BIOCONTROL OF AQUATIC WEEDS

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

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

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

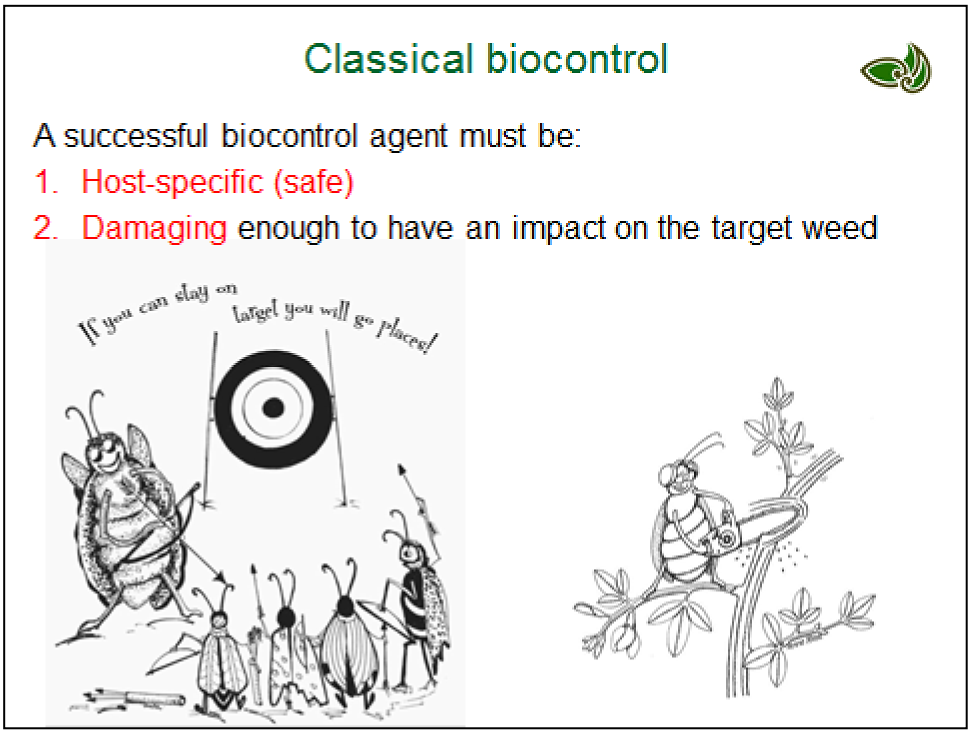
There are a number of advantages to biological control, the main one being that it is highly selective. Once the host range testing is done, it can be assured that the biological control agent will attack only the target weed and nothing valuable, otherwise it will not get a permit for release. Biocontrol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

A disadvantage is that the initial investment is costly, especially for a novel weed biocontrol target; it is often in the region of $1.5 to $3 million dollars. Many biocontrol programmes take advantage of programmes that have been done elsewhere. For example, for woolly nightshade in New Zealand recently, we have used a biocontrol insect that was first introduced into South Africa. It is much cheaper because most or all the host range testing, etc. has already been done. If we do a repeat programme it is cheap.

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

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

Slide 1

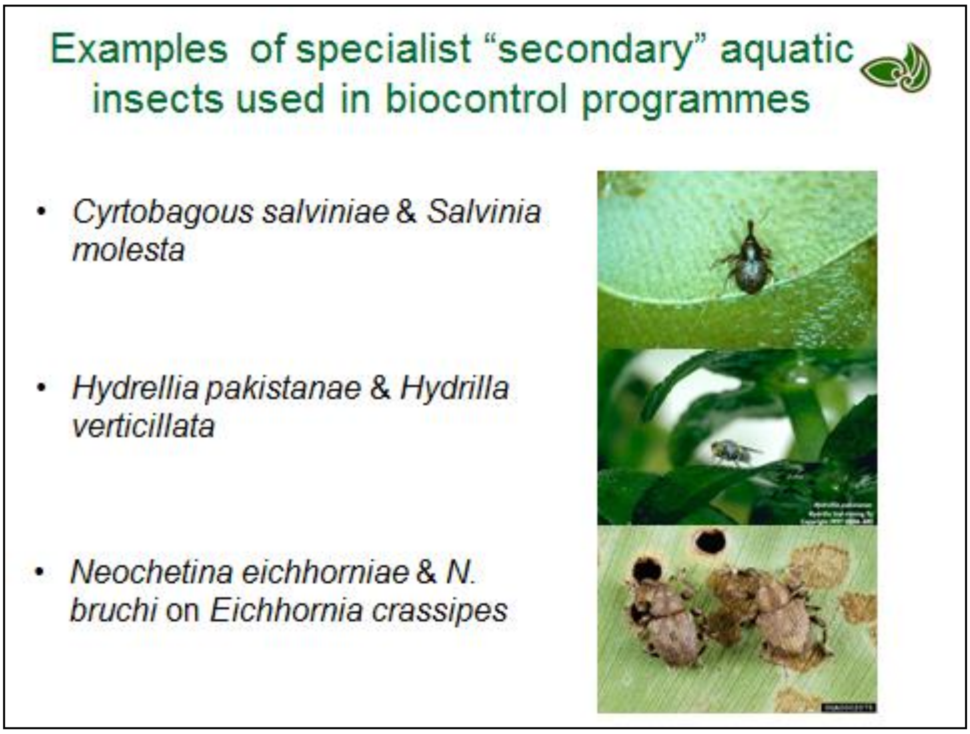


Slide 1 indicates that to be successful there are two key factors in a biocontrol agent. The crucial one is safety, it must be host specific. Permission to release a biocontrol agent will not be given if there is risk of it attacking a native or an economically important plant. The other issue is that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

It is true that many so-called primary aquatic insect herbivores are generalists or periphyton feeders. But many macrophytes, for example, the Hydrocharitaceae, evolved as land plants; and that is where chemical defences co-evolved with insect specialist herbivores. These plants became adapted to an aquatic lifestyle and some specialist insects 'followed their host-plants into the water'.[1]

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

Slide 2



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

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

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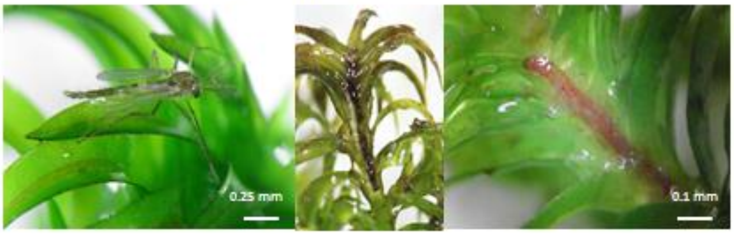
[1] Wilson F 1964: The biological control of weeds. *Annual Review of Entomology,* **9**, 225-244
Cummins KW 1973: Trophic relations of aquatic insects. *Annual Review of Entomology,* **18**, 183-206, Newman RM 1991. *J. N. Am. Benthol. Soc.,* **10**, 89-114

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

Slide 3

"Primary" aquatic insects can also be specialist herbivores

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



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

Slide 4

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

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

Slide 5

Impact of aquatic herbivores

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

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

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

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

Trichopria columbiana

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

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

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

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

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

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

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

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

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

Slide 6

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

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

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

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

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

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

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

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

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

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