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Prospects for classical biocontrol of aquatic weeds in New Zealand

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Biocontrol of aquatics: History

Past perception that most aquatic insect spp. are generalists & biocontrol of aquatic spp. is difficult

Subsequent biocontrol successes against aquatics (e.g. Salvinia, water hyacinth, Azolla) challenged this view[1]

To date, only 1 aquatic weed has been targeted for biocontrol in NZ

Should we be targeting more aquatic weeds?

Alligator weed & *Agasicles hygrophila*

[1]Sheppard, A.W. & Chaboudez, P. (1995) Proc. VII Int. Symp. Bio. Contr. Weeds, pp. 95–102. CSIRO, Melbourne, Australia.

Ranking weed biocontrol targets

Australian Government
Land & Water Australia

final report

knowledge for managing Australian landscapes

Improving Targeting of Weed Biological Control Projects in Australia

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Plant traits predict the success of weed biocontrol

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Summary

1. Biological control (biocontrol) can provide permanent cost-effective control of plant pests, but has variable success. The ability to predict the success of weed biocontrol should improve target prioritisation and the cost-benefit ratio of weed biocontrol.

2. We compiled a data base of the quantitative impacts of weed biocontrol programmes against 80 weed species and tested hypotheses regarding weed traits that contribute to weed biocontrol success using generalised additive models.

3. Modelling and cross-validation indicated that a model with three traits provided good ability to predict the responses of novel species in novel regions. Biocontrol impact varied according to whether a weed was reported to be a major weed in its native range, mode of reproduction (sexual or asexual) and ecosystem (aquatic or wetland versus terrestrial).

4. Biocontrol appears to be highly effective against weeds with the best combination of factors for success (aquatic, asexual species that are not major weeds in their native ranges), whereas most, but not all, programmes against 'difficult targets', which possess the worst combination of factors for success, have failed to result in a substantial impact. An additional analysis provides a preliminary indication that the success of pioneering programmes predicts the success of repeat programmes against the same target weed in other regions.

5. *Synthesis and applications.* Predictions generated by our model will assist weed prioritisation by improving the ability to predict the success of weed biocontrol. Nevertheless, prioritisation must also consider the importance of the candidate target weeds. Species that are predicted to be difficult targets could be targeted for biocontrol, provided that they are sufficiently important to offset the increased risk of failure against the greater benefits of successful control. Further investigation is needed to assess the ability of successful pioneering programmes to predict the success of repeat programmes in other locations, particularly in conjunction with plant traits.

Key-words: invasive plants, prioritisation, selection criteria, target selection

Introduction

Invasive plants can disrupt entire ecosystems and their economic impacts amount to many billions of dollars (Mack *et al.* 2000). Often, the number of weed (or potential weed) species is very large. For example, in New Zealand the 2430 naturalised, alien, vascular plant species (1780 fully naturalised and 650 casual; Howell & Sawyer 2006) outnumber the 2414 native vascular plants (De Lange & Rolfe 2010). Given high diversity of invasive plant species, the limited resources for tackling weed invasions must be prioritised effectively. Classical weed biocontrol tends to be a public, community-level activity carried out by institutions and public departments rather than private enterprise (Van Driesche & Hoddle 2002). The need to account for this public investment should demand robust decision-making processes, with the intention of selecting biocontrol targets that are not just important and have broad social support, but are also biologically and ecologically feasible. In practice, the means by which weed biocontrol targets are selected vary greatly between jurisdictions, and there have been few attempts to develop systems that select targets in a transparent and repeatable fashion.

Rationales for the prioritisation of weed control were proposed by Hiebert (1997), who advocated the development of decision-making tools to rank weeds according to

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Ranking weed biocontrol targets

Investigated hypotheses regarding plant traits that influence biocontrol impact[1,2] & cost[2] of implementing biocontrol, enabling the best weed biocontrol targets to be identified

[1]Paynter Q, Hill R; Bellgard S; Dawson M. 2009 Improving Targeting of Weed Biological Control Projects in Australia. *Landcare Research Contract Report* LC0809/072.

