry templates include:

- Beef & Lamb NZ - The LEP
- DairyNZ - The SMP

Now other Providers:

- Fonterra FEP
- FAR FEP
- Irrigation FEP

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This slide goes back into the history of the development of environment management systems in New Zealand. We need to have confidence in these vehicles. The first environment management system in New Zealand was introduced in 2004, the first published environment management system was in the Deer Farmers' Land Care Manual. I am very familiar with that because I wrote it. In 2007 Beef+Lamb developed their LEP, an interesting exercise, and they went to great pains to be inclusive of every farmer, and to give no farmer any reason to say, 'No I don't want to be involved'.

I put the cartoon sketch in when involved in that working party to try and illustrate the easy first step but unfortunately the cartoonists could not get the angry look off the farmer's face. This is the first time that cartoon has ever been publicised. Some years later

DairyNZ developed a prototype of an environment management system called the Farm Environment Action Plan which was trialled here in the Rotorua catchment on two farms.

I need to explain what an EMS is and the ISO14001, the international standard for environment management systems. It is a very well thought-through plan - Do, Check, Act, Cycle and Continuous Improvement. Nicki Douglas talked about Collective Impact as the goal in the centre. The goal of continuous improvement is what the Council is very keen to promote with farmers and farming groups. It does not matter where they start but engaging in a programme of continuous improvement is fantastic.

This presentation is about costs. Chris Ingle covered this more thoroughly in his presentation, but very roughly, 50 farms are engaged now and the support package is:

Theme 1 - Prevent P mobilising cont.

Good Management Practices that reduce P-loss – just a few examples:

From Rich McDowell 2016

- Adjusting P fertiliser application rates based on soil testing
- Changing the type of P fertiliser used
- Maximising effluent efficiency on pasture
- Standing stock off pasture in wet weather

Effectiveness (%)	Cost (\$/kg P conserved)
5-20	highly cost-effective
0-20	0-25
10-30	25
30-50	125-200

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I used the heading 'Valuation' because the industry has really stepped up which is great. We are aiming to have all farms on board by early 2018. Just remember that the pioneers of the Tarawera project are not the Council but some dedicated leading farmers with BOPRC right beside them.

Theme 1 - Prevent P mobilising cont.

Environment Management System adoption - Tarawera Lakes

~ 50 Farms being engaged now

Support Package:

			Valuation
~ 20 Drystock	LEPs	~\$3,000 ea	\$60,000
~ 30 Dairy	Fonterra FEP	fully funded	\$90,000
	Project Management		<u>\$10,000</u>
			\$160,000*

* Total does not include land owner implementation time

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Good Management Practice (GMP) refers to an evolving suite of tools or practices that can be put in place at a land user, sector and industry level to help achieve community agreed outcomes – such as water quality. Some good management practices actually cost very little and some of these slides show material repeated from Richard McDowell's work. Simple things such as adjusting the P loss application rate to be mindful of the optimal agronomic level for pasture growth can cost very little and be highly cost effective with minimising the loss of phosphorus.

The second low cost possibility with good effect is changing to a less soluble fertiliser. On the bottom line things cost quite a lot more and standing stock off pasture can be quite an expensive process.

Theme 1 - Prevent P mobilising cont.

Critical Source Areas (CSA) – High cost efficiency

The majority (e.g. 80%) of contaminant losses come from a minority (e.g. 20%) of a paddock, farm or catchment's area.

From Rich McDowell 2016 High Intensity Rainfall Event at Kaitake 2006/07

Critical source areas only		Whole farm/sub-catchment	
ΔEBIT	ΔP loss	ΔEBIT	ΔP loss
-2%	-40%	-12%	-48%




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Dealing with critical source areas can achieve high cost efficiency. Rich McDowell did a study of 14 farms around New Zealand and noticed that for only a cost of 2% of earnings before interest and tax, 40% reductions could be achieved which shows that things do not necessarily need to cost a lot of money.

Theme 1 - Prevent P mobilising cont.

What is a Critical Source Area (CSA) for P-loss? :

- **Storm water flow paths**
Ephemeral care vs Stream care
- **Land management mistake**
S... in connection with flow path
- **A high intensity rain storm event**
Rainfall rate exceeds soils infiltration rate – a redline for runoff



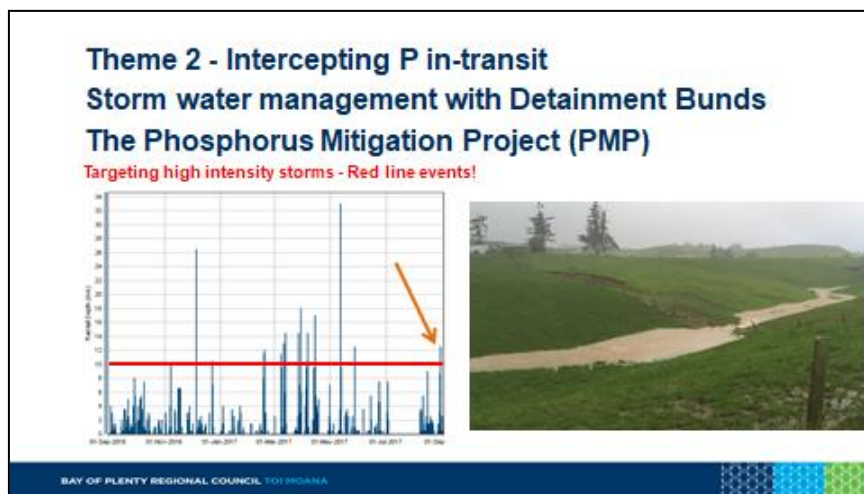
Conclusion: Prevention is better than Cure
50 Tarawera Lakes Farm Environment Plans – CSA focused

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What is a critical source area? Just to take the anatomy a step further, it is a combination of not making mistakes in stream flow paths and ephemeral flow paths. Storms generate water flow where water does not flow usually. Those are the first order streams or ephemeral parts of the landscape on everybody's farm. If a farmer makes a mistake in one of those flow paths he gets caned by high intensity storm events which shift it. The red line is those high intensity storms and I referred to my last fix being Monday night when we had a high intensity storm. That is when phosphorus really leaves the landscape.



This is what a critical source area looks like. There is a major storm flow channel through the middle. The farmer has made a mistake in cultivating and putting a fodder crop there. There will be a number of storm flows through the winter. Normally there are about six a year but this last year has doubled to about 12. Exposing such areas to P-loss risk, disturbed soil, concentrated animal excrement is a critical source area and obviously a change in land management practice there would have avoided that. Other critical source areas include poor timing / placement of fertiliser, inappropriate cultivation of slopes and when such mistakes are in places where storm water run-off can wash over them.



The red line is for phosphorus loss which is generally about 10mm per hour but the important thing is looking at the opportunity to intercept it. It only happens for those tiny points in time normally, only a few hours per year. We have moved from doing the preventative stuff to looking at what we could do to intercept this horse which is about to bolt. That photo was taken on Monday in a paddock near my place. The rain on the roof was only 2.5mm in our catchment rain gauges, so it was not a run-off event. Not a P loss event.

Phosphorus Mitigation Project (SFF 404964)

Advancing on-farm phosphorus loss mitigation in conjunction with applied research on a new mitigation tool - the Detainment Bund



- PhD student – Brian Levine – runs from 2017 to 2019
- Project Manager, John Paterson

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To further hijack this event, I want to talk about the Phosphorus Mitigation Project which is a wonderful project that I work on independently of Council. This is a 'watch this space' slide. Brian Levene, a PhD student, is working here for three years to prove how much phosphorus we can catch in these storms if we build low level earth detainment bunds like that shown in the centre photo.

Lastly the acknowledgements. Greg wishes to acknowledge Dale Williams, Dave Paine, Shay Dean (BOPRC), Phil Commins (contractor), Cam Speedy – papers and reports and OSPRI .

I have taken a lot of material from:

- Rich McDowell 2010 – 2016 various papers / presentations
- Genevieve Carruthers (2005), an Environment Management Systems Australian expert who came here to speak to Rerewhakaaitu farmers some years ago.
- Dylan Clarke (2013) who did the first thesis on detainment bunds for mitigating phosphorus and sediment loss
- Phosphorus Mitigation Project (2017 – 2019) MPI Sustainable Farming Fund and 7 co-funders including all 3 New Zealand Pastoral sectors

Thank you very much.

