Assessing the prospects for biological control of lagarosiphon (*Lagarosiphon major* (Hydrocharitaceae))

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ABSTRACT

The exotic, aquatic weed, *Lagarosiphon major* (Hydrocharitaceae), is widely distributed and spreading throughout New Zealand, where it causes problems for recreational and economic activities, but also confers some benefits. Current control methods do not effect long-lasting control, they are often expensive and they may have adverse environmental effects. Classical biological control may have none of these drawbacks. No classical biological control programmes have been attempted for any species of *Lagarosiphon*, and investigation revealed no records of invertebrates or pathogens that would be potentially useful agents for such a programme. However, surveys in the plant's native range in southern Africa would undoubtedly reveal natural enemies, and a classical biological control programme is technically feasible for New Zealand. Because there is doubt over the desirability and consequences of such a programme—particularly given that other freshwater macrophytes like *Ceratophyllum demersum* may pose greater threats to aquatic environments—the recommended action is to discuss unresolved issues about such a programme with interested and expert agencies. If still considered appropriate, the programme should then proceed to the stage at which potentially useful agents have been identified and prioritised for host specificity testing. The programme should then be reviewed to decide whether an application to the Environmental Risk Management Authority (ERMA) is warranted.

Keywords: *Lagarosiphon major*, Hydrocharitaceae, biological control, New Zealand, aquatic weeds, freshwater plants.

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1. Introduction

Lagarosiphon major, commonly called lagarosiphon[1], is widespread in New Zealand lakes, where it replaces native macrophytes, impedes recreational use of waterways and may interfere with electrical power generation. Because of the difficulty, expense and possible adverse effects of currently used control methods, the feasibility of classical biological control for lagarosiphon was investigated by Landcare Research for DOC in June 2001.

2. Background

The aquatic plant *Lagarosiphon major* (Ridl.) Moss ex Wager is one of several species of exotic Hydrocharitaceae that have established in New Zealand. Others include *Egeria densa* Planch.; *Elodea canadensis* Michx; *Hydrilla verticillata* (L.f.) Royle; *Ottelia ovalifolia* (R.Br.) Rich and *Vallisneria spiralis* L., all of which are problems in New Zealand freshwaters (Mason 1975; Howard-Williams et al. 1987; Rowe & Hill 1989). There are no native members of this family in New Zealand.

Lagarosiphon major is native to southern Africa, has established in parts of Europe (Symoens & Triest 1983), but is not naturalised in Australia (Anon. 2001). It was first recorded in New Zealand in 1950 (Mason 1975) and is now patchily distributed throughout most of the country. However, it has only a limited distribution on the West Coast of the South Island (J. Clayton, NIWA, Hamilton, pers. comm.) and is absent from the Fiordland Lakes despite being present at several sites in the Southland region and in Lakes Wanaka and Dunstan in the neighbouring Otago region (K. Crothers, Environment Southland, Invercargill, pers. comm.; Otago Regional Council 2001). While lagarosiphon does not produce seeds in New Zealand, the plant is likely to spread further as vegetative fragments are transferred between water bodies by boating, fishing, weed harvesters and float planes (but rarely, if at all, by birds) (Johnstone et al. 1985; Howard-Williams 1993).

Lagarosiphon is a national surveillance plant pest (Vervoort & Hennessy 1997), causing a range of problems. It replaces native vegetation (Howard-Williams et al. 1987; Howard-Williams & Davies 1988); dense infestations restrict the passage of boats and limit recreational activities like swimming and angling; storms can tear loose the weed and deposit large masses of rotting vegetation on beaches, spoiling their amenity value; and detached stems may block water-intakes of power stations, impeding electricity generation (Brown 1975; Rowe

[1] Where the term 'lagarosiphon' (not italicised) occurs in this report, it refers to *Lagarosiphon major*.

& Hill 1989). However, lagarosiphon also has beneficial attributes. In some freshwaters, lagarosiphon and some other exotic species are the only aquatic plants that can tolerate the particular conditions, and removal of these plants would further degrade the habitats (P. Champion, NIWA, Hamilton, pers. comm.). It provides habitat for aquatic fauna, and its leaf surfaces support periphyton. Where stands of the plant grow, sedimentation is increased and while this may be detrimental in some areas, elsewhere it is a benefit. (R. Wells, NIWA, Hamilton, pers. comm.).

There is some dispute over the significance of lagarosiphon as a weed, particularly when compared with other invasive aquatic macrophytes. For example, lagarosiphon has been displaced by other species in much of its North Island range and may co-exist with native species under some circumstances. In some waters the impact of this species has decreased since its initial colonisation phase, without any management activities (P. Champion, NIWA, Hamilton, pers. comm.). Currently, the most serious aquatic macrophyte threat is not lagarosiphon but hornwort, *Ceratophyllum demersum* L. (Ceratophyllaceae), and this may be a higher priority for a possible programme of classical biological control (R. Wells, NIWA, Hamilton, pers. comm.).

