Biological Control Initiatives against Water Hyacinth in South Africa: Constraining Factors, Success and New Courses of Action

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Abstract

The success of biological control initiatives undertaken against water hyacinth in South Africa has been variable, despite the establishment of six natural enemy species (five arthropods and one pathogen) between 1974 and 1996. By contrast, successful biocontrol was achieved in a relatively short time frame (4 years) on Lake Victoria in Uganda and in Papua New Guinea, using only the two insect agents, *Neochetina eichhorniae* and *N. bruchi*. The variable results achieved in South Africa have so far been attributed to variable climatic conditions, eutrophication of the aquatic ecosystems and interference from integrated control operations. However, hydrological features, notably the size of the water body, and techniques for establishing agents, may also affect the degree of biocontrol. It is believed that biocontrol is more successful in larger water bodies where wind and wave action increase the mortality of agent-stressed plants. These considerations have prompted several courses of action in South Africa, notably: (i) mass-rearing and re-releases of agents that failed to establish at specific sites; (ii) evaluation of the impact of the combinations of agents already established; (iii) development of management strategies in which biocontrol can be appropriately integrated with existing control operations; and (iv) search for additional agents that are effective under more temperate conditions. The success of these initiatives will ultimately rely on the extent to which water authorities and policy-makers become educated about, and come to accept, the principles of biological control.

THE biological control program against water hyacinth in South Africa was initiated in 1973 and resulted in the release of the weevil *Neochetina eichhorniae* in 1974 (Cilliers 1991). Three agents have since been released, including another weevil *Neochetina bruchi* in 1989, the moth *Niphograpta albiguttalis* (= *Sameodes albiguttalis*) in 1990 and the mirid *Eccritotarsus catarinensis* in 1996 (Julien and Griffiths 1998; Hill and Cilliers 1999). In addition, two agents were inadvertently introduced: the pathogen *Cercospora piaropi*, which was first recorded in 1987, and the mite *Orthogalumna terebrantis*, recorded in 1989 (Cilliers 1991). Despite the high number of established agents (the highest of all the countries involved with this program), the success of these initiatives has been variable. Although several water hyacinth populations in South Africa have been significantly reduced through biological control, notably in the Eastern Cape Province (Hill and Cilliers 1999), the results overall do not compare with those obtained in Papua New Guinea (Julien and Orapa 1999) and more recently on Lake Victoria in Uganda (Cock et al. 2000).

Hill and Cilliers (1999) discussed several factors that have constrained the impact of the arthropod agents in South Africa. These include: (i) cold winters, which

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vastly increase the time taken to control the weed; (ii) highly eutrophic waters in which the weed thrives; (iii) periodic removal of the weed and natural enemy populations through flooding and drought; and (iv) interference from other control methods, notably herbicide applications. This situation has prompted several courses of action in South Africa, which include the search for additional natural enemies that are effective in cooler areas and the development of management strategies in which biocontrol can be appropriately integrated with existing control operations.

In this paper, we further discuss the above constraining factors and suggest two additional factors (viz. the size of the water body and techniques for establishing agents), which might also affect the biocontrol of water hyacinth in South Africa.

Factors Affecting the Efficacy of Biocontrol

Variable climatic conditions

Water hyacinth populations are subject to a wide range of climatic conditions in South Africa, including: (i) high altitudes (above 1500 m), temperate summer rainfall areas, where frosting occurs frequently during the colder months (May to August); (ii) coastal, Mediterranean winter rainfall areas, where frost is absent; and (iii) coastal, subtropical summer rainfall areas. Although all five arthropod agents have become established on water hyacinth throughout this climatic range, this is little doubt that the varying conditions affect their impact.