THE COST OF AQUATIC WEED CONTROL IN THE ROTORUA TE ARAWA LAKES

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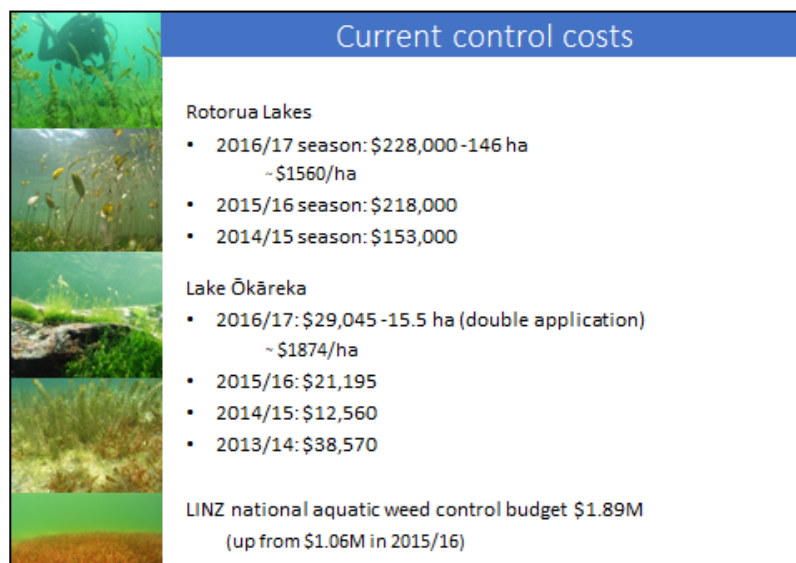
TRANSCRIPT

Firstly, we would like to acknowledge Don Atkinson and the LakesWater Quality Society for the topic. We will present information on the costs of aquatic weed control in the Rotorua, Te Arawa Lakes and thank all of the people who have willingly given us their estimated costs. Hopefully, this provides guidance on what current activities cost and what future scenarios might be feasible.

We will cover current control, organisations and responsibilities, lake focussed management plans, comparative control costs and then considering the future and gaps in the picture of aquatic weed control. This talk draws on all of the talks from the last two sessions yesterday and the talks we have heard this morning.

Currently the control of pests within the Rotorua Te Arawa Lakes is co-ordinated by the Aquatic Pest Co-ordination Group, with members being Bay of Plenty Regional Council, Te Arawa Lakes Trust, Rotorua Lakes Council, Land Information New Zealand, Boffa Miskell, Fish & Game, Department of Conservation and NIWA.

There is a range of activities already happening in the lakes. The Biosecurity Awareness Programme that Hamish was talking about, which is run by Bay of Plenty Regional Council; MPI put some funding into this. There is the Bay of Plenty, Weed Cordon Programme and the Lakes Surveillance Programme involving 8 at-risk lakes, to ensure that new weeds do not get into these water bodies. Then there are the incursion responses in lakes Ōkātina and Lake Ōkareka. There is also the lake weed spray programme co-ordinated by Boffa Miskell, funded by LINZ and also with input from the Regional Council. Other lakeweed work by BOPRC involves harvesting in Lake Rotoehu which is nutrient management rather than a control of the pest plant per se.



These are the costs: \$228,000 was spent on the biosecurity and amenity weed management of the Rotorua lakes. The area treated with diquat was 146 hectares at about \$1,500 a hectare for the control costs. Lake Ōkareka has had an eradication programme for hornwort and reduction of other introduced weed species. There was an initial big investment in 2013 when hornwort was first detected and inputs increased in the following year with a double diquat application showing real benefits. Diquat was used on 15.5 hectares and the treatment costs in 2016/17 were \$29,000 or nearly \$1,900 per hectare.

The Rotorua Lakes' costs (that LINZ run) compare with the national budget of \$1.89M for aquatic weed management. That budget includes a lot of South Island systems as well as lakes like Karapiro in the Waikato hydro-system.

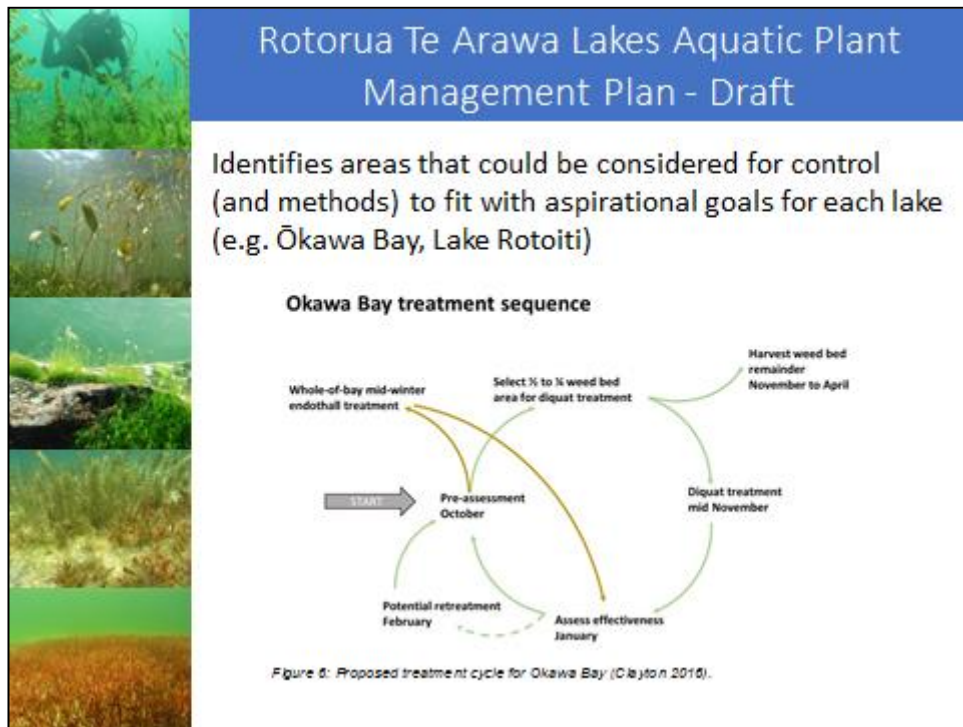
Weed management - The Rotorua, Te Arawa Lakes are 12 separate, very different water bodies, all with different values, human use and each with a unique spectrum of not only the weed types but the issues and impacts that they cause. It is quite different from the water quality issues. Each lake requires a tailored weed management plan. Invasive plants grow where people access the water bodies. It is not about monitoring in the middle of the lake, but rather the littoral zone or lake edge. A lot of nutrients enter via the margin of the water body. It is not just about nuisance weed issues; there is a role for the aquatic plants in nutrient uptake as well as other impacts.

Reactive management addresses the immediate issues and provides tangible benefits at targeted sites. To effectively manage the whole suite of lakes in a long-term goal, we need to account for actions in one lake having an impact on adjacent lakes. The current surveillance plans are integrated into the management plans.

In developing management plans for each lake it is important to define the problems in each lake, identify the weeds, the risks and the impact potential. It is vital that the community and the agencies align and develop a shared vision. Weeds need to be prioritised for each lake, and the plan must clarify roles, and identify the best tools.

The Lake Weed Management Plans have been developed by BOPRC jointly with LINZ and prepared by Boffa Miskell with NIWA technical input. The draft document is currently out there for stakeholder input with medium term goals, guide objectives and outcomes, as signposts pointing the way to the desired destination. These plans are the initial part of the process.

The draft plans identify areas and methods (next page) that could be considered for control strategies to fit aspirational goals for each lake. Within Okawa Bay (Lake Rotoiti) a treatment sequence is presented as a series of flow diagrams. It has to be based on feedback mechanisms; pre-assessment firstly then scenarios to test options, such as using endothall or diquat in split applications, or even a harvester. All the different techniques that could be used for management of each situation like this are being considered.



Below is Okawa Bay; it is about 43 hectares in area. We have done a cost option for the management of Okawa Bay weed. Rohan talked about the spectacular result we got for the eradication of weeds at 0.1 part per million active ingredient of endothall. Three metres is the average depth to which these plants grow, so applying 6 litres per hectare, you would need 258 litres. That is \$7,380 for the aquatic herbicide Aquathol K, plus application costs of \$1,300 per hectare. For one treatment that is \$20,380. However, for maximum effect, you could use the maximum label rate but this \$20,000 ramps up to \$382,000. That is a big difference, and it really needs more than just a dollar figure for how much it costs to control weed.



