Giant Salvinia (*Salvinia molesta*)

Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, 2015
Revised, September 2018
Web Version, 8/19/2109

Photo: Forest & Kim Starr. Licensed under Creative Commons Attributions 3.0 Unported. Available: https://commons.wikimedia.org/wiki/File:Starr_071121-0017_Salvinia_molesta.jpg. (September 2018).

1 Native Range and Status in the United States

Native Range

From Thayer et al. (2018):

"southeast Brazil (Forno 1983)"

According to GISD (2018), *Salvinia molesta* is native to Argentina, Brazil, Columbia and Guyana.

Status in the United States

From Thayer et al. (2018):

"Status: Populations established in the southeast and southwest United States, including Guam, Hawaii, and Puerto Rico. Extirpated from colder climate states (Connecticut, District of Columbia, Kansas, Missouri, Virginia) and eradicated from Northern Alabama and California, and parts of the Carolinas, Florida, and Texas. More than 99% of the Pascagoula River population was killed by storm surge salinity or by being deposited on land during Hurricane Katrina in 2005, thus leaving about 2 hectares of *S. molesta* distributed over ~20 sites (Fuller et al. 2010)."

From Swearingen and Bargeron (2016):

"*S. molesta* is on the Federal Noxious Weed list and can invade most any type of aquatic system."

Means of Introductions in the United States

From GISD (2018):

"The attraction of *S. molesta* as an ornamental plant and as one of particular botanical interest has led to its spread to a far greater extent through intercontinental transport in aquarium and landscaping trades. Its introduction to North America, *S. molesta* is a popular aquarium plant throughout Australia (despite being banned) and continues to be kept in ponds and fish tanks in all States. It is sold through market gardens, pet shops, landscapers, with supplies coming from both wild harvesIt [*sic*]"

"Salvinia molesta is cultivated in public and private aquatic gardens, and nurseries in at least seventeen states in the USA. These sites are potential sources of release into natural systems and interestingly many cultivations are located in areas where infestations have been documented (McFarland et al. 2003)."

Remarks

According to GISD (2018) *Salvinia molesta* has been nominated as among 100 of the "World's Worst" invaders.

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2018):

"Kingdom Plantae
  Subkingdom Viridiplantae
    Infrakingdom Streptophyta
      Superdivision Embryophyta

Division Tracheophyta
Subdivision Polypodiophytina
Class Polypodiopsida
Subclass Polypodiidae
Order Salviniales
Family Salviniaceae
Genus *Salvinia*
Species *Salvinia molesta"*

"Taxonomic Status:
Current Standing: accepted"

From CABI (2018):

"Originally identified as a form of *S. auriculata, S. molesta* was renamed based on its fruiting bodies in 1972 (Mitchell, 1972)"

Size, Weight, and Age Range

From Thayer et al. (2018):

"Size: Paired fronds or leaves 2-4 cm long and 1-6 cm wide"

From CABI (2018):

"Plants…up to 30 cm long, 5 cm wide, mat-forming, mat to 2.5 cm thick (or much thicker, depending on local conditions such as water current, waves, etc.)."

"Leaves… 0.7-3 cm long, to 1.8 cm wide"

Environment

From GISD (2018):

"*Salvinia molesta* […] grows best in still or slow-moving water bodies including ditches, ponds, lakes, slow rivers and canals. In standing water it forms stable floating mats. It grows optimally at a water temperature of between 20°C and 30°C. Buds are killed when exposed for more than two hours to temperatures below -3°C or above 43°C. *Salvinia* is able to tolerate salinity levels one tenth that of seawater, allowing the weed to adapt to a wide range of benthic environments. Its growth rate decreases by 25% at a salinity level of 0.3%. Growth is greatly stimulated by an increase in nutrient levels."

From Thayer et al. (2018):

"*Salvinia molesta* demonstrates tolerance to freezing air temperature, but cannot withstand ice formation on the water surface except when dense mats protect the underlying plants (Whiteman and Room 1991).

"*Salvinia molesta* is strictly a freshwater species, not tolerating brackish or marine environments. In experimental trials, salinity above 7 parts per thousand (ppt) slowed growth and damaged plant tissues. Higher salt concentrations proved lethal. Plants maintained at 11 ppt were killed after 20 hours exposure. Full strength seawater (35 ppt) killed plants in 30 minutes (Divakaran et al. 1980)."

Climate/Range

From GISD (2018):

"*Salvinia molesta* prefers tropical, sub-tropical or warm temperate areas of the world […]"

Distribution Outside the United States

Native

From Thayer et al. (2018):

"Native Range: southeast Brazil (Forno 1983)"

According to GISD (2018), *Salvinia molesta* is native to Argentina, Brazil, Columbia and Guyana.

