Impact of biological control of *Salvinia molesta* on native plant species biodiversity in temperate climates

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Summary *Salvinia molesta* is a Weed of National Significance in Australia, invading freshwater rivers and lakes and resulting in loss of biodiversity. Biological control of salvinia has been successful in tropical areas but has been less effective in temperate regions. Salvinia is still considered an important aquatic weed and continues to spread in many parts of the world. We investigated the potential long-term impact of biological control on biodiversity conservation in the Hawkesbury-Nepean River in Sydney, Australia. Differences in plant communities in salvinia infested and non-infested areas were surveyed and analysed. The project highlights conservation priorities for revegetation and restoration to maximise species diversity following the introduction of biological control of salvinia.

Keywords Biological control, salvinia, biodiversity, native species.

INTRODUCTION

Biological control (henceforth referred to as biocontrol) is considered an important and powerful tool in managing invasive species and numerous weeds have been effectively managed through the use of biocontrol agents (McFadyen 1998). The biocontrol agent *Cytrobagous salviniae* Calder and Sands (Coleoptera: Curculionidae) is one example proving the effectiveness of biocontrol by managing the invasive aquatic weed *Salvinia molesta* D.S.Mitchell (Salviniacea) in a range of countries around the world including Australia (Room and Fernando 1991, Cilliers 1991, Tipping and Center 2003).

In Australia, salvinia is regarded as a Weed of National Significance because of the serious impacts of the plant in freshwater ecosystems and its potential distribution across Australia. Biocontrol has been successful in tropical areas (Room *et al*. 1981) and increased effort has been undertaken in recent years to distribute and establish *C. salviniae* in temperate regions of Australia, such as the Hawkesbury-Nepean River region (Postle *et al.* 2007). In some areas of this temperate region biocontrol has been consistently present for some years and appears to show an effect on the presence of salvinia however no quantified data have yet been recorded (Postle *et al*. 2007).

Weed management through biocontrol provides not only opportunities to study the direct effect on weed populations but also to investigate potential indirect effects on ecosystem communities. While there are numerous data on direct effects of biocontrol on the weed population, indirect effects other than potential effects on non-target species through host-specificity studies are rarely investigated. We would expect positive benefits of biocontrol on native plant communities as a reduction in weed biomass should encourage native species to grow. This should have flow-on effects to other organisms. In recent years some indirect effects of biocontrol have been researched through food web analysis (Willis and Memmott 2003, Pearson and Callway 2003, Lopezaraiza-Mikel *et al*. 2007), but there is still a significant short-fall in research at the community level (Hooper 2001). In Australia, some studies have quantified the impact of invasive plants on Australian ecosystems (review see Grice *et al*. 2004) but there is a lack of quantitative studies on whether areas with biocontrol agents have a better capacity to develop or maintain native plant communities.

Aquatic weeds such as salvinia, water hyacinth (*Eichhornia crassipes* (Martius) Solms-Laubach), and alligator weed (*Althernathera philoxeroides* (Martius) Griesbach) are likely to impact significantly on ecosystem processes and community structure in wetland systems. Salvinia, for example, is associated with oxygen depletion, water flow reduction and loss of aquatic biodiversity (Storrs and Julien 1996). Although, salvinia, water hyacinth and alligator weed have experienced successful management through biocontrol, data on potential changes in plant species diversity post release of biocontrol agents are absent. The success of aquatic weed biocontrol such as the alligator weed flea beetle *Agasicles hygrophila* Selman and Vogt (Coleoptera: Chrysomelidae) in the US (Coulson 1977) and the water lettuce (*Pistia stratiotes* L.) beetle *Neohydrnomus affinis* Hustache (Coleoptera: Curculionidae) in Zimbabwe (Chikwenhere 1994) highlight the necessity of evaluating plant

species diversity after biocontrol has been released and demonstrated an impact of the target plant to determine plant species (native or exotics) that replace the open space left by the managed weed. Water lettuce cover, for instance, was rapidly reduced by *N. affinis* over a period of less than 16 months only to be replaced by other aquatic weeds including water hyacinth (Chikwenhere 1994).

We compared the presence of native plant species in salvinia infested, non-infested and biocontrol sites in the Hawkesbury-Nepean River system in Sydney and discuss the results in view of indirect effect of biocontrol.