Ōkawa Bay Endothall control costs	
	For target concentration of 0.1 ppm = 43 ha at average 3 m deep x 6 L per ha = 258 L (\$7,380 for Aquathol K)
	\$1,300 per hectare for application = \$13,000 for 25% of area - one treatment
	Total - \$20,380
	Maximum rate 5 ppm
	Total - \$382,000

Comparative control costs	
	Hessian bottom lining \$50,000/ha 30 hours/ha
	Suction dredging \$20,000/ha 100 hours/ha
	Harvesting \$10,000/ha running costs only 24 hours/ha
	Herbicides \$1,800/ha Diquat \$15,000/1,000 L (20% a.i.) Endothall \$28,607/1,000 L (51% a.i.) 50 ha/8 hours
	Duration of control not factored into costings

Looking at the various control options, the most expensive is the hessian bottom lining at \$5.00 per square metre or \$50,000 per hectare and taking about 30 hours to cover 1 hectare of lake bottom. Suction dredging using a diver and venturi pump costs about \$20,000 per hectare and 3 times as much time as the hessian.

For harvesting I have used a costing derived from Lake Karapiro and thanks to Andy Bruere and Hamish Lass for a costing of the harvester work in Rotoehu. The running costs are \$10,000 a hectare, not including the purchase of the machine or the disposal costs of the weed. It takes about 24 hours to 3 days to harvest a hectare.

An average cost for herbicide is \$1,800 to \$2,000 a hectare. Boffa Miskell has obtained diquat for \$15,000 per 1,000 litres and endothall at \$28,500 for 1,000 litres. However, the important thing is the active ingredient and herbicidal rate. Diquat is only 20% of the formulation applied. Endothall is just over 50% active in Aquathol K. They are quite a similar cost for the active ingredient and dose rates.

What is not factored into these costings is the duration of control. In the case of harvesting, it is really mowing the lawn and is going to need frequent repeats. With endothall, potentially there is long term control. Rohan showed the advantages of double applications of diquat where initially the plant is knocked down followed by re-growth. A second treatment is much more effective, so there is a range of techniques that can be used to improve outcomes.

The management in the Rotorua Te Arawa Lakes was underpinned by a funded research programme run by John Clayton back in the days of MAF through to the early 2000's. The funding optimised the use of the control tool diquat. In the present we do not have such funding, but there remains a need to ensure that any proposed management actions are independently peer reviewed and scientifically justified. There must be a consistency of approach, best use of resources, protection of public safety, compliance with relevant legislation and statutory monitoring.

Returning to the Okawa Bay example, there are a wide range of costings, There was nearly \$300,000 difference between the maximum and minimum rates using endothall. Compliance agencies could reduce compliance costs, there could more targeted effective control methods and the possibility of lake-wide eradication, which is going to markedly reduce costs.

Monitoring is another important part of a control programme. As soon as something different is done, many observers attribute lake changes to that new action. A good example of effective monitoring is the Hawke's Bay hydrilla eradication programme which the Ministry for Primary Industry funded. They also funded major monitoring of the biota in the lake and water quality. When there was a long hot summer, which led to stratification and problems, we saw the result but could show that the grass carp had been in the lake for 3 years, with no problems in the intervening years and there were no beds of hydrilla involved in the algal bloom. This allows us to conclude that whatever was causing the issue, it was not necessarily from the weed control programme.

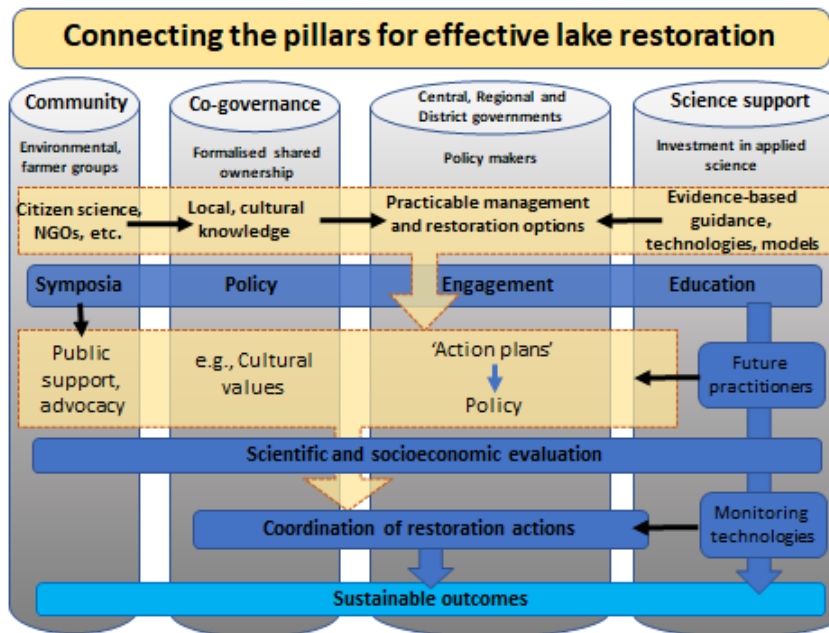
Research will support the implementation of operational plans that come out of this proposed way forward with weed management plans and the best tools, trialling new techniques as they are developed and monitored to assess effectiveness, selectivity, cost efficiency, all feeding back information into the action plan.

What is missing? There are different rationales for controlling weed in these lakes. Biosecurity seems to be the major focus and quite rightly so, but also the impacts of the plants growing and how they interact with water quality in shallow marginal areas is not well understood. Deborah Hofstra talked about restoration and the benefits of doing that work.

There is some confusion about central government agencies? Sections of the Regional Council are also different for each of these goals. Not all legislation is aligned with the goals and can impede progress. For example, the Hazardous Substances New Organisms Act is overseen by the Environmental Protection Authority and there are delays which Rohan talked about such as the label issues with the herbicides, and there are similar issues with rotenone and other formulations that cannot be used in New Zealand at the moment.

We need a pathway for the evaluation of new tools and experimental use permits. When we develop new products, the largest size tanks are 1,600 litres in our testing facility. These new products need to be tried in small areas in the field prior to widespread use,

but we do not have a practical mechanism to do that. Remember with incursions, time is the enemy because they keep on increasing in an exponential way.



Thank you very much David Hamilton for giving us this slide. It reflects what a well-resourced and science-backed programme can provide. These are the water quality management action plans that are happening within these lakes and here in New Zealand we are world leaders and are seeing the benefits of improving water quality. It would be great to have a similar approach to the weed management where everyone is on board and potentially we could have a Rotorua Te Arawa Lakes Biosecurity Research Programme and look at massive gains.

Another example, Peter Beets talked about the work in forestry where they have a research model where all of the plantation forestry groups are contributing to the research programme. They are involved in governance, goal setting, funding and measurement of outcomes. A similar approach could be used with all organisations involved with aquatic weed and pest management. However, in this case not everybody will have the same goals and you are never going to please everyone.

The Aquatic Pests Co-ordination Group is a good start as far as getting everyone together. Currently it is very much focussed on the implementation of these strategies. Maybe if there was a bit more strategic input and policy, potentially there is also a link to the Ministry for Primary Industry led Freshwater Biosecurity partnership, which includes other government departments.

We would really like to thank the LakesWater Quality Society for putting on another splendid symposium and all of the Aquatic Plants Team, thank you for all your input. Big thanks to Marcus Girvan and Kieran Miller from Boffa Miskell for providing a lot of the figures, Dave Mole from LINZ, Hamish Lass, Andy Bruere and Greg Corbett for their input from Bay of Plenty Regional Council and also Geoff Angell (AquaAg), Pieter van der Westhuizen (Etec). Prof David Hamilton and Stu McNaughton (Aquateq) and finally NIWA SSIF F/W Biosecurity Programme funding.

Thank you very much.

NEXT FOUNDATION: PERSPECTIVE ON FUNDING

Jan Hania

NEXT Foundation Environmental Director

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Jan is currently the Environmental Director for the NEXT Foundation, residing in Te Tau Ihu, Nelson. Prior to joining NEXT in 2015, Jan spent 7 years with the Department of Conservation leading teams at district, regional and national level building partnerships and developing large scale collaborative impact projects focused on people, biodiversity and water. Jan was DOC's Conservator for East Coast Bay of Plenty around 5 years ago and was previously on the technical advisory group for Rotorua Lakes back in 2007 whilst leading the implementation of the Lake Taupo Protection Project with Waikato Regional Council.

TRANSCRIPT

I want to congratulate the LakesWater Quality Society for putting this symposium together and the high quality of speakers that have been through. It has been absolutely fabulous for me and a lot of things I am going to say have already been said because what we are looking for in terms of investment, you guys are already doing.

Coming back here after being away for a few years, it is great to see how much the work has progressed and how much is being done on the ground. It is nice to see the impacts being achieved, so well done.

