NSW DEPARTMENT OF
PRIMARY INDUSTRIES

**Salvinia control manual - Readers' Note**

This document is part of a larger publication. The remaining parts and full version of the publication can be found at:

http://www.dpi.nsw.gov.au/aboutus/resources/majorpubs/guides/salvinia-control-manual

Updated versions of this document can also be found at the above web address.

# Part 4: Case studies

# Ewen Maddock Dam: Salvinia management through continuous small-scale mechanical removal

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## Introduction

The information in this case study was provided by Russell Rainbird, Technical Officer with Cal Aqua, Caloundra City Council.

### *Ewen Maddock Dam*

Ewen Maddock Dam is a 371 ha water reserve in Caloundra Shire in South East Queensland. Constructed in 1976, it is now managed by Cal Aqua, a commercial branch of Caloundra City Council. The dam was originally used as a water supply but was taken offline in the late 1980s when other storages were activated. It is currently used for recreation and has significant environmental value, providing habitat for native flora and fauna. It is destined to go back online as a water supply in the next decade.

The dam has a volume of approximately 17 000 megalitres and an average depth of 4.08 metres. The deepest parts of the dam are around 12 metres. Most of the aquatic weeds occur in the lower half of the dam, where the average depth is 2–4 metres. The spillway is 25.3 metres across.

### *The salvinia problem*

Salvinia was first reported on the dam in 1995. Salvinia present on small farm dams in the catchment would wash into Ewen Maddock Dam after heavy rain. Managers had some awareness of the damage potential of the weed, but no budget or strategy to manage a salvinia infestation. Few of the surrounding landholders had the information they needed to control their infestations.


Courtesy Cal Aqua

*Aerial photograph of Ewen Maddock Dam showing the main areas of salvinia infestation in red.*

### *Current salvinia levels*

The main areas of the dam where salvinia is present are marked in red on the aerial photograph below. Natural barriers created by vegetation (sedges, reeds and lilies) and booms help contain the salvinia to these areas and prevent movement into other parts of the dam. The areas are numbered, and the extents of the infestations in each section are as follows:

- section 1: very light infestation, no thick mats present, salvinia is scattered throughout the reeds, inspections are done weekly
- sections 2 and 3: light to medium infestations, small mats are present but confined mainly to reeds, inspections are done weekly
- section 4: medium infestation, some large mats close to shoreline, some salvinia lightly scattered throughout reeds and lilies
- section 5: very light infestation, no thick mats present, inspections are done weekly
- section 6: very light infestation, no thick mats present
- section 7: only scattered salvinia found after heavy rains or wind.

### *Management issues*

The use of herbicides on the water was a sensitive issue for local residents, and broadscale use of herbicides on the dam had been unpopular in the past.

> *We are limited in what we can do, because the public are very sensitive to the use of herbicides. We can use them but we have to really limit what we use them for and how we use them.*
>
> **National Salvinia Workshop, Grafton***

*Comments from a presentation by Russell Rainbird to the National Salvinia Workshop in Grafton in September 2005 have been used throughout this section.

A commercial harvester was engaged to remove salvinia, but it caused large amounts of damage to other native aquatic vegetation. The action of the harvester was also aiding the spread of cabomba (another serious invasive aquatic weed) throughout the dam. Enough complaints were received from conservation groups and birdwatchers to have the harvesting stopped.

An alternative strategy was needed that would have less impact on the environment. A technical officer was made responsible for managing aquatic weeds as well as other aspects of the water reserve, including water quality sampling and fire management; however, a lack of available staff and resources was accepted as part of the problem.

## The management strategy

The successful management strategy is based on small-scale mechanical removal combined with strategic use of herbicides, biocontrol, manual removal and a public awareness campaign. The in-house development of

Russell Rainbird

*The salvinia on the dam is maintained at physically and financially manageable levels.*

a mechanical scoop proved to be a more selective method of physical removal, causing less damage to native vegetation; operating at much lower cost than a broadscale harvester; and allowing management to be adaptive and ongoing.

### *Aim and objectives*

The aim is to maintain the salvinia at the current levels, which are considered to be physically and financially manageable.

> *Our main goal is to keep it at a level where we can control it—that's the key thing—not letting it get past that point.*
>
> **National Salvinia Workshop, Grafton**

Work is rarely required in the main body of open water (section 7 on the aerial photograph), as the salvinia is contained and kept within the other areas.

> *We've only got salvinia in certain areas, and that's where we try to keep it. If it gets out into the open, there's no way the scoop would get on top of it. We have natural barriers created by sedges and water lilies, and we use those barriers as containment lines, making sure it never gets past them.*
>
> **National Salvinia Workshop, Grafton**

Integrated management is carried out over the year on an ongoing basis, as shown in the table on the next page.

### *Containment*

Floating booms are used in key areas such as across inflows, swimming areas or small bays and inlets to help with control. There are four sites where booms are used on a regular basis (1 × 100 m StormFlex® pipe; the others ranging between 20 m and 50 m StormFlex pipe).

Floating booms are also used to contain salvinia to the areas that dry out when water levels recede.

### *Small-scale mechanical removal*

Small-scale mechanical removal is done with a removable mechanical scoop attached to the bow of a 5.25 m aluminium boat and worked like a front-end-loader bucket. An aluminium bar at the front of the scoop pushes native vegetation under the water, at the same time releasing any trapped salvinia and causing it to be caught in the scoop. This allows for selective removal of salvinia, minimising damage to native aquatic plants. The scoop can be raised and tilted to dump loads of salvinia on shore.

Russell Rainbird

*Small-scale mechanical scoop in operation.*

| INTEGRATED STRATEGY FOR MANAGEMENT OF SALVINIA AT EWEN MADDOCK DAM | | |
|---|---|---|
| **Method/technique** | **Application** | **Timing/season** |
| Containment | Floating booms are installed before physical removal and herbicide treatments; to contain salvinia that will be stranded; and to separate biocontrol areas. One permanent boom prevents spread into the main area of open water. | Year-round |
| Small-scale mechanical removal | The mechanical scoop used in all accessible areas to remove salvinia and push it into areas that dry out when water levels recede. | Year-round, particularly after rain when water levels are high |
| Herbicides | Glyphosate is sprayed over piles of harvested salvinia as a precaution to prevent reinfestation. Glyphosate is used to treat stranded salvinia around the shoreline. Glyphosate strip treatments are applied to thicker mats to assist biocontrol. Immerse® herbicide is used to treat scattered salvinia amongst other vegetation close to the shore. | Year-round |
| Biocontrol | Biocontrol releases are made in areas inaccessible to the scoop. Biocontrol prevents salvinia establishment beyond vegetated areas. Established biocontrol populations are considered as safeguards should salvinia levels increase dramatically. | Releases early spring |
| Manual removal | Small amounts of salvinia that occur in areas used for swimming and recreation are manually removed. | On an as-needed basis, mainly after heavy rains or winds |
| Monitoring | Both the dam itself and the surrounding catchment are monitored regularly. | Weekly (dam), late winter (surrounding catchment) |
| Public awareness | A Catchment Care Information Kit is distributed to surrounding landholders. | Ongoing |

The scoop is constructed from aluminium tubing fitted with wire mesh that acts as a strainer, allowing water to flow through and trapping the salvinia. A prototype was constructed out of PVC pipe to see if the concept would work. The scoop is capable of removing 4.5 tonnes of salvinia a day, depending on the distance the boat has to travel between loads. A single load averages 150 kg, and an operator can do between 25 and 30 loads per day. In 2005, the scoop removed approximately 75 tonnes of salvinia in over 74 hours of operation.