The main, current control methods include the application of herbicide (usually Diquat), mechanical and suction dredging and weed matting, but all these have substantial disadvantages; particularly their cost, their failure to give long-term control and, for some, the question of adverse environmental effects, whether actual or perceived (Tanner & Clayton 1984; Haley 2000). A classical biological control programme, using invertebrates or pathogens that attack only *Lagarosiphon major*, appears to offer some prospect of a safe, sustainable, effective and—in the long-term—cost-effective solution to the problems caused by this weed. Conversely, existing control methods have one distinct advantage over classical biological control in that their impacts are largely restricted to the areas where they are applied, whereas a classical biological control agent may spread to areas where lagarosiphon is considered beneficial.

3. Objectives

The objectives of the current study are to:

- Summarise the literature and current information available from biological control of weeds researchers worldwide on the current status of classical biological control of *Lagarosiphon major*.
- Assess the likelihood of success of such a programme in New Zealand.
- Review the steps necessary for a biological control programme for lagarosiphon in New Zealand and propose a realistically costed programme for DOC to consider implementing.

4. Sources of information

Information for this report was obtained by searching online databases (CAB Abstracts, Current Contents, Agricola, New Zealand Science) and internet sites for information on *Lagarosiphon*; by cross-referencing known references; and from: Paul Champion, NIWA, Hamilton; John Clayton, NIWA, Hamilton; Keith Crothers, Environment Southland, Invercargill; Pauline Syrett, Landcare Research, Lincoln; Rohan Wells, NIWA, Hamilton.

5. Main findings

5.1 CURRENT PROGRAMMES AND POTENTIAL AGENTS FOR BIOLOGICAL CONTROL

No classical biological control programmes have been attempted anywhere for any species of *Lagarosiphon* (Julien & Griffiths 1998).

Internationally, there are no records of invertebrates associated with *Lagarosiphon major*, but the nematode *Aphelenchoides fragariae* has been recorded attacking the apical tips of *Lagarosiphon cordofanus*, causing shoot dwarfing (Herr & Knuth 2000).

The only records of invertebrates associated with *Lagarosiphon major* in New Zealand are of three native insects recorded from the upper Clutha river (Hill & Hoddle 1991, unpubl. report; P. Syrett, Landcare Research, Lincoln, pers. comm.). These were larvae of the damselfly *Xanthocnemis zealandica* (Odonata: Coenagrionidae) and the beetle *Rhantus pulverosus* (Coleoptera: Dytiscidae), and the aquatic caterpillar *Nymphula nitens* (Lepidoptera: Pyralidae). The first two are predatory, so offer no prospects for lagarosiphon control; *N. nitens* feeds on many aquatic weeds, including native species.

There are no records of pathogens attacking *Lagarosiphon major*.

5.2 PROSPECTS FOR ACHIEVING SUCCESSFUL CONTROL OF LAGAROSIPHON THROUGH BIOLOGICAL CONTROL

While no natural enemies of *Lagarosiphon major* have been recorded from the plant's native range, this is because none have been sought. A survey would undoubtedly disclose invertebrates that feed on the plant, and might also identify pathogens. The primary question is whether any of these would be sufficiently host-specific to justify proceeding further with a biological control programme in New Zealand. This could only be answered by research on those species' host preferences. However, the absence of native Hydrocharitaceae in

New Zealand improves the likelihood of finding natural enemies of *Lagarosiphon major* with the required degree of host specificity. R.L. Hill and M.S. Hoddle, in an unpublished 1991 DSIR report, considered that the total pool of potential control agents for lagarosiphon could be defined relatively easily, because only a small part of the species' native range is likely to provide a broad climate match to New Zealand conditions. This conclusion is also supported by studies suggesting that the species does not vary greatly throughout its range (Triest 1990; Hill & Hoddle 1991, unpubl. report), so that matching natural enemies to a particular biotype of the plant would probably not be required. However, while defining the pool of potential agents may be straightforward, we have no idea how big that pool might be. Hill and Hoddle's report quotes a letter from Dr Gary Buckingham: 'The literature holds little promise for helping to evaluate the potential of a project against aquatic weeds... Too little is known about aquatic herbivores. There are approximately 41 genera and 350–400 species in the Erirrhinae, Stenopelmini and Bagoini. Almost all of these are on aquatic plants, many submersed species, but only 10–20% of the host-plants are known. There are c. 90 species of donaciine chrysomelids with little known about their hosts or biologies. Many are associated with roots of submersed plants.' While this provides some encouragement that agents which attack submersed weeds might be found, it still sheds little light on the prospects for finding suitable candidates for biological control of lagarosiphon.

