2.13 Giant and Common Salvinia

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Salvinia molesta D.S. Mitchell; *Salvinia minima* Baker; free-floating ferns in the Salviniaceae family. Derived from *Salvinia* (after Antonio M. Salvini) and *molesta* (Latin: nuisance, annoying, troublesome) and *minima* (Latin: small, minor)

Introduced from Brazil (*Salvinia molesta*), Central and South America (*Salvinia minima*)
Found throughout the southern US

Introduction and spread

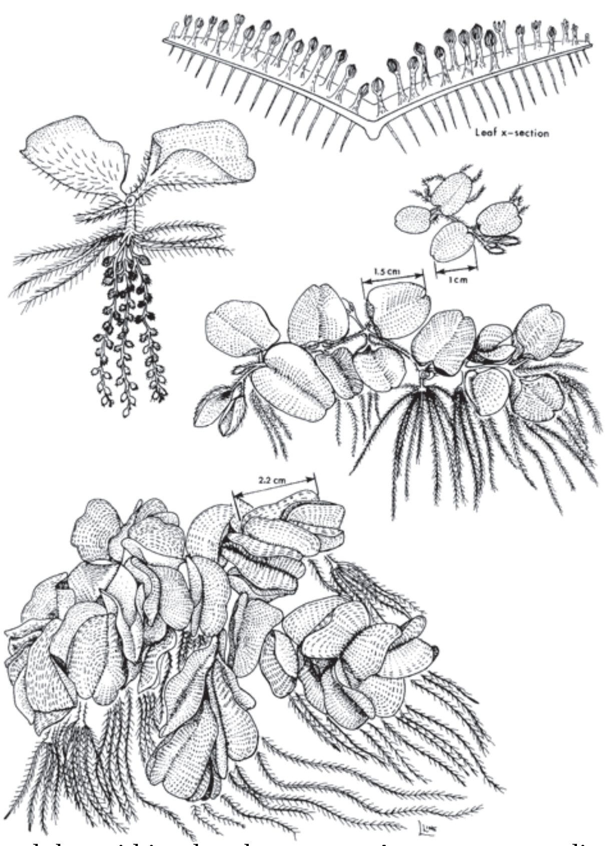
Water ferns in the genus *Salvinia* are members of the Salviniaceae family. There are 12 species of *Salvinia* reported worldwide, seven of which originate from the New World tropics (the Western Hemisphere). None of the *Salvinia*

species are native to North America, but two species – *Salvinia minima* and *Salvinia molesta* – have been introduced from South America and are currently established in the US. Both species were likely introduced into the US through the nursery trade as ornamental plants for water gardens or through the aquarium plant industry.

Salvinia molesta, commonly known as giant salvinia, is native to southeastern Brazil and was first found outside its native range in Sri Lanka in 1939. Giant salvinia quickly became a widespread weed problem in Sri Lanka, infesting rice paddies, reducing flows in irrigation channels and blocking navigation in transportation canals. Today, giant salvinia is considered one of the world's worst weeds and has become established in over 20 countries including Africa, India, Indonesia, Malaysia, Singapore, Papua New Guinea, Australia, New Zealand, Fiji, Cuba, Trinidad, Borneo, Columbia, Guyana, Philippines, and the US Territories of Puerto Rico and the Virgin Islands. In 2013, giant salvinia was added to the list of 100 of the World's Worse Invasive Alien Species by the International Union for Conservation of Nature (http://www.iucngisd.org/gisd/100_wort.php).

