SUCCESS STORIES AND THE WAY FORWARD

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

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

TRANSCRIPT

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

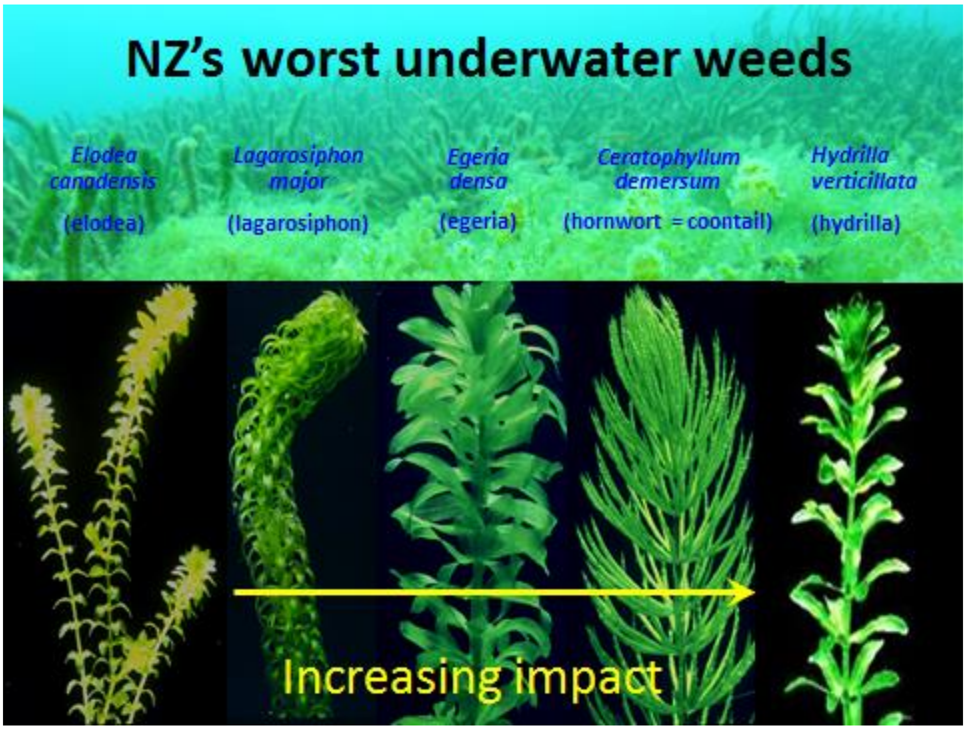
Nutrients can have major effects on weeds. The Waikato Lakes have flipped from a steady state with native aquatic plants, to invasive weedy plants (and weed problems), to an alternative state with permanent algal domination. Weeds are preferable to algae. The Waikato lakes such as Lake Hotoananga were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

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

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

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

Slide 1



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

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

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

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

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

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

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

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

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

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

Slide 2

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

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

Slide 3

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

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

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

Slide 4

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

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

In 1960 diquat proved that it could control the weeds. It was able to target the nuisance species, had little impact on natives and was bioactive for a very short time. It was an incredible success in the Rotorua Lakes. It controlled hornwort, elodea, egeria and lagarosiphon. Used at the very low concentration of 1-2 part per million, it was about 10 times less concentrated than the sodium arsenite spray that was not effective.

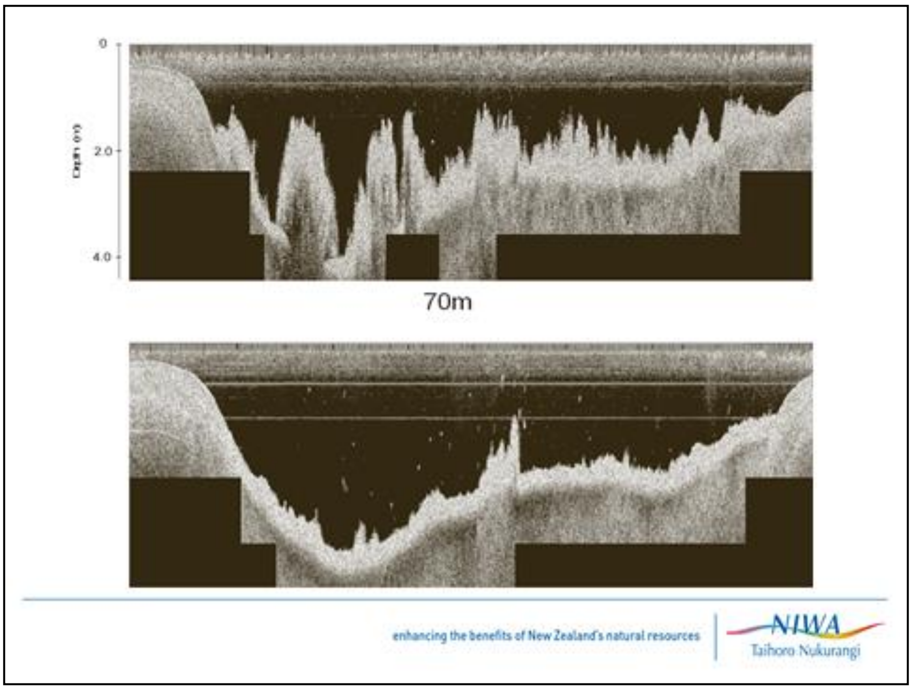
NIWA has worked on further refining herbicide formulations, some of which have been adopted by chemical manufacturers and applicators with incorporation into consent conditions for weed control. Today Aquagel is accepted as a useful additive that helps better target weeds growing in water below the surface.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

