Azolla filiculoides Lamarck (Pteridophyta: Azollaceae) control in South Africa: a 10-year review

M.P. Hill, A.J. McConnachie and M.J. Byrne

Summary

Azolla filiculoides Lamarck (red water fern) is a floating aquatic fern that was introduced to South Africa in 1948 and, by 1990, had infested a large number of water bodies and impacted water utilization and aquatic biodiversity. The frond-feeding weevil, Stenoplemus rufinasus Gyllenhal, was released against this weed in 1997. Pre-release studies showed this agent to be host-specific, damaging, capable of a high rate of population increase and had a wide thermal tolerance. The weevil was released at 112 sites throughout South Africa and rapidly dispersed to all sites of A. filiculoides. Quantitative post-release evaluations revealed that the weevil caused a dramatic reduction in the populations of the weed, with local extinctions occurring at the majority of the sites within the space of a year. In the last 10 years, the weed has reoccurred at a number of sites. These re-infestations did not reach the levels recorded before 1997 and were brought under control by the weevil. The weevil has shown the predicted wide thermal tolerance in the field and an ability to disperse unaided, up to 300 km. Despite local extinctions of the host plant, the weevil has been able to persist by moving between infestations of the weed. A. filiculoides no longer poses a threat to aquatic ecosystems in South Africa and is considered to be under complete control.

Keywords: Stenoplemus rufinasus, post-release evaluation.

Introduction

The frond-feeding weevil, Stenoplemus rufinasus Gyllenhal, was imported from Florida, USA, in 1995 and was released as a biological control agent for the floating aquatic fern, Azolla filiculoides Lamarck (red water fern), in South Africa in 1997. Pre-release studies showed that the weevil was host-specific (Hill, 1998) and was subsequently shown to be very damaging (McConnachie et al., 2004), with a broad thermal tolerance (McConnachie, 2004), and should therefore contribute to the control of the weed throughout its range in South Africa. Some 10 years after the initial releases of the weevil, we test these pre-release predictions. The review presented in this paper is based on country-wide field surveys by the authors during 1999, two in 2000, 2001 and 2006, ad hoc opportunistic surveys while on field trips for other aquatic weeds or from material collected by other biological control researchers, conservation bodies or land owners. In all cases, identity of the weed and the weevil were confirmed by one of the authors.

Host specificity

S. rufinasus was collected on Azolla caroliniana Willdenow in Florida, USA, and imported into quarantine in South Africa in late 1995. As this weevil was targeted for release on A. filiculoides in South Africa, it was initially considered a new association (Hokkanen and Pimentel, 1984) on A. filiculoides, and this was used as an initial explanation for the weevil’s dramatic impact on the weed. However, a recent revision of species of the American Azolla species based on leaf trichomes and glochidia has synonymized A. filiculoides and A. caroliniana (Evrard and van Hove, 2004). Accordingly, A. caroliniana now refers to A. caroliniana sensu Willednow (=A. filiculoides) and A. caroliniana sensu
Mettenuis (=A. cristata). Thus, the weevil is no longer considered to be a new association on A. filiculoides.

The laboratory host range of S. rufinasus was determined through adult no-choice oviposition and larval starvation trials on 31 plant species in 19 families (Hill, 1998). These trials showed that, while A. filiculoides was significantly the preferred host, some development also occurred on Azolla pinnata ssp. africana (Desv.) R.K.M. Saunders and K. Fowler, Azolla nilotica De Caisne Ex. Mett. and A. pinnata ssp. asiatica R.K.M. Saunders and K. Fowler. The first two species are considered to be indigenous to southern Africa, while the last species is introduced. Hill (1998) concluded that performance on these species was so poor in comparison to that on the target species that they would be unlikely to support field populations, and thus, the weevils should be cleared for release.

In the last 10 years, ad hoc surveys have been carried out on all three non-target species. Weevils have been recovered from Azolla pinnata ssp. africana at two sites in the Kruger National Park but in very low numbers in comparison to those found on A. filiculoides. The resultant impact on this non-target species is still to be quantified.