[2]Paynter, Q., Overton, J. M., Hill, R. L., Bellgard, S. E. & Dawson, M. I. (2012) Plant traits predict the success of weed biocontrol. *Journal of Applied Ecology*, 49, 1140-1148.

Predicting biocontrol impact: analytical approach

- Compiled a list of traits identified during a literature review as hypothetically important determinants of biocontrol success

- We searched CAB Abstracts, Biocontrol books & Google for quantitative information regarding the impact of biological control against weeds worldwide & traits of those weeds

Biocontrol impact: analytical approach

- Quantitative impact data collected in different ways (e.g. % cover; stems m^{-2}; weed biomass): so we converted impact data into proportions to standardise impact data
- e.g. if a weed density was reduced from 100 to 10 stems m^{-2}, following biocontrol then the reduction in stem density = 90%

Biocontrol impact: analytical approach

If multiple data for a weed, we used the most recent, if it updated past studies, or calculated an average impact if they measured impact at different localities

If no biocontrol agents established or anecdotal reports of “trivial impact” we assumed biocontrol impact = zero, even if quantitative data lacking

Impact & trait data for 80 weeds, but we averaged impacts for congeneric spp. with identical traits: reducing number of species/genera analysed to 69

Modelled the efficacy of biocontrol against the plant trait factors using generalized additive models

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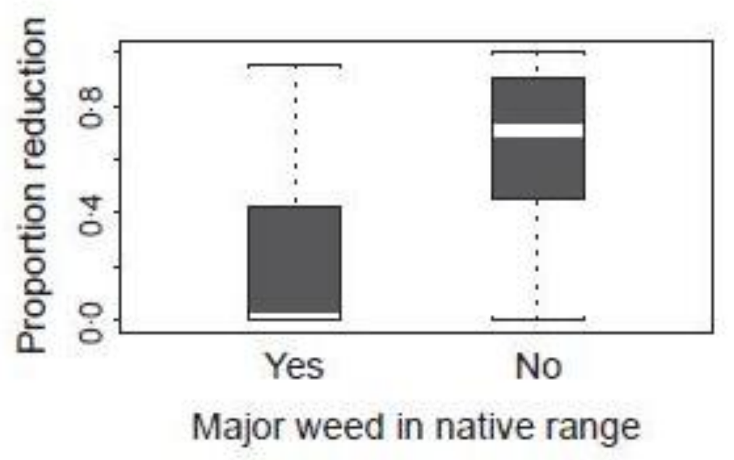
Factors that influence biocontrol impact

1. Major weed in native range Y/N

- Surrogate measure of abundance. Weeds which were not weedy (& so unlikely to be abundant) in the areas from which the biocontrol agents were imported, tend to be successfully controlled in the countries of introduction



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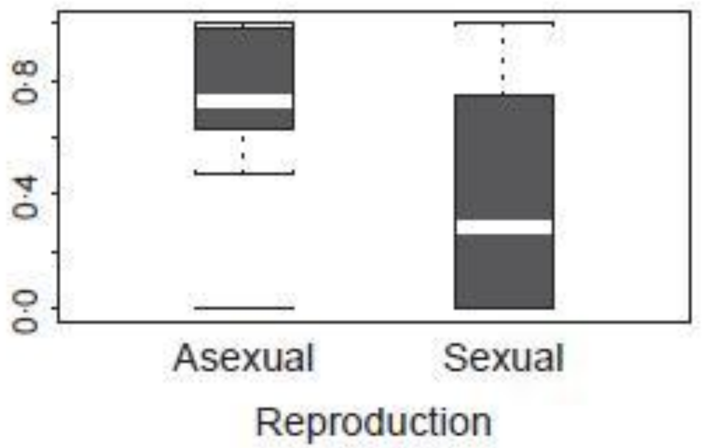
Plant traits & biocontrol impact

2. Mode of reproduction of the target weed (Asexual/Sexual):

- Genetic diversity can cause biocontrol to fail due to host-plant resistance
- Mode of reproduction infers genetic diversity (bottlenecks during introduction can result in genetically uniform populations of asexual spp., recombination of genes from parent plants should result in a range of different genotypes of sexually reproducing spp.).

