Before and after shots from a Sepik lagoon.

Cyrtobagous salviniae, the tiny South American weevil that is one of the main biological weapons in the fight against salvinia.

Mic Julien

A MARAUDING WEED IN CHECK

With worrying exceptions, notably in Kakadu National Park, a minute weevil has triumphed over the devastating water weed, salvinia

The largest organism in the world is the 30-metre, 120-tonne blue whale. Correct? Unfortunately, no. Nor was it *Supersaurus* (an even larger relative of *Brontosaurus*), whose weight and size remain a tantalising mystery.

The biggest single organism ever to live on this planet began to die in 1980, at the age of 41. It weighed in excess of 20 million tonnes, covered more than 2000 sq. km and, to add to the confusion, occurred in widely separated locations from South America to Africa.

It was, in fact, an aquatic fern named salvinia (*Salvinia molesta*) — which could truthfully be described as a single organism because the entire species is a genetically identical clone, one enormous floating plant comprising individuals spread by branching growth and fragmentation.

Salvinia molesta first became established outside its native range in 1939, in Sri Lanka. From then until the 1980s it continued to extend its range — each time introduced by human action — to South Africa, Botswana, Kenya, Zambia, Madagascar, the Philippines, Malaysia, Singapore, Indonesia, Fiji, India, Australia, Papua New Guinea and, as late as 1986, the Ivory Coast in West Africa.

A single small plant may grow to form a thick mat covering more than 100 sq. km in just 3 months — choking lakes and waterways, reducing populations of aquatic plants and animals and in some countries threatening the livelihoods of hundreds of thousands of people. Indeed, in at least one case salvinia was responsible for human deaths: in Papua New Guinea in the late 1970s, several people from a village on the shores of Chambri Lake died when their canoe became mired in a mat of weed as they attempted to paddle to the nearby Sepik River. Unable to extricate themselves or to reach safety, they succumbed to thirst and exhaustion.

The apparently uncontrollable spread of salvinia became a matter of urgent concern around the world, especially in Third World nations. In the late 1960s and early 1970s, three insects identified as natural enemies (a moth, *Samea multiplicalis*; a grasshopper, *Paulinia acuminata*; and a 2-mm-long weevil, *Cyrtobagous singularis*) were collected from *Salvinia auriculata* and released in Africa, Fiji, India and Sri Lanka.

Mic Julien

In some areas, such as the Magela Creek floodplain in Kakadu National Park, salvinia is proving difficult to control: temperature fluctuations between wet and dry seasons may be inhibiting reproduction of *Cyrtobagous salviniae*.

None of them provided successful control of the weed. Their poor performance was partly explained in 1972, when it was realised that the troublesome weed was not *Salvinia auriculata* but a new species, *S. molesta*.

Armed with this knowledge, the CSIRO Division of Entomology in 1978 assembled a team, led by Dr Peter Room and including Dr Wendy Forno, Dr Ken Harley, Dr Don Sands, Mr Richard Kassulke and Mr Mic Julien, to search for the native range of *S. molesta* and to locate natural enemies that could provide some form of biological control. Dr Forno discovered its native range in south-eastern Brazil, and she collected specimens there of what were at first thought to be the weevil *Cyrtobagous singularis*.

Dr Sands, Dr Forno and Mr Kassulke bred the weevil under strict quarantine in Australia and studied the species' biology and host specificity, confirming that there was little possibility of it attacking plants other than the target weed. Further studies by Dr Sands determined that this 2-mm-long weevil, although similar to *C. singularis*, was in fact a new, undescribed species, subsequently named *C. salviniae*.

It proved to be a formidable enemy of *S. molesta*, attacking the weed with two effective strategies. Adult weevils eat salvinia buds, preventing further growth and spread of the weed, while their larvae feed on the roots and tunnel into buds and along rhizomes, breaking the link between roots and shoots and thus killing the plant. Further, weevil populations continue to expand until they destroy salvinia entirely in each location, then apparently crash due to starvation of the larvae and emigration by the adults.