*Making this scoop was a lot of trial and error. We originally tried the same shape with PVC pipe and chicken wire. Then we used a hand winch, which got the operators very fit … and it was very slow.*

**National Salvinia Workshop, Grafton**

A stainless-steel bracket fixed permanently to the bow allows the scoop to be attached with minimum effort, taking two people a few minutes to lift and attach the scoop to the boat. The detachable scoop allows the boat to be used for other purposes. The boat is fitted with additional foam beneath the deck to increase buoyancy and comply with standards.

Russell Rainbird

*The removable mechanical scoop.*

Russell Rainbird

*The scoop has a load capacity of 150 kg.*

Russell Rainbird

Russell Rainbird

*Two people can lift and attach the scoop.*

*The scoop is attached to a stainless steel bracket fixed permanently to the bow.*

The scoop is raised, tilted and lowered on a hydraulic ram fitted to the centre of the bow, powered by a 12-volt hydraulic power pack. It is capable of lifting over 300 kg but has been limited to 150 kg per load for buoyancy and safe manoeuvrability. The power pack is stowed at the rear of the boat beside the engine transom, helping to balance the boat and conserve deck space. Initially a hand winch was tried, but the loads were too heavy.

The scoop is also used to push large mats of salvinia into areas that dry out when water levels are low, or up onto the bank to about 3 metres above the shoreline.

### *Herbicides*

The salvinia that is removed with the scoop is dumped at designated areas on shore, spread out, and sprayed with glyphosate 360 g/L (Weedmaster Duo® or Envirospray 360®) to prevent any possible recontamination during the time it takes to dry out.

> *The boat is fitted with a 100-litre spray tank and a 5-hp Honda diaphragm pump at the rear behind the driver's seat, which also helps with balance. So when the operator has finished scooping, he just goes all around the shoreline wherever there are piles of salvinia and sprays them.*
>
> **National Salvinia Workshop, Grafton**

The salvinia that becomes stranded when water levels recede is also treated with glyphosate herbicide, either from the boat or from a 4WD or ATV (all-terrain vehicle) from the banks. This is imperative, as stranded salvinia can stay alive and reinfest open water when water levels rise.

In biocontrol areas, glyphosate strip treatments are used to prevent salvinia mats from becoming too thick; these treatments allow the biocontrol to be more effective.

Immerse® herbicide is used to treat scattered salvinia that is trapped among aquatic vegetation close to the shore (too close to access with the scoop).

### *Biocontrol*

Biocontrol alone is not considered acceptable because of the time frames involved and the use regimes of the dam, but it is seen as providing a safeguard for the dam should the salvinia ever reach unmanageable levels. A number of releases are made each year to ensure that weevils are always present.

Weevils are released in areas that are inaccessible for the boat and scoop—usually in small coves or inlets where edge vegetation and water depth make it difficult to use the scoop.

Weevils are obtained from Brisbane City Council and released two or three times a year (about three batches of 200 adults each time). Weevils can be lost when sections of salvinia are stranded after water levels drop, adding to the rationale to carry out a number of releases each year.

Weevils successfully prevent the salvinia from moving out beyond the vegetated areas into open water.

> *Anywhere we can't get the scoop into we use biocontrol. There are some large areas where the other vegetation restricts the success of the weevil, but we know the weevils take refuge there.*
>
> **National Salvinia Workshop, Grafton**

Russell Rainbird

*The scoop is raised and tilted on a hydraulic ram to dump loads on shore.*

### *Manual removal*

If water levels rise quickly after rain, containment booms can give way, allowing the salvinia to escape. Any salvinia that gets into areas used for swimming and recreation is manually removed.

### *Seasons and timing*

Salvinia growth is greatest over the warmer months (November to February), and slow to dormant when water temperatures drop below 15 °C (March to July). Salvinia starts to build up from about August onwards.

The scoop is used year-round, but particularly when water levels are high after inflows of stormwater following rain. This allows better access, and takes advantage of areas that will dry out when water levels recede.

> *After rain we get large mats washed down into the dam, so we push them to an area that will be high and dry when the water level goes down.*
>
> **National Salvinia Workshop, Grafton**

Weevil activity increases when temperatures consistently above 15 °C are recorded. Herbicide treatments are carried out year-round.

### *Monitoring*

Regular monitoring is incorporated into the ongoing management routine, with most of the infested areas inspected weekly.

Inspections of the surrounding catchment are started in winter to allow time to enforce compliance regulations, if required. Reinfestation from surrounding dams is likely as soon as the wet season starts (peak rainfall occurs from December to March/April).

> *We keep a good eye on the dam; if it gets out into the rest of the dam we scoop it. There is a manager there all the time, so it's early detection and it works.*
>
> **National Salvinia Workshop, Grafton**

### *Public awareness*

A public awareness campaign in the form of a Catchment Management Info Kit was developed to inform and help landholders, making aquatic weed management less reactive and more proactive. This has received positive feedback from landholders, but further help for landholders in the catchment to eradicate small infestations is required before salvinia management costs on the dam will decrease any further.

## Costs and resources

Two permanent full-time staff (a technical officer and a leading hand) are responsible for the day-to-day management of salvinia and other aquatic weeds, as part of the overall management of the dam. Salaries for the two permanent staff take up the major portion of the weed control budget for the dam.

The leading hand carries out most of the operational work of scooping, spraying, maintaining booms, and inspection, with help from the technical officer, who is responsible for aquatic weed administration and management (including water hyacinth and cabomba),

as well as other aspects of the dam's management (including water sampling and fire management). Casual operational staff are employed on an as-needed basis, as the control work is adapted to the conditions and extent of the infestation at any one time. In 2003, over 300 operational hours were spent on salvinia control (scooping, spraying, booms, inspections), whereas in 2004 operational hours were 180.

### *Capital costs*

Capital costs for the boat and scoop range between $5000 and $7000, depending on the size of the boat, outboard motor, power pack, etc. (This does not reflect costs associated with the scoop's in-house development.)

### *Operational costs*

Approximate operational costs (fuel, herbicides and operators) in 2005 were $8902 (see table below).

> *The scoop operator is very good, he uses two to three tanks of fuel a week, he's very careful … so the costs per week are only in the hundreds not in the thousands compared to other big harvesters.*
>
> **National Salvinia Workshop, Grafton**

## Key points

Small-scale mechanical removal allows the infestation to be maintained at a manageable level, with minimum resource inputs; however, it must be carried out continuously and must be integrated with other methods to be successful.

There is a constant process of adaptive management and decision-making to ensure that control efforts are able to maintain salvinia levels in response to rainfall and water levels, salvinia growth, recreational use patterns and environmental values.

**APPROXIMATE COSTS OF SALVINIA CONTROL AT EWEN MADDOCK DAM IN 2005**

| 2005 operational cost item | Usage over year | Cost | Cost over year |
|---|---|---|---|
| Scoop operator | 74 hours | $30.00/h | $2220 |
| Fuel | 40 L/week | $1/L | $2080 |
| Herbicide | 4.7 L on dumped piles<br>102 L on stranded weed | $120 per 20 L | $642 |
| Spray operator | 132 hours | $30.00/h | $3960 |
| Total | | | $8902 |

*The small-scale removal is not a method for if it gets out of control—if that happens you'd really have to reassess the whole situation. But we've maintained it at a manageable level for over 10 years now.*

**National Salvinia Workshop, Grafton**

### *Successes*

The current integrated management strategy is maintaining a manageable level of salvinia in Ewen Maddock Dam at any given time and is supporting the dam's recreational and environmental values and uses.