The first report of giant salvinia outside of cultivation in the US occurred in 1995 when it was discovered in a small, private pond in South Carolina. Once identified, it was quickly eradicated from this site with the use of herbicides. Although this initial infestation was successfully eradicated, giant salvinia has since been reintroduced and has spread throughout the southern US. Significant infestations have been reported in more than 90 locations in more than 41 freshwater drainage areas of 15 states (Alabama, Arizona, Arkansas, California, Georgia, Hawaii, Florida, Louisiana, Mississippi, Missouri, North and South Carolina, Oklahoma, Texas and Virginia) and the District of Columbia. Giant salvinia is currently listed as a Federal Noxious Weed by the US Department of Agriculture (www.aphis.usda.gov/ppq/weeds/), which prohibits its importation into the US as well as its transport across state lines. However, giant salvinia must be listed as a noxious species by individual states to prohibit sale and cultivation of the species within that state. Fourteen states currently list giant salvinia as a noxious weed or a prohibited weed/plant pest. Since this species is not currently designated as a noxious weed by all states, the expansion of giant salvinia will likely continue. Quarantine and sale of giant salvinia by the nursery industry has been difficult to enforce nationwide. In fact, a recent survey of mail-order catalogs and on-line commercial vendors for water garden enthusiasts revealed that giant salvinia was among the many noxious aquatic plants readily available for purchase over the internet.

Salvinia minima, hereafter referred to as common salvinia, is native to Central and South America. Outside its native range it has established in Bermuda, Puerto Rico, Spain and North America. Common salvinia was first reported in the US in 1928 along the St. John's River in Florida. The source of this first introduction to a natural area was likely the result of an unintentional release from a grower whose cultivation ponds had flooded. Since then, populations have been recorded in more than 80 freshwater drainage areas across the US. According to the most recent distribution records reported by the USGS Nonindigenous Aquatic Species Database, common salvinia is found in 17 states including Alabama, Arkansas, California, Florida, Georgia, Idaho, Louisiana, Maryland, Massachusetts, Mississippi, Missouri, New Mexico, New York, Ohio, Oklahoma, South Carolina and Texas. Similar to giant salvinia, common salvinia is widely available through the water garden trade. Although it continues to infest new regions, common salvinia is not listed as a Federal Noxious Weed; however, it is currently listed as a prohibited plant in Florida and a noxious weed/plant in North Carolina and Texas.



Description of the species

Common and giant salvinia are free-floating aquatic ferns with a horizontal stem or rhizome that floats at or just below the water surface. A pair of floating leaves or fronds (leaves of ferns are referred to as "fronds") are produced at each node along the rhizome. Fronds are bright green in color, oval in shape, possess a central midrib and are covered with numerous stiff, white hairs. It is thought that the function of these leaf hairs is to repel water and thus aid in plant buoyancy. An easy way to distinguish giant salvinia from common salvinia is by the shape of the hairs on the upper surface of floating fronds. The hairs on the fronds of giant salvinia form cage-like structures at the tip that resemble an eggbeater or kitchen whisk, whereas the hairs on common salvinia fronds are open at the tip and have a fringed appearance.

Common and giant salvinia lack true “roots” but possess delicate, finely-dissected submersed fronds. Submersed fronds are brown and resemble roots and serve a similar function by absorbing nutrients from the water. Sporocarps (structures that hold the fern’s spores) are borne in chains or clusters on submersed stalks but do not bear fertile spores. Sporocarps are not found at all plant nodes but often develop and are more abundant later in the growing season or when nutrient conditions are poor.

Both giant and common salvinia favor stagnant or slow-moving water habitats of lakes, ponds, rivers, streams, oxbows, ditches, canals, swamps, marshes and rice fields. Under favorable growing conditions, both species can form dense, expansive plant mats that can completely cover the water surface. Optimal growing conditions include full sunlight and warm (75 to 85 °F), nutrient-rich waters with a pH of 6 to 7.5. Upper and lower temperature thresholds for growth are about 95 and 50 °F, respectively. Both giant and common salvinia have a low tolerance to salinity and cannot survive in brackish or marine environments.

Reproduction

Giant and common salvinia are ferns, so they do not produce flowers or seed. As mentioned above, both species produce sporocarps that may contain spores but the spores are not thought to be viable. As a result, giant and common salvinia reproduce solely by vegetative means through fragmentation or the production of new plants from lateral and terminal buds. Stems may have as many as 5 buds per node and each bud is capable of developing new fronds. In addition, horizontal stems or rhizomes break apart very easily and produce fragments that disperse and develop into mature individual plants.

