Box 5. (continued)

C. Results of planimetry assessment of a water body (0.116 km²) during a 30-month period following the release of a biological control agent.

Month	Weed cover (%)	Weed cover (m²)	Comments
Oct 1991	8.2	9,512	Relatively small amounts of weed
Jan 1992	11.9	13,804	Water levels very low
Apr 1992	52.5	60,900	Extensive weed cover
Jul. 1992	81.2	94,192	Weed showing signs of weevil damage
Oct 1992	86.8	100,688	Damage levels increasing
Jan 1993	27.8	32,248	Weed cover markedly reduced
Apr 1993	1.8	2,088	Generally very little weed
Jul 1993	2.2	2,552	Some new growth of weed
Oct 1993	1.8	2,088	Weed heavily damaged
Jan 1994	0.5	580	Very small amounts of heavily damaged weed
Apr 1994	0.1	116	Very sparse weed cover

D. Change in weed cover (%) on a natural water body following the release of a biological control agent.

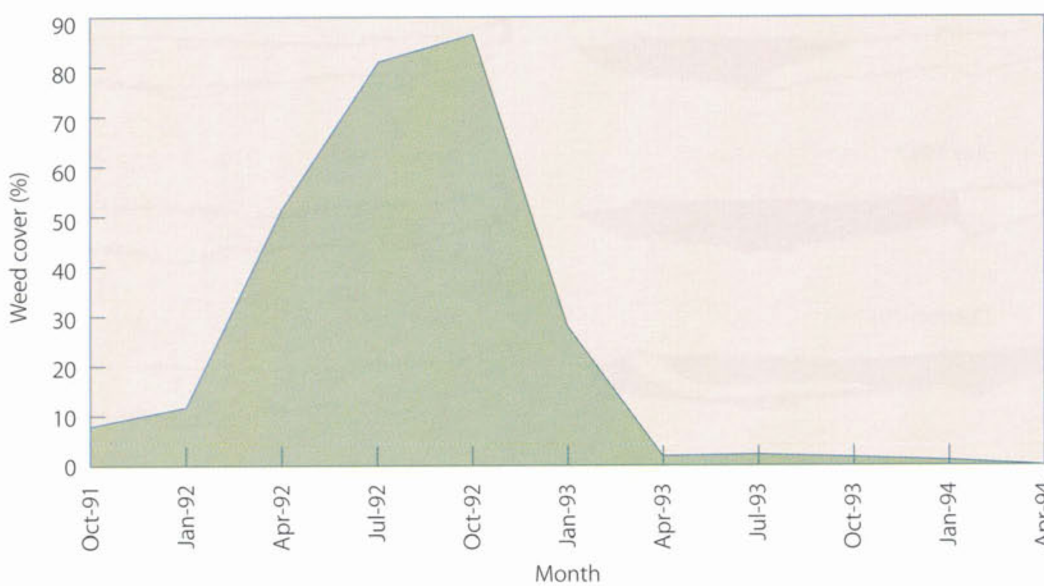

Photo: M. Julien

Measuring leaves and counting weevil feeding scars during monitoring in the Sepik River, Papua New Guinea

Time series photography

If resources for detailed, long-term planimetry studies are not available, then a series of photos of an infestation taken before and at regular intervals after the release of a control agent provides a good visual record of the impact of the agent. As with planimetry techniques, such photos are best combined with ground monitoring techniques.

In taking before and after photos it is important to:

- select a photography site which allows a good view of the water body or infestation (e.g. an elevated site);
- select a site which is easily located even after several years (this may require marking the site);
- include in all photos the same natural landmarks, which are unlikely to change;
- carry a copy of the initial photo as a reference on each occasion; and
- standardise the lens type and settings for each photo.

Several photographs demonstrating the decline in water hyacinth cover on three water bodies are shown in Box 6.

8.2. Integrated management

Biological control can provide the key component in any water hyacinth control program. However, the management of the whole system needs to be considered and additional control and management strategies may be required. Integrated management programs are site-specific and will depend greatly on the hydrological and nutrient status of the system, the extent of the infestation, the climate of the area and the usage, if any, of the water body.

Photo: M. Julien

Aerial surveys, in conjunction with ground monitoring provide important information on the impact and spread of *Neochetina* weevils

Box 6. Time series photographs showing sites before and after control by *Neochetina* weevils.

Location: Taway Lagoon, Sepik River, Papua New Guinea (insects released upstream in Sepik River, March 1989, control achieved by mid 1995)

Before Control

Photo: M. Julien

February 1995

After Control

Photo: M. Julien

August 1997

Location: Waigani Lake, Papua New Guinea (insects released March 1993, control achieved by August 1995)

Before Control

Photo: M. Julien

November 1993

After Control

Photo: M. Julien

August 1995

Location: Mt Spencer, Australia (insects released 23 November 1977, control achieved by November 1981)

Before Control

Photo: A. Wright

June 1977

After Control

Photo: A. Wright

November 1981

Table 7. Level of water hyacinth control and time taken to achieve this following the introduction of *Neochetina* spp.

