Salvinia

Biological Control Field Guide

www.dpi.nsw.gov.au/weeds

NSW GOVERNMENT | NSW Environmental TRUST | NSW GOVERNMENT Department of Primary Industries

Salvinia

Biological Control Field Guide

Paul Sullivan
Invasive Species Officer – Biocontrol
NSW Department of Primary Industries, Tamworth

Lesley Postle
Professional Officer
NSW Department of Primary Industries, Menangle

ISBN 978 1 74256 252 0

Published by the NSW Department of Primary Industries, a part of the Department of Trade and Investment, Regional Infrastructure and Services.

Copies available from NSW DPI, Elizabeth Macarthur Agricultural Institute, Menangle and the NSW DPI Bookshop at www.dpi.nsw.gov.au/aboutus/resources/bookshop

Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (January 2012). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up-to-date and to check currency of the information with the appropriate officer of the NSW Department of Primary Industries or the user's independent adviser.

Always read the label

Users of agricultural (or veterinary) chemical products must always read the label and any Permit, before using the product and strictly comply with the directions on the label and conditions of any Permit. Users are not absolved from compliance with the directions on the label or conditions of the Permit by reason of any statement made or omitted to be made in this publication.

Authors: Paul Sullivan, Invasive Species Officer – Biocontrol, NSW DPI, Tamworth.
Lesley Postle, Professional Officer, NSW DPI, Menangle.

Production: Barry Jensen, Designer, Publication Services, NSW DPI, Orange.

Contents

INTRODUCTION 4

What is biocontrol of weeds? 4

THE SALVINIA PLANT – *SALVINIA MOLESTA* 4

Growth habit 4
Reproduction 4
Ecological damage – problems caused 5

THE SALVINIA WEEVIL – *CYRTOBAGOUS SALVINIAE* 5

Life cycle 5

BIOCONTROL SUCCESS 6

Expectations 7

HABITAT CONDITIONS 7

Assessing your site 7

BIOCONTROL AND INTEGRATED CONTROL OPTIONS 9

When can you use biocontrol alone? 9
When to look at other options 9
Herbicides plus biocontrol 9
Harvesting plus biocontrol 10

CONTROL OPTIONS – PROS AND CONS 10

Herbicides 10
Mechanical removal 10
Manual removal 11
Biocontrol 11

FREQUENTLY ASKED QUESTIONS 12

IS YOUR SITE SUITABLE FOR A BIOCONTROL PROGRAM? 13

IMPORTANCE OF MANAGEMENT PLAN TO AVOID OTHER WEEDS TAKING OVER 14

ACQUISITION OF SALVINIA WEEVILS 14

Transport and storage of salvinia weevils 15

HOW TO RELEASE WEEVILS 16

MONITORING METHODOLOGY 16

USEFUL REFERENCES 17

SALVINIA MONITORING SHEET 18

PHOTOCOPIABLE FLYER – HOW TO GET THE BEST OUT OF SALVINIA WEEVILS 19

Lesley Postle

Salvinia showing egg beater shaped hairs repelling water droplets

Lesley Postle

Primary form salvinia (top) with secondary form salvinia starting to fold (bottom)

Tertiary salvinia

Paul Sullivan

Introduction

This field guide was produced in 2012 and reflects the most recent research and up to date information available. It provides practical advice for those carrying out biological control (biocontrol) of *Salvinia molesta* D S Mitchell (Pteridophyta).

What is biocontrol of weeds?

Biocontrol of weeds is the use of natural enemies to reduce the vigour or reproductive potential of an invasive alien plant. Natural enemies will remove the plant's competitive advantage until its vigour is reduced to a level comparable to or less than that of the natural vegetation. In doing so, this creates a balance between a weed and its natural enemies (referred to hereafter as biocontrol agents or agents). When using biocontrol, eradication is not possible or indeed desirable because an amount of the weed needs to be present to sustain an ongoing population of biocontrol agents. The agents are imported from the weed's native geographic range after extensive testing to ensure host specificity. Host specificity means that biocontrol agents will not live on any other plants. Biocontrol agents can be insects, mites, fungi, bacteria or any other living organisms.

The Salvinia plant – *Salvinia molesta*

Salvinia molesta is a very unusual aquatic fern with tiny egg beater shaped hairs on its leaves which repel water and enable it to float. It also has false leaves that form roots underwater. Salvinia was introduced into Australia in the 1950s as an ornamental plant for fishponds and aquariums because of its pretty colour and extremely quick growth. It has become highly invasive, is now a Weed of National Significance (WoNS) and is considered to be one of the world's worst aquatic weeds.