I want to give a background on the NEXT Foundation, how we came to exist, a bit of a repeat on what Nicki Douglas covered this morning on collective impact and how to get that at scale. I will then talk about how we are trying to implement that in some of our projects around the country. I will also look at our investment portfolio on healthy rivers, which we have not really started yet, but ideas on how we get to that place as well.

NEXT Foundation's vision is to create a legacy of environmental and educational excellence for the benefit of future generations of New Zealanders. Education and the environment have been chosen as the two categories for support and investment because we consider that they have the greatest potential to inspire and create lasting value for New Zealanders. We aim to empower young people today and the leaders of tomorrow. Education opens the door to personal development, economic opportunity and innovation for society as a whole. New Zealand has an excellent education system, but there are a wide range of initiatives that can drive higher achievement and outcomes, including innovative projects at the edges of traditional systems.

We will invest in projects that strive for educational excellence to provide all New Zealanders with the opportunity to fulfil their potential and develop into talented individuals with the skills and confidence to confront the challenges and embrace the opportunities of a globalised world economy.

New Zealand's natural environment is the foundation of not only our economy but also our sense of identity. Our vision is to ensure our natural environment remains healthy so that

it will continue to provide us with the essential resources that underpin a thriving and prosperous New Zealand. Focussing principally on conservation, there are many threats to be managed or overcome such as habitat loss, introduced predators, urbanisation and water use.


The NEXT Foundation was endowed by a couple of very generous New Zealanders, Neil and Annette Ploughman, who are very smart and also very dedicated New Zealanders. It was launched in March 2014 and through their acumen and business they gifted \$100 million over 10 years, a substantial amount of resource to New Zealand for the outcomes they envisaged. It is a different kind of approach, a spend down strategic approach with a timeframe to spend the money focusing on outcomes and ensuring that they are sustainable in the long term.

We look at large scale interventions of \$3 to \$15 million per project over 10 years hoping that whatever we invest in will be sustained in the long term. They need to be transformational and inspirational so others will take these exemplars and follow them, and business like and rigorous. A critical element which lots of people have already talked about today is leadership. It is collective leadership, not about individuals and throughout all of our programmes.


We not only support people with funding but we bring lots of networks from the businesses that we have worked with over the years and the work we have done between each of us in various organisations. It is also helping people to be successful in their own personal or organisational missions. It is not just about money. There is other stuff, social capital that we can bring to these projects.




NEXT Education Initiatives




— Strategic leadership development for principals




— Digitally enabled learning system for lower decile communities of schools




— Digital literacy for teachers




— Digitally enabled and collaborative learning for Rotorua district




— Promoting richer language in the first 1,000 days




Innovative teacher training for top graduates and professionals to reduce educational inequality



Business School endowment fund



International exchange scholarships for business students



Predator Free New Zealand - Martin Kessick talked about this earlier and brought to bear the co-benefits of Predator Free, particularly on erosion and its impacts here in the Rotorua Te Arawa Lakes.

Healthy rivers and environmental education - A whole business approach on education and here in Rotorua there is the able leadership of Leith Comber in the Ngā Pūmanawa e Waru collective doing fantastic work, enabling leadership development and digital access with the schools and there are others around the country doing similar great work.



Environmental Investment so far



Rotorua Island (2008)

- A public conservation park and sanctuary for threatened species 83ha



Project Janszoon (2012)

- Transforming ecological health of the Abel Tasman National Park
- 2015 Green Ribbon Supreme Award winner – 22,000ha



ZIP (2015)

- A partnership to design, evaluate and implement innovative technologies to eradicate and defend large scale areas from predators providing sustained protection for biodiversity



Taranaki Mouna Project (2016)

- A large scale collaborative partnership project to restore and sustain ecological resilience to Taranaki Mouna
- 34,000ha and beyond

Predator Free Wellington (2016)

Te Urewera / Poutiri-Ao-ō-Tane / Cape to City

These are some of the environmental investments so far. My focus is the environmental side of the NEXT business. Prior to NEXT forming, the Ploughman's invested in 2008 to restore Rotorua Island, an area of 83 hectares, as a public conservation park and sanctuary for threatened species. It is now completely predator free and fully restored with an education centre as well.

The family and advisors then looked at Project Janszoon in 2012, a restoration of Abel Tasman National Park. Whilst developing that it became obvious there was not enough focus on research and development of tools to control predators so we then built a public-private partnership company called Zero Invasive Predators (2015) (ZIP) to design, evaluate and implement innovative technologies to eradicate and defend large scale areas from predators providing sustained protection for biodiversity.

In 2016 we moved on to the Taranaki Mounnga Project, which I lead. This was a large scale collaborative partnership project to restore and sustain ecological resilience to the mountain, ranges and islands of Taranaki from pests and restore and revitalise wildlife; a large area of 34,000 hectares and beyond.

In partnership with Wellington City Council and the Greater Wellington Regional Council we are supporting Wellington's mission to become the first Predator Free capital city in the world.

There are other projects and approaches as in Te Uruwera, Poutiri ao ō Tane and Cape 2 City in Hawkes Bay and others around the country that I have worked with in the past that we take learnings from, both in values, systems and the human dynamics of how we might build these sorts of projects at scale.

Other NEXT Environmental Investment and Support

-  • Grant Ryan - Entrepreneurial Leadership
- Open source learning
- Artificial Intelligence
- Advanced technology to detect and lure predators

-  • James Mansell – Thought and practice leadership
- A high-trust, lower-cost alternative to enable data integration and reuse
- High trust, high value
- Participant controlled, inclusive
- <http://datacommons.org.nz/>



Other investments that we support are a project called Cacophony led by an entrepreneurial engineer called Grant Ryan using artificial intelligence and open-sourced learning to go much faster on video and acoustic detection and lures for predators to use

in the field. We also support James Mansell in a Data Commons project because we believe that presenting data in a more clear and meaningful way will enable people to own their problems and better contribute to the solutions.

When looking for investment opportunities it is important to provide assurance. We are not risk averse, in fact we look for the high risk areas, but we provide assurance to other investors as well as ourselves that the programmes enhance or are sustainable in the long term. They must have effective and compatible partners, as you have in the Rotorua Te Arawa Lakes Project. There must be a clear and coherent purpose that everyone aims for and is socialised across the agenda which in itself should be adaptive and emergent. Of course leadership is key and we look for projects which can be scaled and replicated. If we can provide a learning to share across the country to change the entire system we have been successful.



The Tomorrow Accord
PARTNERSHIP AND COMMITMENT

The NEXT Foundation's investment with Partners

- Game-changing conservation interventions for biodiversity gain and community engagement

NZ Government's commitment

- Ensure projects are well supported
- New Zealanders gain benefits
- Biodiversity outcomes are maintained

The Tomorrow Accord was brokered with the Government in 2014, led by Nick Smith at the time, who was the Minister of Conservation. It says that if we invest up front in achieving transformation, doing the heavy lifting such as providing abundant species in a particular place or removing predators or cleaning up some waterways, then the Government will maintain those outcomes in the long run. This means we invest in the large spend up front and the maintenance costs will be picked up by Government. That provides investors, not only us but others whom we bring to the party, a whole lot more assurance and commitment to other projects because then you can take your spend further and enhance the potential for innovation and other shared input.

Slide 13 - Nicki Douglas covered collective impact really well this morning and I can see a lot of the elements in the conversations today. But we need to think about how to lift the scale up. We do biodiversity here, waterways there and social impact elsewhere. However we must take a far larger scale approach to achieve the outcomes to save our rivers and bring back biodiversity.