Slide 5

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

Slide 6

Slide 7



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

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

Slide 8

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

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

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

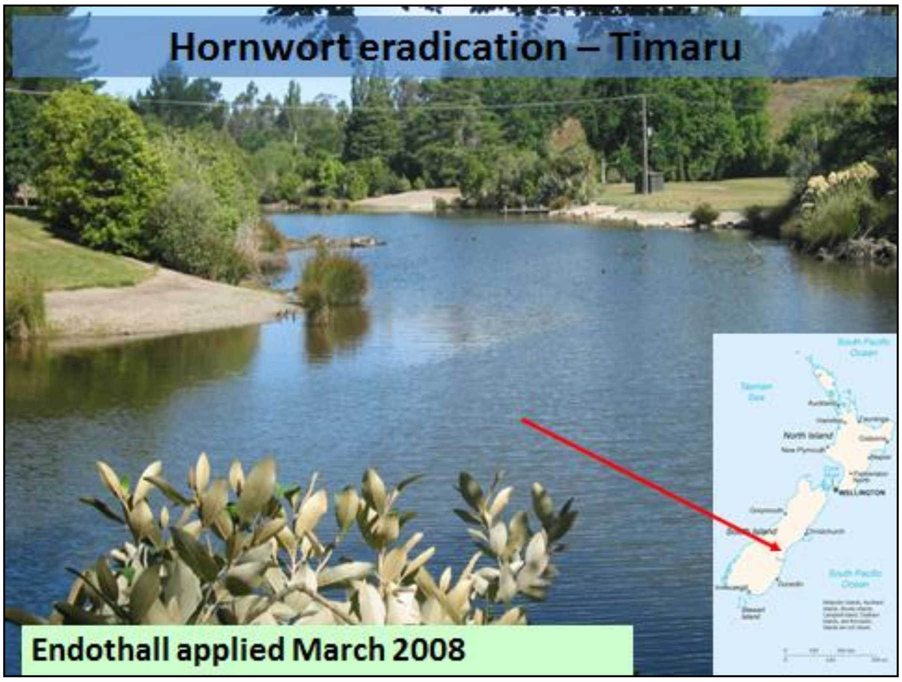
NIWA has evaluated endothall in the field. A number of cold water bodies up to 2 ha at the bottom of the South Island were tested targeting lagarosiphon. The tests were carried out using the maximum label rate of 5ppm down to 50 times less than that label rate. We achieved lagarosiphon eradication even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

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

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

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

Slide 9



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

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

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

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

Slide 10

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

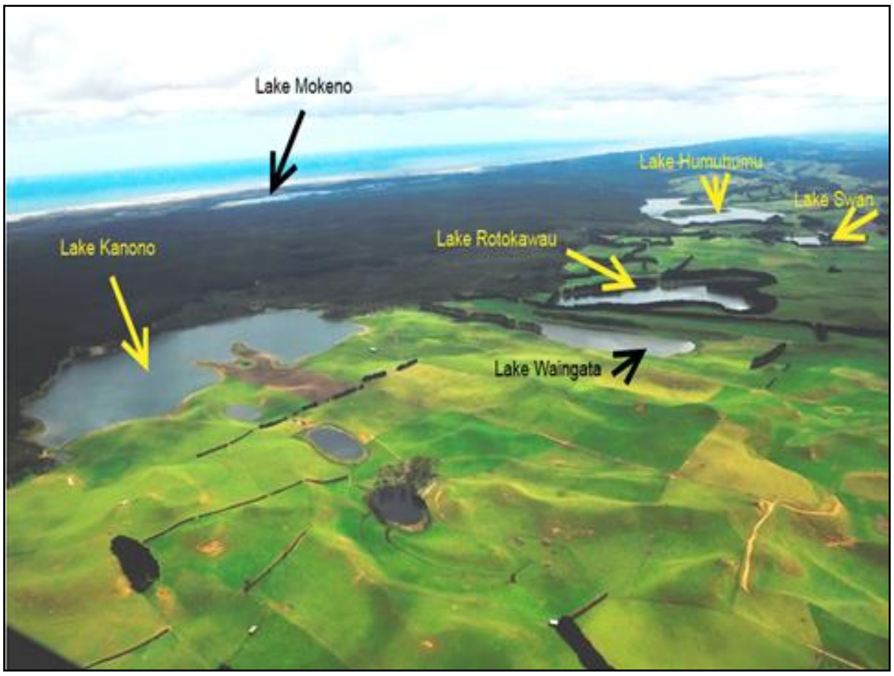
Northland is using grass carp strategically, for hornwort and egeria. They have been put in Lake Swan (which had hornwort and egeria) as it was a threat to very high value lakes in the immediate vicinity **Slide 11**.