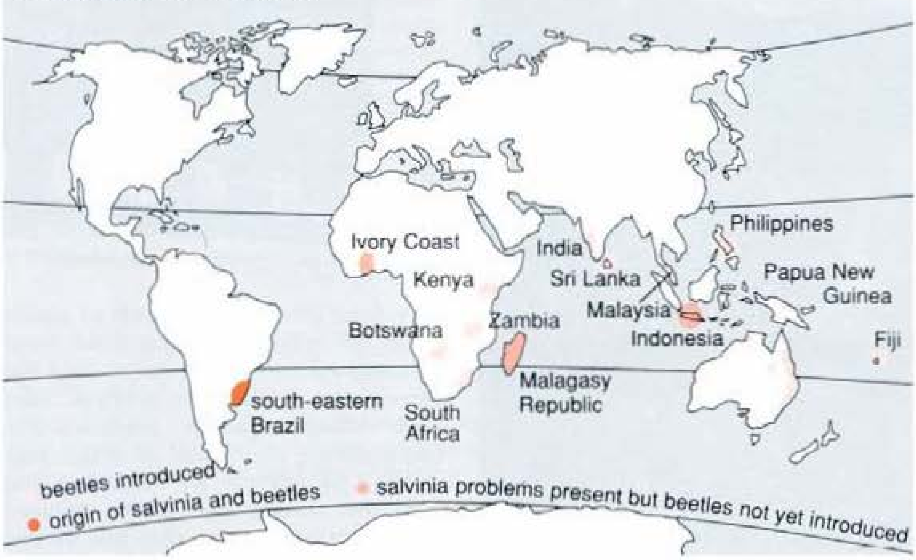
In June 1980 the first batch of adults to be released in the field were confined in floating cages on Lake Moondarra (an 800-ha artificial lake near Mount Isa in north-western Queensland), about half of which was covered by salvinia. By December that year the weevils had to be released from their cages, since they had all but consumed their food supply. By May 1981, some 3000 weevils had multiplied into 100 million and an estimated 8000 tonnes of weed was consumed in the final 3 months before Lake Moondarra was cleared of salvinia and the weevil population died out. This early success was repeated at other locations in Queensland with weevils harvested from Lake Moondarra.

In 1982 the CSIRO team, in collaboration with the United Nations Development Program and the Papua New Guinea government, began a project to control salvinia choking the Sepik River system. Early results were alarming: Papua New Guinean salvinia had a low local nitrogen content, which meant it had a low food value to the weevils, and within six months only about 40 weevils were still alive out of the 570 insects originally released.

An infestation of aquatic alligator weed in the George's River area succumbs to attack by flea beetles and moths.

Mic Julien

Salvinia around the world



However, when Dr Room applied urea to the host plant to increase its nitrogen levels, insect numbers rose to 3000 in less than 3 months. The weevils continued to breed outside the area that had been fertilised, and subsequent investigations showed that damage by increasing numbers of weevils also increased nitrogen concentrations in the weed.

Salvinia is still present in Papua New Guinea, although it is becoming difficult to find: in 1984, some 2 million tonnes of the weed covered an estimated 250 sq. km; today isolated patches of weed cover less than 2 sq. km, their spread prevented by a small surviving population of weevils. The CSIRO team responsible for this remarkable achievement was awarded the 1985 UNESCO Science Prize.

The same success story has been repeated in Sri Lanka (with financial assistance from the Australian Centre for International Agricultural Research, or ACIAR), India, South Africa and Botswana: in waterways where the weevils have been introduced, the weed has turned from green to brown as larvae tunnelled into buds and rhizomes, and at most sites has been brought under full control within 1–2 years; in a few locations, destruction has occurred so rapidly local residents thought a herbicide had been used! Despite the large quantities of nutrients in the form of rotting mats of weed released into waterways, there are no reports of algal blooms or water quality problems, and residual populations of weevils are confining salvinia to very small areas (less than 1% of their former size).

More recently, weevils have been released in the Philippines, Malaysia, Fiji, Zambia and Kenya. Progress in these countries is promising. *S. molesta* is present in the Malagasy Republic, the Ivory Coast, Indonesia and Singapore, but so far no requests to introduce weevils have been received.

In some areas salvinia infestations are proving difficult to control. The weed has spread along the coast of New South Wales as far south as Sydney and its hinterland: Mr Julien has found that control in these areas has been variable, since the climate is less favourable for weevils. At locations where it has been achieved it has taken longer — 2–3 years — than in warmer regions, while at other locations microclimatic or other environmental factors have prevented the weevils' survival.