Growth habit

Under ideal conditions salvinia grows very fast. Infestations can double their size in eight days or less. As salvinia develops, the young flat leaves (primary form) grow larger and start to fold (secondary form). The salvinia leaves get larger and more folded (tertiary form) and large infestations form dense mats which can completely cover the surface of the water. High nutrient levels (especially nitrogen) often found in disturbed environments and water bodies near or within farms favour the proliferation of aquatic weeds including salvinia.

Reproduction

Reproduction of salvinia is only vegetative. It reproduces by forming new branches which break off. Ferns are non-flowering plants which usually reproduce via spores which are normally contained in sporocarps under the leaves. The sporocarps of salvinia are spherical balls attached among the roots, but they are either empty or contain sterile spores.

Paul Sullivan

Mature (tertiary form) salvinia with sporocarps

Paul Sullivan

A dense mat of salvinia appears like solid ground

The salvinia weevil

Paul Sullivan

Ecological damage – problems caused

As the plants mature into tertiary form, they take up more and more space and form a dense mat. These mats prevent most light from entering the water, killing underwater plants. The salvinia leaves which are under the mat get little light and die. They sink to the bottom of the water and create a layer of organic matter which rots on the floor of the water body. This rotting matter breaks down using oxygen which it gets from the water. As the dissolved oxygen level in the water decreases, anaerobic conditions are created which can kill most of the fish, plants and animals living in the water.

Dense mats of salvinia can have the appearance of solid ground and therefore be a danger to humans and animals. The mats restrict use of the water for irrigation, livestock or recreational use.

The salvinia weevil – *Cyrtobagous salviniae*

CSIRO discovered the native range of salvinia in Brazil in 1979, and collected insects from these plants.

The salvinia weevil, *Cyrtobagous salviniae*, was chosen for host specificity testing and importation. Adult weevils feed on the salvinia plant, but most damage comes from larvae tunnelling into the plant's rhizome, (or stem). This causes the plant to turn brown, lose buoyancy and sink.

Life cycle

Weevils can live for about six months, and the complete life cycle takes six to eight weeks.

Weevils emerge from cocoons attached to the plant 'roots'. The weevils are brown in colour and darken to black within 5 days. Adult weevils can be found on all parts of the plant both above and below water.

Paul Sullivan

Weevils turn from brown to black in about five days

Lesley Postle

Salvinia weevil (1.5–2.5 mm)

Lesley Postle

Weevil egg (0.5 mm)

Lesley Postle

Weevil larva (3 mm long)

Eggs are laid in the folds of leaves, or in the rhizome or buds.

Larvae are white and grub like and feed initially on the outside of the plant for a few days before tunnelling inside the rhizome to feed.

All stages of the weevils' development are temperature dependent. The optimum temperature range for egg laying is between 23–31˚C. Eggs can be laid all year round in tropical climates although weevil reproduction does slow down during winter months. In temperate regions of Australia, eggs are laid from early spring and weevils will continue reproducing until daytime temperatures start to drop significantly in the late autumn. Egg production has been observed in the field when mean air temperatures were between 16–17˚C and the mean water temperature was 17–18˚C.

Biocontrol success

Salvinia weevils were released on Lake Moondarra in Queensland in 1980. They were a spectacular success. Within 14 months, 200 hectares of salvinia had been converted to open water.

After years of success in many tropical countries, the weevil has recently been shown to control salvinia in temperate areas. Good control has been achieved on the Hawkesbury–Nepean River and on many creeks and dams in the Sydney and Hunter regions of NSW.

Peter Room

Lake Moondarra, Queensland, Australia, covered with salvinia before biocontrol (above) and 14 months after use of biocontrol (below)

Peter Room

A three year trial in the Hawkesbury–Nepean region of NSW showed that biocontrol can be very successful in temperate areas if managed appropriately. Weevils controlled infestations on rivers within four months, while control on most creeks and dams was slower and in a few cases uncontrolled after three years due to heavy shading or where the salvinia mat was very dense.

Economic benefits of biocontrol

"Last year Australian biocontrol science turned a $4 million investment into a $95 million return…and did the same the year before, and the year before that, effectively all the way back for 100 years. An average benefit-cost ratio of 23:1 over that time period is simply a brilliant investment."

The Hon. John Kerin, former Federal Minister for Primary industries, January 2006.
Weedwatch CRC Weed Management Newsletter – March 2006

Lesley Postle

Hawkesbury–Nepean River after biocontrol

Lesley Postle

A problematic site with shade, shallow water, a dense salvinia mat, and other weeds growing on top of the mat

Expectations

Although spectacular results are possible, and have also happened in temperate regions, it can take a number of years for weevils to control some sites.

Factors such as shade, density of the salvinia mat, temperature, nutrient availability and water quality are thought to affect the population build up of the weevil. Research into these issues is continuing.

Habitat conditions

Weevils prefer open water with little or no shade since reproduction is temperature dependent.