In the high elevation areas of South Africa (highveld), the plants and insects remain dormant for up to 5 months of the year (May–September). Despite this, there is some evidence that agent-induced stress inflicted on the plants during summer increases the mortality of the plants which suffer cold stress during the following winter (Cilliers and Hill 1996). However, plant populations increase rapidly with the onset of spring (late September and October) while the resurging insect populations, which have to regenerate from considerably lower numbers because of cold-induced mortality and low reproductive output, do not reach damaging levels until the end of summer (March and April), only to 'crash' during the following winter. Consequently, unlike the situation in tropical and subtropical areas, the agents persisting in temperate areas seldom reach the population densities required to severely stress the weed, and successful biocontrol thus takes considerably longer. Unfortunately, water authorities often regard such time lags as unacceptable and the water hyacinth mats are invariably subjected to other control methods, notably herbicide applications and mechanical removal, which further reduces the natural enemy populations (Center et al. 1999).

The Mediterranean climate typical of the Western Cape Province may also have had a negative impact on the agents, which appear to have been ineffective in this region. However, the reasons for this are unclear, as the effect of cool, wet and frost-free winters and hot, dry summers on the agent populations has not been determined. In addition, other factors such as flooding and eutrophication (see below) also limit the efficacy of biocontrol in this region.

By contrast, biocontrol has been considerably more successful in the coastal and subtropical areas of the Eastern Cape (EC) and Kwa Zulu-Natal (KZN) provinces. This has occurred in both integrated control programs, such as at Lake Nsezi on the Nseleni River near Richards Bay (KZN) (Jones and Cilliers 1999), and pure biocontrol programs, such as at New Year's Dam near Alicedale (EC) (Hill and Cilliers 1999). However, even in the subtropical areas of South Africa, eutrophication (see below) has hampered the efficacy of biocontrol.

Although not quantified, the range of climatic conditions under which water hyacinth occurs in South Africa certainly has an effect on the natural enemy populations and thus the degree of biocontrol. Whereas successful biocontrol usually takes 3–5 years in tropical areas (Harley 1990), it takes considerably longer (8–10 years) under more temperate situations. As a remedy, insect species that have short generation times and which are capable of rapid population increases during the 6-month growing season of water hyacinth in South Africa should be targeted for release. Such agents have already been identified in South America and include a petiole-mining dolicopodid flies *Thrypticus* spp., a delphacid *Megamelus* sp. and a dictyopharid *Taosa* sp.

Eutrophication of aquatic ecosystems

Many of the rivers and dams in South Africa receive run-off which is highly polluted with nitrates and phosphates arising from agricultural activities. These eutrophic waters enhance the growth of water hyacinth and other aquatic plant species, both native and introduced, to such a degree that aquatic weed problems should be regarded as a symptom of eutrophication. A positive implication for biocontrol is that natural enemy

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populations may proliferate because of higher quality host plants (Room 1990). Alternatively, the impact of the natural enemies may be negated by the extraordinary plant growth caused by rapid leaf production. This appears to be the case at Hammarsdale Dam (KZN) where both *N. eichhorniae*, established since 1989, and *E. catarinensis*, established since 1998, have reached very high population densities but appear to have had little impact on the weed population.

Although Hammarsdale Dam occurs in a warm-temperate area where the insects are not affected by frost, this seems to be negated by severe pollution. Indeed, during the summer months some 50% of the dam's inflow is made up of effluent from textile industries and a wastewater treatment plant and this increases to 100% of the inflow during winter. Eutrophic conditions ideal for water hyacinth populations to proliferate thus persist throughout the year. Current post-release evaluations at this site have indicated that, although the density of the weed population has not been reduced, the two agents appear to have reduced the size of individual plants. Other factors may thus have played a role at Hammarsdale Dam. One explanation is that the system may be too small for wind and wave action to continually disturb the weed mat and thereby enhance plant mortality (see below).

Four other agents have been released at Hammarsdale Dam— *N. bruchi* and *C. piaropi* in 1989 and *N. albiguttalis* and *O. terebrantis* in 1991—but none have become established. Possible reasons for this include inadequate release techniques (see below) and host-plant incompatibility in the case of *N. albiguttalis* which is poorly suited to the tall plants with elongated petioles typical of this site. Further releases of these species are under way.