The development of the scoop allows the management strategy to be based around continuous small-scale mechanical removal, with good integration of other forms of control.

The realisation that ongoing management is required has allowed resource inputs to be reduced over time, once considerable time and effort was dedicated to developmental approaches.

*For something like salvinia it has to be a permanent thing, like a tug of war. You have to apply permanent pressure to the weed, you can't just come in and do things now and then—luckily our management have accepted that.*

**National Salvinia Workshop, Grafton**

### *Failures*

The initial broadscale harvesting caused an unacceptable level of damage to the native aquatic vegetation, and also spread cabomba. Broadscale use of herbicides was considered unacceptable by the surrounding landholders and the general public.

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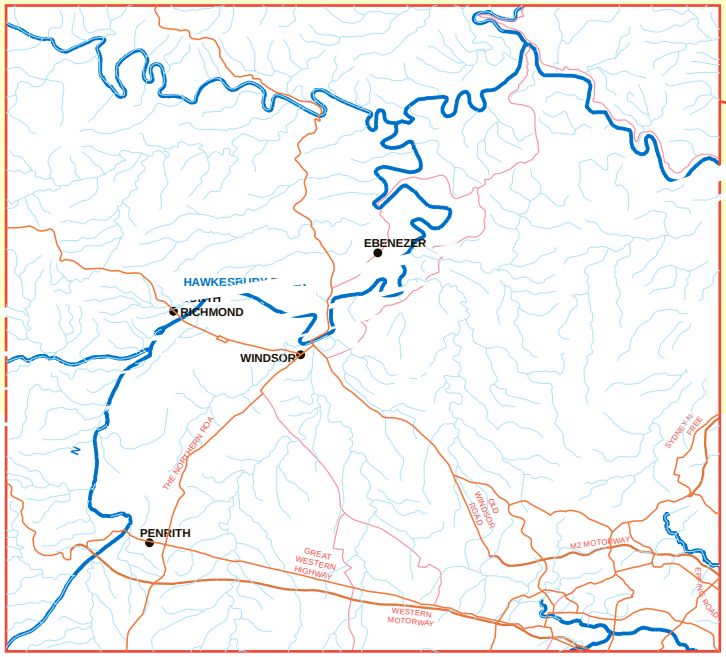


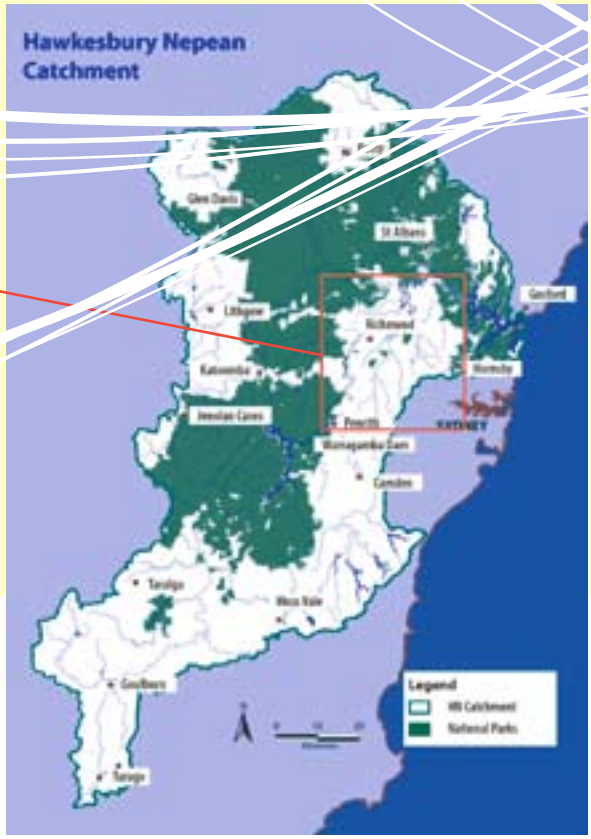


Cartoscope Pty Ltd

# Hawkesbury River: Managing salvinia on the Hawkesbury—a $1.8 million cooperative effort

*Contributing author: Rebecca Coventry*

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## Introduction

This case study highlights the extensive costs and effort associated with the successful mechanical removal of a salvinia infestation from a major coastal river.

### *The Hawkesbury River*

The Hawkesbury River drains the Hawkesbury Nepean catchment, an area of 22 000 km$^2$ with a population of approximately 1 million. The river is located north-west of Sydney, and the catchment provides most of Sydney's water supply from the Warragamba Dam. Agriculture in the catchment generates $1 billion annually, and the river is a popular recreation and fishing destination with a high public profile.

### *The salvinia problem*

Small amounts of salvinia had been present in the Hawkesbury Nepean River system for some time before an alarming increase in levels in late 2003. Over summer 2003, ongoing drought and high temperatures led to low flows and increased water temperatures in the river. Combined with high nutrient levels, this allowed large stretches of river to become covered with salvinia. The infestation was concentrated mostly between the townships of Penrith and Windsor, including North Richmond, Ebenezer and Yarramundi. By May 2004 approximately 347 ha of multilayered salvinia infested 88 km of the river and

*Over 88 km of the river was covered with salvinia.*

*Thick, multilayered mats covered large sections of the river*

Rebecca Coventry

its tributaries. This is now recognised as possibly the largest temperate infestation of salvinia to ever occur in Australia.

### *Current salvinia levels*

An ongoing salvinia monitoring program, including biocontrol, ensures that salvinia is now maintained at a manageable level in the river system and is not interfering with river usage or environmental values. The main channel is largely clear of salvinia, with only small amounts remaining caught against snags or rocks or among other vegetation. Some of the creeks and tributaries, backwaters and farm dams within the catchment still contain salvinia, and these are carefully monitored and treated. Managers are now facing other aquatic weed problems because of continued drought and high nutrient levels.

### *Management issues*

Complete coverage of parts of the water surface by thick mats of salvinia had extremely high impacts on the river's commercial, recreational and environmental values.

Contingency funding was not on hand, and emergency funding applications had to be made to the Federal Government by the Hawkesbury Nepean Catchment Management Authority.

Collaboration and coordination were required between the many levels of authority relating to the management of the river and the salvinia. The river was officially closed to boating from South Windsor to Sackville for 12 weeks in April 2004 to allow control efforts to proceed safely and unhindered.

## The management strategy

Management efforts began on 27 April 2004, with an expected duration of 6 months. The initial aims were to mechanically remove the salvinia biomass from the main navigable stretch of the infestation (from the Windsor bridge to the saltwater confluence at the junction of the Colo River) and to dispose of the harvested material on land. This task proved to be larger and more complex than originally anticipated, and after 4 months it was apparent that further funding would be required. A second injection of funding in August 2004 allowed more effort to be dedicated to the removal efforts, as well as providing

Rebecca Coventry

*The main channels are largely clear of salvinia.*

Rebecca Coventry

*Small amounts remain caught against snags.*

Rebecca Coventry

*An industrial boom was placed across the river to prevent downstream movement.*

for biocontrol releases and herbicide follow-up treatments.