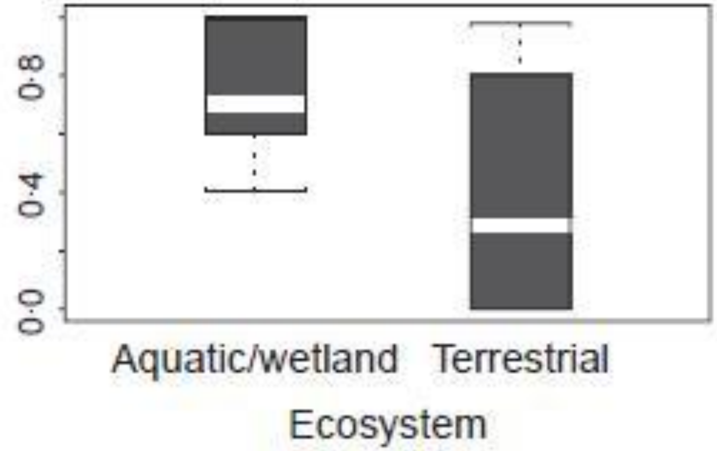


Paynter, Q., Overton, J. M., Hill, R. L., Bellgard, S. E. & Dawson, M. I. (2012) *J. Appl. Ecol.*, 49, 1140-1148.

Plant traits & biocontrol impact

3. Ecosystem ('Aquatic/wetland' or 'terrestrial'):

- This tested the observation that biocontrol impacts appeared to be higher on aquatic weeds than terrestrial weeds[1]



[1]Sheppard, A.W. & Chaboudez, P. (1995) *Proc. VIII Int. Symp. Bio. Contr. Weeds*, pp. 95–102. CSIRO, Australia.

Plant traits & biocontrol impact

Major weed in native range	Reproduction	Ecosystem	Proportion reduction from biocontrol
No	Asexual	Aquatic/wetland	0.93
No	Sexual	Aquatic/wetland	0.77
No	Asexual	Terrestrial	0.80
No	Sexual	Terrestrial	0.50
Yes	Asexual	Aquatic/wetland	0.69
Yes	Sexual	Aquatic/wetland	0.36
Yes	Asexual	Terrestrial	0.41
Yes	Sexual	Terrestrial	0.15

Paynter, Q., Overton, J. M., Hill, R. L., Bellgard, S. E. & Dawson, M. I. (2012) Plant traits predict the success of weed biocontrol. *Journal of Applied Ecology*, 49, 1140-1148.

Plant traits & biocontrol impact summary

1. System good at picking winners & costing targets

2. Biocontrol can succeed against ‘difficult targets’ (e.g. heather scores ‘yes’ for weed in native range, sexual & terrestrial)

3. BUT probability of success is lower, so should only target such spp. if they are worth it (i.e. the most important targets) or if there is strong evidence that natural enemies are important in native range

Factors that predict cost of biocontrol

1. Area of origin: ease/cost of identifying & surveying for natural enemies varies regionally, e.g.

Heather beetle *Lochmaea suturalis*: a renowned heather pest in Britain was an obvious choice for heather biocontrol in NZ

Tradescantia leaf beetle *Neolema ogloblini.* 1st misidentified as *Lema obscura*. Detective work eventually unearthed obscure references revealing true identity. Impacts in Brazil undocumented

Predicting cost of biocontrol

2. Taxonomic isolation & host testing complexity:

1 = laboratory no-choice tests only (cheap);

2 = 1 + laboratory choice test (more expensive);

3 = 2 + plus native range field testing/surveys (most expensive)

Average ‘testing complexity’ score = 2.78 for agents targeting weeds with native or valued congeners vs 2.08 for spp. without ($P < 0.01$)

3. Novel vs repeat (“piggybacking”) programmes

	Total no. spp tested	Total no. spp tested *in NZ*
Novel programme	51.6	51.6
Repeat programme	53.2	9.36

Prioritising aquatic weeds

- The best targets should be the most serious weeds
- We excluded weeds targeted for eradication on a national level (unsuitable targets for biocontrol)
- We used the Aquatic Weed Risk Assessment Model (AWRAM) scores[1] for aquatic weed impacts

$$\text{Overall score} = \text{AWRAM score} \times \text{Biocontrol impact score} \times \frac{1}{\text{Biocontrol cost score}}$$

[1]Champion, P.D.; Clayton, J.S. (2000). Border control for potential aquatic weeds. Stage 1 Weed risk model. Science for Conservation 141. Department of Conservation, Wellington.