The different agents established on water hyacinth have differing plant requirements. *Niphograpta albiguttalis* requires plants with actively growing, young tissue and is therefore unlikely to establish on plants growing under oligotrophic (i.e. unpolluted or unenriched) conditions. Heard and Winterton (2000) showed also that *N. bruchi* is more damaging than *N. eichhorniae* under eutrophic conditions. In addition, Jamil and Hussain (1993) showed that uptake of heavy metals by the two *Neochetina* species reduced female fecundity and might thus prevent their establishment in weed populations that have assimilated high concentrations of heavy metal pollutants. These considerations emphasise the importance of host plant quality when trying to establish agents on water hyacinth.

A strategy for the biocontrol of water hyacinth at Hammarsdale Dam should involve new approaches. These would include: (i) reducing the effluent inflow into the dam; (ii) releasing large numbers of the better-suited *N. bruchi* to ensure establishment; (iii) allowing sufficient time for biocontrol to be effective; and (iv) manipulating the water level in the dam to allow periodic flushing of the system.

Interference from herbicide control operations

In South Africa, the control of water hyacinth relies heavily on the application of herbicides, and this policy has been antagonistic to biological control for two reasons. Firstly, certain herbicide formulations used on the weed in South Africa, especially those with high surfactant content, cause high mortality in the natural enemies. Although *N. eichhorniae* was resistant to most herbicide applications, those that contained diquat as an active ingredient were toxic to the weevil (Ueckermann and Hill 2000). These authors also found that all herbicides tested, with the exception of one glyphosate-based product that contained no surfactants, were toxic to the mirid *E. catarinensis*. Secondly, herbicidal destruction of water hyacinth populations, especially in impounded systems, causes extensive mortality of the sessile immature stages and dispersal of the adult stages, when the weed mats start to sink. Re-infestation of these treated sites occurs via seed germination and isolated plants that were left unsprayed and the water hyacinth populations proliferate in the absence of natural enemies (Center et al. 1999).

Solutions to these problems, currently under investigation, include: (i) using herbicide formulations that are less toxic to the natural enemies; (ii) re-inoculating plants that are overlooked during herbicidal applications; and (iii) accepting the concept of leaving untreated 'reserves' to act as refugia for the agents. Ultimately, successful integrated control of water hyacinth in South Africa will rely on a change in the attitude of water authorities. This will entail their acceptance that the control of water hyacinth depends on reducing the level of nutrients flowing into the water bodies, allowing sufficient time for biocontrol to take affect and limiting the use of herbicides, particularly formulations that are damaging to the agents.

Hydrological features

The influence of hydrological features on water hyacinth infestations and subsequent biological control has

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often been underestimated. This is illustrated by three recent examples of successful biocontrol of water hyacinth, namely the lagoons of the Sepik River in Papua New Guinea (Julien and Orapa 1999), Lake Kyoga in Uganda (Ogwang and Molo 1999) and Lake Victoria in Uganda (Cock et al. 2000). All three systems comprise large, deep-water bodies with a wind fetch greater than 2 km (Clayton 2000). In these situations, the two weevil species reduce the size of the plants, the plants sit lower in the water and the weed mats loosen and fragment more easily. The mats are then further fragmented by wind and wave action, which also kills many plants and causes the mats to sink, as occurred at Lake Victoria (Ogwang, pers. comm.). Alternatively, the small mats may be flushed out of the system, as occurred down the Nile River off Lake Kyoga (Ogwang and Molo 1999) and down the Sepik River in Papua New Guinea (Julien, pers comm.).