The secondary aim was to develop a strategy for the ongoing management of the remaining salvinia in the system, in order to prevent any future recurrence.

### *Cooperative project management*

The control effort was overseen by a project officer from NSW DPI, through an executive committee made up of various state and local government authorities, catchment managers and community representatives. An Operations Committee was made up of officers from the Waterways Authority and Hawkesbury River County Council, and other involved parties such as officers from the EPA, Sydney Water and NSW Fisheries. The Operations Committee met weekly. An on-river management team was on call 24 hourly to ensure efficient weed removal through boom management, making use of flow, tides and winds, and to carry out support activities such as additional boom placement, movement and maintenance, and removal of debris.

Some of the issues encountered with the mechanical removal effort included organising RTA clearances for the movement of oversized machinery; finding weighbridges to weigh weed loads; obtaining council and private landowners' permission to stockpile weed; getting regulatory approvals from government departments (EPA for stockpiling; the Department of Planning and Natural Resources [DIPNR] for constructing ramps, DPI to transport noxious weeds, and the National Parks and Wildlife Service for access through national parks).

In July 2004, an expert panel of salvinia specialists was convened to assess progress and advise on the management of options and on future actions. They concluded that the harvesting effort was exemplary and needed to be followed up with herbicide applications, and that trial biocontrol releases needed to be made. A scientific trial program was then designed to establish and monitor the viability of salvinia weevils as an ongoing control option.

### *Mapping*

An aerial survey was carried out by helicopter in May 2004 to determine the exact extent and density of the infestation. Most of the salvinia was between Penrith and Sackville on the main stretch, and in numerous creeks, tributaries and farm dams.

### *Containment*

The logistics of containing an 88-km stretch of salvinia on a major river system were complicated. An appeal was made for more oil retention booms, and several kilometres of booms were provided on loan by the Waterways Authority and the Sydney Ports Authority.

The booms were used to delineate collection zones, allowing salvinia to accumulate in strategic areas where the harvesters could then remove it. The placement of the booms made use of the river flows, tides and wind, and the booms were opened and closed as needed 24 hours a day to maximise the accumulation of salvinia.

Booms are still used to contain salvinia to strategic areas where it can be mechanically removed, subjected to weevils, or treated with herbicide.

### *Broadscale mechanical removal*

A team of broadscale harvesting machines operated non-stop over an 8-month period between April and December 2004. Initially, two harvesters with 13 $m^3$ load capacities were used. These were supplemented for a 12-week period over June, July and August by a 26 $m^3$ load capacity harvester. Without the addition of the third harvester, it is doubtful whether the bulk of

*Two 13 m³ load capacity harvesters were operating on the river for an 8-month period.*

*The 26 m³ load capacity harvester allowed the operation to be successful.*

Rebecca Coventry

the infestation could have been removed before the next growth season.

An amphibious Truxor® craft was used to cut, push and collect weed from difficult-to-access areas and move it to areas where the larger harvesters could remove it.

A barge was adapted to collect weed, and it was able to move faster than the harvesters over longer distances. This was useful in the shallower creeks where small amounts of weed were spread out over some distance, and also in the final clean-up operations along the river.

Shore conveyor ramps were used in some places to move the weed from the harvesters to the shore, unloading either into dump trucks or compacting garbage trucks, or dumped in piles and moved by backhoe or bobcat. In other places the harvesters unloaded directly to the garbage trucks.

Each compacting garbage truck took about 11 t of compacted weight (equivalent to up to 10 harvester loads, or 19 $m^3$). Each truck or harvester team offloaded between three and five truckloads a day (averaging 133 $m^3$ per day).

The large harvester unloaded onto a shore conveyor into a giant dump truck, and the salvinia was then stockpiled on site. Over 12 weeks the harvester removed 72 500 $m^3$ of salvinia from an 8 km stretch of river.

In total, an estimated 140 000 t of salvinia was removed by the harvesters over a 14-month period.

Occasional harvesting of weed mats is carried out against the booms that are still in place in certain parts of the river.

### *Disposal of harvested weed*

The removal of these amounts of salvinia from the river created a significant disposal issue. Removed salvinia had to be stockpiled, and a number of associated problems arose, including the presence and growth of another notifiable noxious weed, alligator weed, (*Alternanthera philoxeroides*) in the stockpiles. The disposal sites therefore had to be set up to manage alligator weed outbreaks, including quarantining and bunding the stockpiles and ensuring appropriate hygiene practices were carried out (e.g. machinery washdown). Alligator weed outbreaks had to be treated with herbicides and monitored.

An agreement was reached with the Hawkesbury City Council to dispose of the salvinia to their waste management facility, and to temporarily stockpile the weed until composting could be organised.

Most of the stockpiles are now undergoing recycling for commercial compost production.

### *Herbicides*

Follow-up treatment with herbicides was necessary where salvinia remained lodged in areas that were inaccessible to the mechanical removal effort, or where salvinia was left along the edges of channels after the bulk had been removed by harvesters.

Community concern towards the use of diquat herbicides led to an application to the APVMA for a permit to use dual salt glyphosate herbicide.

Herbicide treatments commenced in September 2004 and continued for 11 weeks. Two teams treated 88 km of river (remnant salvinia) using 645 litres of the dual salt glyphosate herbicide Weedmaster Duo® applied under permit.

Follow-up spraying consisted of three teams spending 2 days per month treating any remaining salvinia with herbicide. A total of 203 L of glyphosate herbicides

Rebecca Coventry

*Stockpiles of harvested salvinia.*

Andrew Docking

*One of the stockpiles of composting salvinia covering approximately 1 ha.*

was used for initial follow-up over a 4-month period between December 2004 and March 2005.

Ongoing follow-up spot spraying of regrowth salvinia was then done, particularly after rain. Less than 30 L of glyphosate was used for follow-up spot spraying over the 6 months after March 2004.

### *Biocontrol*

There was a commonly held perception that the salvinia weevils (*Cyrtobagous salviniae*) would not be successful in a temperate climate. It was not known how well weevils would survive over winter, or if they did, how long they would take to build up viable populations to a level where they could successfully control salvinia over the warmer months.

However, the obvious need to have an ongoing management strategy supported trial releases of weevils, and a decision was made that biocontrol releases should be attempted and monitored. Two sites within the Hawkesbury catchment were known to have had effective weevil populations established, and this supported the possibility of broader effective use of biocontrol.

Weevils were released on a monthly basis from August to December 2004. Massive releases were made in strategic locations (over the whole extent of the infestation, and in different environments (four sites on the main channel of the river, four on creeks and billabongs, and four on farm dams). The total number of weevils released is thought to be approximately 124 000. A number of the mass release sites were protected with booms to provide nursery areas.

An extensive research project was designed to further understand the success of the biocontrol agent in cooler climates. A project officer was appointed to carry out biocontrol monitoring on a weekly basis. The twelve weevil release sites were intensively monitored. Quadrats (2 × 2 m) were anchored in the release sites, and data loggers were attached to collect water temperatures and air temperatures.

Initial findings are that the weevils are surviving, with over 90% of the salvinia in the quadrats showing some degree of damage, and the weevils have moved beyond the release sites. However, final determination of the future reliability of weevils in the Hawkesbury system will require populations to be monitored for at least three, and possibly five, consecutive winters.