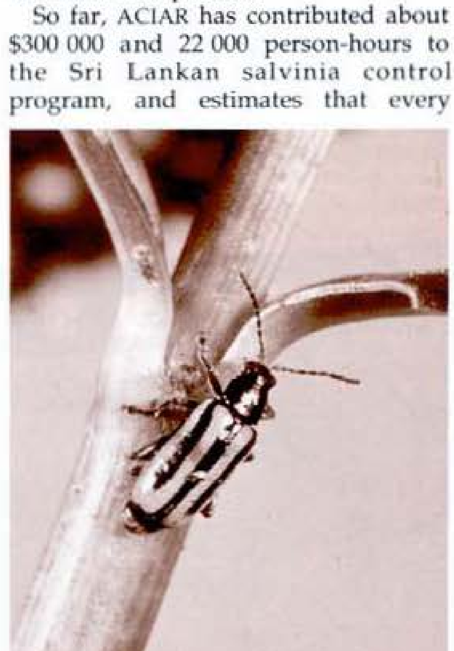
At the opposite end of the scale the weevil — although it has become established since its release in 1983 — has failed to control salvinia in Kakadu National Park.

The Australian National Parks and Wildlife Service is so concerned about the devastating effects of the weed in the Magela Creek system, from downstream of the township of Jabiru to tidal areas of the East Alligator River (a distance of some 20–30 km) that it has contracted the Division of Entomology to study the problem and to improve control. One hypothesis to be explored by Mr Julien, the project leader, is that high water temperatures experienced in billabongs during the dry season cause disruption of the weevils' life cycle and prevent the high levels of damage needed to control the weed.

The value of biological control has been demonstrated amply in Sri Lanka. That country's benign tropical environment and its primary agricultural industry of paddy rice-growing were ideal for salvinia, which before a control program began in 1986 affected approximately 25% of the country's 50 000 reservoirs. Between then and the beginning of 1989, Dr Room, in collaboration with the National Resources, Energy and Science Authority of Sri Lanka, other government bodies and researchers from the University of Kelaniya, Colombo, released weevils at 96 locations. Today, almost all infestations have been controlled.

A recent ACIAR study has looked at the economic costs and benefits of salvinia infestation and eradication in Sri Lanka. Apart from power, transportation and environmental costs, losses in rice production (through competition with rice plants and interference with paddy drainage) and fishing — together with the effects of an unstable political situation — made salvinia a direct threat to the livelihoods of most of Sri Lanka's 16·5 million people. Human health costs also increased, since weed infestations provided an ideal environment for the reproduction of the mosquitos that transmit malaria, filariasis, dengue fever and encephalitis.

So far, ACIAR has contributed about $300 000 and 22 000 person-hours to the Sri Lankan salvinia control program, and estimates that every



The flea beetle *Agasciles hydrophila* sinks alligator weed by boring holes in stems, which leads to rotting of the submerged plant.

dollar invested represents a return, in terms of recovered agricultural productivity, of $53.

Those results are, obviously, very encouraging — especially since financial recovery begins within 3 months of the initial 'investment' of weed-eating weevils — but Sri Lanka is not the only country to benefit from the Division of Entomology's biocontrol research effort. Not even affluent nations can afford perpetual herbicide-spraying and mechanical-removal programs for salvinia: biological control therefore offers a means of coming to grips with pests that threaten economic as well as environmental disaster, in a way that significantly reduces both economic and environmental costs.

Carson Creagh

More about the topic

Biological control is solving the world's *Salvinia molesta* problems. P.M. Room, *Proceedings of the Seventh European Weed Research Society/Association of Applied Biologists Symposium on Aquatic Weeds, Loughborough, U.K., 1986*, 271–6.

'Biological Control of Salvinia.' J.A. Doeleman. (Australian Centre for International Agricultural Research: Canberra, 1990.)

Ecology of a simple plant–herbivore system: biological control of Salvinia. P. Room, *Trends in Ecology and Evolution*, March 1990, **5**, 74–9.

The South American moth *Vogtia malloi* ringbarks alligator weed stems from the inside.