In South Africa, many of the impoundments are small (< 100 ha), shallow (<10 m) basins and are therefore not subject to wind and wave action. Although the agents can inflict severe damage on the plants, with up to 30 adult weevils per plant in some areas, the lack of physical stress on the mats prevents them from breaking up and the plants from sinking. Furthermore, some areas in certain impoundments are too shallow (<0.3 m) for the plants to sink and the roots merely rest on the substrate, as occurred at New Year's Dam near Alicedale. Lack of wind and wave action, coupled with an inability to flush these impounded systems, has prevented the spectacular success observed in Papua New Guinea, Lake Victoria and Lake Kyoga from being repeated in South Africa.

South African river systems that are infested with water hyacinth but which have not been impounded, present a different problem for biological control. Most African rivers are prone to periodic flooding and drought, which cause unscheduled, sporadic removals of both weed and agent populations. This results in water hyacinth resurging from dormant seed banks and, in the absence of the agents, proliferating to reach pre-biocontrol levels. In these situations, redistribution of the natural enemies and close monitoring of the weed populations is necessary to restore biological control.

Techniques for establishing agents

The use of appropriate release techniques may prove critical in ensuring the establishment of natural enemies on water hyacinth. Establishment relies on the release of large, healthy populations of the agents onto healthy plants in the field. In South Africa, the release of the two weevil species as adults has mostly ensured establishment, while the pathogen, mirid, mite and moth are more likely to establish when individual plants, heavily infested with them, are placed into the weed populations. All releases must be made in sheltered areas that are protected from disturbance by both biotic or abiotic factors. Numbers released have also proved crucial, since large or multiple releases have a higher chance of ensuring establishment. Indeed, the very low numbers (less than 100) of *N. bruchi* released at several sites in South Africa may well explain its failure to establish in some areas and its poor distribution. Furthermore, the very large releases of *Neochetina* species carried out on Lake Victoria (greater than 100,000) appears also to have contributed to the spectacular success of biocontrol.

A series of dossiers on the rearing, release and monitoring of natural enemies for water hyacinth is being produced by CSIRO Australia. One has already been completed for the two *Neochetina* species (Julien et al. 1999), while others are either in press (e.g. that on the moths, *N. albiguttalis* and *Xubida infusella*) or in preparation (e.g. that on the mite, *O. terebrantis,* and the mirid, *E. catarinensis*). These publications will provide essential information on the techniques needed to ensure the successful establishment of agents for water hyacinth.

Successful Biocontrol: a South African Case History

One of the best examples of successful biocontrol of water hyacinth in South Africa is New Year's Dam, a 150 ha impoundment near Alicedale (EC). In 1990, when the weed mat covered some 80% of the dam, around 200 adult *N. eichhorniae* were released. The weevils became established, spread throughout the population and by 1994 had reduced the weed mat cover to less than 10% of the dam's surface area. The remaining plants were small (10 to 20 cm tall) and unable to sink because of very shallow water. *Niphograpta albiguttalis*, *O. terebrantis* and *E. catarinensis* were released in 1996 but failed to establish, possibly because of both incorrect timing of the release (middle of winter) and the very poor condition of the surviving plants. By 1998, the weed mat cover had increased to 80% of the water surface, but, with no further releases, *N. eichhorniae* once again reduced this to around 10% by 2000. This system is thus considered to be under biological control and three factors appear to have contributed to this.

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Firstly, the system is oligotrophic in that the sustaining catchment is fairly small, sparsely populated and does not support intensive agriculture or industry. Run-off into the dam is thus low in nitrates and phosphates and even before the introduction of the weevils, the plants were small (<35 cm) and nutrient-stressed. The weed's resurgence in 1998 may have been initiated by above-average rainfall in this semi-arid area, which significantly increased the nutrient input to the dam. A small resident weevil population, caused by the reduced weed mat and poor quality of the plants, allowed the resurging mat to temporarily 'escape' the weevils, which then took 2 years to respond and restore biocontrol.

Secondly, climate appears to have played a significant role in the success of the weevils. New Year's Dam is situated in a warm temperate region characterised by spring and autumn rainfall, summer temperatures of 20–35°C and winter temperatures that seldom drop below 10°C. Consequently, the life cycle of *N. eichhorniae* might be protracted during the winter months but their populations are not hit by frosts.