Weevil activity is still occurring and is very encouraging.

### *Seasons and timing*

It was essential to remove as much of the weed biomass as possible over the cooler months before the following summer growth season. Harvesting continued into summer, but by this time enough weed had been removed to allow progress to exceed weed growth.

### *Monitoring*

The follow-up treatment program called for weekly reporting on the state of the river and its tributaries for the period from December 2004 to May 2005. This was done by mapping and photographing any weed presence.

All remaining presences of salvinia are carefully monitored. The biocontrol trials also provide an opportunity for ongoing monitoring.

### *Ongoing management*

There may be a need to release large numbers of weevils every year in early spring to assist the winter-surviving populations to reach a point where they can exert control over each season's salvinia growth.

Ongoing surveillance of the river system and the catchment should continue on a regular basis to

prevent such an extensive outbreak from occurring again. The off-river source infestations have been located and are under inspection and treatment regimes in cooperation with the relevant local government authorities.

The works program was finalised in June 2005, with the realisation that salvinia management will need to be ongoing on the river system until significant and long-term changes in flow and nutrient levels are achieved, reducing the risks of repeated outbreaks. Efforts to reduce nutrient loads in the system have been recommended.

## Costs and resources

The mechanical removal effort cost around $8000 per day, including machines and ancillary plant, staff input and all incidentals such as fuel.

The NSW Government contributed a total of $954,000, with additional in-kind costs of over $200,000. The Australian Government contributed $650,000 through the Natural Heritage Trust (NHT).

## Key points

The extensive effort to remove the bulk of the infestation relatively quickly was justified. The only other way of removing the bulk of the infestation would have been to use broadscale herbicide treatments, which were not publicly acceptable in this situation and would also have created a secondary problem of decomposing weed biomass in an already nutrient-overloaded waterway.

The realisation of the extreme effort and cost of managing such an extensive infestation has ensured that ongoing salvinia management is now part of the River Health Strategy for the Hawkesbury Nepean catchment.

### *Successes*

The effective use of booms increased the efficiency of the harvesting effort to the point that the salvinia biomass could be removed before the following growth season.

Early results are indicating that, with careful release strategies and monitoring, the salvinia weevils can provide effective biocontrol in temperate areas. This has also allowed reduced dependence on herbicides and harvesting for ongoing control.

### *Failures*

Daily problems and logistical issues were encountered throughout the project, and many unforseen circumstances needed to be dealt with. Initially there was no clear delineation of responsibilities between the parties and organisations involved, hindering any quick responses to the salvinia problem. There is now a clear salvinia management plan in place for the Hawkesbury Nepean catchment.

## Contacts

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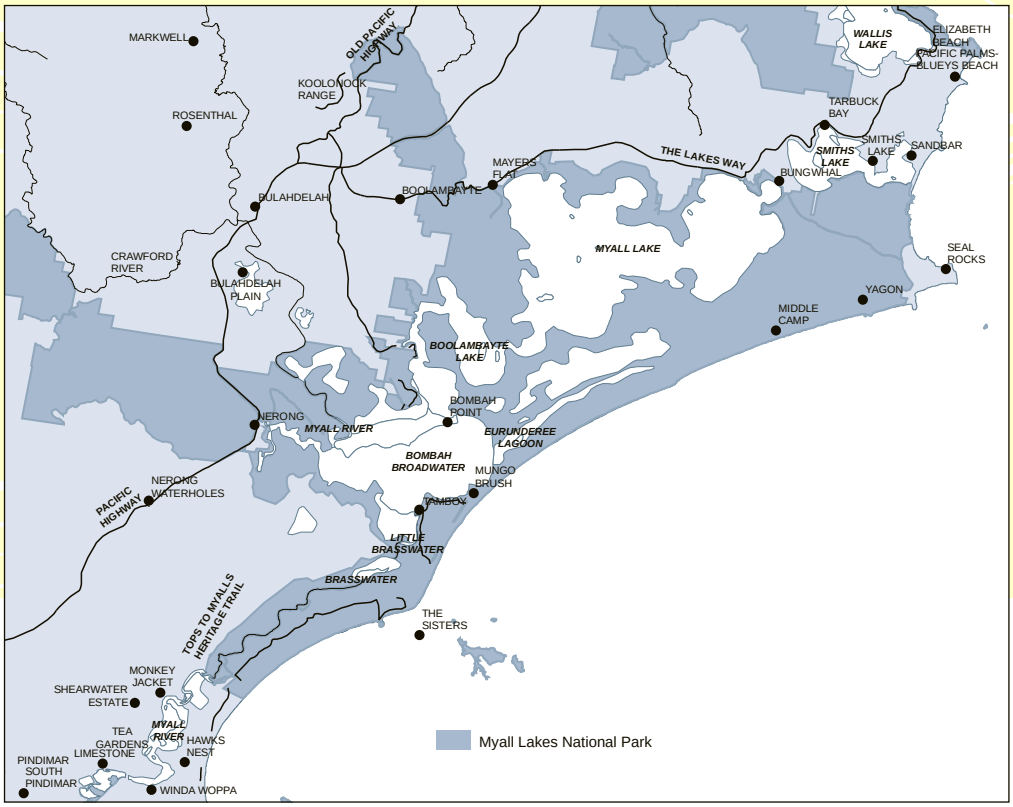


# Myall Lakes National Park: Successful eradication of salvinia through extensive manual removal

## Contents


- Introduction
- The management strategies
- Costs and resources
- Key points
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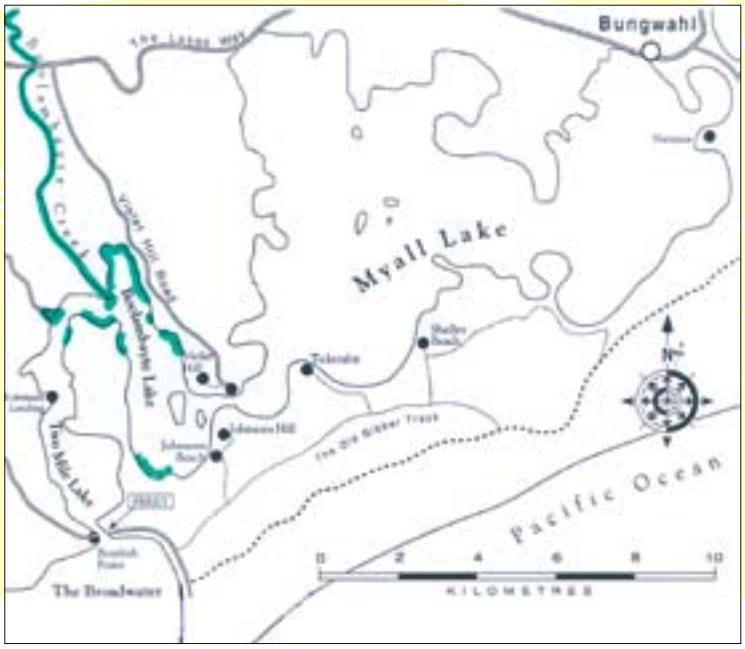
## Introduction

### *Myall Lakes National Park*

Myall Lakes National Park is in the warm temperate region of the Mid North Coast of NSW, approximately 100 km north of Newcastle. The park covers an area of 44 000 hectares and contains the largest natural coastal lake system in NSW. The 10 000 ha system of interconnected lakes, creeks and rivers is known as the Myall Lakes system and contains three main lakes: Boolambayte Lake, Myall Lake and the Bombah Broadwater. The lakes are fed by Nerong Creek, Two Mile Lake, the Myall River and Boolambayte Creek (see map below).