An individual giant salvinia can double in size in as little as 5 to 7 days when conditions are favorable. Some reports have calculated that a single giant salvinia plant can multiply to cover 40 square miles in 3 months under optimal growing conditions. With such an explosive growth rate, giant salvinia can quickly cover lakes and rivers, forming vegetative mats up to 3 feet thick. Common salvinia also has a rapid growth rate and can form dense mats, but is usually less aggressive than giant salvinia.

The major means of dispersal within and among lakes for giant and common salvinia is vegetative spread by fragmentation. Plant populations expand laterally within a lake through rhizome and lateral bud growth, whereas long distance dispersal is mostly the result of fragmentation. Plants easily adhere to boats, trailers, motors and other amphibious vehicles and can be transported to new locations. Animals (livestock, turtles, wading birds and waterfowl) may also contribute to the spread and dispersal of salvinia.

Problems associated with giant and common salvinia

Both giant and common salvinia can alter aquatic ecosystems in many ways. Dense growths can form a physical barrier on the water surface and hinder recreational activities such as boating, swimming, fishing and water skiing. Vegetative mats of salvinia can also impede navigation, impair flood control, limit irrigation, clog water intakes, decrease waterfront property values and cause problems in rice, catfish and crawfish production systems. Occasionally, other plant species (including grasses and small trees) will colonize or grow on mats of giant salvinia and create massive floating islands that can trap sediments and cause waterbodies to fill in over time.

Ecologically, extensive salvinia mats restrict light penetration and impede gas exchange between the water and atmosphere. Limiting light availability reduces photosynthesis of submersed aquatic plant communities and reduces water temperature. Low dissolved oxygen levels in the water are detrimental to fishes and other aquatic organisms and promote the accumulation of organic matter as microbial degradation is reduced. Changes in water quality can significantly impact the health of aquatic habitats and often result in declines in number and diversity of plant, invertebrate and animal communities. The loss of open water habitat also reduces the use of these areas by migrating waterfowl and wading birds (Sections 1.3 and 1.4).

Public health issues are also of concern. Both species of salvinia provide breeding habitats for mosquitoes and associated mosquito-borne illnesses (e.g., West Nile virus, malaria, encephalitis – Section 1.5). In Sri Lanka, it was reported that giant salvinia served as an important host plant and breeding habitat for mosquitoes which transmit filariasis (elephantiasis). Increases in the occurrence of schistosomiasis (which is transmitted by snails) have also been linked with large infestations of giant salvinia in developing countries.

Management options

Giant and common salvinia can be managed using herbicides, biocontrol agents, manual or mechanical harvesting, water level manipulation or a combination of these methods. Selecting the best management strategy depends on site-specific management goals and objectives, site characteristics, size and density of the infestation, proximity to sensitive plant or animal species, water body uses and budget constraints. The key to successfully managing giant and common salvinia is to recognize the problem early when infestations are small and can be easily contained. Small mats of salvinia are easily broken up by wind and wave action and are spread throughout large bodies of water. Once giant or common salvinia become well established and cover large areas, management becomes more difficult, time consuming and costly and may require multiple applications of a treatment method over a number of years to achieve maintenance control.

Herbicides (Section 3.7.1) can provide effective short and/or long-term control of giant and common salvinia depending on the choice of product and the method and frequency of application. Of the herbicides currently registered by the US Environmental Protection Agency for use in aquatic sites, ten provide good (> 75%) to excellent (> 90%) control of giant or common salvinia. The most widely used herbicides against these weed species include diquat, glyphosate, flumioxazin and carfentrazone-ethyl. Glyphosate applied in combination with diquat (plus appropriate surfactants; Section 3.7.3) is currently the most frequently used treatment for the management of giant salvinia in the US.

