SALVINIA

A Comprehensive Guide To:

I.D., Treatment and Prevention

Authored by Brittany Pondeljak

Aquatic Technologies, 2021

AQUATIC TECHNOLOGIES

The Water Treatment Experts!

TABLE OF CONTENTS

INTRODUCTION

Salvinia is a free floating aquatic fern.

Salvinia (salvinia molesta) is found in all Australian mainland states but is more common in NSW and QLD.

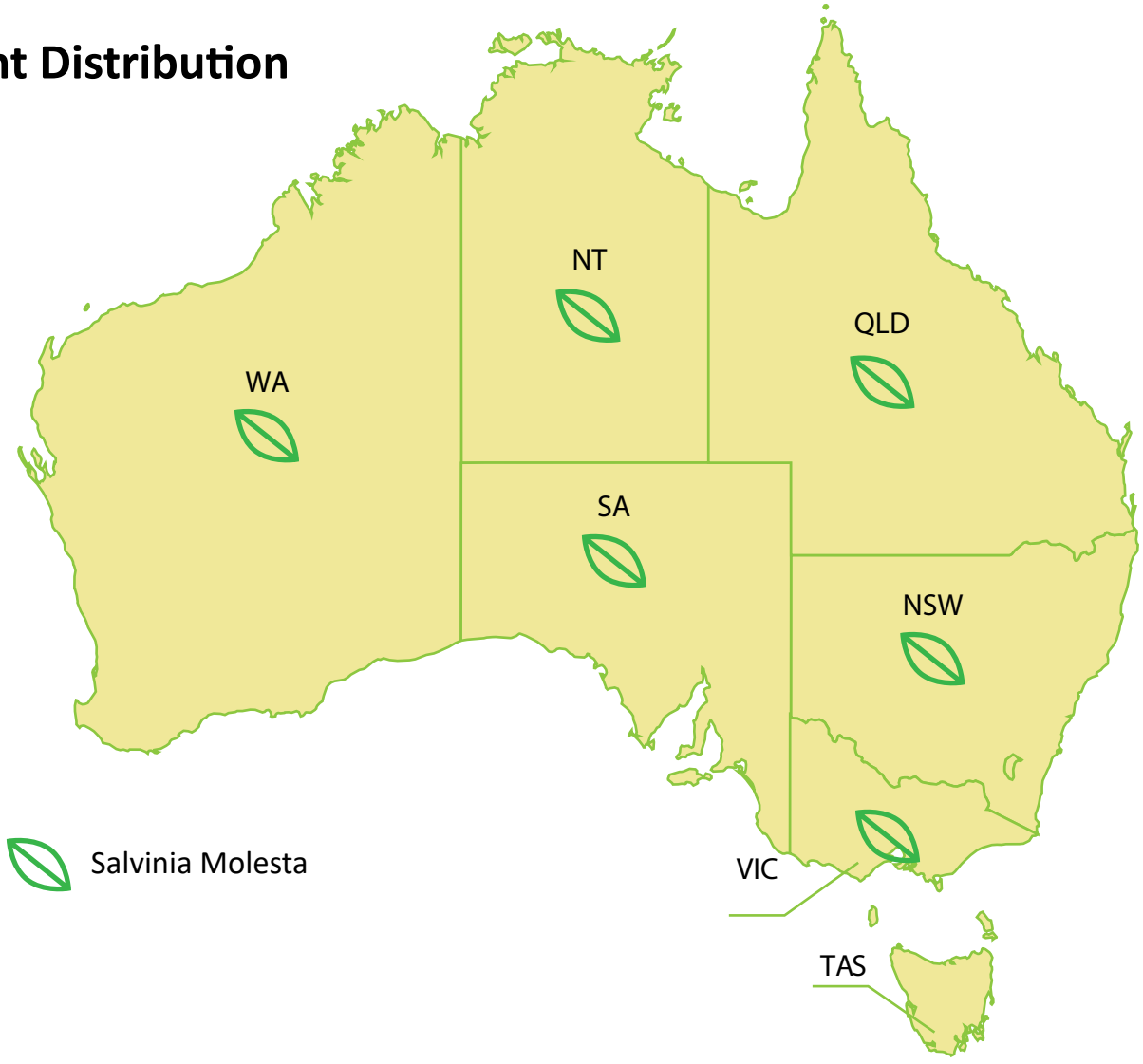
It is an introduced species that is extremely invasive. It can form dense mats that cover the entire water surface in freshwater systems.

ABOUT THIS GUIDE

The information presented here provides a detailed guide on how to identify, manage and treat Salvinia in varying freshwater situations.

It is designed to enable the user to make an informed decision on what management approach is best suited to their unique situation.

Current Distribution



HOW TO IDENTIFY SALVINIA

Scientific name:	*Salvinia Molesta*
Common name:	Salvinia, Giant Salvinia
Description:	Salvinia is a free floating fern that is made up of pairs of oval, green to brown leaves connected by a horizontal stem. When infolded their appearance has been compared to the wings of a butterfly. Thin, white, whisk-shaped hairs on the upper surface of the floating leaves are a notable feature of the plant. Under the water, each plant produces other leaves that look like a small bunch of brown roots. Spore structures develop in long chains among filaments of the submerged leaves but are functionally sterile.
Habitat:	Stationary and slow-moving water bodies, especially where nutrients are high including ornamental ponds, fish ponds, dams and irrigation dams. Mainly a weed of tropical, sub-tropical and warmer temperate regions, though it will grow in water bodies in semi-arid areas.
Distribution:	NSW, NT, QLD, SA, VIC, WA
Reproduction:	Salvinia reproduces vegetatively, its floating branches readily break apart and form new plants.
Dispersal:	These plants are mainly spread by water and wind. They are spread to new areas by the disposal of garden waste as well as by animals and vehicles. [1][3-5][11]

WHY TOO MUCH SALVINIA IS BAD

Salvinia is a free floating aquatic fern that is an introduced species in Australia [1]. It originates from South America and prefers tropical, sub-tropical and warmer temperate regions [3]. Salvinia is declared a noxious (harmful) weed by every state in Australia [1], and can be more resistant to treatment compared to other problem aquatic plants [2].