Top three submerged aquatic weed biocontrol targets in NZ

Weed	Weed Importance (AWRAM) score	Biocontrol Effort score	Biocontrol Impact Score	Total score
Lagarosiphon major (Oxygen weed)	60.0	12.0	93.0	465.0
Egeria densa (Brazilian waterweed)	64.0	13.0	69.0	339.7
Ceratophyllum demersum (Hornwort)	67.0	28.0	69.0	165.1

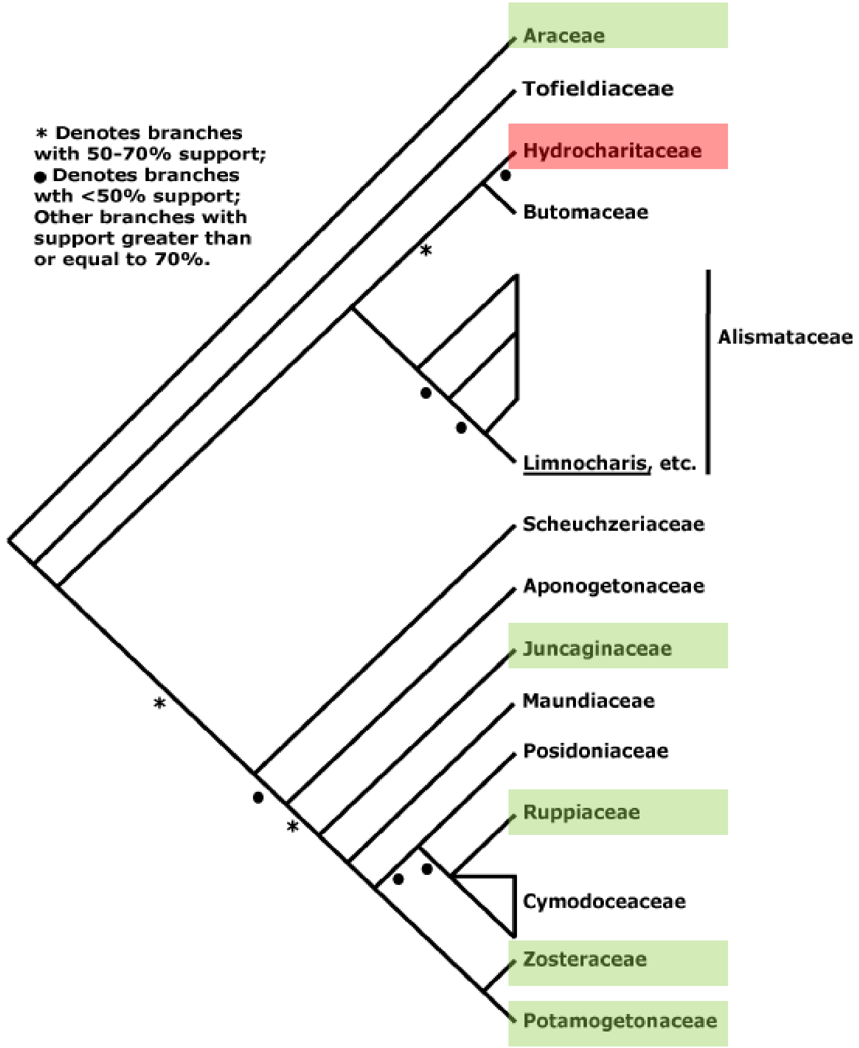
Lagarosiphon & Egeria

Both belong to the family Hydrocharitaceae in Order Alismatales

No native NZ spp. in Hydrocharitaceae

Native plant spp. in more distantly-related families: Araceae, Juncaginaceae, Ruppiaceae, Zosteraceae & Potamogetonaceae