Collective Impact

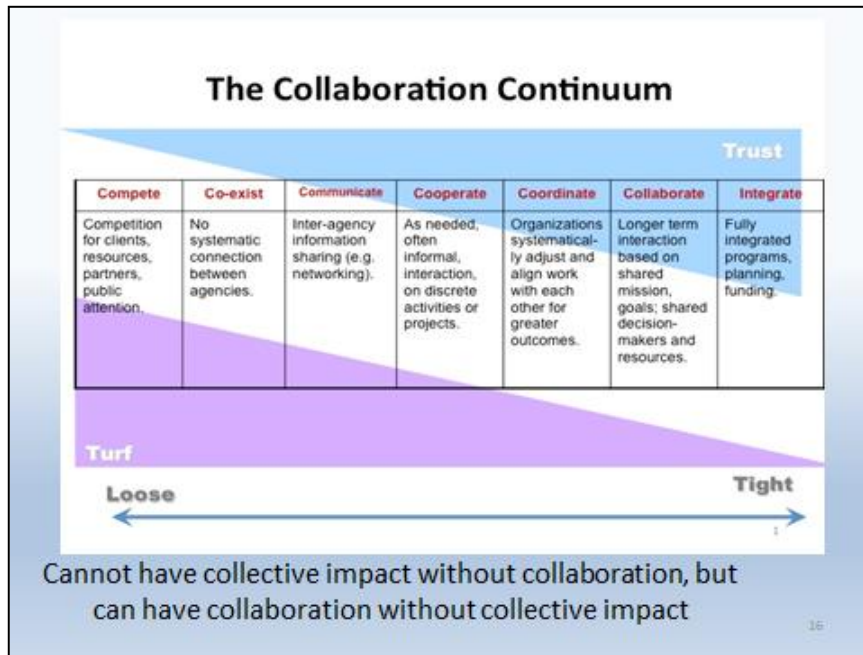
- 5 conditions to enable collective impact
 - Common agenda
 - Design for success of network, not organisation
 - Shared measurement, collective infrastructure
 - Mutually reinforcing activities
 - Continuous communication – multiple opportunities
 - Backbone support – scaleable and replicable
- Need to develop and showcase examples of collective impact for multiple outcomes including environmental in NZ
- http://ssir.org/articles/entry/collective_impact
- <https://www.collectiveimpactforum.org/tags/community-investments>
- <http://www.collaborationforimpact.com/tag/collective-impact-in-australia/>

Collaboration is required to fix the wicked adaptive and intractable issues, complex and complicated systems:-

- Incomplete or contradictory knowledge
- Large economic burden
- Many different views and vested interests
- Difficult to frame
- Reactions (cause/effect) not clear
- Diverse stakeholders with unique experience
- No right or wrong path
- Needs objective measure of success

Nicki mentioned the Cynafin Framework but we do not talk enough about the external drivers from things like climate change. Prof David Hamilton talked yesterday about the increase in lake temperatures and how that is going to affect dissolved oxygen and therefore the ecosystems. How will that change the overall systems and those places being looked after? We are not doing enough. We need to think about how we operate fast changing systems and have good values and approaches to deal with these difficult intractable issues coming our way.

Collaboration, as most of you know, is working across power differentials for a common purpose. There are different groups with different authorities and resources but if we can bridge those and build trust by action we achieve that common purpose. There is far more capability to achieve an outcome if you can convene across the system and keep everyone on the same page through efficient and effective communications. The example from the Hunua Project in Auckland this morning was quite amazing. If we can integrate across systems at scale and think about outcomes not just for ecosystems, for water, human elements and terrestrial ecosystems, then there is a far greater chance of succeeding.



Collaborating is not doing things in silos, understanding where the common ground is and supporting each other in having a clear purpose to achieve that common goal. I am sure many of you would have seen this in the past.

Why do we need biodiversity? Because it is in decline. It is quite chilling to think of the number of species and birds being chewed every day by the predators out there in the environment – we think 70,000 a day. Some 3,000 iconic species, both flora and fauna, are endangered. There are 168 of our unique native bird species. But our investment will never solve that problem alone so we need to get much better and smarter. We have new risks coming from climate change which are going to cause chaos in the ecological systems and we have to learn to deal with it. Spending will go towards saving infrastructure rather than biodiversity. We must act quickly.

**Parliamentary Commissioner for the Environment
Jan Wright**

Taonga of an Island Nation: Saving Our Birds, 2017

- Securing a representative selection of high biodiversity sites against the pressures of weed and pest problems
- “...a portfolio of areas like Taranaki Mounga...large...”
- ensuring that populations of all key species are robust
- Engaging the NZ public in this challenge
- “...support for, and co-ordination of community groups...”

Taking action NOW – the next two decades will be critical

I was pleased to see Jan Wright's report come out recently. She provided us with a vision for the country to build abundant, resilient, and diverse populations of species. She was talking about birds, but it gave us assurance that our work was on the right track when she said that we need to be working at scale. Here in the large area of the Rotorua Te Arawa Lakes systems you are all looking at outcomes together, with multiple agencies working for a common purpose and engaging your public in that challenge.

It is one of the things that we do not do very well, engage the public and communities. We do not tell the story well enough in my view but we could get better and work on it far more collectively. Community groups are where the action hits the ground and it empowers those groups to be even more effective but we have to be doing it now.

A bit more detail on some of our projects. Project Janszoon based in Abel Tasman National Park. There was an initial investment which was a contractor, being DOC in this case, and funder, being us. Two parties shifting what was merely around \$60,000 a year biodiversity budget and is now up to about \$1.2 million. There is a 20,000 hectare trapping network and regular 1080 campaigns. Half a dozen species have been translocated back into the park and coincidentally the tourist numbers have gone from 140,000 five years ago to over 300,000 last year. There are quite significant changes and it is also providing us with learning for other projects as well.



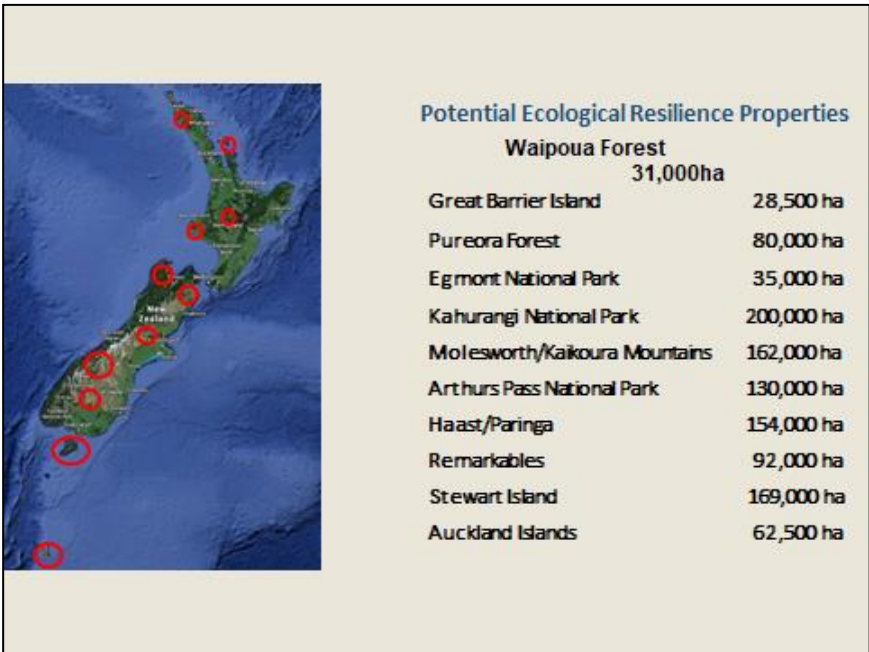
I want to talk about building collaborations, Zero Invasive Predators (ZIP) being one example. It is a private public company with charitable status, primarily a partnership between DOC and the NEXT Foundation but a separate company of its own. It is also funded by the Morgan Foundation (Gareth Morgan), Jasmine, which is his son Sam, various dairy companies, all funding at quite a high level, about \$4 million a year in total. They provide technologies, methodologies, tools to eradicate predators and they are tracking really fast. We think we are getting close to a possum eradication tool.

ZIP's purpose is to secure New Zealand's biodiversity by developing innovative, strongly supported technologies to **remove** predators from mainland sites and **protect** those sites from reinvasion.



ZIP's purpose is all about research and development of new tools and techniques to remove predators. That is all they do. They do not do social engagement, nor do they do the science or a lot of written papers that one would normally expect when doing research and development. They are getting to the tools and getting the tools out there as fast as they can.

I mentioned ZIP because I do not think we understand it well enough. Most pest programmes are largely around suppressing or controlling numbers. But ZIP is a different kind of science with different tools. We need better detection and to be ruthless, getting every last critter or it's wasting our money. That is the mind-set we must bring to the challenge of Predator Free 2050.



After Janszoon was underway we started to look across the country to invest. We asked DOC where we could go if we had the opportunity to do other large scale investments. We looked closely at all these large potential ecological resilience properties. In the end we chose Taranaki Mouna for a number of reasons. It is iconic, has a mix of dairying in the wider catchment, a strong possum self-help programme led by the Taranaki Regional Council and a large connected community. If we could be successful there and provide exemplars and templates then we could roll these models out elsewhere in the country. To be clear though, NEXT is on the backseat. We are helping to build it but in the end the community, Iwi and locals will be leading this project in years to come.