Dense mats of salvinia discourage weevil population build-up, as the pupae are probably unable to access sufficient oxygen from the de-oxygenated water. Shallow water is detrimental to weevil survival as it is prone to drying out and may experience temperature extremes.

Assessing your site

Shade

Unless the entire site is in shade, it is still worth considering biocontrol. The release area should be in sunshine for most of the day. Once the salvinia in the sunny area is controlled, the shaded salvinia may then be able to float into the sunny area or can be moved manually. If the weevils are unable to control the shady area, other control methods may have to be employed.

Permanent water

Unless there is permanent water all year round, it will not be worthwhile releasing weevils at the site.

Case study – Camden

Recently two large dams near Camden, NSW were revisited and a weevil population which had been established in the late 1980s was still present and controlling salvinia 26 years after the initial release.

In 2010 salvinia was able to out-compete the weevil for a brief period and cover the dam. This was the first time this had happened in many years but a few months later the salvinia was controlled, turned brown and sank.

However, densely matted salvinia in a third, small dam next to the large dams has never been controlled probably because it is cooler and heavily shaded.

Paul Sullivan

Farm dam in Camden with large weevil population, salvinia brown and about to sink

Lesley Postle

A dense mat of tertiary salvinia at Mackenzie's Creek, NSW

Ron Aggs

Releasing salvinia weevils in a thinned out quadrat

Water hyacinth taking over a site where 100% salvinia cover was controlled by weevils

Paul Sullivan

In general, the best chances of success for salvinia biocontrol are where the site:

- Is a reasonably large water body
- Has a sunny position
- Has salvinia cover less than 70% (This may be achieved using other control methods first)
- Has little risk of flooding, drying out or experiencing temperature extremes

Salvinia cover

If the salvinia is tertiary form and has formed a dense mat, it will be necessary to thin out the salvinia first. Ideally, harvesting or herbicides will be used to reduce the biomass. If herbicides are used it is advisable to wait at least six weeks before releasing weevils.

If large scale thinning is not possible, then the release area itself (at least 2–3 m^2) should be thinned out to 30% open water using a rake.

Other weeds

If other weeds are present or growing in or around the mat, they will need to be taken into account. Spraying or harvesting may need to be undertaken to control weeds such as water hyacinth or alligator weed. The salvinia weevil will not control other plants.

Running water

Salvinia biocontrol works best on rivers and creeks, and less well on dams. This is probably due to the reduced oxygen levels under the dense mats that form on dams. However, biocontrol can work on dams, particularly if the salvinia cover is not too dense and temperatures are appropriate. Where there is running water, it is important to prevent salvinia from spreading to other sites using booms. Booms may also be useful to contain the growing weevil population if the salvinia is likely to move downstream.

Oxygen

Weevils will probably not reproduce below approximately 40% dissolved oxygen saturation. It may be worth testing the oxygen levels using an oxygen meter at a site before trying biocontrol. Weevils will have a better chance of building up good populations at higher oxygen levels.

Lesley Postle

Hawkesbury–Nepean River. October 2006

February 2007

Lesley Postle

Lesley Postle

Longneck lagoon, Pitt Town, Western Sydney. The salvinia mat turned brown and sank after 14 months.

Paul Sullivan

A small dam near Windsor, NSW where the salvinia mat was thin and the water reasonably deep. Weevils found sufficient refuge where salvinia plants were caught amongst some reeds for a population to survive for six years.

Biocontrol and integrated control options

When can you use biocontrol alone?

Biocontrol works well at sites where the water is flowing or has good depth. A release site needs at least 30% clear water and to have little shade. In sites like these, as long as there are no other problematic weeds present, it is possible to use weevils alone. If other weeds are present, these also need to be controlled in a manner that doesn't conflict with the presence of the weevils.

Examples of sites where biocontrol alone has worked well in the temperate Sydney region are the Hawkesbury–Nepean River, Longneck Lagoon at Pitt Town, and a small dam near Windsor, (see photos previous page and above). Also see the Camden case study on page 7.

When to look at other options

If a site has not begun to be controlled after three years of weevil presence, then it may be time to consider integrating biocontrol with other options. Sometimes harvesting part of the dam or waterway can be enough to give biocontrol a chance to work.

Herbicides plus biocontrol

Herbicides can be used to thin out a salvinia infestation so that weevils have a better chance of building up a population and gaining control. However, because

Case study – North Arm Cove – Great Lakes Council

The particular characteristics of this site having multiple small isolated ponds and a water body in excess of 7 hectares made eradication of salvinia unlikely.

An integrated approach to weed control was used at this site. An initial pass with herbicide for a 10 m strip around the edge of the dam reduced the density of salvinia enabling better establishment of the weevil. Weevils were released in 2004, with additional releases in 2007, 2008 and 2009.