The Myall Lakes National Park has very high conservation value, containing unusual freshwater ecosystems and Ramsar-protected wetlands, and providing habitat for 352 species of birds and animals (including 29 threatened species). The lakes system is an important breeding area for fish stocks and adds significant value to the NSW commercial fishing industry; the park provides for recreational activities such as camping, swimming, boating, fishing, canoeing and sailing.

The system drains an extensive catchment with only a narrow exit channel, and water levels rise significantly with rainfall runoff. The lakes contain both fresh and brackish water, and salinity fluctuates with runoff and the limited tidal inflows into the system. The Bombah Broadwater has the highest levels of salinity, whereas the Myall Lake itself remains mostly fresh.




Adapted from Clark & Gatenby 1998

*Map of the Myall Lakes system showing the areas of salvinia infestation in green.*

### *The salvinia problem*

Salvinia was deliberately introduced as an ornamental plant to a dam in the upper catchment in 1995, and was then washed into the upper Boolambayte Creek during floods. A few small infestations developed into a 2 km length of infested creekline 4.5 km upstream from the national park.

Efforts were made to control this infestation. A floating boom (supplied by the Waterways Authority) was positioned at the lowest point of the infestation, and Great Lakes Council treated the weed with two applications of diquat herbicide. The diquat herbicide killed the bulk of the infestation but also killed native vegetation on and near the banks. Semi-exposed mud surfaces with large amounts of rotting vegetation made access for follow-up spraying too difficult, and consequently follow-up treatments were not carried out. Salvinia biocontrol weevils (*Cyrtobagous salviniae*) were released in summer but failed to establish, possibly because of shading by the overstorey vegetation.

The infestation was thought to be contained, but after heavy rainfall in May 1998 salvinia plants that had survived the diquat treatments escaped the boom and were washed into the lower reaches of the creek and into the national park. The ensuing mild winter and very low salinity levels during spring allowed the entire length of Boolambayte Creek to become infested with tertiary stage salvinia.

By 1999 a tertiary infestation was present in the park, along a 5 km length of lower Boolambayte Creek that reached 1 km from the mouth of the creek into Boolambayte Lake. The Waterways Authority installed a Marine Notice on the creek, closing it to all vessel movements.

Isolated plants were recorded in nearby sections of the lake system (Korsmans Landing and Violet Hill). Scattered infestations were also occurring in the surrounding wetlands and foreshores, to the point that 20 km of creek and lake foreshore had become infested (see map below). All three stages of growth were occurring within the park, and the salvinia was growing in open creek channels, amongst flooded swamp forest, and in the sedges lining the edges of the foreshores.

### *Current salvinia levels*

By 2000 (3 years after the control efforts began), only scattered primary form plants were occurring in the national park. Two years later only a few single plants were being found. By 2002 no salvinia had occurred in Boolambayte Creek or Lake; however, a 'bucketful' of salvinia had been removed from a dam on an adjoining private property and salvinia had been reported on other dams in the catchment. Follow-up control and monitoring continued, and to date there has been no reoccurrence of salvinia in Myall Lakes National Park.

### *Management issues*

The presence of salvinia in Myall Lakes was considered to be potentially the greatest ecological threat to the park's protected aquatic ecosystems. Extensive infestations could occur if a rise in water levels and prevailing winds were to carry the salvinia into Myall Lake, where salinity is low. The open waters of the main lakes received enough wind and wave action to prevent large mats from forming, but the fringing wetlands, foreshores and embayments were all under threat of being infested with tertiary stage salvinia.

It was difficult to predict how salinity levels in the system were affecting the distribution of the salvinia, as the salvinia was growing in brackish water with salinity levels higher than what was considered toxic in the scientific literature. Then, in 1998, a large inflow of freshwater runoff diluted salinity levels and provided ideal growth conditions for salvinia over much of the system. Historically both Boolambayte Lake and Myall

*Fine mesh containment fence on the downstream side of the boom.*

Mel Schroder

Lake provided ideal conditions for salvinia (salinity levels between 1.3 and 2.0 parts per thousand), whereas the salinity of the Bombah Broadwater fluctuated to levels possibly high enough to kill salvinia (between 1.0 and 10.0 ppt).

Before 1998, cooperation between adjoining landholders and management agencies had been difficult and had prevented proper follow-up from taking place. Once the infestation had entered the national park a Coordinated Control Strategy was developed, steered by the NPWS.

## The management strategies

Control efforts were initiated in 1997 and a Salvinia Eradication Strategy and Works Program drafted by the NPWS. A Coordinated Control Strategy was developed in 1998 and implemented in 1999, and a 5-year Management Strategy was developed later in 1999.

### *Aims and objectives*

The short-term aim was to control salvinia in the Boolambayte Creek and Boolambayte Lake and prevent spread to the Myall Lake.

The long-term aim was to completely eradicate salvinia from Myall Lakes National Park. Eradication was considered feasible through a combination of containment fencing, manual removal and herbicides, with extensive follow-up and monitoring over at least 3 years.

### *Prioritisation*

The infestation was prioritised into management areas to ensure resources were allocated where the biggest threat of establishment of tertiary stage salvinia or further spread was occurring.

The highest-priority area was the tertiary infestation. This was to be contained and removed, with follow-up and monitoring on a weekly basis.

High-priority areas included wetlands and bays protected from wind and wave action and receiving freshwater runoff. The four known edge infestations in Boolambayte Lake were to be removed, with follow-up on a fortnightly basis.

Medium priority was given to areas where salvinia had been removed, but where wind and wave action was high and freshwater inflow was low. These areas were to be spot-checked monthly for at least 1 year.

Low priority was given to any sheltered bays and wetlands within Myall Lake, and to the remainder of the system. These were checked four times a year, and the priority level would be changed if salvinia were found. No salvinia was found in any of the low priority areas.

### *Surveying and controlling the source of the infestation*

The areas outside the park were surveyed to establish the distribution of salvinia in the upper catchment, starting with the areas adjoining the property known to be the source of the infestation. Contractors undertook the survey work and treated any salvinia found, using manual removal and herbicides.

### *Containment*

Containment of the existing infestation was a primary objective for the control and management of the infestation.

A series of four mesh containment fences were constructed on Boolambayte Creek with the aim of completely preventing downstream movement of salvinia. The fences consisted of one trash fence (10 × 10 cm mesh) installed above three finer mesh fences (10 × 10 mm mesh). The trash fence trapped larger debris and prevented damage to the finer fences.

*Park staff undertaking manual removal with scoops and garbage bags.*

Mel Schroder

The three fine fibreglass mesh fences were placed in a herringbone arrangement at strategic bends in the channel, anchored on the creek bank and reaching three-quarters of the way across at right angles to the flow. This allowed access for maintenance to the fences and prevented total loss of the fences in high flows. The fences required regular cleaning and maintenance and were monitored for trapped salvinia, either 1 day a month or as required, depending on the conditions.

The containment fences effectively prevented any further downstream movement of salvinia into the lakes system.

### *Manual removal*

Manual removal was chosen as the lead approach for the control effort. Although it was labour intensive, its low environmental impact made it suitable for use in a sensitive system.