To add to this, the growth of salvinia can be prolific. Under optimal conditions, an infestation of the plant can double in size in less than 3 days [7][8]. Salvinia's growth depends on temperature and nutrient levels. It experiences the fastest growth in temperatures between 20 °C and 30 °C [8]. The levels of the nutrient nitrogen in a water body determine how many buds a plant will produce [8].

Dense mats of salvinia can blanket the entire surface of a water body, mats as thick as 1 m have been reported [7][9]. This can give rise to physical and chemical changes in the water beneath which can dramatically impact the water's quality [2][7][8].

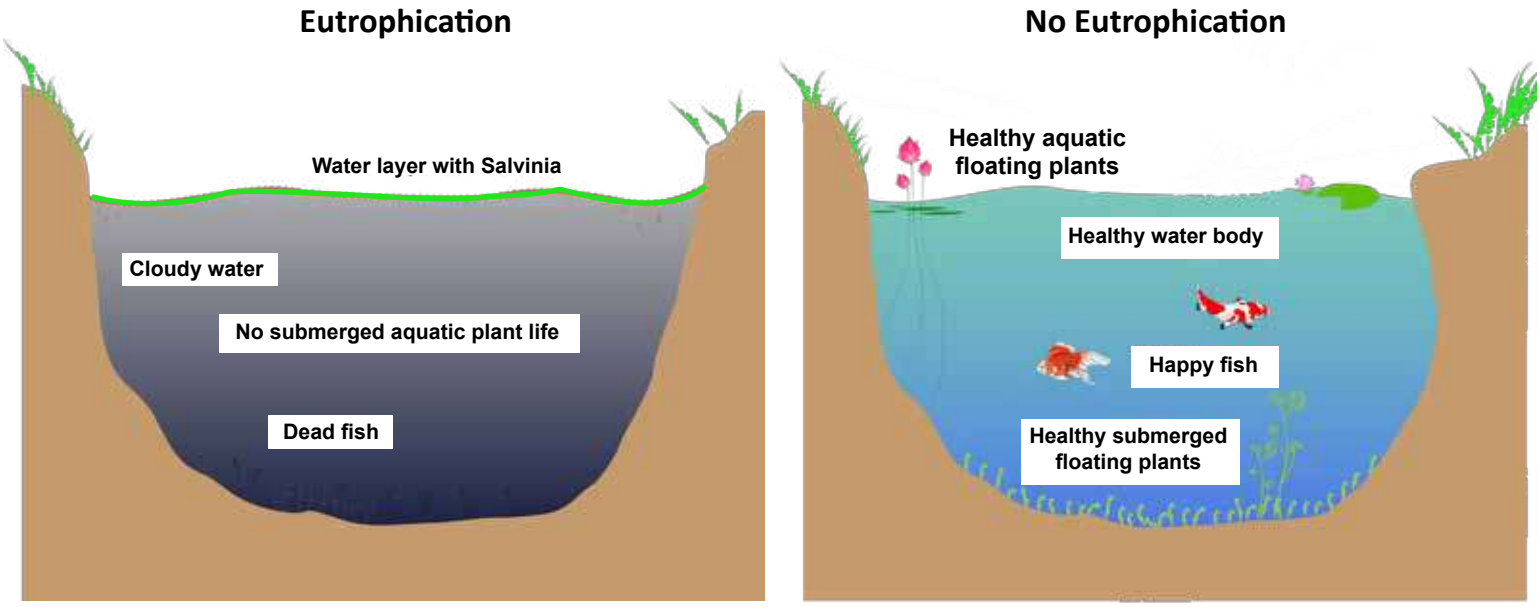
The dense growths of salvinia act as a physical barrier on the water's surface. It can interfere with light penetration into the water column. With less light, its shades out plants and reduces the ability of vegetation in the lower levels of the water body to photosynthesise [2][8][11] If respiration begins to overtake photosynthesis, it will lead to an increase in dissolved carbon dioxide and a reduction of the pH of the water [7].

The presence of salvinia also impacts gas exchange between the water and the air. The mats formed prevent oxygen diffusion into the water, thereby dramatically decreasing the level of dissolved oxygen in the water [7][8][11].

Low levels of light and oxygen in the water impact the communities of plants and animals living in the water below, deteriorating biodiversity and habitat of the aquatic ecosystem [6].

The process of salvinia decomposing also reduces the amount of dissolved oxygen in the water. This creates a hostile environment that does not have enough oxygen to support most life, especially fish [7][10][11].

HOW SALVINIA CAN GROW OUT OF CONTROL



FUN FACT: SALVINIA GROWS FAST!

Salvinia reproduces asexually and is an extremely fast growing plant. They are able to double their mass within 2-3 days.

SALVINIA HAS MANY USES!

Salvinia has traditionally been used as an eco-friendly treatment of Blackwater effluent in sewage treatment plants. In dry areas Salvinia is used as a mulch for crop near waterbodies and has also been successfully used to produce biogas.


Salvinia Molesta

What is phosphorus?

Salvinia can become a dominant feature of a water body when there is an abundance of the nutrient Phosphorus [26].

Phosphorus is an essential plant nutrient needed for DNA, RNA and energy transfer [27] and most often controls aquatic plant and algae growth in freshwater [28].

Phosphorus is found in:

- fertilizers
- human and animal wastes
- decaying organic matter
- naturally in rocks and other mineral deposits

There are few natural sources of phosphorus and it is often a limiting nutrient in aquatic systems [28].