By May 2010 a greater than 95% reduction of salvinia vegetative biomass had been achieved.

Terry Inkson

The site in 2004

Terry Inkson

May 2010

Paul Sullivan

Harvesting allows oxygen to enter the water

Lesley Postle

Salvinia can grow back from the tiniest piece of salvinia hidden among reeds

salvinia sinks to the bottom and rots, it reduces the oxygen in the water. Sufficient time for water quality to improve may be needed before releasing weevils.

Harvesting plus biocontrol

Experience has shown that biocontrol can be highly effective on sites that have been previously harvested. It is thought that an improvement in water quality is achieved when a large amount of biomass is removed. This allows oxygen to enter the water and the process of harvesting further oxygenates the water. Water quality is not compromised because the salvinia mat is disposed of on the land, and does not sink to the bottom of the river or dam.

Case study – Pitt Town dam

Weevils were released on a dam at Pitt Town in August, September, October and November of 2004. This dam was monitored monthly for three years. Although tip damage averaged 55% throughout the dam by March 2006, the salvinia was not controlled and maintained almost 100% cover.

In November 2006 this dam was harvested and approximately 90% of the salvinia was removed from the surface of the water. Further weevil releases were made. By March 2007 tip damage had reached 100% and the salvinia was looking brown. It started to sink in April and by July there was clear water.

Control options – pros and cons

Herbicides

There are environmental and practical problems associated with using herbicides in and around waterways, and in most states and territories a licence will be required. Herbicides may also have a negative effect on fish and other aquatic organisms through chemical contamination of the water and de-oxygenation.

It can take several treatments before a water body is free of salvinia and this can be expensive. Often water bodies are still infested with salvinia even with repeated treatments. The salvinia will grow back quickly if any small pieces of the plant are left behind (these may be less than 5 mm in length) or if the site is reinfested with salvinia from water bodies higher up in the catchment.

Eradication of salvinia on small water bodies can occasionally be achieved in one treatment, but it is more usual for further treatments to be needed. Sites should be monitored and re-treated regularly after treatment. Larger sites can take up to three years to be controlled by herbicides.

Mechanical removal

Harvesting is very expensive (approximately $2500 per day (2011)) and needs to be used as part of an integrated management plan because it can only partially remove the salvinia. Follow up treatment with herbicides and/or biocontrol is required.

Harvested material needs to be stored and disposed of carefully. Salvinia may be contaminated with other weed species which can then be spread into new

Lesley Postle

Salvinia weevils

Paul Sullivan-

Monitoring can help determine whether frost, poor nutrients or salvinia weevils have turned the salvinia brown

areas or onto land, e.g. alligator weed. Legislative requirements under the noxious weeds act may require additional controls on the disposal of the harvested material, and this may increase the cost of managing the harvested salvinia.

Manual removal

Small infestations can be controlled by manual removal, but it is labour intensive, expensive and may have health and safety implications.

Biocontrol

Biocontrol should always be considered in any management plans for control of salvinia but it may need to be used in combination with other control methods. In the long-term it is cheap and safe for the environment. It gives long-term sustainable control with minimal maintenance once the weevil is established.

It is ideal for large areas, environmentally sensitive areas, sites where access is not possible for spraying or harvesting, sites susceptible to re-infestation and sites where water is being used for stock watering. The weevils will also disperse to other areas including inaccessible or difficult terrain.

With biocontrol, there is no danger of off-target damage to, or removal of other desirable plants which can occur with herbicides or harvesting.

Biocontrol should not be used where eradication is to be attempted unless it is to thin out a large area prior to eradication.

Training is needed to achieve the best results.

Advantages and disadvantages of various salvinia control methods when used alone

HERBICIDES	YES	NO
Labour intensive?	√	
Expensive?	√	
Long term results	sometimes	sometimes
Environmentally friendly?		√
Training required?	√	

MECHANICAL REMOVAL	YES	NO
Labour intensive?	√√	
Expensive?	√√	
Long term results?		√
Environmentally friendly?	√*	
Training required?	√	

* If care taken not to spread other weeds

MANUAL REMOVAL	YES	NO
Labour intensive?	√√√	
Expensive?	√√√	
Long term results?	sometimes	sometimes
Environmentally friendly?	√	
Training required?	OH&S	

BIOCONTROL	YES	NO
Labour intensive?		√
Expensive?		√
Long term results? (no eradication)	√	
Environmentally friendly?	√	
Training required?	√	

Rebecca Coventry

Pink and green azolla with salvinia in the centre

Paul Sullivans

Tertiary salvinia on left of boom, newly grown secondary salvinia on right

Frequently asked questions

How can I be sure I have salvinia and not some other plant?