Introduced

According to GISD (2018), *Salvinia molesta* has established populations in: Australia, Bangladesh, Bermuda, Botswana, Burkina Faso, Cote D'iroive, Cuba, Fuji, France, French Polynesia, Ghana, India, Indonesia, Italy, Japan, Kenya, Madagascar, Malaysia, Mauritius, Mexico, Namibia, New Caledoinia, New Zealand, Papua New Guinea, Philippines, Portugal, Reunion, Senegal, Singapore, South Africa, Sri Lanka, Swaziland, Thailand, Trinidad, Uganda, United Republic of Tanzania, United States, Vanuatu, Zambia and Zimbabwe (PIER 2012, EPPO 2012).

Means of Introduction Outside the United States

From Thayer et al. (2018):

"The first establishment outside of its native range was in Sri Lanka in 1939 (Room 1990), by the Botany Department at the University of Colombo. The species continued to be introduced to other warm regions of the world intentionally as an aquarium and water garden plant, and unintentionally as a contaminant in shipments of other aquatic plants (Oliver 1993; Nelson 1984). Once established in a new region, the plant is likely spread as a hitchhiker on boats, trailers and other recreational gear. Local movement between waterbodies may be facilitated by birds and aquatic mammals (Mitchell and Thomas 1972)."

From GISD (2018):

"The attraction of *S. molesta* as an ornamental plant and as one of particular botanical interest has led to its spread to a far greater extent through intercontinental transport in aquarium and landscaping trades. Its introduction to North America, *S. molesta* is a popular aquarium plant

throughout Australia (despite being banned) and continues to be kept in ponds and fish tanks in all States. It is sold through market gardens, pet shops, landscapers, with supplies coming from both wild harves[t] […]"

"Boat: *Salvinia molesta* may be spread within and between water-bodies by contaminated boats, boat trailers, motors and recreation and fishing gear. […]

"Garden escape/garden waste: The plants popularity with pond and aquarium owners, its floating mechanism of dispersal and its rapid growth rate have made it an especially good candidate for garden escape. Most incursions of the weed into natural habitats in Australia are thought to be due to the cultivation of salvinia by aquarium or pond owners and its subsequent release due to floods or intentional dumping by humans into the environment (ARMCANZ,2000).

"Off-road vehicles: *Salvinia molesta* may be spread over long distances (within or between waterbodies) on anything entering infested waters, including boats, trailers, vehicular wheels, engine intakes, fishing gear, recreational gear and boots (Howard and Harley, 1998; McFarland et al., 2003).

"On animals: Animals may also contribute to vegetative spread; hippos in Africa and water buffalo in Austraila [sic] have been recorded to carry *Salvinia molesta* both within and between water-bodies (Miller and Wilson 1989, Storrs and Julien 1996, in McFarland et al., 2003; Howard and Harley, 1998).

"On animals (local): *Salvinia molesta* reproduces vegetatively and is dispersed by wind and water (PIER 2012).

"Water currents: Vegetative propagules of *Salvinia molesta* may be spread within water-bodies by water currents (Howard and Harley 1998)."

Short Description

From Thayer et al. (2018):

"Free floating, aquatic fern. Consists of horizontal stems that float just below the water surface, and produce a whorl of three leaves (technically fronds) at each node. The upper pair of floating or emergent leaves are green in color and ovate to oblong in shape. The lower submerged leaf is brown, highly divided and resembles and functions as a root. The lower leaves may grow to great lengths (up to 25 cm), and by creating drag, act to stabilize the plant (Mitchell and Tur 1975; Room 1983).

"Upper surfaces of green fronds are covered with rows of white, bristly hairs (papillae) (Mitchell 1972), which divide into four thin branches that soon rejoin at the tips to form a cage. The resulting structures resemble tiny eggbeaters. This characteristic eggbeater structure can reliably distinguish *S. molesta* from the morphologically similar *S. minima* that has unjoined hairs (Wunderlin and Hansen 2011). These specialized hairs create a water repellent, protective covering (Mitchell and Thomas 1972).

"Sporocarps develop in elongated chains among the submersed leaves. *Salvinia molesta* is known for its egg-shaped sporocarps that end in a slender point. Mature plants can produce large quantities of sporocarps, which are actually outer sacs that contain numerous sporangia. However, the sporangial sacs are usually empty of microscopic spores or with only a few deformed remnants. Being a pentaploid species, *S. molesta* demonstrates irregularities during meiosis that prevent spore formation and result in functionally sterile plants (Loyal and Grewal 1966; Mitchell 1979).