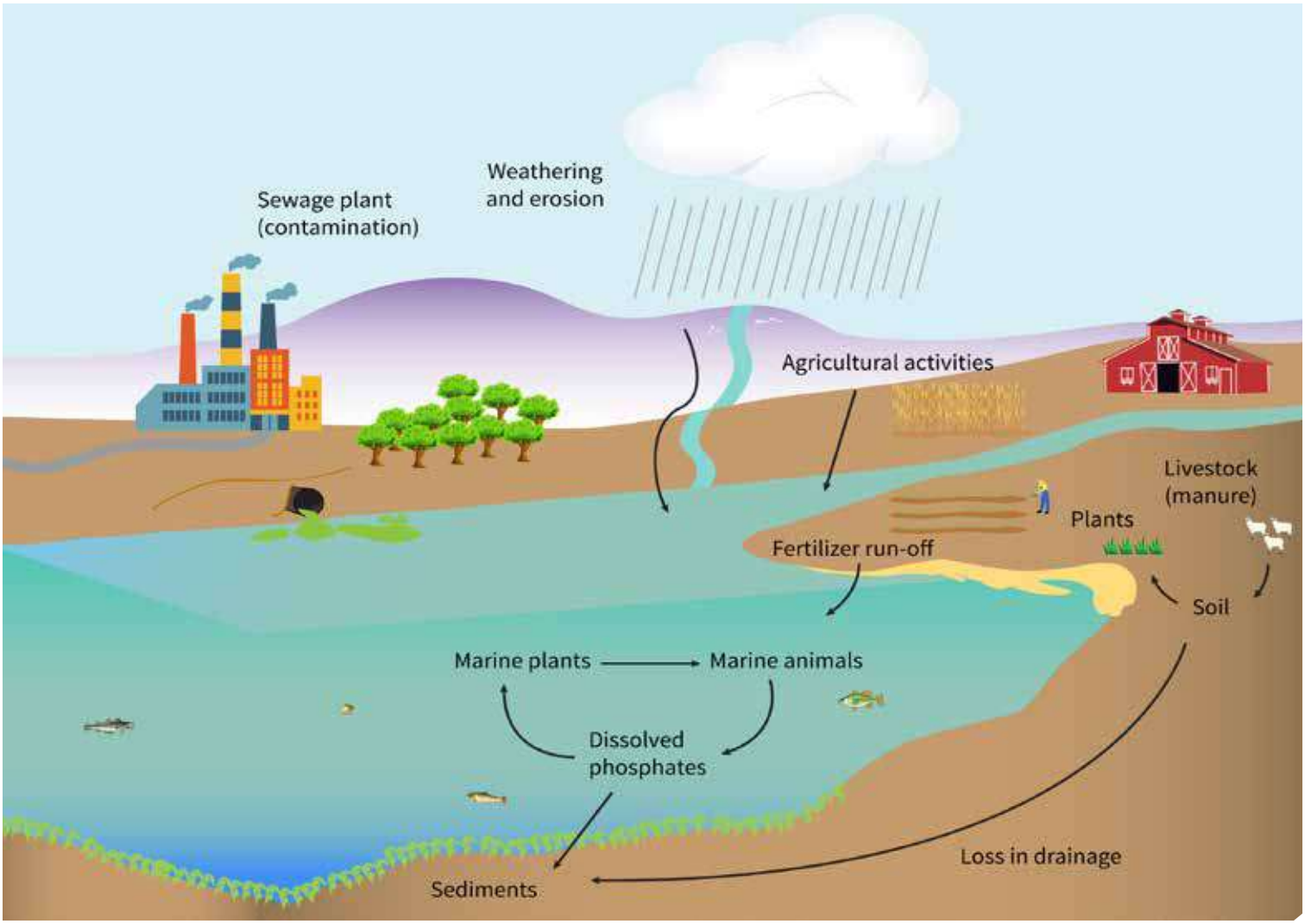
How does phosphorus get into the water?

- Fertilizers
- Run-off (after a storm or heavy rain)
- Erosion of topsoil into the water
- Sewage
- Decomposing organic matter
- Natural weathering of rocks
- Bushfires

Phosphorus levels in water bodies have significantly increased worldwide because of fertilizer use, as well as from municipal and industrial wastewater [27].

Australian soils and surface waters are naturally low in phosphorus [29] and our native plants have adapted to these low levels whereas introduced pastures and crops have not. Therefore, we synthetically apply phosphorus through agricultural fertilizers, manure and organic wastes to keep these non-native crops healthy. This activity is primarily where excess phosphorus can enter our water ways.

Because our native plants are highly efficient at utilising the small amounts of available phosphorus, when there is an excess it enables plants like Salvinia to grow extensively to the point where they can become problematic.



HOW TO IDENTIFY THE RIGHT SALVINIA TREATMENT FOR YOUR SITUATION

Treatments currently avaliable

Currently there are 2 main types of treatment available. These are:
- Aquatic herbicides (chemical & natural based)
- Physical removal (manual & machine)

To determine which treatment will suit your situation best, you must first categorise the severity of your Salvinia bloom.

How Severe is your Salvinia Bloom?

Primary Growth Stage

0-30% of the water body is covered in Salvinia
Primary growth occurs in the early stages of an infestation, when plants are not crowded.
The water surface is clearly visible between plants and the plant is lying flat on the surface of the water [8].

Secondary Growth Stage

30-60% of the water body is covered in Salvinia
Secondary growth occurs when the water surface is barely visible but the Salvinia is still only a single layer [8].

Tertiary Growth Stage

60-100% of the water body is covered in Salvinia
Tertiary growth occurs when the plants become crowded and mature in infestation. The water surface is no longer visible preventing light from entering the water [8].

Multilayered Growth Stage

100%+ of the water body is covered in Salvinia
Tertiary weed mats can become multilayered, displaying ridge-like thickenings as layers build up affecting the water beneath by eliminating submerged plants and algae, preventing photosynthesis and blocking oxygen diffusion from the air resulting in an anaerobic environment [8] [12].

Primary Growth Stage

Example of Salvinia in its primary growth stage. Notice how much free water is present and how spread out the individual plants are!

Secondary Growth Stage

Example of what Salvinia can look like in its secondary growth stage. Salvinia can appear as red or green or a combination of both colours. Notice how the water is barely visible.

Tertiary Growth Stage

Example of what Salvinia can look like in its tertiary growth stage. Salvinia can appear as red or green or a combination of both colours. Notice how the water is no longer visible.

Multilayered Growth Stage

Examples of what Salvinia can look like in its multilayered growth stage.

Salvinia can appear as red or green or a combination of both colours. Notice how dense the Salvinia has become and there is no visible water at all.

Once you have categorised your Salvinia bloom, you can then choose your treatment. Use the table below to help you:

	Treatment Options			
Growth Stage	Herbicide: chemical-based	Herbicide: natural-based	Physical removal: manual	Physical removal: machine
Primary	✓	✓	✓	
Secondary	✓	✓	✓	✓
Tertiary	✓		✓	✓
Multilayered	✓			✓

What you use your water body for will also play a role in the type of treatment most suitable for you. For example if you are unable to withhold using the water for 10-days, then a traditional herbicide may not be suitable.

There are different treatment methods available to suit most types of water bodies. Continue reading to find out which treatment is most suitable for your waterbody.