The initial phase involved 20 personnel (park staff and Conservation Volunteers Australia) for a 2-week period working in a 2 km section of dense salvinia in Boolambayte Creek. Staff and volunteers wore waders in shallower sections (between 10 cm and 50 cm water depth) and paddled canoes in deeper sections. They used pool scoops to retrieve the salvinia from amongst the reeds and other vegetation, and the salvinia was collected in 20-litre garbage bins and heavy-duty plastic garbage bags, composted, and then buried under landfill.

Two park staff and two contractors worked on the infestations in Boolambayte Lake for over 80 days.

The follow-up that was carried out over the next 2 years was undertaken by contractors (two people over 20 days) and park staff (two people over 10 days).

In total, approximately 15 km of salvinia along the shoreline in widths of between 10 m and 200 m was removed manually. More than half a tonne of salvinia was removed by hand during spring in 1998. A staff timetable was used to allocate human resources over the control effort.

Manual removal was also seen as an opportunity to provide accurate survey information about the rate of spread and the area of infestation. Anyone performing manual removal provided records of the location and extent of the salvinia, and efforts were made to map the known infestations on a 1:25 000 scale topographic map.

### *Herbicides*

AF100®* was chosen as the most appropriate and effective herbicide for small-scale use. Diquat herbicide had been used outside the park but had caused difficulties for follow-up. The non-selective nature of diquat herbicide was also considered inappropriate for use within the national park.

In January 1999 the NSW Environment Protection Authority issued a licence to NSW NPWS to use AF100 herbicide on salvinia in the national park. AF100 had been reviewed for use in Kakadu National Park by the Australian Nature Conservation Agency and had been found to be appropriate for use in environmentally sensitive areas owing to its low persistence in the soil and water, low hazard to users, and low hazard to mammals, fish and other plants from residues in the water. AF100 has no spray drift, is not water soluble, and is applied in low volumes.

Some degree of damage was expected to occur to native free-floating aquatic ferns, such as *Azolla* species, but the threat of salvinia to their habitat justified any damage to native floating ferns at the time of application. A small amount of physical damage to a native sedge (*Baumea* sp.) was noted in one area but was not considered to be long-term or irreversible, and it was minimised through careful application.

* AF100® is now available as Agricrop Immerse® Floating Herbicide.

Mel Schroder

*Applying AF100 herbicide to salvinia among sedges with a knapsack sprayer.*

A number of 'eight-point tests' were carried out to determine whether the use of AF100 would be detrimental to the threatened frog species in the park (the Wallum Froglet and the Green and Golden Bell Frog), with the outcome that the use of AF100 would not have a significant impact on either species.

AF100 was effective on primary-form salvinia floating amongst reeds and sedges and in open water, and all follow-up control involved a combination of spot spraying with AF100 and manual removal.

AF100 was applied with hose and hand-gun by boat (two aluminium boats with 100-litre spray units), and by knapsack sprinkler sprayers on foot.

### *Biocontrol*

The likelihood of achieving biological control of the salvinia was considered to be improbable in the short term, and unsuccessful attempts to release and establish the weevils had been made further up the catchment. This lack of success was thought to have been due to the presence of the overstorey vegetation that occurred in most areas where the salvinia was present.

### *Seasons and timing*

The works program was conducted immediately after salvinia had been washed into the park in April–May, in order to maximise control efforts and remove as much salvinia as possible while it was in slow growth over the cooler months. Follow-up and monitoring then occurred over the following spring and summer.

The 5-year management strategy was reviewed in May each year to take advantage of the slow growth period over winter should major interventions be required.

### *Monitoring*

Intensive monitoring was critical to the objective of eradication, as literally every plant had to be removed or treated as it was found. Staff were advised that monitoring should take place for at least 3 years after the initial eradication effort to be confident that the infestation had been eradicated.

In all infested areas, monitoring took place weekly, for up to 6 months, after the bulk of the salvinia had been removed. Monthly monitoring was then carried out for the rest of the 3-year period, with particular diligence during the peak salvinia growth periods. All other areas were monitored four times a year. This level of monitoring continued until 2005 to ensure that all salvinia plants had been removed from the system. Contractors were employed to help park staff with the extensive monitoring regime.

Monitoring efforts are now directed to high-risk areas (protected embayments and wetlands with low salinity levels) and times when large amounts of fresh water flow into the system after heavy rainfall. Other parts of the system are checked at least once a year.

### *Public awareness*

A Community Involvement Strategy was prepared by NPWS in 1999 and helped with the control effort. Community involvement also made the closure of waterways to users more acceptable. The strategy involved:

- the distribution of information sheets and 6-monthly newsletters to all target user groups, including professional fishermen, recreational fishing groups, the yacht club, council, NSW Waterways, houseboat hire companies, neighbours, cruise operators and park visitors. A 'Wanted Dead or Alive' information sheet asked visitors to record sightings of salvinia on a map provided on the back of the sheet and report them to park staff.

| COSTS OF SALVINIA CONTROL PROGRAM IN 2000 | |
|---|---|
| **Item** | **Cost** |
| Staff and human resources | $40,613 |
| Plant and equipment | $1,200 |
| Vehicles | $374 |
| Materials (herbicides, mesh, waders, scoops) | $1,030 |
| Overheads/administration | $4,583 |
| Contractors | $23,500 |
| **Total project costs** | **$71,300** |

- A community field day was held to increase awareness and encourage involvement in the control program (the manual removal component and the monitoring). Other agencies were also involved (Fisheries, Waterways, NSW Agriculture).
- Notices were placed throughout the park in information bays.
- Local media campaigns were used to promote community awareness and encourage reporting of salvinia infestations.

NHT funding helps to provide continued community education and awareness.

## Costs and resources

The control program cost over $100,000 over the 4-year period before 2002. This was considered inexpensive in comparison with a fully established infestation throughout the system. As an example, the costs incurred in 2000 were as shown in the table above.

## Key points

The integrated management strategy that aimed to eradicate salvinia from the park is considered to have been successful. No salvinia has been found to date. Monitoring is still an important part of the day-to-day management of the lakes system within the park and in the upper catchment.

### *Successes*

The extensive manual-removal efforts and the use of the selective herbicide AF100 provided effective control. It was understood that a single plant would have the ability to reinfest the entire system and that intensive, long-term follow-up and monitoring efforts were imperative to the eradication effort.

The coordinated efforts to control the salvinia before it spread throughout the system or reached the tertiary mat-forming stage were critical. The work involved in manual removal was justified: tertiary infestations amongst protected vegetation (i.e. paperbark swamp) would be impossible to eradicate given the biomass involved, the sensitivity of the system to certain control methods, and the inability of the biocontrol weevil to control salvinia growing in shaded conditions.

### *Failures*

The initial assumption that two diquat treatments and a floating boom would prevent the infestation from reaching the national park was proved incorrect. A lack of follow-up after the diquat treatments and flood rainfall allowed regrowth salvinia to escape the boom and move downstream into the national park.