Thirdly, and most importantly, no other control methods have been employed at this site. The town of Alicedale, which obtains all its water from the dam, supports a small community, and the weed has never severely affected the quality or quantity of water. In addition, the infestation does not threaten any infrastructure and is not regarded as a source of infestation for other nearby catchments and rivers. Consequently, the national water authorities are under no pressure to control the infestation in the short-term and are thus prepared to allow biocontrol to operate in isolation.

Discussion

Problems with biological control of water hyacinth are presumably not unique to South Africa and are likely to be experienced elsewhere in the world. Although the biocontrol program in South Africa has been less successful than those implemented in other tropical areas of the world, it has, nevertheless, lessened the overall impact of water hyacinth. Besides the few situations where water hyacinth infestations have been significantly reduced, the plants have generally become smaller in size. Indeed, some 20 years ago plants of 1 m and taller were frequently recorded while today plants in mature stands seldom exceed 0.6 m on average (C. Cilliers, unpublished data). Smaller plants cause less-extensive mats, which pose less of a threat to infrastructure. In addition, the natural enemies reduce the rate of mat expansion after disturbances, notably flooding, manual removal and herbicide applications. As a result, water authorities are able to reduce the number of herbicide applications at many of the control sites, leading to considerable economic and ecological savings.

The success achieved at New Year's Dam has not been repeated elsewhere in South Africa and this has prompted several courses of action. Firstly, there are several sites where some of the agent species have failed to establish and these have been targeted for redistribution. Mass-rearing and re-releases are aimed at establishing the full suite of natural enemies at all sites throughout the country, to ensure that inappropriate release methods used previously were not the cause of non-establishment. Secondly, the impact of certain agents on the weed, notably *E. catarinensis*, *O. terebrantis* and *C. piaropi*, is unknown. Laboratory and field studies have been initiated to quantify the efficacy of these agents, both in isolation and in combination with the other species, and thereby facilitate the development of improved management strategies for water hyacinth. Thirdly, additional agents are under investigation, and recent surveys in northern Argentina (Cordo 1999) and the upper Amazonian region of Peru (H. Cordo et al., unpublished data) have revealed several species that might be suitable for release in South Africa. These include: (i) the grasshopper *Cornops aquaticum* which is very damaging but not suitably host specific (Oberholzer and Hill 2001), (ii) several species of the petiole-mining fly *Thrypticus*; (iii) the delphacid *Megamelus;* and (iv) the dictyopharid *Taosa*. These species have favourable attributes, notably the fact that, despite their tropical origin, they thrive in the cooler regions of Argentina (Buenos Aires province) suggesting adaptations to more temperate climates. In addition, all have short generation times (less than 40 days) and are thus capable of rapid population increases. These species may thus be suitable for release in the cooler areas of South Africa where rapid population increases during the summer months could cause more damage to water hyacinth populations than the agents currently established.

Although some 26 years have elapsed since the first release of a biological control agent against water hyacinth in South Africa, the program has remained very active in researching additional ways of controlling the weed. However, the emphasis has shifted from a purely biological to a more integrated management approach, which includes aspects of biocontrol, herbicide applications, manual removal, hydrological control and nutrient control. The

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References

Center, T.D., Dray, F.A., Jubinsky, G.P. and Grodowitz, M.J. 1999. Biological control of water hyacinth under conditions of maintenance control: can herbicides and insects be integrated? Environmental Management, 23, 241–256.

Cilliers, C.J. 1991. Biological control of water hyacinth, *Eichhornia crassipes* (Pontederiaceae), in South Africa. Agriculture, Ecosystems and Environment, 37, 207–217.

Cilliers, C.J. and Hill, M.P. 1996. Mortality of *Eichhornia crassipes* (water hyacinth) in winter following summer stress by biological control agents. In: Moran, V.C. and Hoffmann, J.H., ed., Proceedings of the IX International Symposium on Biological Control of Weeds, 21–26 January 1996, Stellenbosch, University of Cape Town, Cape Town, South Africa. p. 507 (abstract).