Occasionally salvinia can be mistaken for azolla which is an Australian native aquatic fern, and doesn't pose much of a problem. Salvinia has entire leaves with tiny egg beater shaped hairs while azolla's leaves are multi-divided and smaller. Study the photograph above and the other photographs in this field guide. Salvinia can appear bright green or brown when it is frost damaged or dying from herbicides or biocontrol. Azolla looks green, pink or brown. See photo above and the picture of azolla on next page.

Will biocontrol eradicate the weed?

The aim is not to eradicate the plant, but to reduce its incidence to low levels that do not cause significant economic or environmental damage. Eradication is rarely possible with biocontrol, and carries the danger that the insect population will die out, and the weed will then return. The ideal situation is to achieve a dynamic equilibrium where both the plant and the insect survive at low levels without causing economic damage.

What else will the weevils eat? Are they safe?

Biocontrol agents are host specific, which means they only eat one species of plant (this is salvinia for the salvinia weevil). Many people are concerned about biocontrol because of the problems Australia has with, for example, the cane toad. Salvinia weevils have undergone extensive testing to ensure that they are safe for our environment and industries.

Will insecticides, herbicides or other chemicals kill the biocontrol agents?

Yes. Biocontrol agents are usually adversely affected by pesticides, especially insecticides. The application of herbicides within weevil breeding nursery sites should also be avoided because it depletes the food source for the weevils.

Who do I talk to about salvinia biocontrol?

You can get advice from your local council Weeds Officer about using biocontrol for your site. Additional information can be obtained from Paul Sullivan Invasive Species Officer – Biocontrol, NSW DPI, Tamworth and weevils can be obtained from the NSW DPI rearing facility at Grafton – (02) 6640 1600.

How much does it cost?

The NSW Department of Primary Industries will charge a minimal amount to provide weevils, either $500 or $1000 per year depending on the number of tubs required. A tub will normally contain a minimum of 150 adult weevils plus eggs and larvae, but these numbers can be much higher.

How long will it take to work?

Biocontrol is a natural process. Weevil populations require time to increase until their population is large enough to have an impact on the salvinia infestation. Establishment times will vary. It may take up to three years before the weevils start to have a significant impact on the weed infestation. However, in ideal conditions, salvinia weevils have destroyed large salvinia infestations in as little as four months in temperate climates in the Sydney region as well as in tropical areas.

How can I tell whether it is working?

Weevils cause damage to the growing tips of salvinia plants. This damage can be monitored to see if the weevil population is increasing. See pages 16 and 17.

Salvinia which has obvious feeding holes, and is starting to look brown will have a good weevil population in it. Beware of mistaking weevil feeding holes with larger holes, which are made by the larvae of the salvinia moth – *Samea multiplicalis*. See page 13. The salvinia moth was released onto salvinia in Australia before the weevil, and although it has established well, it does not kill the plant.

Does anything predate on the weevils?

Adult weevils may be eaten by birds, spiders and fish, but generally weevils are well protected, living within the salvinia plant, and do not seem to be adversely affected by predators in Australia.

Paul Sullivan

Moth larvae holes

Paul Sullivans

Weevil feeding holes

Is your site suitable for a biocontrol program?

Follow the chart to determine whether to proceed with biocontrol:

1. Has the weed been correctly identified as *Salvinia molesta*?

Yes Go onto Question 2. ▼ ▶ No make sure that the weed you have is definitely salvinia. It may be confused with the Australian native – Azolla

Look at the following pictures or if in doubt, contact your local council Weeds Officer.

Rebecca Coventry

Azolla

Paul Sullivan

Salvinia

2. Is the site likely to be re-infested from another area?

Yes Go to Question 3. ▼ No Is eradication possible?

Yes Carry out eradication using other control methods

No Go to Question 3 ▼

3. Is the salvinia from this site a threat to other uninfested areas?

Yes Try and eradicate

Consider herbicides and boom off area to prevent dispersal

No Go to Question 4. ▼

4. Does your site

	Yes	No
a. Have more than 70% salvinia cover?		
b. Have a lot of shade?		
c. Have shallow water?		

A biocontrol program is likely to be a good option for your site if you answer no to all of the questions in number 4. If you answer yes to any of these questions, you may wish to consult page 9 before implementing a biocontrol program. However it may still be worth using biocontrol in conjunction with another control method especially if you only answered yes to question 4a as the salvinia can be thinned out. Biocontrol can be used as part of an integrated weed management plan.

Paul Sullivan

Often several aquatic weeds grow together

Paul Sullivan

Harvesting multiple aquatic weeds

Importance of management plan to avoid other weeds taking over

A successful weed management plan includes much more than just control.

Site specific plans need to be negotiated with all stakeholders including the landowner for best results. There is no point in beginning a control program unless long-term plans are in place for follow-up monitoring and treatment.