## Contacts

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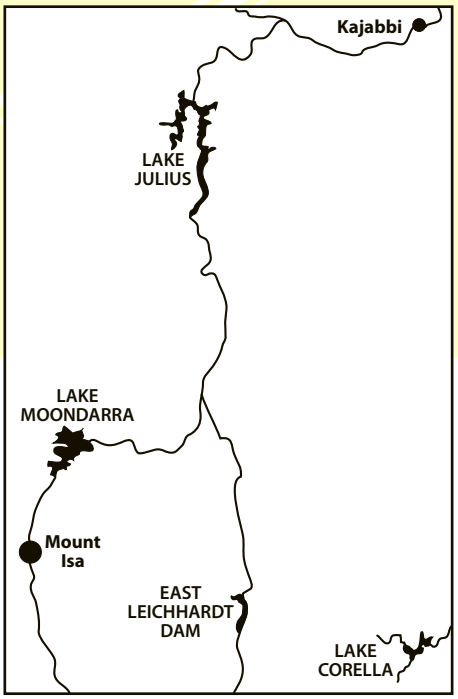
# Lake Moondarra: Biological control of salvinia over three decades

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## Introduction

This case study highlights the successful, ongoing use of the salvinia biocontrol weevil *Cyrtobagous salviniae* on Lake Moondarra in Western Queensland. This use of the salvinia weevil was the first successful attempt at biological control of salvinia in Australia.

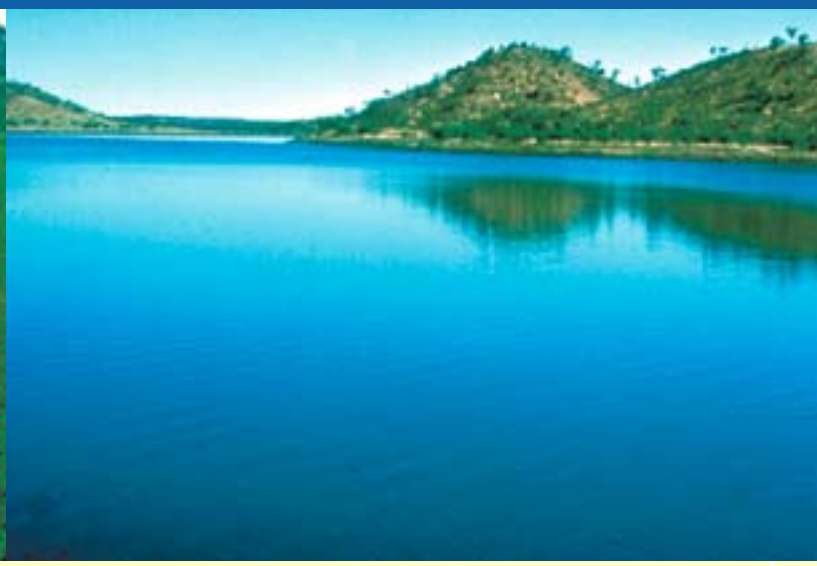
### *Lake Moondarra*

Lake Moondarra is 20 km north of Mount Isa in the dry tropics of Western Queensland. The lake was constructed in 1957 by Mount Isa Mines on the western branch of the Leichhardt River, as both as an industrial water supply for the mines, and a domestic water supply storage.

The dam has a storage capacity of 106 000 ML, and a surface area of 2375 ha at capacity, with an average depth is of 6 metres.

The lake is used for recreational pursuits, including freshwater fishing, and is also the main water supply for the city of Mount Isa.

*The salvinia infestation on Lake Moondarra in 1978.*



*Lake Moondarra in 1981, after successful biological control.*

NRM&E Photo Library

### *The salvinia problem*

In 1978, the most extensive salvinia infestation in Australia occurred on Lake Moondarra, covering some 400 hectares with an estimated at 50 000 tonnes of fresh weight of weed. Attempts had been made to control this infestation with aerial (helicopter) applications of herbicide, but these were abandoned in 1979 after costs reached $160 000, and the salvinia was growing faster than the herbicide could kill it.

### *Current salvinia levels*

Salvinia remains on the lake at very low levels, with only scattered plants around the edges and in some of the creeks and inlets. The open water is salvinia free, and complete coverage of the open water has not occurred since the biocontrol was introduced.

## The management strategy

The management of salvinia on Lake Moondarra took the form of the first successful trial releases of the salvinia weevil in Australia. Since then, salvinia management still centres around biocontrol, with re-releases of weevils made whenever salvinia levels appear to be increasing.

### *Aims and objectives*

The aims of the biocontrol releases on the lake were to attempt to bring the infestation to an acceptable level; and to consider the potential for using the salvinia weevil to control salvinia elsewhere in Australia. The biocontrol releases were part of a closely monitored research program.

### *Biocontrol*

In June 1980, approximately 1500 adult weevils were released into a salvinia-covered inlet on the lake. Two lots of 500 weevils were released into caged quadrats, and the remaining 500 were released near the cages.

By late December 1980, weevils had reduced the volume of salvinia in the cages by about 80%, and were causing visual damage to plants outside the cages. Fresh salvinia was added to the cages and the doors were left open. Weevils then began to move away from the heavily damaged salvinia, seeking out new undamaged plants further up the inlet.

In late January 1981 another 1500 adult weevils were released about 300 m from the inlet, and 10 large bags of weevil- infested salvinia were taken from the original release site to the opposite side of the lake.

In February, a storm swept the remaining weevil-infested salvinia out of the inlet into the main body of the lake.

By late March, the salvinia across the lake had started to turn brown and become waterlogged. By mid-April, the entire infestation was dark brown, and sampling showed that there were between 60 and 80 adult weevils per square metre, suggesting that the population had grown to over 100 million adult weevils. By this stage, 90% of buds showed damage.

By the end of May there was very little salvinia left on the lake, and samples were showing that the weevil population had decreased to about 6 million adults, with a 99% bud damage level. By August 1981, there was less than 1 tonne of salvinia remaining on the lake.

### *Time frame and expectations*

The biocontrol process occurred in two phases over an 11-month period. The weevils were initially released in June and built up in numbers and distribution over an 8-month period, taking advantage of the mild winter conditions associated with the dry tropical climate.

Once the weevils had become well distributed in high enough numbers, control occurred very quickly over a 3-month period, in which the salvinia browned off, died and sank.

From that point onwards, it was expected that the salvinia and the weevils would be able to coexist on the lake in a dynamic equilibrium at low population densities, unless either the remaining weevils or the salvinia was destroyed due to stranding if water levels receded dramatically.

### *Ongoing management*

The small amounts of remaining salvinia are monitored for any increases. Re-releases of weevils are made if the salvinia levels appear to be increasing, particularly after a good wet season (i.e. growing out from the edges of channels or starting to form small mats in the creeks and inlets). New weevil releases have been made only twice in the past 10 years.

## Key points

Biocontrol has been used successfully over a 30-year period, to keep salvinia at low levels. Weevils are actively managed in accordance with fluctuations in the salvinia levels, and the lake is monitored on an ongoing basis.

It is important to note the time taken for the weevil populations to build up and disperse to the point they were able to provide control (8 months). Climatic conditions also remained ideal over the establishment period.

### *Successes*

The releases of large numbers of weevils into protected areas of the lake allowed the release populations to become established within 6 months. Secondary releases were made 6 months later to assist with population growth.

Weevil distribution across the 400 hectare infestation was assisted manually and by wind action from a storm. However experience elsewhere has shown that weevils are able to disperse quite rapidly once localised populations increase. Once the weevils had become well distributed across the entire infestation (8 months after initial releases were made), control occurred relatively quickly and spectacularly (3 months).

### *Failures*

Initial efforts to control the infestation with herbicides were abandoned due to the high costs, and the ability of the salvinia to outgrow the effects of the herbicides.

## Contacts

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