A secondary, but important, question is whether any of the candidate agents would, if introduced to New Zealand, effect a useful degree of control of lagarosiphon. Unfortunately, for any biological control agent this is extremely difficult to predict; thus, Cullen (1992) commented: 'This is a continual source of frustration and a waste of resources, yet attempts to do better are notoriously difficult and make little progress, to the extent that many workers feel it is not worthwhile, preferring to rely on release of the agent as the only valid test of finding whether it will be successful.' Nevertheless, it is possible to improve the likelihood of success, particularly by placing high priority on agents that directly attack the problem stage of the plant or the life history stage immediately preceding the problem stage. In New Zealand, *Lagarosiphon major* has a very simple life history with no sexual reproduction, so that most agents that attack vegetative parts of the plant in its native range would seem to offer good prospects for successful control. In situations where there is potential for the weed to disperse by drifting down rivers and streams, an agent that weakens or severs roots or stems might hasten this dispersal, but this would probably occur anyway. Moreover, as the main method of spread is physical transfer by human activity (see Section 2), this risk is likely to be more theoretical than actual. A more serious risk is that agents that weaken or sever roots or stems might, in some cases, exacerbate the problem of weed fragments blocking power generation intakes. If these organisms were to be excluded from the range of possible candidate agents, then the pool of candidate agents would probably be reduced substantially.

Apart from technical questions relating to the feasibility of a biological control programme, there is considerable doubt over whether such a programme would advance beyond the stages at which approval from the Environmental Risk Management Authority (ERMA) would be required. At these stages, several major objections from interested agencies would be likely. For example, objectors may be concerned with damage to beneficial populations of lagarosiphon, and with an inability to restrict an agent to areas where removal or reduction of lagarosiphon is desirable; another example concerns such possible detrimental effects of biological control as increased blocking of power generation intakes. These issues should, therefore, be addressed as far as possible before committing resources to a biological control programme for lagarosiphon.

5.3 STEPS NECESSARY FOR A BIOLOGICAL CONTROL PROGRAMME

The steps necessary for a classical biological control programme have been well discussed by Harley & Forno (1992) and Forno (1997). Some of these steps have already been undertaken in New Zealand; others have been partially addressed and some, because they occur late in any programme, cannot yet be undertaken.

The first step is to initiate the programme. This covers processes such as reviewing the problem and identifying—and, if possible, resolving—conflicts of interest relating to whether the plant's weedy characteristics outweigh its useful ones. It also encompasses reviews of current knowledge on the biology and ecology of the weed and its natural enemies, and identification of any attempts at biological control. With the completion of this report, most of these processes have been carried out for lagarosiphon and an important issue has been identified. This is the question of whether removing lagarosiphon may, in some circumstances, have detrimental rather than beneficial effects. For example, in some Waikato Lakes, should lagarosiphon be removed, the cleared area may be colonised not by the original, native macrophytes but by extensive growths of algae (R. Wells, NIWA, Hamilton, pers. comm.). This establishment of a stable, algal-dominated lake system after removal of aquatic macrophytes is well documented in the international literature (e.g. Scheffer et al. 1993; Perrow et al. 1997; Donabaum et al. 1999). Whether this would occur if the lagarosiphon infestation were to be gradually reduced, as is typical of many weed biological control programmes, rather than suddenly removed, is not certain. However, biological control may offer the prospect of re-establishing native macrophyte communities, and this may be worth investigating experimentally. In other cases, removal of lagarosiphon may result only in its replacement by one of the other exotic, weedy macrophytes (Coffey & Clayton 1988). These and other issues relating to lagarosiphon's beneficial effects should be thoroughly and openly discussed with other researchers and interested parties, particularly NIWA's Aquatic Plant Management Team.

The second step is to gain approval and funding for work on the weed. This would be largely an internal DOC matter, as approval from ERMA would not be needed until later in the process.

Step three encompasses the procedures necessary to identify candidate agents in the target plant's native range. This would require surveys of *Lagarosiphon major* in southern Africa to identify the plant's natural enemies, then prioritisation of those considered worthy of further investigation. Landcare Research has good links with researchers in southern Africa and could undertake this work either directly or in collaboration with those researchers. A likely time frame for this would be 2 years, with an indicative cost, based on other biological control programmes carried out by Landcare Research, of $150 000.

The fourth step, to survey the fauna of lagarosiphon in New Zealand, could proceed concurrently with step three, and would probably best be conducted by NIWA's Aquatic Plant Management Team under sub-contract to Landcare Research. An indicative cost, based on similar surveys carried out by Landcare Research, would be $35 000.