MATERIALS AND METHODS

Vegetation surveys were carried out in aquatic ecosystems across the Hawkesbury-Nepean River catchment area. A one off sample was taken at 30 sites at the peak of the growing season. At each site five quadrats of 5 × 3 m were randomly placed in the water with a minimum distance of 30 cm from the water's edge to limit sampling terrestrial vegetation. Native and exotic plant species were surveyed and recorded in salvinia infested (weed sites), non-infested (native sites) areas and areas where biocontrol was applied. The total number of exotic and native plant species was then analysed across weed infested, biological control and native areas. The difference in species numbers (natives and exotics) between the three different sites was determined by using analysis of variance (ANOVA).

RESULTS

Plant species diversity (exotics and natives) was relatively low at all the 30 surveyed sites. No weeds were recorded at the non-infested (native) sites and the difference between the number of weeds at salvinia infested sites and sites where biocontrol had been applied was not significant. There was also no significant difference in the number of native species recorded between native sites, weed sites and biocontrol sites (Figure 1).

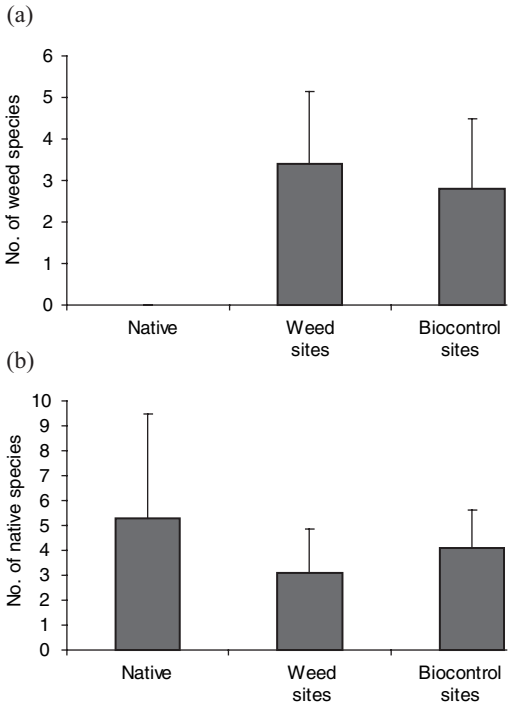

Figure 1. Distribution of (a) exotic species and (b) native species at native, weedy and biocontrol sites.

DISCUSSION

The study showed that overall plant species diversity, including weed and native plants was low across the surveyed sites in the Hawkesbury-Nepean River area. One contributing factor is believed to be the long history of disturbance in the area through sand mining and agriculture since the arrival of European settlers in Australia (Benson and Howell 1993). However, weedy areas containing a range of weeds were mostly dominated by the two weeds salvinia and dense waterweed (*Egeria densa* Planch). This dominance of one or two aggressive weeds appears to be another significant factor contributing to the low diversity of plants suppressing other weed or native species. The dominance of a few aggressive species, which are mostly weeds, provides a limitation for host-specific biocontrol, because biocontrol generally only targets one weed species. In an environment that contains multiple weed species, therefore, effective biocontrol of one weed species may indirectly support the spread of another dominant species in the area especially when they occupy the same space as seen with water lettuce in Zimbabwe (Chikwenhere 1994).

Biocontrol of salvinia in the Hawkesbury-Nepean River area appears to show an impact by reducing salvinia biomass and, therefore, opening up space. As a result in many areas this space is taken over by other dominant weed species such as *E. densa* which rapidly increase, giving little chance for native species to spread. Moreover, the effect of biocontrol of salvinia appears to fail to encourage common native species to re-establish and increase. Native species occurring in weedy areas are different to native species in biocontrol areas and there are a range of native species that are present in native areas that are completely absent in weedy and biocontrol areas.

In conclusion the study highlights three aspects in regard to indirect effects of biocontrol; (1) the indirect effect of biocontrol in environments with multiple weed species, (2) a possible link between biocontrol and native species restoration and (3) the priority to develop a list of native species under risk that guides revegetation and restoration strategies to maximise species diversity following the introduction of biocontrol of salvinia.

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