Cock, M, Day, R., Herren, H., Hill, M.P., Julien, M.H., Neuenschwander, P. and Ogwang, J. 2000. Harvesters get that sinking feeling. Biocontrol News and Information, 21, 1–8.

Cordo, H.A. 1999. New agents for biological control of water hyacinth. In: Hill, M.P., Julien, M.H. and Center T.D., ed., Proceedings of the 1st IOBC Global Working Group Meeting for the Biological and Integrated Control of Water Hyacinth, 16–19 November 1998, Harare, Zimbabwe, 68–74.

Harley, K.L.S. 1990. The role of biological control in the management of water hyacinth, *Eichhornia crassipes*. Biological News and Information, 11, 11–22

Heard, T.A. and Winterton, S.L. 2000. Interactions between nutrient status and weevil herbivory in the biological control of water hyacinth. Journal of Applied Ecology, 37, 117–127.

Hill, M.P. and Cilliers, C.J. 1999. A review of the arthropod natural enemies, and factors that influence their efficacy, in the biological control of water hyacinth, *Eichhornia crassipes* (Mart.) Solms-Laubach (Pontederiaceae), in South Africa. African Entomology, Memoir, 1, 103–112.

Jamil, K. and Hussain, S. 1993. Biochemical variations in ovaries of water hyacinth weevils *Neochetina eichhorniae* (Warner) exposed to heavy metals. Indian Journal of Experimental Biology, 31, 36–40.

Jones, R. and Cilliers, C.J. 1999. Integrated control of water hyacinth on the Nseleni/Mposa rivers and Lake Nsezi in Kwazulu-Natal, South Africa. In: Hill, M.P., Julien, M.H, and Center T.D., ed., Proceedings of the 1st IOBC Global Working Group Meeting for the Biological and Integrated Control of Water Hyacinth, 16–19 November 1998, Harare, Zimbabwe, 160–167.

Julien, M.H. and Griffiths, M.W. 1998. Biological control of weeds: a world catalogue of agents and their target weeds. Fourth Edition. CABI Publishing, Wallingford.

Julien, M.H., Griffiths, M.W. and Wright, A.D. 1999. Biological control of water hyacinth. The weevils *Neochetina bruchi* and *Neochetina eichhorniae:* biologies, host ranges and rearing, releasing and monitoring techniques for biological control of *Eichhornia crassipes*. Canberra, ACIAR Monograph No. 60, 87p.

Julien, M.H. and Orapa, W. 1999. Structure and management of a successful biological control project for water hyacinth. In: Hill, M.P., Julien M.H. and Center, T.D., ed., Proceedings of the 1st IOBC Global Working Group Meeting for the Biological and Integrated Control of Water Hyacinth, 16–19 November 1998, Harare, Zimbabwe, 123–134.

Oberholzer, I.G. and Hill, M.P. 2001. How safe is the grasshopper, *Cornops aquaticum* for release on water hyacinth in South Africa? In: These proceedings.

Ogwang, J.A. and Molo, R. 1999. Impact studies on *Neochetina bruchi* and *Neochetina eichhorniae* in Lake Kyoga, Uganda. In: Hill, M.P., Julien, M.H. and Center, T.D.. ed., Proceedings of the 1st IOBC Global Working Group Meeting for the Biological and Integrated Control of Water Hyacinth, 16–19 November 1998, Harare, Zimbabwe, 10–13.

Room, P.M. 1990. Ecology of a simple plant–herbivore system: biological control of *Salvinia.* Trends in Ecology and Evolution, 5, 74–79.

Ueckermann, C. and Hill, M.P. 2000. Impact of herbicides used in water hyacinth control on the natural enemies released against the weed for biological control. Report to the Water Research Commission No. 78. (in press)

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