Step five, while not essential, is highly recommended. It comprises ecological studies of the weed and its natural enemies, and it has two parts. The first is to compare the ecology of the weed in its native range with its ecology in New Zealand. Apparently, very little is known about the ecology of *Lagarosiphon major* in southern Africa, but the weed has been well studied in New Zealand (e.g. Coffey 1970; Clayton 1982; Howard-Williams et al. 1987; Howard-Williams & Davies 1988; Schwarz & Howard-Williams 1993; Rattray et al. 1994; Rattray 1995). Ecological studies in Africa could be coordinated by Landcare Research through collaboration with the aforementioned researchers; in New Zealand, any further ecological studies (if the latter were deemed important) would probably best be conducted by NIWA's Aquatic Plant Management Team under sub-contract to Landcare Research. These studies could begin at any stage before the release of any agent in New Zealand, and a priority would be to determine the consequences of gradual rather than sudden removal of large areas of the weed. The second part of step five is to study the ecology of potential biological control agents; this would have to take place in southern Africa and could be coordinated by Landcare Research.

Step six is to determine the host range of potential biological control agents. This is an essential step and must progress outside New Zealand until sufficient information is available to justify an application to ERMA to import the potential agent into quarantine for further host-range testing. The initial testing would have to be carried out in southern Africa. Landcare Research could coordinate this testing through its links with South African researchers and the International Institute of Biological Control (IIBC). To determine the host range of two or three agents, to the stage where a successful ERMA application would be likely, would require 3 years.

The seventh step is to gain approval to import agents into quarantine for further host range testing. An application to ERMA would be prepared and submitted by DOC, supported, if appropriate, by other interested agencies such as Regional Councils and electrical power generation companies. Landcare Research would not be an applicant, and its role in this process would be to provide expert technical advice. However, if approval for importation into quarantine were granted, Landcare Research, probably in collaboration with other expert agencies like NIWA, could complete the host range testing. This would require a further 1–2 years.

Upon completion of host range testing, a further application to ERMA would be required; this would seek approval for the release in New Zealand of any suitable agents. Again, Landcare Research would not apply for this permission, and DOC and/or other agencies would drive this process.

If ERMA were to grant approval for the release of one or more agents for control of lagarosiphon, these agents would still have to be reared in cages through one or more generations: first, to ensure that the founding individuals carried no diseases or parasitoids; and second, to rear sufficient individuals for field releases. The number of generations required to achieve these goals, and hence the time needed, is difficult to determine because we know nothing of the biology of any potential agent. A minimum period would be 1 year, but a more likely estimate is 2–3 years.

The overall time frame from a decision to proceed with a biological control programme for lagarosiphon to the widespread release of the first agent in New Zealand would be 8–10 years.

The final stages of a biological control programme overlap considerably. They comprise a substantial effort to mass-rear and release the control agent, and research to determine how well it is establishing and what impact it is having on the weed problem. For most weeds, these steps generally take many years, with the major effort occurring over an initial 3–5 year period.

In most biological control programmes for weeds, several potential agents are identified. In those cases the steps following the prioritisation of those potential agents usually occur sequentially for each agent, with those steps beginning 2–3 years apart for each agent.

To take a biological control programme for lagarosiphon to the point at which potential agents have been prioritised for subsequent host range testing would take 2 years and cost approximately $185 000. At that point the prospects should be reviewed.

6. Conclusions

Prospects for biological control of lagarosiphon are difficult to assess because so little is known about the plant in its native range. Natural enemies of the plant undoubtedly exist, and it would be straightforward to initiate a biological control programme. There is doubt, however, over the desirability and consequences of such a programme. These issues should be resolved before proceeding further.

7. Recommendations

- In view of the more serious threats posed by other freshwater macrophytes such as *Ceratophyllum demersum*, there is a need to re-evaluate the appropriateness of committing resources to a biological control programme for lagarosiphon.
- There is a need to discuss issues relating to the beneficial effects of lagarosiphon and the possible detrimental effects of a biological control

programme for this plant with other interested parties, particularly NIWA's Aquatic Plant Management Team. If a biological control programme was considered desirable, then further recommendations would be to:

- Survey lagarosiphon throughout New Zealand to determine which invertebrates and diseases are currently associated with the plant in New Zealand ($35 000).
- Survey *Lagarosiphon* spp. in southern Africa to identify and prioritise potential agents for a biological control programme in New Zealand ($150 000 in total over 2 years).
- Identify any further research on the ecology of *Lagarosiphon major* and/or the potential agents that would improve the effectiveness and efficiency of a biological control programme.
- Review the proposed programme to determine whether to proceed.

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