Types of Aquatic Herbicides

All approved aquatic herbicides can be used on all species of Salvinia but not all aquatic herbicides are effective against all growth stages.

The following Aquatic Herbicides are successful on primary and secondary growth stages:

- AQ200
- Calcium dodecyl benzene sulfonate
- *Glyphosate
- Orange Oil

The following Aquatic Herbicides are successful on tertiary stages of growth:

- AQ200
- *Glyphosate

The following Aquatic Herbicides are successful on multilayered stages of growth:

- AQ200

Benefits of chemical control:

Typically only one full application with follow up spot treatments advised.
Kills Salvinia fast (7-14 days) [13].

Disadvantages of chemical control:

Treated plants remaining in the water can cause deoxygenation within the system, affecting water quality [30]. However, if left untreated water quality will continue to decline. Treating with aquatic herbicides may see a short term decline in water quality, however once cleared a rapid recovery takes place.

Possibility of spray drift onto non-target vegetation [30].

There is a withholding period is once the herbicide has been applied meaning the water cannot be used for either irrigation or watering stock until the breakdown of the herbicide (excludes orange oil) [30].

Treated plants remaining in the water can cause oxygen to deplete within the system, affecting water quality [8]. However, if left untreated water quality will continue to decline. Treating with aquatic herbicides may see a short term decline in water quality, however once cleared a rapid recovery takes place.

There is the possibility of spray drift onto non-target vegetation.

There is a withholding period once the herbicide has been applied meaning the water cannot be used for either irrigation or watering stock until the breakdown of the herbicide (excludes orange oil).

The below table summarises the effectiveness of various herbicides on the growth stages of free-floating aquatic weeds.

Herbicide	Primary Stage 0-30%	Secondary Stage 30-60%	Tertiary Stage 60-100%	Multilayered 100%+
Orange oil (Natural-based)	✓	✓	×	×
AQ200	✓	✓	✓	✓
*Glyphosate	✓	✓	✓	×
Calcium dodecyl benzene sulfonate	✓	✓	×	×

Primary: early stages of infestation, crowded plants, water surface visible
Secondary: moderate infestation, water surface barely visible
Tertiary: mature infestation, water surface is not visible
Multilayered: display ridge-like thickening as layers build up

* **In 1997, the APVMA implemented new regulations regarding the usage of Glyphosate in aquatic environments within Australia. These regulations stipulated that Glyphosate is no longer permitted for use in treating weeds that grow in or over bodies of water in Australia. Furthermore, the application of Glyphosate via spraying across open water surfaces or allowing Glyphosate to enter bodies of water is strictly prohibited. Instead, may only be used for the treatment of dry drains and channels, as well as the dry margins of dams, lakes, and streams. Additionally, users must ensure that water does not return to these treated areas within a 4-day period after application. Therefore, using Glyphosate herbicides in water is not permitted. Only use an approved aquatic herbicide like AQ200 in such cases [36].**

	AQ200	*Glyphosate	Calcium dodecyl benzene sulfonate	Orange Oil
Mode of action	• Contact herbicide that causes rapid plant injury in exposed tissue through disruption of photosynthesis [14].	• Disrupts the shikimic acid pathway through inhibition of the enzyme 5-enolpyruvyl-3-shiki-mate phosphate (EPSP) synthase. The resulting deficiency in EPSP production leads to reductions in aromatic amino acids that are vital for protein synthesis and plant growth [15] [16].	• Reduces buoyancy causing plant to sink [17].	• Disrupts cuticle, breaking down or dissolving the waxy coating on plant cell walls. Contributes to the desiccation or burndown of young tissues [18] resulting in the plant losing its ability to retain water [19]. The damaged leaf cells leak water and the plants die of dehydration [20].
Timing of application	• Throughout the entire growing season; Control of early growth is recommended [17].	• When plant is actively growing [23].	• During primary and secondary growth stages only to floating plants only [17].	• Throughout the entire growing season [21] [22].
Waiting period	• Plants absorb AQ200 rapidly; plant decline is usually within less than 7 days post treatment [17].	• Following treatment, plants will gradually wilt, appear yellow/brown, and will die in approximately 2 to 7 days [23].	• Needs at least three applications and anything from a week to three weeks between applications [17].	• Plants will begin to sink within the hour after application. Full results may take up to 7 days [17].
Use restrictions/ Precautions	• Do not use herbicide in muddy water or on vegetation coated with mud or algae [17].	• Does not work on solid plant mats or where no water surface is visible [17]. • Do not treat weeds under poor growing or dormant conditions [17]. • Is not effective on submerged aquatic plants [23]. • Do not treat in water with high turbidity [17].	• Free water must be visible for application [17]. • Only works on floating ferns [17].	• Avoid a single heavy application; instead apply several light applications over a 1-3 week period [17]. • Apply when weed infestation is small, rather than advanced. Do not spray dense solid mats with no visible water surface. Water bodies with an average depth of less than 1 metre should not be treated [17].
Breakdown in water	• AQ200 is rarely found longer than 10 days after application and is often at levels below detection 3 days after application [14] [24]. • Binds tightly to clay particles in the water and the bottom sediments, where it becomes biologically unavailable [14] [24].	• The concentration of glyphosate is reduced through dispersal by water movement, binding to the sediments, and break-down by microorganisms [23]. • Glyphosate's half-life is between 3 days and 19 weeks depending on water conditions [23].	• Calcium dodecyl benzene sulfonate takes between 24 hours and 7 days to vaporise, depending on weather conditions (it takes longer on overcast days) [17].	• Non-persistent which means it decomposes rapidly, preventing the accumulation of compounds in soil and its subsequent influence on non-target organisms [25].