THE STORY SO FAR

Background and Development

- Government and NEXT agree on Tomorrow Accord 2014
- 10 Large scale sites proposed to NEXT from DOC
- Taranaki iwi hosted in Abel Tasman
- Taranaki Mouna selected by NEXT Board Dec 2015
- Founding Parties of Taranaki iwi Chairs, NEXT and DOC
- Agree to an MOU April 2016
- Founding Sponsors Announced - \$24M over 10 years
- PFNZ2050 announced 2016

Taranaki Iwi Chairs Forum Department of Conservation
Te Papa Atawhai **NEXT FOUNDATION**
Investing in our land, our people

Initially we worked with DOC to build the portfolio and establish the programme. The Tomorrow Accord got off the ground in 2014 providing our backers with the assurance that their money would be well spent and the impacts achieved. We hosted Taranaki Iwi at Abel Tasman to show the work that was being done and how effective it is if applying those collective impact approaches. We signed an MOU with all parties and looked for other sponsors. It is now a \$24 million project committed for the next 10 years to eradicate predators and bring back species to restore the mountain's vitality once again.

Once we had the plan built and convened the partners, we were able to ask other potential sponsors and founding partners if they would like to invest as well. We have Shell New Zealand and some may disagree but they have been very helpful, not just in their rigour but also their understanding of community processes and bringing some 'commons' approaches to our engagement.

Sam Morgan of Jasmine Social Investments is helping as well and the Taranaki Savings Bank Community Trust is very important. They bring a lot of insight into how that community works and help to fund the work programmes. Landcare Research is alongside providing research background to our project as we progress.

The Project Outcomes:

- The ecological resilience of Taranaki Mounga is restored
- Taranaki iwi Chairs and community, supported by local, regional and national government embrace and sustain the transformation
- The Taranaki Mounga Project inspires other communities and investors to address NZ's ecological challenges at landscape scale

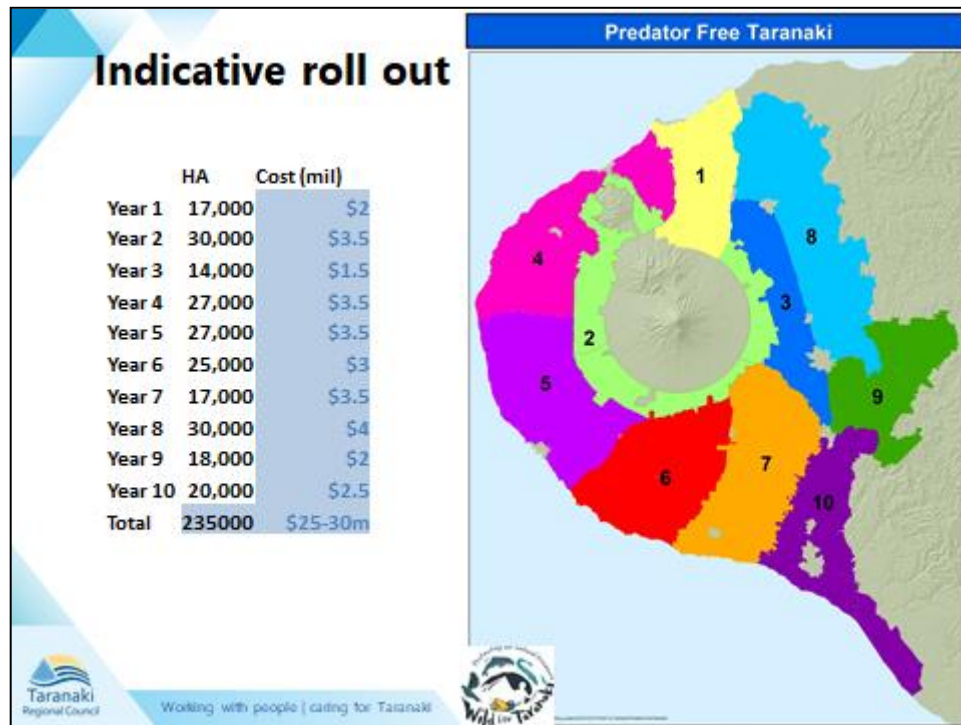
We do not do IP; we like to share all our knowledge and learning as much as we can.

Nicki touched on values and purpose this morning and these are really important. Systems that are changing fast are potentially chaotic and it is essential to move fast or if evidence is missing and decisions must be made, it is important to have good values, based on integrity which come from the Iwi of Taranaki.



It has inspired the Regional Council to think about how they move towards a Predator Free Taranaki. They have a plan to roll out each year for predator control across the region off the back of their possum control programme. They will be trialling some possum eradication techniques in that region this year.

This programme has an objective to encapsulate health and wellbeing as part of the whole solution as well. Rangatahi are co-designing excursions and learning on the mountain to achieve health and wellbeing benefits from being involved in conservation and learning skills. There are some simple things going on. Someone with no shoes, who has lived in New Plymouth all their life and never been to the mountain is now part of designing a programme to help other youth get involved in this project. That is important for the long term sustainability of projects like this.

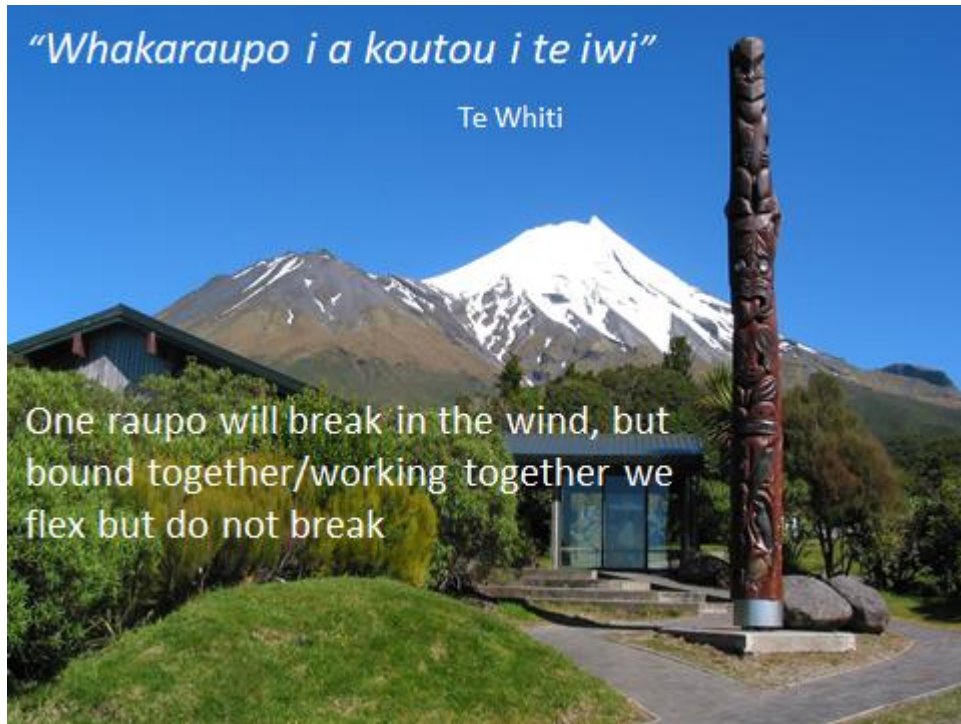


There have been a lot of challenges and there always will be. No one has gone to eradication at this level before so finding technical capabilities is difficult. We have to build as we go. It takes time to develop partnerships operating with common values, to build trust and to share the stories like this. It has taken three years for us to get started. Systems for maintaining and sharing data do not exist and we need to move that along and tell our story in more meaningful ways so people in communities understand the problem and the solutions. We will be investing in that more as we go forward. As scaling up occurs, maintaining agile and effective management and co-ordination systems have to change as more people get involved. It is important to have the right kind of efficient process for sharing learnings and involving others.

In conclusion:

- To make impact at scale we need to provide investment assurance because there are always other investors interested in our progress because they could help in other projects.
- The common vision, common metrics and values are important to share learnings as you cannot manage what you cannot measure.
- A common agenda so the various players across the organisations are working for the same goal.
- The backbone infrastructure is far more important than people realise, administration, printing newsletters, bank accounts, all needs to be done well.
- There are multiple opportunities to connect and build for the network, not just the organisation on its own.

There is a major opportunity and more access to meaningful data in layman's language. If we can empower communities to own their waterways, own the problems, we have a better chance to sustain the solutions. We are looking to work in that space as well.



Kia ora mai tatou

QUESTIONS

Andy Bruere, BOPRC: I have a question for Hannah Mueller around the valuation of Lake Rotorua. You say it is worth about \$122 million annually. The cost for recovery is just under \$100 million being spent on the lake. My first question is does that sound like good value and are we spending enough do you think?