Promising for biocontrol (oligophagous agents may be sufficiently specific)



Lagarosiphon major

Native to South Africa

Also a major weed in Ireland

Recent collaboration between Irish & S. African scientists indicates several phytophagous insects attack *Lagarosiphon* in S. Africa[1], including *Hydrellia lagarosiphon* & a Chironomid midge c.f. *Polypedilum* sp.

[1]Baars, J. R., et al. (2010) *Hydrobiologia*, **656,** 149-158.

Hydrellia lagarosiphon[1]

c.f. *Polypedilum* sp.[2]

[1]Baars, J. R., et al. (2010) *Hydrobiologia,* **656,** 149-158.

[2]Photos from Jan-Robert Baars (University College Dublin)

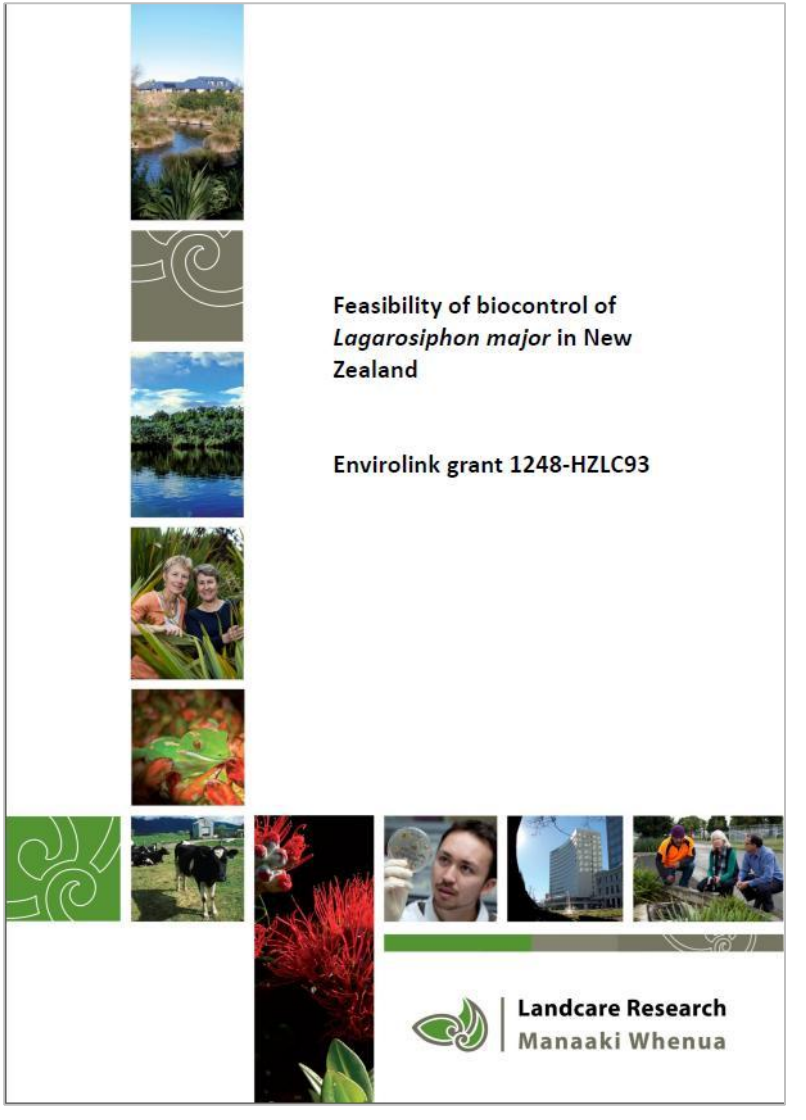
Lagarosiphon major

Host-range testing of the *Hydrellia* fly & midge (cf *Polypedilum* sp.) are underway in Ireland