There are five main steps to good weed management plans:

1. Prevention – vigilance is needed to prevent weed infestation in the first place and a rapid response is required when new weeds occur. Nutrient levels in water bodies should be reduced where possible, through changing land use, irrigation strategies and reduced fertiliser use.
2. Act early – weed infestations are much easier to control when they are small.
3. Control – a long-term control plan should be put in place as soon as possible once an infestation is detected.
4. Replacement – where appropriate, sites should be restored using native plants.
5. Maintaining the site – regular monitoring for a number of years needs to be carried out to ensure that the target weed does not return and that other weeds do not replace the target weed.

There is little point in carrying out a control program, with or without a biocontrol component if numbers 4 and 5 are neglected. If nutrient levels are high and regular monitoring is not carried out, it is very likely that other weeds will invade a site where salvinia has been removed. Once a site has suffered a major salvinia infestation, the ecology of the site is weakened, other fauna and flora has been killed and it becomes easier for other weeds to invade. Such sites should be a higher priority for attention as they are especially vulnerable and may remain problematic. Other weeds may take over from the target weed. The emergent weed may even be more difficult to control than the original target weed and contingency plans need to be in place in the original management plan to take this into account.

In the case of salvinia, for example, water hyacinth, alligator weed or cabomba may take over, and these are difficult and expensive to control.

Other weeds to look out for in aquatic habitats in NSW include:

Alligator weed, Cabomba, Elodea, Egeria, *Ludwidgia peruviana,* Sagitarria, Senegal tea, Water hyacinth, Water lettuce

You can also consult *Recognising Water Weeds – Plant Identification Guide*, available from weeds@dpi.nsw.gov.au or the Weeds Hotline: 1800 680 244.

Acquisition of salvinia weevils

The National Aquatic Weeds Management Group and NSW Department of Primary Industries established a salvinia biocontrol rearing facility at the Grafton Agricultural Research and Advisory Station.

The facility supplies salvinia weevils to local government areas in NSW.

Lesley Postle

Rearing facility at Grafton Agricultural Research and Advisory Station

How does the facility operate?

Weed control authorities or local councils that wish to use the facility are invited to contribute approximately $500–$1000 per year to provide the facility with an operating and maintenance budget.

Occasionally this facility may not be able to supply weevils for a short period due to climate or other unforeseeable conditions.

Brisbane County Council also rear salvinia weevils and may be able to supply small quantities on occasion.

In general it is not advisable to transfer weevils from one release site to another because of the risk of spreading other weeds such as alligator weed. If there is no other option, this practice can occasionally be carried out by collecting salvinia and sinking it to allow the weevils to rise to the surface onto one or two small clean plants. This method allows weevils to be extracted from the salvinia and released alone. For more information or assistance with biocontrol agent acquisition contact Paul Sullivan on (02) 6763 1175.

Paul Sullivan

When weevil infested salvinia is sunk, weevils rise to the surface and congregate on a small piece of floating salvinia

Transport and storage of salvinia weevils

(A licence is required for transporting noxious weeds. This can be obtained from NSW Department of Primary Industries)

1. **Arrange schedule**

   Weevils should be in transit for the shortest possible time, although they can survive in cool boxes for up to a week. Make sure that personnel and landowners are expecting the weevils so that they can be released as soon as possible.

2. **Collection of weevils**

   The easiest way to transport weevils is with salvinia plants. Polystyrene or plastic boxes can be used, with most of the water drained out.

3. **Keep cool**

   It is essential when transporting salvinia weevils to keep the boxes cool and in the shade especially when the weather is very hot. Plastic boxes can overheat even in cool weather in ten to fifteen minutes if left in the sun. An enclosed air conditioned vehicle is preferable. Always park in shade during rest breaks on the journey, and check that boxes are not overheating.

4. **Storage**

   If weevils are to be stored for a short time, they can be kept in salvinia plants, in a single layer floating on ordinary water. Weevils can be stored outdoors, or in an air conditioned office, shade or greenhouse. Their temperature tolerance means they will tolerate low temperatures down to 0°C but do not tolerate temperatures above 40°C for very long. Do not allow them to dry out.

5. **Which life cycle stages to release?**

   If releasing weevils in autumn, make sure that adult weevils are present as this is the stage that will overwinter. During warmer months, it is fine to release material which contains mostly eggs and larvae.

Rebecca Coventry

A weevil release on a dam

How to release weevils

Season

Salvinia weevils are best released in the spring to allow them maximum time in the warmer months for the population to increase.

Releases can be done in the winter months if adults are present, as they will overwinter and be present to begin egg laying as soon as the weather warms up. Larger and/or subsequent releases may be needed.

Number

An approximate guide to the number of weevils to release together in a small area of 2–3 m^2 would be a minimum of 200 adults. However, in practice, it is not always easy to count the number of weevils released.