Country/site	Agent	Time (yrs)	Level of control achieved	References
Argentina/Dique Los	*N. bruchi*	4	weed cover reduced by 67%	1
		6	weed cover reduced 90-95%	1
Australia/Crescent Lagoon	*N. eichhorniae*	2	-	2
India/Hebbal Tank	*N. eichhorniae*	2.7	weed cover reduced by 95%	3
India/Agram Tank	*N. bruchi*	3.25	weed cover reduced by 90%	3
USA/Louisiana	*N. eichhorniae*	1.2	-	4
USA/Texas	*N. bruchi*	3	weed cover reduced by 90%	5
Papua New Guinea/eutrophic lake	Both spp.	2.5	weed cover reduced from 70% to 20%	6
Papua New Guinea/floodplain lagoon	*N. eichhorniae*	6	weed cover reduced from 30–80% in numerous lagoons to less than 10%	6
Zimbabwe/Manyame River	Both spp.	5	weed cover reduced by 55%*	7
Zimbabwe/Lake Chivero	Both spp.	5	weed cover reduced by 85%*	7
Uganda/Lake Kyoga	Both spp.	4	lake nearly free of weed	8

*achieved in conjunction with herbicides

References: 1. DeLoach and Cordo (1983); 2. Wright (1979); 3. Jayanth (1987); 4. Goyer and Stark (1984); 5. Cofrancesco (1984); 6. Julien and Orapa, unpub. data; 7. G. Chikwenhere, pers. comm. 8. Ogwang and Molo (1997).

The aim of any biological control program is not to eradicate the weed, but to reduce its abundance to a level where it no longer causes a problem. Small infestations of water hyacinth will continue to harbour populations of the control agents so that if regrowth of the weed occurs the control agents can build up rapidly to restore control. Once established, the process should be largely self-perpetuating and self-regulating. Additional releases or redistribution from other areas may be required as new catchments are invaded by water hyacinth, or if severe flooding flushes out water hyacinth and the associated control agents, and weed reinfestation occurs.

Biological control will take some years to reduce water hyacinth levels (Table 7). Although it is not possible to generalise about the time required to achieve biological control, it is evident that, under favourable conditions, very high levels of control can be achieved in 3–5 years. Until adequate control occurs other management strategies, including physical removal and the prudent use of herbicides, may be required to maintain critical areas of water bodies weed-free. Once biological control has reduced the population of the weed, additional controls should not be required in most areas. However, at some critical sites continued monitoring and the judicious use of physical and chemical control options will be required to prevent short-term reinfestation of the weed.

Good watershed management will help reduce the water hyacinth problem. High nutrient levels, brought about through processes such as deforestation, agricultural and urban run-off, and discharge of industrial and urban waste, promote the growth of water hyacinth (Harley et al. 1996). Reducing nutrient inputs from these sources will slow the rate of growth and spread of the weed, and further improve the effectiveness of control agents.

Chapter 9
Conclusion

Biological control offers sustainable, environmentally friendly, long-term control of water hyacinth. Many of the costs associated with control using natural enemies occur early in a program and relate to collecting and identifying potential agents, conducting detailed host-specificity tests to determine their safety, and establishing a mass-rearing program to obtain large numbers for release. For water hyacinth, however, there is extensive experience with biological control in several countries, and implementation now amounts to a transfer of technology at a relatively low cost.

The two *Neochetina* weevils should be the first agents used in a biological control program. They have been widely studied and have a proven record of providing significant reductions in water hyacinth infestations.

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Glossary

aerenchyma
Plant tissue containing large intercellular air spaces.

anaerobic
Lacking oxygen.

aquatic plant
Plant which lives in or is closely associated with water.

arthropod
Member of the phylum Arthropoda, including insects, mites, spiders and crustaceans.

axillary buds
Buds arising in leaf axils.

chlorosis
Yellowing of normally green plant parts.

cocoon
Silky covering or envelope spun by larvae of many insects, in which the pupal stage develops.

crown
The point at which the root of a plant joins the stem.

daughter plant
Plant that results from vegetative growth from another plant.

epidermis
Outermost layer of cells in plant or animal.

eradicate
Remove or destroy completely.

eutrophic
Rich in nutrients.

head capsule
Sclerotised cuticle surrounding head of insect.

herbaceous
Non-woody seed-bearing plant.

herbivorous
Feeding on plants.

host-specific
Restricted to a particular host.

hydroelectric
Generating electricity by utilisation of water power.

hydrological regime
Fluctuations in the level and/or flow of water.

instar
Stage between moults during larval or nymphal development.

invertebrate
An animal not having a backbone.

lamina
Flat sheet-like structure, e.g. the blade of a leaf.

ligule
Narrow projection from the base of a leaf.

morphology
The form or appearance of an organism.

necrosis
Death of a piece of tissue.

nocturnal
Active by night.

ovoid
Oval with one end more pointed than the other.

parenchyma
Tissue consisting of living thin-walled cells with inter-cellular spaces containing air.

perennial
Persisting for a number of years.

petiole
Slender stalk joining leaf to stem.

pristine
In original condition, unspoiled.

propagation
Breed by natural processes from the parent stock.

pupa
An insect in the stage of development between a larva and an adult.

pupate
Become a pupa.

ramet
An individual member of a clone i.e. the mother plant and each daughter plant separately.

self-fertilise
The fusion of male and female gametes from the same individual as opposed to cross fertilisation in which the gametes come from different individuals.

stamen
Male fertilising organ of a flowering plant.

stolon
Horizontal stem or branch that develops roots at points along its length, forming new plants.

style
Narrow extension of the ovary supporting the stigma, within the female flower.

sustainable
Able to be maintained continuously.

vascular tissue
Tissue containing vessels for conducting sap.

vector
A carrier of disease.

vegetative reproduction
Reproduction by non-sexual means, involving unspecialised plant parts which may become reproductive structures, in the case of water hyacinth this is the stem.

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