Distribution

Temperature is one of the major factors influencing insect development (Stewart et al., 1996) and has been implicated as a major contributing factor in the success or failure of biological control programmes. McClay and Hughes (1995), Stewart et al. (1996) and Good et al. (1997) have shown that failure of establishment of several biological control agents could be directly attributed to climate incompatibility of the agent to its area of introduction. A. filiculoides has a temperate distribution in South Africa and was especially problematic in the high-lying areas of the country where air temperature ranges between 11°C and 32°C in summer, and −9°C and 12°C in winter (Schulze, 1997). Therefore, McConnachie (2004) undertook a series of semi-field experiments on the dispersal ability of S. rufinasus and predicted that the weevil would be a moderate disperser, capable of short-distance flights among patches of A. filiculoides. Inference from field evidence, however, revealed that the weevil is capable of three different dispersal patterns: within site, short dispersal between close sites and long-distance dispersal. It appears as though often a single female will find a mat of the weed, oviposits and the resultant population then move out in a concentric wave destroying the mat. Once food quality declines, the adults disperse to other red water fern infestations in the vicinity (up to 20 km away) and the original mat rapidly rots and sinks. This results in mass mortality of the immature weevil stages. This behaviour has also been recorded from Florida in the United States (T. Center, personal communication). Short-distance dispersal flights of up to 20 km allow S. rufinasus to find most of the mats in a limited area; however, dispersal distances of up to 350 km have now been recorded (McConnachie et al., 2004).

The weevil was originally released at 112 sites throughout South Africa (McConnachie et al., 2004), and it has now been recorded from an additional 42 sites. The weed reoccurred at 22 of the original 112 release sites up to 2 years after the initial clearing. The weevil has since been able to relocate and clear the weed at all of these sites. Average clearance time was within 10 months. S. rufinasus is now widely established throughout South Africa, and there is no need to artificially distribute the agent. We underestimated the dispersal capabilities of this agent in our original predictions.

Impact on the weed

The ultimate aim of biological control is to reduce the weed population to below an economic or ecological threshold (De Bach, 1964), but this is often not achieved using a single agent, and additional agents or intervention from other control methods are required (Stilling and Cornelissen, 2005). S. rufinasus was first released as 300 adults on a 1-ha pond of red water fern in Pretoria in December 1997. In January 1998, the weevils were still present, and by February, the red water fern mat had sunk and more than 30,000 adult weevils were reared from 2 m² of rotting red water fern. This dramatic population explosion occurred at all of the subsequent release sites of the agent. We were able to monitor 91 of the 112 original release sites around South Africa, all of which were completely controlled, with an average time to control being 6.9 months (McConnachie et al., 2004). Where the weed has re-infested.
sites from germination of spores, the weevil has re-
located and controlled these infestations within a
year. The weevil has not failed to control a single site
where it has been released and monitored. Hill (1998)
expected that “S. rufinasus had the potential to contrib-
ute to the control of the weed.” Indeed, an additional
agent, the flea beetle, Pseudolampsis guttata (LeConte),
was imported from Florida, USA, into quarantine in
South Africa and screened for release but rejected due
to a lack of host specificity (Hill and Oberholzer, 2002).
We clearly underestimated the impact of this weevil,
and this is a good example of where a thorough pre-
and post-release evaluation should be undertaken on an
agent before additional agents are considered.

A full cost/benefit analysis was performed on the
A. filiculoides biological control programme (McCon-
nachie et al., 2003), which showed that the economic
returns would increase from 2.5:1 in 2000 to 13:1 in
2005, and are predicted to increase to 15:1 by 2010.
Based on the field evidence, there is no reason to sug-
gest that this prediction is an underestimate.

Conclusion

A. filiculoides is considered to be under complete bio-
logical control in South Africa in that it no longer poses a
threat to the biodiversity and utilization of waterways
in that country. The factors that have contributed to the
success of this programme include an agent that has
an exceptionally high rate of increase (Hill, 1998),
which is a voracious feeder on the weed both as larvae and
adults (McConnachie et al., 2004), is a good disperser,
is thermally tolerant to the South African climate
(McConnachie, 2004) and does not appear to be subject
to significant predation or any parasitism.

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