Best practice shows that at least two large tubs of weevil infested salvinia should be released at each release site, and if possible a repeat release should be carried out a month or two later.

If it is a larger site, four to six tubs may be more appropriate.

The number of tubs will often be dictated by the number of sites to be treated, availability of weevils and space in transport vehicles.

All the weevil infested salvinia should be put in the same place at the release site. It should not be spread around. The weevils need to be close together in order to mate and reproduce. They will disperse as the population increases.

When releasing into a dense mat, clear an area of at least 2–3 m^2 of salvinia to allow clear water to show through. Put the weevil infested material into this space (see photograph above). Try to create the space in a deep area that will not dry out and close to the bank so that the salvinia will be accesible for monitoring. At least one third of the surface area should be maintained as clear water while establishing weevil populations.

When releasing weevils, always make sure there are two people present and that other occupational health and safety procedures are in place.

Mark the release site with a floating boom, or a post, and take a photograph from a spot that is easy to find again.

A sequence of photographs should be taken from the same position and aimed at a reference point.

Monitoring methodology

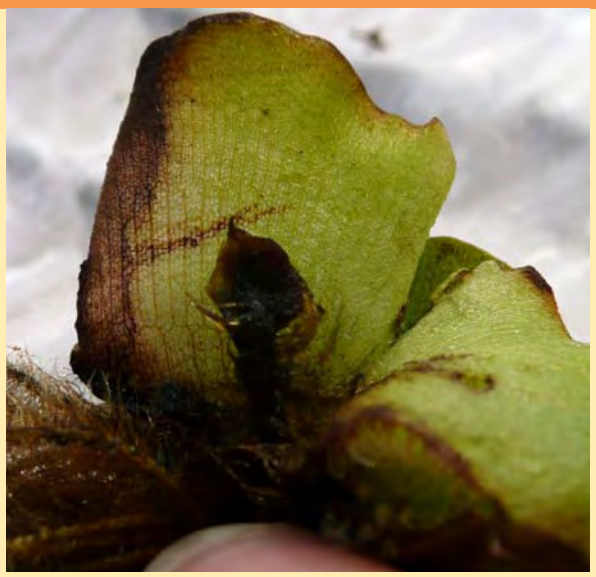
Why is it necessary to monitor?

- to determine weevil establishment and population increase
- to detect spread of the weevil
- to assess plant damage
- to modify control methods
- to provide reports and feedback

Weevils may be lost due to drought, floods, herbicide spraying, extreme temperatures, loss of food supply or other adverse conditions causing the population to decrease. In this case a decision needs to be made whether to re-release or to implement another control strategy.

Paul Sullivan

Healthy salvinia growing tip



Paul Sullivan

Weevil damaged growing tip

What to look for when monitoring?

Tip damage is a good indicator of weevil activity. The growing tips of weevil damaged plants become black and soft, due to feeding by adults in the leaves and by larvae inside the rhizome.

Counting the percentage of tips that are damaged can be done by choosing 50 plants and checking the growing tips of each one. Double the number of damaged tips to get a percentage. When tip damage gets above about 70–80% it is almost certain that control of salvinia will soon be achieved.

Number of adult weevils seen while assessing tip damage should also be recorded.

Once tip damage near the release site is above 50%, counts can be done further away to assess spread of the weevil. Distances of 2 m, then 10 m, then 30 m, then 50 m etc. may be appropriate depending on the geography of the site.

Case study

At a trial site in Western Sydney, the salvinia weevil successfully controlled a large infestation on a creek line, but water hyacinth rapidly filled the space vacated by the salvinia.

Paul Sullivan

Water hyacinth takes over after salvinia biocontrol

While assessing the site, it is important to take notice of what is replacing the salvinia weed.

If other weeds are taking over, then additional control will have to be undertaken.

Useful references

Salvinia Control Manual. NSW Department of Primary Industries. Available at:

www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications

Recognising Water Weeds – Plant Identification Guide. Available at:

www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications

Sullivan P.R., Postle L.A., Julien M., 2011. Biological control of *Salvinia molesta* by *Cyrtobagous salviniae* in temperate Australia. *Biological Control* 57, 222–228.

Sullivan, P.R., Postle, L.A., 2010. Low temperature reproduction of *Cyrtobagous salviniae*: good news for biological control of salvinia in a temperate climate. *Journal of Aquatic Plant Management* 48, 92–96.

Postle L., Sullivan P., Popple G., 2007. How to find your weevils in the spring: new thinking on monitoring methods for salvinia biological control in temperate regions. *Proceedings of the 14th Biennial NSW Weeds Conference*, Wollongong.

Sullivan P.R., Postle L.A, Holtkamp R.H., 2008. The salvinia weevil *Cyrtobagous salviniae* controls salvinia in temperate Sydney. 16th Australian Weeds Conference, Cairns.