*** In 1997, the APVMA implemented new regulations regarding the usage of Glyphosate in aquatic environments within Australia. These regulations stipulated that Glyphosate is no longer permitted for use in treating weeds that grow in or over bodies of water in Australia. Furthermore, the application of Glyphosate via spraying across open water surfaces or allowing Glyphosate to enter bodies of water is strictly prohibited. Instead, may only be used for the treatment of dry drains and channels, as well as the dry margins of dams, lakes, and streams. Additionally, users must ensure that water does not return to these treated areas within a 4-day period after application. Therefore, using Glyphosate herbicides in water is not permitted. Only use an approved aquatic herbicide like AQ200 in such cases [36].**

TREATMENTS AQUATIC TECHNOLOGIES OFFER

AQ200 Aquatic Herbicide + Wetting Agent Treatment

Preparing AQ200 + Wetting Agent Solution:	Applying AQ200 + Wetting Agent Solution:	Spot Treatment:
Step 1) Combine 400mL of AQ200 with the 150mL of Wetting Agent and dilute in 100L town/tank water (please note it is important to use town/tank water for this application). *Always put 80 per cent of the required water into your clean sprayer before adding the chemicals, then slowly add the other 20 per cent of the water. This avoids frothing of the spray mix.*	Step 2) Spray diluted mixture directly onto Salvinia using a shower spray (not a mist spray). Ensure all Salvinia is covered. *If Salvinia is at 100% coverage, it is advised to physically remove some prior to spraying OR ensure a heavy wetting application is applied.*	Step 3) Spot treat any remaining plants 1-2 weeks after a full application. Continue to spot treat until Salvinia is no longer visible. *Check beneath rocks, lily pads and reeds etc. for any hidden Salvinia plants.*

1L of AQ200 + 500mL Wetting Agent will treat between 250m² – 500m² of surface area depending on how dense the Salvinia coverage is.

Tips for eradicating:

• If Salvinia is layered or at 100% coverage, physically remove some Salvinia to thin it out before commencing herbicide treatment OR ensure a heavy drenching is applied.

• It is best to treat on a day with no rain and minimal wind

• Spot treat any remaining plants

• Check beneath rocks, lily pads and reeds etc. for any hidden Salvinia plants.

Notes:

• Use PPE when handling AQ200 including; gloves, goggles, mask, overalls/protective clothing

• DO NOT use treated water for human consumption, livestock watering or irrigation purposes for 10 days after application

• AQ200 is best applied with a spray unit

• Use a shower spray (do not mist)

• Limit overspray as this can affect non-target terrestrial and aquatic plants.

Orange Oils: Natural Treatments

Preparing Orange Oil Solution:	Applying Orange Oil Solution:	Spot Treatment:
Step 1) Dilute 1L of Orange Oil per 100L of water.	Step 2) Spray diluted Orange Oil directly onto Salvinia using a light shower spray (not a mist spray). Ensure that the full surface area of the water is treated (even where no Salvinia is present). Spray onto Salvinia enough to change their normal colour (plants darken and show an oily sheen). Spray a light coverage over any free water present.	Step 3) Spot treat any remaining plants 1-2 weeks after a full application. Continue to spot treat until Salvinia is no longer visible.
Always put 80 per cent of the required water into your clean sprayer before adding orange oil, then slowly add the other 20 per cent of the water. This avoids frothing of the spray mix.	*If Salvinia is at 100% coverage, you must physically remove some until the Salvinia is single layered and there is free water present prior to spraying.*	*Check beneath rocks, lily pads and reeds etc. for any hidden Salvinia plants.*

1L of Orange Oil will treat between 250² - 500m² of surface area depending on the Salvinia coverage.

Tips for eradicating:

• For large infestations covering up to 90% of the water's surface – partially remove sections of the infestation to create space for the treated matter to sink. In such instances, we recommend applying an extra 20% of the product to ensure saturation.

• This product works best when surface matter is small and manageable. It's advised to do several light applications, instead of a single heavy dose.

Aquatic Technologies have found best results when Orange Oil is applied on day 1, day 2 and day 4.

• It is best to treat on a day with no rain and minimal wind.

• Spot treat any remaining plants until no longer visible.

Notes:

• Use PPE when handling Orange Oil including; gloves, goggles, overalls/protective clothing.

• Orange Oil is best applied with a spray unit.

• Use a shower spray (do not mist).

• Ensure your shower spray is not too powerful, you want to lightly coat the Salvinia not blast at it as this may cause the product to wash off.

Physical Removal: Salvinia Skimmers

Physical removal can be a labour-intensive method, but has the advantage of being ecologically benign [30]. Small infestations of Salvinia in accessible areas can be removed with rakes and fine-mesh nets, and used as either fodder or compost [30].
The disadvantage of this method is that under optimal conditions, Salvinia can double its population in 2 to 10 days [30] [31] [32-34].

Advantages of physical removal:

• Removes extra nutrients caused by the breakdown of Salvinia thereby reducing the likelihood of future blooms.

• A dense coverage consumes a lot of oxygen leaving little left for fish and other aquatic organisms. Avoids fish kills by ensuring adequate oxygen levels remain.

• Removes habitat for breeding mosquitoes.

Aquatic Surface Skimmers

can be used on all species of Salvinia and primary, secondary and tertiary growth stages. This method is best used in conjunction with spray treatments or when partial removal is desired.

Physically removing Salvinia from the water's surface will reduce the likelihood of future blooms by decreasing the amount of nutrients in your water. Nutrient-rich water lets aquatic vegetation thrive, meaning you might experience more infestations of unwanted Salvinia.

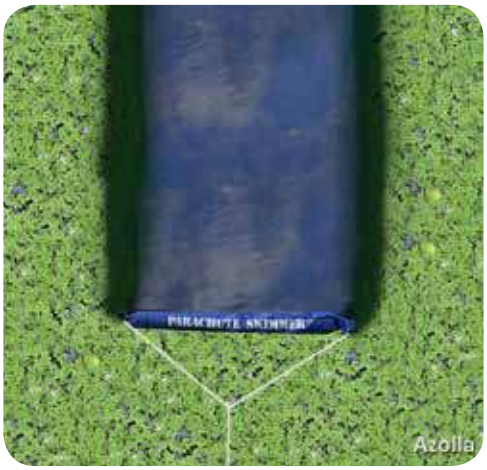
Easily remove Salvinia from your water body in 4 steps:

1. Toss the skimmer in the water
2. Slowly pull it back in using the string attached
3. Dump the Salvinia out onto the bank or into a container for easy transport
4. Repeat

Tips:

• Keep collected Salvinia away from water's edge to avoid re-contamination

• Use the collected Salvinia on your garden! Salvinia is a great fertilizer.



Aquatic Harvesting

Amphibious Aquatic Harvesting machines can be used on all species of Salvinia and is better suited to larger infestations where chemical treatment is not desirable or practical.