The second question is what is the value of water quality restoration in other catchments where lakes are not receiving water at the bottom of the catchment; it is just a river catchment or a farming catchment?

Hannah Mueller: Thanks Andy. Is it worth spending money on restoring the lake? Yes it is definitely worth spending money. I think that I have shown that. There is economic benefit associated with improving an ecosystem, not only a cost associated with the degradation but also a gain in value associated with restoring an ecosystem. While we do not usually incorporate those kinds of values in our management decisions, neither do we look at it that way, and it is definitely worth exploring those values and incorporating them into our equation.

The second question was what are the values of other receiving water bodies that are not lakes and different kinds of catchments? Was that the question?

Andy Bruere: Yes, probably more along the lines – if you have a lake at the end as a receiving catchment, what happens if there is no lake? What is the value of restoration there and how do you account for that?

Hannah Mueller: If there is something else other than a lake ... an estuary or ?

Andy Bruere: There is no lake, just a farming catchment and then it goes to an ocean.

Hannah Mueller: That is a really good question. It is not something that I have thought about before but in terms of ecosystem values, even though there may not be a lake at the end of a catchment, there are still other ecosystems worth protecting, whether it be forested land or something else that provides ecosystem services. I certainly have not looked at any other examples but it is definitely worth studying for other catchments as well.

Paul White, GNS: For my sins, I have done resource and economic valuation work with Basil Sharp at the University of Auckland so I have a comment to your question Andy and also a question for you Hannah.

Andy, the value of the Waikato River for industrial production alone is \$2 billion capital value, so it can be done, and the numbers are big. I would recommend you look at the total economic valuation, Hannah, because firstly it gives bigger numbers and makes our work look much more impressive. You do that by capitalising your annual costs or benefits.

My question to you Hannah is how did you get the profit figures for farmers in your catchment study?

Hannah Mueller: Thanks for that. I have looked at total economic value before and am certainly familiar with the concept but this was just a very brief snapshot of what I have worked through in the last year.

The profit figures for farmers were based on a representative value taken from a couple of studies done throughout the Rotorua Region. They were an average value looking at productivity values of the dairy, dry stock and forestry land use so they are not really a land value as such. They are not the sale value but an averaged value of how much profit can be taken.

Paul White: Okay, did that include interest and tax?

Hannah Mueller: No, not in that figure.

Warren Webber, LWQS: A question for Jan. You were not here yesterday afternoon when we looked at figures on funding for weed control and my recollection is around \$1.8 million per year is provided by LINZ for weed control in lakes throughout New Zealand, is that correct?

Jan Hania, NEXT Foundation: \$1.9 million

Warren Webber: \$1.9million. There you go, pretty small. We have some exciting technology coming through with endothall. As I see it, we will struggle to implement what we need with that sort of funding. Is this the sort of thing, as a national or even a regional programme that the NEXT Foundation might be interested in?

Jan Hania: Unless it is going to change the system across the country, probably not. I think we would look for things that are going to be sustained in the long term. I could not say straight off but that is in my thinking at the moment.

Paul Champion, NIWA: One of yesterday's talks was the restoration of native vegetation and if that could be achieved then that would be equivalent to the terrestrial examples that you were talking about.

CLOSING COMMENTS

Don Atkinson, Chair, LakesWater Quality Society

I would now like to invite Emeritus Professor Warwick Silvester and Dr Kit Rutherford to the podium to give a summation of what we have done over the last two days. Their comments come with a lot of experience because Warwick reminded me today that he did the same thing back in 2001. It is an enduring programme. They have both been very intimately involved with the Rotorua Te Arawa Lakes and the Rotorua catchment in particular. Kit has done the Rotan plan within it and both have been involved in the Technical Advisory Group.

Dr Kit Rutherford

There are two slides (at the end of this summary) before you rush screaming from the room. We are going to play a tag team. Because I put this table together, I will probably start off and Warwick has offered to come in with his philosophy from time to time.

Firstly I would like to look at the second and third line about monitoring. We have heard a lot about monitoring and what struck me is that we have the tried and true traditional monitoring techniques - TLI, LakesSPI and Fyke netting (SCUEP) and they have produced excellent information. Five lakes are improving and we have two that are deteriorating. The question cropped up - why Rotoiti? Science questions have come out of that monitoring. We also heard about innovative monitoring techniques such as eDNA, Tai koura and autonomous monitoring buoys and I summarise those by saying, 'Wow'.

The eDNA, which sounds a little like testing sewage to find out which of the university dorms is smoking marijuana, clearly has potential and once developed, is going to be fantastic. The Tai koura is really exciting. It is Maturanga Maori at its best and the potential to engage stakeholders.

I go back to what the politicians tell us, and we have heard it all before, stakeholders want simple, practical, cost-effective solutions based on sound science. But we have Prof David Hamilton and others telling us that life is complex. Sometimes it is nitrogen, sometimes phosphorus or the weather causes things to change. We can resort to modelling but as a group of scientists we are still faced with complexity and uncertainty, and decision-making in the face of uncertainty is a huge challenge.

This leads into the need for trust, leadership and dialogue and so many times we see that complexity and uncertainty is an excuse for inaction. I am sure Warwick will have some wise philosophy about that topic.

Professor Warwick Silvester

Going right out to left field now, I want to talk about what happened when I did this sixteen years ago at the first symposium. The contrast between this meeting and the first one is enormous. There were two things that struck me at that original symposium. It was a meeting about all the data and trying to get the regional and district councils to talk to each other. I could not believe just how much friction there was. This meeting is such a contrast because we have a large number of groups talking to each other over the past 15 years and coming up with an amazing body of data, all done within a community of cooperation. The results are enormous.

Not only that, this meeting has achieved far more. It addressed the problems of the lakes and then moved way outside to other environmental areas which impinge upon our

attitude toward the lakes, particularly last night at the sustainability forum. It was very illuminating to bring Rod Oram here to talk and also brilliant to introduce a school boy. It opened up so many subjects that relate very much to the problems being resolved for the lakes. I will talk about that again in a minute.

Dr Kit Rutherford

Just finishing off this slide, it takes a community to save a lake. I would like to reiterate what people are saying, how the LakesWater Quality Society team have, through their symposia, brought together so many of the community over the years to discuss the issues of the Rotorua Te Arawa Lakes. It is a wonderful example of exactly that – a community saving lakes. I compare what has happened in the Ruataniwha where I have been closely involved. As of yesterday the proposal to produce a dam in the head waters and irrigate 30,000 hectares of the Plain has finally been shot in the head. The process was carried out so badly and in such a marked contrast with the way things have been worked through here. The Hawke's Bay Regional Council failed to take the community with them and that led to so much anger, bitterness and resentment. It is going to take a long time in the Hawke's Bay for people to get over that process.

But it is not all plain sailing:-

- Todd McClay said, 'Decisions are best made at a local level with national standards'. The cynic in me said, 'Yes, we had a national standard of wadeable rivers'.
- John Green, bless him, was able to stand up and say, 'We cannot let the politicians make the decisions' and alluded to the Nordic model. For those of you who are unfamiliar with it, that is where non-negotiable environmental goals are set.
- Rod Oram reminded us of Geoffrey Palmer's assessment of the Resource Management Act, which was his baby of course. He had always intended to have very strong national policy statements and somehow not very many of those have emerged. As a young scientist, I was involved in the RMA and we expected to put up lots of water quality standards to support the RMA. Somehow that process got hijacked.

Professor Warwick Sylvester

Again I will move sideways because we are here to honour famous men. I have been at this game for some time and there are a group of people I have identified that have made this all possible. Twenty years ago it was an impossible task and only a few people who cared. There is No.1 - Ian McLean. It has been said before and I am going to say it again, the work that Ian has done has been absolutely brilliant. He took on a task, which for many of us would have seemed impossible, to deal with this enormous problem and bring groups together that were fighting over territory. It was an amazing feat and I give you honour. Arise Sir Ian. Thank you.

That was followed by a number of people, and excuse me if I mention names. First of all John Green and Don Atkinson, who have taken over the mantle of organising the LakesWater Quality Society and the work goes on. It has been brilliant. I have worked with a few within the Regional Council too, particularly Paul Dell and Andy Bruere. I mention them because they managed the whole programme and also had a relationship with the farmers who respected them. They also talked to us, the scientists. I used to go to TAG meetings, a place of common minds with a common goal and they went very well. I want to honour those two as well - Andy, and Paul Dell who has gone up north to do good things.