Diquat, flumioxazin, carfentrazone-ethyl and chelated copper formulations are non-selective contact herbicides that are typically applied as foliar sprays. Injury symptoms (severe leaf browning) are visible one day following application and plant death occurs within 3 to 4 days of treatment. Contact herbicides are fast-acting but have little or no movement inside plant tissues, so only plant tissues that come into contact with the herbicide are affected. Glyphosate is a non-selective, systemic herbicide that is applied to foliage, absorbed through the leaves and moves throughout the plant. Injury symptoms (leaf yellowing and browning) appear seven days after glyphosate application and plant death occurs by 28 days after treatment.

Other systemic herbicides that are effective, but slower-acting and used to a lesser extent against these two salvinia species, include imazamox, fluridone, penoxsulam, topramezone and bispyribac-sodium. Imazamox is effective on common salvinia but shows little or no activity on giant salvinia. Both species are susceptible to penoxsulam, bispyribac-sodium and fluridone. These herbicides require long contact times (60 to 90 days) to achieve control of salvinia, whereas imazamox has a shorter contact time requirement (7 days). Contact time refers to the length of time the target plant must be in contact with or exposed to a lethal dose of herbicide to achieve control. If contact time is not maintained because of water exchange or other factors that can cause dilution, plant control will be reduced. Imazamox and penoxsulam can be applied as a foliar spray or as a submersed application to the water column, whereas fluridone is effective only as an in-water treatment. Although in-water herbicide applications can be effective for treating these floating weed species, this method may not be feasible for sites where high water exchange or flow affect herbicide contact time and may be prohibitively expensive in larger systems.

Giant and common salvinia can be difficult to manage using herbicides because they are small floating plants that produce dense stands with plants layered on top of one another. This layering of plants presents a challenge when applying herbicides to foliage because plants in lower layers of the mats are protected from herbicides by plants in the upper layers of the mats. If plants are dense and a thick vegetative mat has formed, multiple applications will be required to achieve successful long-term control. In addition, giant and common salvinia can survive short dewatering or drawdown events and can persist on moist soils; therefore, spraying shoreline areas in addition to plants on the water surface is important to prevent re-infestation via surviving plant material. Long-term management with herbicides requires follow-up monitoring to spot-spray any plant material that survived the initial application. As a good management practice, herbicides should be routinely rotated and/or combined with other control strategies to minimize the potential development of herbicide resistance (Section 3.7.2).

Several insects have been investigated as biological control agents (Section 3.6.1) against salvinia species, but the salvinia weevil (*Cyrtobagous salviniae*) is recognized throughout the world as the insect of choice for management of giant and common salvinia. This insect feeds and reproduces only on plants in the Salviniaceae family. The salvinia weevil is a small (less than 1/16 inch long) black weevil that, like salvinia, is native to South America. Adults feed on floating fronds and rhizomes but prefer newly formed buds. The larvae of the salvinia weevil are white, 1/8 inch long and feed within the floating and submersed fronds, rhizomes and buds. Feeding by the larvae is often more destructive than that of adults. The combined feeding action of adults and larvae can be devastating and can impact field populations of giant and common salvinia in several months as opposed to the longer periods of time required by other insect biocontrol agents. Attacked plants turn brown in small patches that merge together until the whole colony loses structural integrity, becomes waterlogged and sinks. Although never intentionally released, the salvinia weevil was first detected in Florida in 1960, where it is now widespread and feeds primarily on common salvinia. Initial attempts to release weevils collected from Florida to manage giant salvinia in Texas and Louisiana were ineffective. This prompted researchers to seek permission from the Technical Advisory Group and the USDA-APHIS-PPQ (US Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine – see Section 3.6), to release a strain of the salvinia weevil from Australia which was highly effective in overseas applications. Permission was granted in 2001 and the Australian weevils were released in east Texas and western Louisiana only. The weevils, have become established in some localized sites and are beginning to impact giant salvinia populations. However, recent evidence suggests that *C. salviniae* fail to overwinter in temperate locales in Texas and Louisiana. The inability of *C. salviniae* to oviposit (lay eggs) and for larvae to develop below water temperatures of 66 °F and 63 °F, respectively, indicates the importance of water temperature as a limiting factor for the successful establishment of this biological control agent. Following cold winters, additional releases of *C. salviniae* will be required to reestablish the insect.