Aquatic harvesters can remove the bulk of an infestation in accessible areas, and other control methods are then required for the remnant Salvinia left close to edges, or in shallow or inaccessible areas.

Brittany Pondeljak ©

HOW TO PREVENT SALVINIA BLOOMS

The best practice to minimise Salvinia blooms is to maintain a healthy water body. As described previously, one of the main contributing factors to excessive. Salvinia growth is phosphorus.

Phosphorus can be controlled by:

- Limiting run-off
- Reduce fertiliser use
- Prevent top soil erosion
- Manure handling management
- Soil conservation practices
- Restoring wetlands and riparian buffers

Phosphorus Removal

Phoslock - Removes excess phosphorus

Developed by the Australian CSIRO, Phoslock is a highly effective product that removes excess phosphates from any body of water.

Phoslock is a unique modified bentonite clay granule that effectively locks phosphorus into its own particles, which then sink to the bottom of the water body. These particles then become part of the natural sediment – so there's no need to remove them after application.Phoslock will continue to absorb phosphorus released from the sediment and new phosphorus inputs until it is saturated, giving long-lasting results.

Preparing Phoslock Solution:	Applying Phoslock Solution:
Step 1) Mix Phoslock in batches into an aqueous slurry You can spread the granules straight from the container across the water's surface if an aqueous slurry is too difficult (for small applications only).	Step 2) Apply evenly across the water's surface using a spray unit or by pouring the phoslock slurry from a container.

25kg of Phoslock is applied for every 100m² of water surface area.

Tips for application:

- Ensure there is visible water when applying Phoslock
- Mix phoslock into water using a paint mixer
- Add phoslock slowly to ensure even mixing

Notes:

- Use PPE when handling Phoslock including; gloves, mask, goggles, overalls/protective clothing
- Phoslock is best applied with a modified spray unit
- An Aerated water body will enhance and prolong the Phoslock treatment

Maintaining a healthy water body

A healthy water body consists of native plant and animal populations interacting in balance with one another as well as nonliving things.
In a healthy ecosystem there will be:

- An energy source (primarily the sun)
- Living organisms (primary producers, consumers, decomposers)
- Non-living things (water, soil, rocks etc.)
- Dead/decaying matter

Freshwater ecosystems differ greatly from one another depending on type, location, and climate, but they nevertheless share important features [25]. By knowing what's normal for your water body will help you maintain a healthy ecosystem.

Water Features:
1. Flow pattern – defines where the water comes from. Knowing the source of your water can be indicative of factors that may influence water body health.

2. Sediment and organic matter – raw materials that create physical habitat structure as well as supply energy sources to sustain aquatic plants and animals. Knowing what inputs are going into your water body will help you manage its overall health.

3. Temperature and light – regulate metabolic processes, activity levels, and productivity of aquatic organisms. These factors change seasonally and aquatic plants and animals have adapted tothese changes. Knowing what is regular for your water body will help you monitor any unusual changes.

4. Nutrient and other chemical conditions – regulate pH, water quality and plant and animal productivity. An imbalance will likely be displayed by algal blooms, excessive aquatic plant growth, foul odours or changes in animal behaviour.

5. Plants and animals – influences ecosystem function and community structure. A diverse range of aquatic plants and animals indicate a healthy ecosystem. When one species becomes dominant, it is indicative of an imbalance within the water body.

By monitoring the status of these five features, you can more easily distinguish where an imbalance might be and rectify the issue.

Signs that your water body is unhealthy:

- Odours (foul, sulphur, rotten-egg)
- Water clarity (turbid water can be indicative of health concerns)
- Algal blooms
- Excessive aquatic plant growth
- Dead animals
- Fish consistently swimming near the water's surface

An essential feature for water body health not listed above is oxygen, known as dissolved oxygen in the context of water.Dissolved oxygen is an essential requirement for living aquatic organisms.

Most of the organisms that inhabit fresh water constantly consume dissolved oxygen (DO).
In order for life to be sustained this oxygen must be replenished, and in many waters this can be accomplished by a process called re-aeration (surface water taking up oxygen from the overlying air) [35].

However, re-aeration is only effective if the water is moving and mixing rapidly enough for the DO to reach deeper water before oxygen reserves become depleted [35].

In rivers and streams, the constant flow of water is the likely source of re-aeration and mixing in freshwater systems [35], however the same cannot be said for slow moving water bodies such as dams and lakes.

In northern parts of Australia, a substantial amount of habitats are highly productive and very warm, therefore oxygen consumption rates are very high [35].

As a consequence the re-aeration rates required in order to maintain oxygenation are often highest at the sites that are most poorly re-aerated [35].

Some large exposed waterbodies such as lakes can be partially re-aerated by winds, but some freshwater habitats are too small and/or sheltered to allow wind mixing to fully replenish oxygen reserves [35].

Waterbodies that cannot rely on re-aeration will primarily rely on submerged photosynthetic organisms (plants and algae) to produce enough DO during daylight hours to meet the needs of the entire ecosystem during the night [35].

Biological oxygenation of this kind can be surprisingly effective; nevertheless it is still very common to find that DO concentrations have fallen to potentially life-threatening levels by the time the sun rises each day [35].

Changes to this type of ecosystem can greatly influence DO levels and collapse it entirely e.g.

- water clarity
- depth
- amount and type of submerged plants
- nutrient availability

Nowadays, DO can be maintained artificially via aquatic aerators. This is a reliable way to ensure the basic health needs are met of all aquatic life in managed waterbodies.

AERATION

Water aeration is the process of increasing or maintaining sufficient oxygen levels of water in both natural and artificial environments.

Aeration is a common tool used in pond, dam, lake, and reservoir management to maintain healthy waterbodies by addressing low oxygen levels or controlling algal blooms.

Artificial aeration can help reduce algal and noxious aquatic plant blooms by encouraging the growth of beneficial aerobic bacteria.

These bacteria consume excess nutrients that is otherwise available to aquatic plants and algae.