Results indicate the fly is both highly damaging & likely to be sufficiently specific for introduction to NZ (but some NZ plants still need to be tested)

Work on the midge is continuing

An Envirolink report is available with more details



Egeria densa

Native to South America

Also a major weed in USA

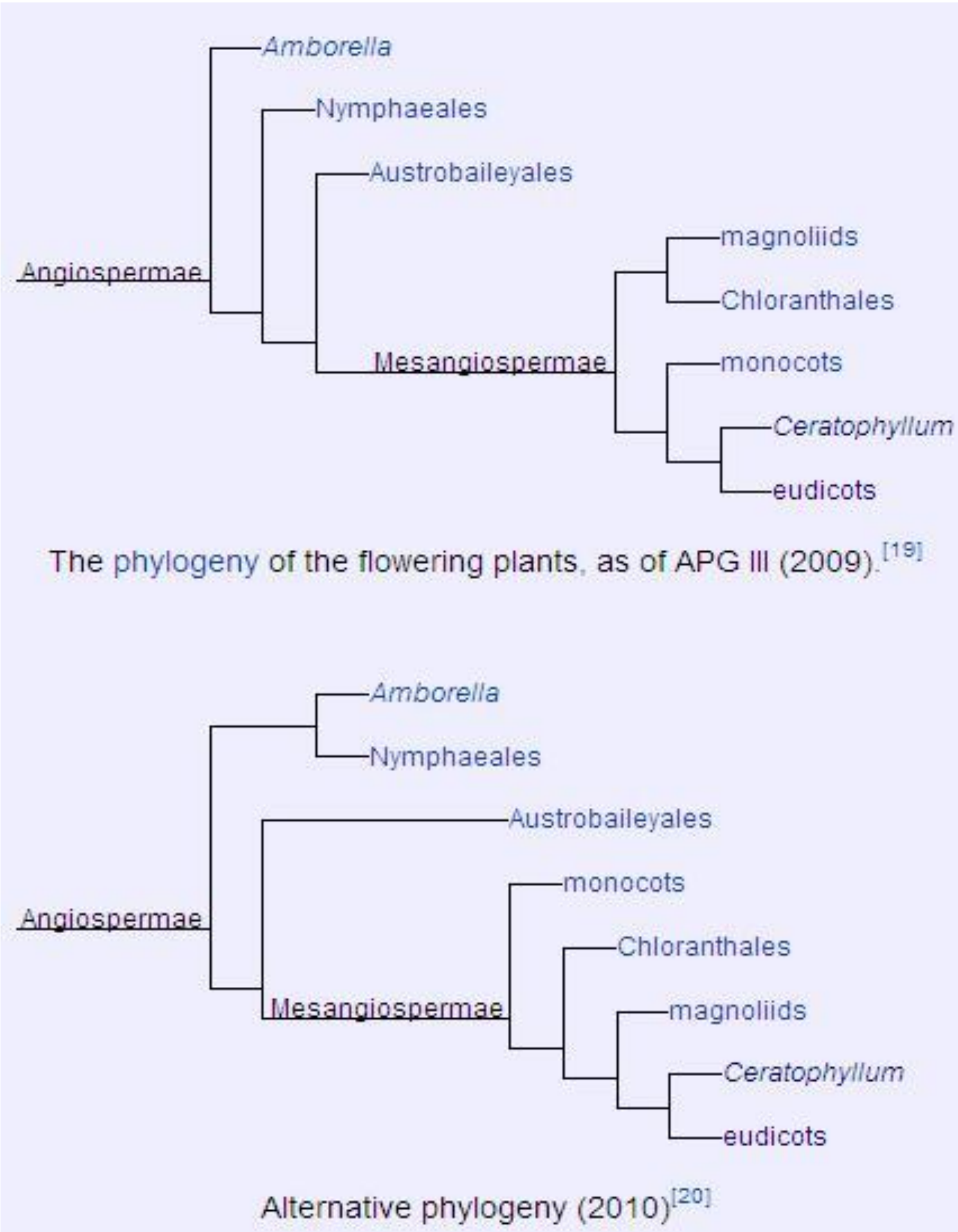
Recent surveys in Argentina indicate promising agents exist including *Hydrellia* flies[1]

Host-range testing has been done in the USA & indicated '*Hydrellia* sp. 1' is almost certainly sufficiently host-specific for introduction into NZ (development confined to one clade of the Hydrocharitaceae)

Feasibility study is being prepared

[1]Cabrera Walsh, G. *et al.* (2013) *BioControl*, 58, 133-147.