The potential utility of fungi as a biocontrol agent against giant salvinia has been investigated. Isolates of the fungal pathogens *Myrothecium roridum* and *M. verrucaria* have been evaluated as bioherbicides against several invasive weed species, including giant salvinia. While some isolates were shown to be virulent against salvinia, to date, plant pathogens have not been developed as biopesticides for use against this species.

Herbivorous fish such as triploid grass carp (Section 3.6.2) and tilapia (*Oreochromis* sp.) have been evaluated as possible biocontrol agents against salvinia with limited success. Laboratory feeding studies showed that while tilapia will consume giant salvinia, it is not their preferred food if other food sources are available. Other studies have shown that salvinia provides little nutritional benefit to herbivorous fishes.

The effectiveness of mechanical methods (Section 3.5) or manual removal (Section 3.4) is limited but may be useful in the early stages of an infestation or when a localized population is found on a small water body. If mechanical harvesting methods are employed, plant material must be properly disposed of in upland areas where the potential for contamination of other water bodies is minimized. Mechanical removal is not economically feasible once giant or common salvinia is well established and covers large areas. However, combining mechanical removal with herbicide applications can be an effective integrated weed management strategy. For example, in 2003, the Hawaii Department of Agriculture was successful in controlling 300 acres of giant salvinia on Lake Wilson on Oahu using multiple applications of the herbicide glyphosate combined with mechanical removal techniques. Excavated plant material was safely disposed of in nearby pineapple fields.

Other management options (Section 3.4). Floating booms have been used to contain and limit the spread of giant and common salvinia in some systems but are generally only utilized to confine plants to one location while other management strategies such as herbicides or weevils are deployed. Drawdowns can be a low-cost, effective management approach in some situations where water levels can be manipulated. However, dewatering must occur over a long period of time to allow plants to become stranded on dry land where they will desiccate and/or be exposed to freezing temperatures. Plant material can remain viable for several months if stranded shoreline mats are dense and underlying moisture is present. Decaying plant material along shorelines can be unsightly and plant fragments can easily be blown back into the system.

Summary

Giant and common salvinia are fast-growing, mat-forming aquatic ferns that can quickly cover the water surface of lakes, rivers and other wetland habitats. They are aggressive competitors that reproduce only by vegetative means. The plants can tolerate a wide range of growing conditions but prefer warm, nutrient-rich waters and full sunlight. Giant and common salvinia prefer freshwater environments and will not colonize saline or brackish waters. Once established, herbicides can be used to effectively manage these plants; however, multiple applications, follow-up monitoring and spot treatments may be required to maintain long-term control. Introducing insect biocontrol agents such as the salvinia weevil can be effective for maintenance control in some systems. The salvinia weevil has been especially successful in Florida for keeping common salvinia populations in check. Preventing the spread of this plant through citizen watch programs, boat launch surveillance and enforcement and compliance with laws to prevent the cultivation, sale and transport of these species will be important for containing and minimizing further spread of giant and common salvinia in the US.

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Page 79: Giant salvinia at Lake Wilson, Oahu; Linda Nelson, USACE ERDC
Page 80: Line drawing; University of Florida Center for Aquatic and Invasive Plants
Page 81 upper: Common salvinia; Ted Center, bugwood.org
Page 81 lower: Giant salvinia; Mic Julien, bugwood.org
Page 83: *Cyrtobagous salviniae* on giant salvinia frond; Scott Bauer, bugwood.org