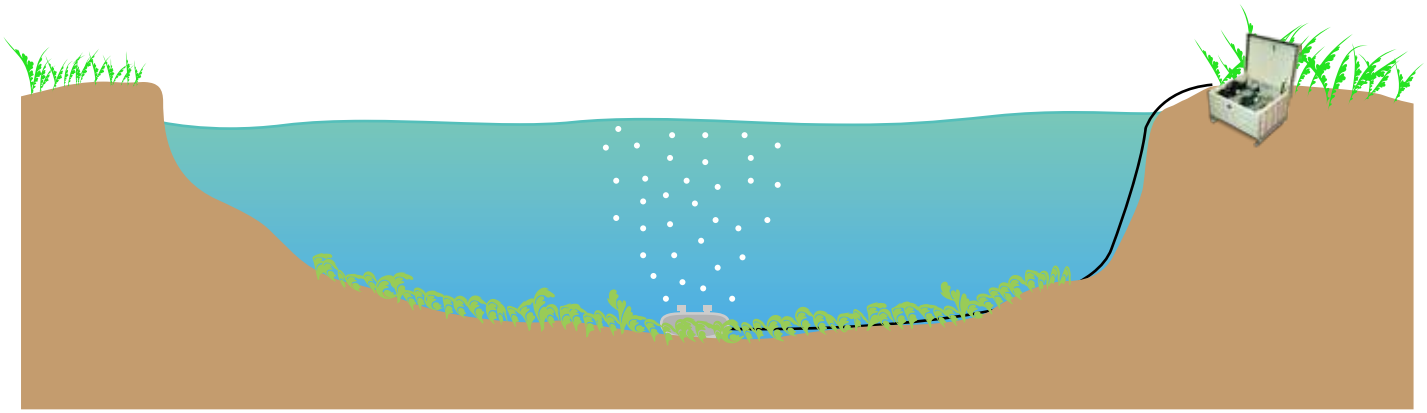
Not only do these bacteria reduce the amount of nutrient availability, they help prevent a build-up of “muck” at the bottom of the water body. This muck can house noxious gases that can lead to foul odours and muddy water.

An aerated water body will have reduced algal blooms, normalised aquatic plant growth, adequate oxygen availability, no foul odours, improved water clarity and a reduction in muck accumulation.

Subsurface aeration:

Subsurface aeration is designed to release bubbles from the bottom of the water body and allow them to rise by the force of buoyancy. Diffused aeration systems utilize bubbles to aerate as well as mix the water to prevent stratification (water stratification is when water masses with different properties - salinity, oxygenation, density, temperature - form layers that act as barriers to one another preventing mixing). Water displacement from the expulsion of bubbles will cause a mixing action to occur, and the contact between the water and the bubble will result in an oxygen transfer.

Subsurface aeration is better suited to deeper waterbodies where stratification is more likely to occur.

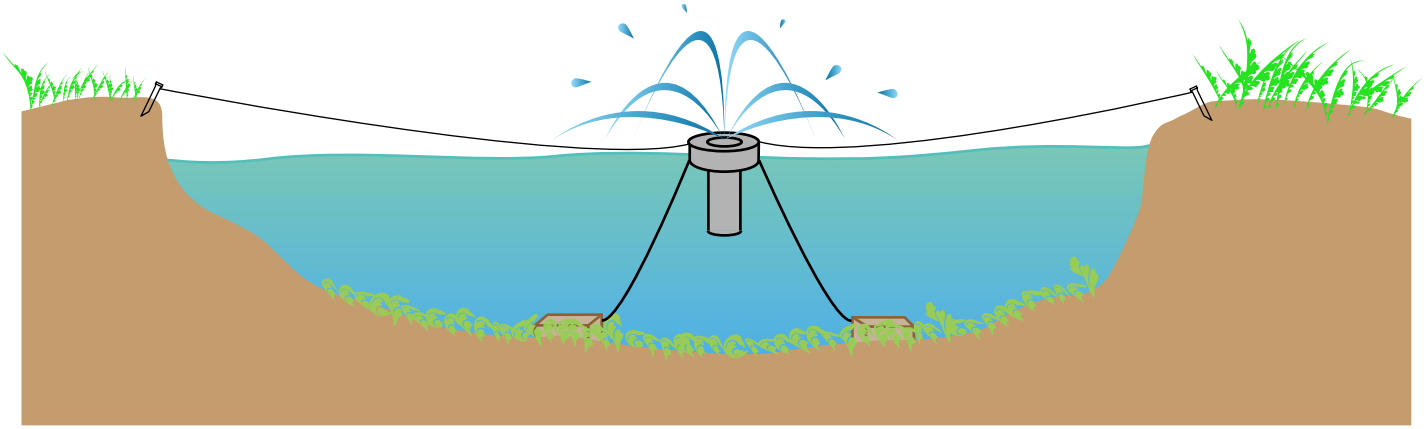


Surface aeration:

Surface aeration is designed to mimic re-aeration (surface water taking up oxygen from the overlying air). The surface aerator disrupts the surface of the water body allowing adequate air-water contact for successful oxygen diffusion.

In a fountain surface aerator, the water droplets created have a large surface area through which oxygen can be transferred and as they fall back into the water body, the droplets mix with the rest of the water and transfer the oxygen.

Surface aeration is better suited to smaller, shallower waterbodies.



References

[1] Sainty GR, Jacobs SWL. Waterplants in Australia: A Field Guide. 4th ed; Sainty Books: Potts Point, Australia, pp. 14-15.

[2] Hussain N, Abbasi T, Abbasi SA. "Vermiremediation of an invasive and pernicious weed salvinia (Salvinia molesta)", Ecological Engineering, vol 91, pp. 432-440, 2016.

[3] Brisbane City Council (2021) Salvinia: Salvinia molesta – From: Online Weed Identification Tool. Available at https://weeds.brisbane.qld.gov.au/weeds/salvinia. Accessed 13/12/2021.

[4] Department of Primary Industries and Regional Development (2021) Salvinia: declared pest - From: Agriculture and Food. Available at https://www.agric.wa.gov.au/declared-plants/salvinia-declared-pest. Accessed 13/12/2021

[5] Mukherjee A, Knutson A, Hahn DA, Heinz KM. "Biological control of giant salvinia (Salvinia molesta) in a temperate region: cold tolerance and low temperature oviposition of Cyrtobagous salviniae", Biocontrol, vol 59 (6) pp. 781-790.

[6] O'Sullivan C, Rounsefell B, Grinham B, Clarke, W, Udy J. "Anaerobic digestion of harvested aquatic weeds: water hyacinth (Eichhornia crassipes), cabomba (Cabomba Caroliniana) and salvinia (Salvinia molesta)", Ecological Engineering, vol. 36 (10), pp. 1459-1468, 2010.