Dr Kit Rutherford

These discussions very quickly turn to cost benefit and equity. Costing material things is easy because they are bought and sold. Hannah introduced us to non-market values and several have dabbled in that area and explored ecosystem services. It is a highly contentious area but clearly one that opens up the discussion to get away from, 'How much does it cost to build a fence?' to 'How much production will be foregone if I alter the way in which I farm?'

Now, Rod Oram and Rob both talked about changing behaviour. 'Stop giving away value' was the way Rod Oram put it. We want good growth and not bad growth. Nobody in this room or in the country would disagree with any of that but why doesn't it happen? Rob Fenwick made the point that it is leaders who stimulate innovation and leaders appear at random. I would put myself in the group of timid followers.

We are going into sheep milking but as timid followers we need information, incentives and guidance. So we need leaders and a shared vision.

I would like to say that leaders are not that rare on the ground. Sir Toby Curtis shows fantastic leadership with this statement, 'When you grow up beside a lake it becomes part of you'. Those sorts of leadership statements take us back to this big shared vision. Something I have taken out of this symposium, rather than getting bogged down in nitty-gritty and finding reasons not to do things, is that if we concentrate on shared visions and talk about them we will make progress.

Professor Warwick Sylvester

I wanted to talk about the anti-science movement because it has been one of my big bugbears and have had to put up with the anti-science movement for the past 50 years or more. When someone comes to talk to me about such things in their belief system I have developed a habit of saying, 'Don't tell me what you believe, tell me what you understand'. We had an amazing paper by Dave Hansford on this whole movement which was most enlightening, but also very dispiriting because it is out there and growing.

I take heart in using the LakesWater Quality Society as an example of taking science into the community, working with scientists and ensuring that science has a place. The model that this Society, scientists, the community and the two Councils work within is amazing and it needs to be written. I have talked to Ian twice about this during the meeting and wondering whether Ian and others might like to write this up as a case history of the way in which good science can work with the community to have good outcomes. I think this is an amazing sociological experiment that has worked.

Dr Kit Rutherford

Nick Smith said, 'We don't want to talk about the good and bad guys, we want to have some action, we polarise issues too much.' I thought, for goodness sake Nick, this is exactly what you do in parliament. Why don't you get some common ground between the parties?

Coming back to Jan Wright's recent paper, she pointed out the awfully sad picture that New Zealand gives on its approach to climate change. The graph for carbon is going up very quickly. In Britain the graph for carbon is going down because they have had a cross-party agreement in parliament and come up with legislation to fight climate change. Many other countries in Europe have also done this very well with cross-party agreements and have attacked the problem. Don't give me good guy, bad guy. Get on with it guys and at the end of the month we might start to think about that.

Finally, we had a talk about who owns the water. I agree that the Iwi situation is bad and our talk about water is going nowhere. Mary de Winton gave us the idea of the commons. Water is the commons and remembering the eighteenth century problem with the commons, there are a lot of parallels in how it was treated 200 years ago. We might take some lessons from that because the problem of the commons in Europe is similar to our situation here.

Professor Warwick Silvester

I would like to reiterate what an amazing conference this has been and an enormous step up since 2001. It has showed enormous progress, not least of which back then was the discussion to appoint a chair in lakes restoration and management. I want to salute David Hamilton and the work that he has done which has generated so much information on what we are doing here.

We have had papers from David Hamilton, Paul White and our other modelling friend here, Kit Rutherford. These are the three modellers that have inputted into the whole system and moved things forward enormously. Their protégé, Chris McBride, gave that brilliant paper this morning. He has taken over the mantel and David has moved on to greater things in Australia. Chris, I congratulate you and the LakesWater Quality Society on a fantastic conference which has raised so many other environmental issues out of the work that has been done.

Thank you.

Don Atkinson

Thank you Warwick and Kit. That is a fantastic summation.

I will wrap up from the Society's point of view and say we can leave this symposium knowing that we have a community to restore a lake. That has been demonstrated on all levels and it is a great achievement. All the stakeholders that are involved in this process have come together to achieve a common purpose.

I do want to leave a few challenges with the Bay of Plenty Regional Council, the Rotorua Lakes Council, with DOC and with Government. We have demonstrated clearly that there are opportunities to address the issues that we have raised at this symposium in our three different sections.

We cannot allow the catfish to get away on us. We must eradicate and nothing else would be acceptable. Think about them in the upper streams in the Rotorua Region taking out all the trout or down the Kaituna at the other end to the sea. That is the potential. Eradication is the only way we find acceptable.

Our second section of the symposium was lakeweed and clearly we have the tools available. Our Society is frustrated that the consent process is taking so long but I am sure that the relevant people will focus on ensuring that the tools are available. Plans are in process to allow endothall to be used across all our lakes. The funding in relation to the value of these lakes, as demonstrated by Hannah, is relatively minor to the total cost that we have expended to date. It is not petty cash but it is a minor portion of the total investment that has been made and we cannot afford to allow these lakes to deteriorate with invasive weeds such as hornwort and lagarosiphon.

Our final focus was the Tarawera Lakes complex and it is great to see the build happening at last. We started to focus on it just two years ago and work has been going on in the background but it is far more complex than we ever thought. The questions are hard but

the solutions are not unattainable to restore those lakes to where they ought to be as prize possessions of this district and country. From our Society's point of view it has been fantastic to see the cooperation and willingness to move things along and I congratulate everybody.

To the presenters, can I say absolutely excellent. All the papers built on each other and established a total picture. Thank you very much.

Thank you very much to the chairs and to my committee. There is an enormous amount of work that goes into these symposiums. Thank you also to everybody else who has been involved in bringing about such a successful three days.

Finally, thank you all for attending. We will circulate you by email to understand your thoughts about the symposium which will be helpful for building our understanding.

Science knowledge	Gaps in the science	Uptake by stakeholders
Strong research BoPRC-UoW TAG & STAG, etc.	Complexity: sometimes N, sometimes P, affected by climate, varies between lakes etc. → Need for modelling → Complexity/uncertainty Decision making in the face of uncertainty Requires trust, leadership, dialogue	Stakeholders want simple, practical, cost-effective solutions, based on sound science Complexity/uncertainty an excuse for inaction
Monitoring – traditional TLI LakeSPI Fyke netting (CPUE)	5 improving, 3 stable, 2 deteriorating	Rotoiti: DO depletion. Tarawera: high P – why? Citizen science – depth sounders map weed beds Catfish/koi – commercial fishery?
Monitoring – innovative eDNA Tai koura autonomous monitoring buoys	Wow! Matauranga Enables sophisticated modelling	Engage stakeholders
Pest control Planning/Toolbox Successful eradication – small lakes Novel techniques – hessian matting Risks from 1080 – shown to be low Terrestrial pests – possums, wallabies	Responsibilities divided between agencies Ad hoc – differences between Councils 24 years to register Endothall!	Public ‘buy in’ – cleaning boats/gear Stakeholder concerns about ‘poisons’ Science denial
	But it’s not all plain sailing...	Evidence-based science. Stakeholders – science interaction. It takes a community to save a lake Strong community engagement: Te Arawa Lakes Trust, Lakes Council, BoPRC, LWQS, working groups, TAG, STAG

<p>Decision making</p> <p>Cyclical, build trust Listen/empower</p>	<p>Wadeable!</p> <p>Vigilance</p> <p>Shared vision - plan - act/monitor - communicate Evidence-based science (eg 1080)</p>	<p>McLay: Decisions best made at the local level with national standards Green: Can't let the politicians make the decisions. Nordic model – non-negotiable environmental goals Palmer: RMA intended to set national policy but.. Oram/Fenwick: Need both carrot & stick</p> <p>Douglas: people coming together Hansford: rising tide of science denial</p>
<p>Costs – reasonably easy</p> <p>Benefits & cost/benefit?</p> <p>Who benefits/who pays?</p> <p>Innovation</p>	<p>'Non market' values Smith: Treasury 'valuing' National Parks</p> <p>Mueller: explored Ecosystem Services at Rotorua</p> <p>US timid 'followers' need information, incentives, guidance</p> <p>Shared vision</p>	<p>Smith: Cap & trade a success (Taupo) but 'grand parenting' difficult. 'Natural capital'. Fenwick: to chair a group investigating natural capital in decision making</p> <p>Oram/Fenwick: change behaviour. Stop giving away 'value'. 'Good growth' not 'bad growth'</p> <p>Fenwick: Leaders stimulate innovation – random process finding leaders</p> <p>Curtis: When you grow up beside a lake, it becomes part of you.</p>

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