Slide 11

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

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

Slide 12



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

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

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

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

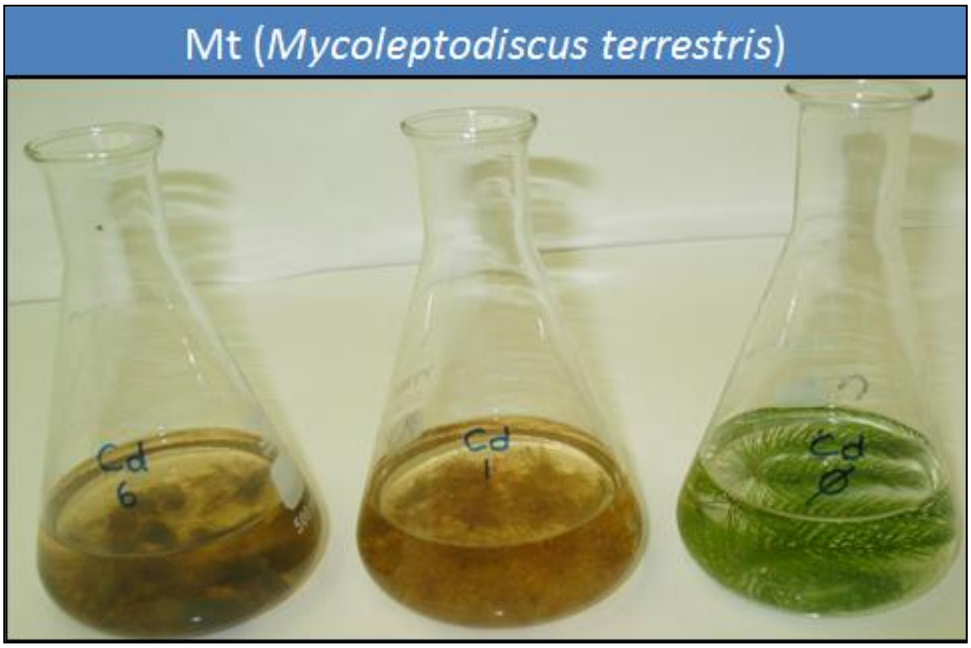
The black swans are doing a fantastic job in biocontrol. They are out there every day and probably remove more weed than we ever will. Swans graze to 0.8 metres, but then can be a nuisance by soiling lawns and beaches (left).

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

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

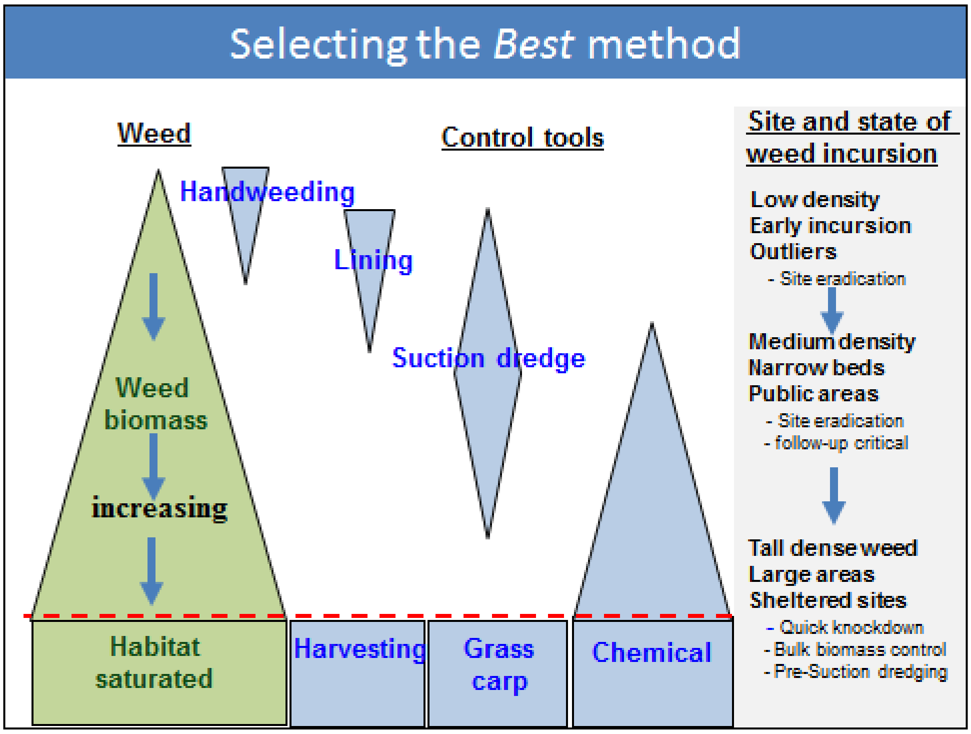
A naturally occurring fungus, *Mycoleptodiscus terrestris* (MT) can be concentrated and applied to hornwort with remarkable results, even more effective than a chemical herbicide in the laboratory. At this stage (March 2015) such success in the field has not been achieved. **(Slide 13)**

Slide 13



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

Slide 14



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