Hennecke, B., Postle, L., 2006. The key to success: an investigation into oviposition of the salvinia weevil in cool climate regions. In: Preston, C., Watts, J.H., Crossman, N.D. (Eds.), *Proceedings of the 15th Australia Weeds conference*. Weed Management Society of South Australia, Adelaide, pp. 780–783.

Salvinia monitoring sheet

Site name: ..... New release site / re-release site (circle one)

If re-release site

How did the salvinia react to previous weevil releases? .....

Date collected ..... Date released.....

Quantity released (number of adults or number and size of tubs).....

Name of releaser:..... Organisation .....

GPS coordinates* (Latitude and Longitude – decimal) South ..... East:.....

* Give accurate description and map if no GPS available (i.e. NE edge of bridge crossing, Haven Road 50 m West from Pacific Highway)

Water body type and size:.....

Approximately depth (m)..... Size of infestation (ha)..... Salvinia cover (%) .....

Age and growth stage (i.e. primary, tertiary, multi-layered mat):.....

Map of site

(Draw water body, where release was made, presence of trees & structures and north)

Count 50 growing tips for evidence of damage and multiply by 2 to record % tip damage:

Date	Percentage tip damage	No. of adults

What is the maximum estimated distance the weevils have moved from the original release point (in metres):

From the original release point, in which direction have the weevils moved?

❑ North ❑ East ❑ South ❑ West

What is the total area of salvinia affected by the weevil?

Length (m) ..... x Width (m)..... =..... m^2

In what condition is the salvinia, where the weevils are present?

❑ Excellent condition (green and growing vigorously)

❑ Good condition (mostly green, but with some paleness)

❑ Poor condition (mostly yellow/bleached)

❑ Stressed

❑ Other

Please comment on any event or process that may have affected the weevils or the release site. For example flood, fire, drought, herbicides, insecticides, vandalism etc.

How to get the best out of salvinia weevil releases

Salvinia – a weed of national significance

Photo: Rod Ensbey

Photo: NRME Photo Library

Photo: Andrew Petroeschevsky

Photo: Rebecca Coventry

Selecting a release site

Selecting the right site maximises the initial survival and establishment rate of the salvinia weevils.

Select release sites with:

- actively growing salvinia (new bright green tip growth)
- open areas that receive direct sunlight for a major part of the day
- free-floating salvinia in at least 10 cm depth of water

Don't select sites with:

- heavily-shaded areas where there is an over-storey of other vegetation
- shallow water that may dry up seasonally
- salvinia cover more than 70% (salvinia can be thinned out by either herbicides or harvesting prior to using biocontrol).

Releasing the weevils

At the selected site release at least 200 adult weevils together in one 2 metre × 2 metre area. As a guide this normally equates to two × 40 litre tubs.

Releasing them in one place helps keep the population together, which increases breeding rates and leads to faster control. At large sites weevils can be released into a 2 metre × 2 metre quadrant, which helps contain them whilst population establishes.

Don't scatter small populations of weevils (less than 300) across the entire site as this increases the likelihood of the population dying out.

NSW GOVERNMENT Department of Primary Industries

11003 – Jan 2012

How to get the best out of salvinia weevil releases

Salvinia – a weed of national significance

Photo: CSIRO Entomology

When releasing the weevils:

1. pick a spot as deep as possible by the water's edge
2. thin out the weed mat in an area of approximately 2–3 m^2 where the weevil infested salvinia can be placed in direct contact with the infestation
3. ensure the infested salvinia is in contact with the water surface
4. complete and return the weevil release form to your supplier.

If using extracted adult weevils they can be tipped from the small containers directly onto the infestation in the one area.

Ensure that salvinia has been positively identified before you introduce host salvinia containing weevils.

Photos: Tweed Shire Council

12–36 months after release – salvinia appears healthy

1 month after photograph 1 – salvinia turns brown due to weevil damage

2 months after photograph 1 – weevils begin to collapse mat

3 months after photograph 1 – control achieved

How long can it take for weevils to work?

Populations of weevils can take from 4 months to several years to form a sufficient population and cause the floating salvinia mats to collapse. During this time the salvinia can appear healthy with very little visual evidence of the weevils' impact.

The following photos show that given sufficient time an increasing population of weevils can control salvinia.

Regularly monitor the weevil population (every 2–3 months) to determine if it's increasing.

Detailed information about carrying out a salvinia biocontrol program is contained in the *Salvinia Biocontrol Field Guide* and the *Salvinia Control Manual* available from the NSW DPI website.

national aquatic weeds management group

Australian Government

NSW GOVERNMENT

NSW Environmental TRUST

NSW GOVERNMENT

Department of Primary Industries

10990