[7] European and Mediterranean Plant Protection Organisation (EPPO). "Salvinia molesta D.S. Mitch", EPPO Bulletin, vol 47(3), pp. 531-536, 2017.

[8] NSW DPI, Salvinia Control Manual, Orange, NSW: NSW Department of Primary Industries, 2006.

[9] Hussain N, Annasi T, Abbasi SA, " Generation of highly potent organic fertilizer from pernicious aquatic weed Salvinia molesta", Environmental Science and Pollution Research, vol. 25, pp. 4989 – 5002, 2016.

[10] Garlich N, Garcia GL, de Oliveira AC, dos Santos KP, Pitelli RA, Ferreira MdC, da Cruz C. "Electrostatic spraying of imazamox to control the floating aquatic plant Salvinia molesta and its effects on environmental indicators of water quality", Journal of Environmental Science and Health, vol. 56(3), pp. 251-258, 2021.

[11] McFarland DG, Nelson LS, Grodowitz MJ, Smart RM, Owens CS. "Salvinia molesta D.S. Mitchell (Giant Salvinia) in the United States: A Review of Species Ecology and Approaches to Managment", Aquatic Plant Control Research Program; US Army Corps of Engineers, 2004.

[12] R.A. Janes, J.W. Eaton, K. Hardwick, "The effects of floating mats of Azolla filiculoides Lam. And Lemna minuta Kunth on the growth of submerged macrophytes' ', Hydrobiologia, vol. 340, pp. 23-26, 1996.

[13] Vencill W, Armbrust K. Herbicide Handbook. Lawrence K, editor. Weed Science Society of America; 2002.

[14] Skogerboe JG, Getsinger KD, Glomski LAM. Efficacy of diquat on submersed plants treated under simulated flowing water conditions. Journal of Aquatic Plant Management 2006;44:122-125.

[15] Tomlin CDS. The Pesticide Manual: A World Compendium. 14th ed.; British Crop Protection Council: Hampshire, UK, pp. 545- 548, 2006.

[16] Vencill WK. Herbicide Handbook," 8th ed.; Weed Science Society of America: Lawrence, KS, pp. 231-234, 2002.

[17] Westerdahl HE, Getsinger KD. Aquatic plant identification and herbicide use guide. vol 2, ed. Mississippi: Mississippi: US Army Corps of Engineers, Waterways Experiment Station, 1988.

[18] Soltys D, Krasuska U, Bogatek R, Gniazdowska A. Allelochemicals as Bioherbicides — Present and Perspectives. In Herbicides - Current Research and Case Studies in Use, IntechOpen, 2013

[19] Messerschmidt O, Jankauskas J, Smith F. Limonene-containing herbicide compositions, herbicide concentrate formulations and methods for making and using the same. United States of America Patent US 8,273,687 B2, 25 September 2012.

[20] Koperek E. Organic Herbicides. World Agriculture Solutions, Pennsylvania, 2015.

[21] NSW Government, Salvinia - Smothers Dams and Waterways, New South Wales DPI, 2015.

[22] Environmental Sustainability Office of Estate and Commercial, Weed Management Plan, Sydney: Western Sydney University, 2020.

[23] Wisconsin Department of Natural Resources, "Glyphosate Chemical Fact Sheet" [Fact sheet]. https://dnr.wi.gov/lakes/plants/factsheets/Glypho- sateFactsheet.pdf

[24] Siemering GS, Hayworth JD, Greenfield BK. Assessment of Potential Aquatic Herbicide Impacts to California Aquatic Ecosystems. Archives of Environmental Contamination and Toxicology 2008;55(3):415-431.

[25] Ribeiro R, Lima M. Allelopathic effects of orange (Citrus sinensis L.) peel essential oil. Acta Botancia Brasilica 2012;26(1):256-259

[26] R. J. M. Temmink, S. F. Harpenslager, A. J. P. Smolders, G. van Dijk, R. C. J. H. Peters, L. P. M. Lamers, M. M. L. van Kepmen, "Azolla along a phosphorus gradient: biphasic growth response linked to diazotroph traits and phosphorus-induced iron chlorosis," Scientific Reports, vol. 8, 4451, 2018.

[27] Conley DJ, Pearl HW, Howarth RW, Boesch DF, Seitzinger SP, Havens KE, et al. Controlling Eutropication: Nitrogen and Phosphorus. Science 2009;232:1014-1015.

[28] Gorde SP, Jadhav MV. Assessment of Water Quality Parameters: A Review. Journal of Engineering Research and Applications 2013;3(6):2029-2035.

[29] Cary PR, Weerts PGJ. Growth and nutrient composition of Azolla pinnata R. Brown and Azolla filiculoides Lamarck as affected by water temperature, nitrogen and phosphorus supply, light intesity and pH. Aquatic Botany 1992;43:163-180.

[30] Hill MP, McConnachie AJ. The Biological Control of Azolla filiculoides Lamarck (red water fern). Department of Zoology and Entomology, Rhodes University and Weed Research Division, Plant Protection Research Institute, Agricultural Research Council, South Africa, 2000.

[31] Hussner, A. (2010): NOBANIS – Invasive Alien Species Fact Sheet – Azolla filiculoides. – From: Online Database of the European Network on Invasive Alien Species – NOBANIS www.nobanis.org, Date of access 24/03/2021.

[32] Qiu YL, Yu J. Azolla – A Model Organism for Plant Genomic Studies. Genomics, Proteomics & Bioinformatics 2003;1(1):12-25.

[33] Hasan MR, Chakrabarti R. Use of algae and aquatic macrophytes as feed in small-scale aquaculture: a review. FAO Fisheries and Aquaculture Technical Paper, No. 531. FAO. 2009. Rome, Italy.

[34] G. M. Wagner, "Azolla: a review of its biology and utilization," The Botanical Review, vol. 63, pp 1-26, 1997.

[35] Baron JS, Poff NL. Sustaining Healthy Freshwater Ecosystems. Water Resources Update 2004;127:52-58.

[36] NRA Chemical Review Section. NRA special review of glyphosate. NRA Special Review Series, no. 96.1. Canberra: National Registration Authority for Agricultural and Veterinary Chemicals; 1996.