Hornwort *Ceratophyllum demersum*



Phylogeny

Family Ceratophyllaceae
Order Ceratophyllales (one of five clades within the Mesangiospermae).

No NZ native Ceratophyllales

Ceratophyllales diverged from other plants >100 million years ago (most recent analysis suggesting divergence during the early Cretaceous period) & is not closely related to any other extant plants.

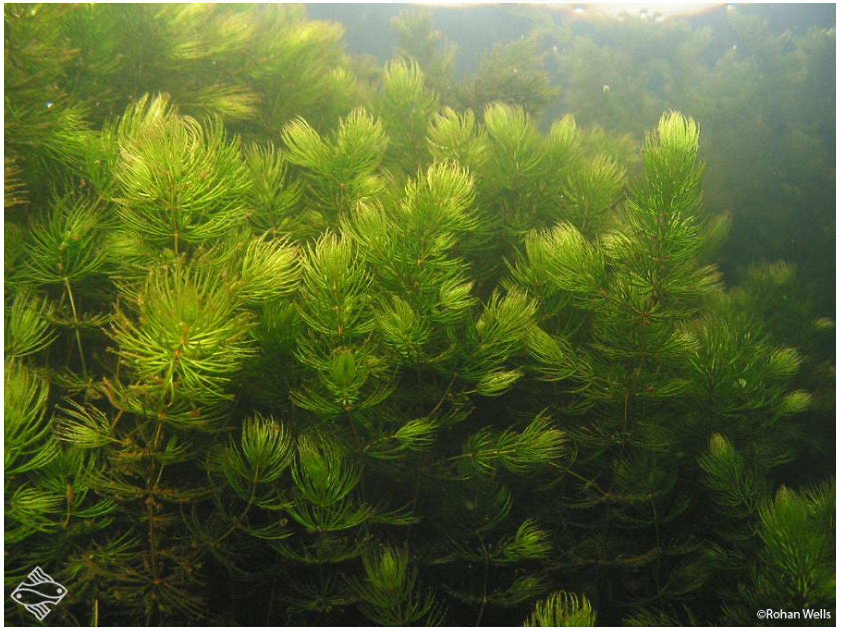
Ceratophyllum demersum

Global distribution, but recent molecular work indicates NZ population comes from Australia

Worst NZ submerged aquatic weed

Herbivores & diseases virtually unstudied – a biocontrol programme would have to start from scratch

Feasibility study is being prepared



Potential concerns

- Biocontrol may increase fragmentation making eradication harder in eradication/containment areas (risk already addressed for *Hydrellia lagarosiphon* which was shown to reduce fragment viability);

- Anglers may object to biocontrol if the habitat for fish is reduced &;

- Weeds e.g. Lagarosiphon are some of the few plants which can withstand the degraded conditions in some fresh waters. Their removal may further degrade the habitat. Additional interventions may be required to restore such lakes prior to/in tandem with the release of biocontrol agents.

Summary

- To date biocontrol has had limited application on aquatic weeds in NZ
- Some of the worst aquatic weeds in NZ may be highly amenable to biocontrol. *Hydrellia* flies attack both Lagarosiphon & Egeria & similar *Hydrellia* flies has a major impact on the submerged aquatic *Hydrilla* in the USA[1].
- We hope to begin new programmes against submerged aquatics (in collaboration with NIWA) in the very near future

[1]Grodowitz MJ, et al. 2004. *Hydrellia pakistanae* and *H. balciunasi*, insect biological control agents of hydrilla: boon or bust? Proc. XI Int. Symp. Biol. Contr. Weeds. Pp. 529–538.