"Three growth forms have been described where individual leaves can range from a few millimeters to 4 centimeters in length. During early colonization small leafed, thin plants lie flat on the water surface. As populations expand, leaves curl at the edges in response to self-competition. Later a vertical leaf position is attained as mature plants press into tight chains to form mats of innumerable floating plants (Mitchell and Thomas 1972; Mitchell and Tur 1975)."

Biology

From Thayer et al. (2018):

"Reproduction is strictly vegetative as spores are sterile (Mitchell 1979). Under favorable natural conditions, biomass can double in about one week to 10 days (Mitchell and Tur 1975; Mitchell 1979). Biomass weights of live plants approach those recorded for floating waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) (Mitchell 1979).

"*Salvinia molesta* demonstrates tolerance to freezing air temperature, but cannot withstand ice formation on the water surface except when dense mats protect the underlying plants (Whiteman and Room 1991).

"*Salvinia molesta* is strictly a freshwater species, not tolerating brackish or marine environments. In experimental trials, salinity above 7 parts per thousand (ppt) slowed growth and damaged plant tissues. Higher salt concentrations proved lethal. Plants maintained at 11 ppt were killed after 20 hours exposure. Full strength seawater (35 ppt) killed plants in 30 minutes (Divakaran et al. 1980)."

From GISD (2018):

"The plant propagates by vegetative growth and sporadic fragmentation, resulting in small vegetative propagules that are dispersed by water currents (Jacono 2003)."

"Depending on the climate *Salvinia molesta* may be either a perennial or an annual. In non-tropical regions it may function as an annual but it will still produce significant growth during the summer period. In nutrient rich waters it may reach a density of 30,000 small plants per m^2 and under ideal growth conditions it can double its biomass in two days. The plant passes through three identifiable growth stages, the development of which are determined by environmental conditions). The growth of single ramets (plantlets) is known as the primary growth stage and the growth of a linear chain of ramets is known as the secondary growth stage. Finally, the formation of a compact vegetative cluster is known as the tertiary phase (ARMCANZ ANZECC 2000; ARMCANZ ANZECC 2000; WAPMS 2003; Jacono 1999)."

Human Uses

From GISD (2018):

"Floating aquatic weeds have been used for mulch, compost, fodder, paper making, handcrafts and bio-gas generation (Howard and Harley, 1998). The main impediment to the commercial use of floating aquatic weeds such as Salvinia is their high water content, which is often up to 90% of the harvest wet weight. Thus a large proportion of the harvest is water, while only a small proportion is actually plant matter. The high growth rate of aquatic weeds may lead to an optimistic evaluation of their commercial use but the commercial [*sic*] benefits are negligible [*sic*] in comparison to their known wide-ranging negative socio-economic and environmental impact (Julien Center and Tipping 2002; Mitchell D. Pers. Comm. 2005)."

From CABI (2018):

"*S. molesta* is not only efficient at removing nutrients from water but also in removing heavy metals, making it potentially useful in a variety of wastewater applications (Shimada et al., 1988). Experimentally, it concentrates phosphorus, nitrogen, potassium, manganese, iron and zinc in dry tissues by about 10, 2, 1, 5, 3, and 10,000 times their respective concentrations in the water and appears to have some potential in water purification (Parsons and Cuthbertson, 1992). *S. molesta* has been used in a variety of mining remediations around the world (Sukumaran, 2013; Ashraf et al, 2011; Prasad, 2010), and has also been used in treating high-nutrient swine farm runoff water (Yang and Chen, 1994)."

From Thayer et al. (2018):

"Few have researched the beneficial effects of *S. molesta*. Due to its floating habit, *S. molesta* was utilized to treat sewage and industrial effluent (Finlayson et al. 1982). Asian countries have supplemented livestock fodder with *S. molesta*, and utilized it as a compost and mulch (Oliver 1993; Thomas and Room 1986)."

Diseases

No information was found.

Threat to Humans

From CABI (2018):

"Infestations of *S. molesta* contribute to human health problems. Dense mats of *S. molesta* are an important plant host of Mansonia spp. mosquitoes (Diptera: Culicidae), which have been identified as vectors of West Nile Virus, St. Louis Encephalitis, Venezuelan Equine Encephalitis and rural elephantiasis (Pancho and Soerjani, 1978; Chow et al., 1955; Ramachandran, 1960; Lounibos et al., 1990). It also shelters mosquito species that are responsible for the transmission of encephalitis, malaria and dengue fever in other areas (Creagh, 1991/92). Infestations also harbour snails that transmit schistosomiasis (Holm et al., 1977)."

3 Impacts of Introductions

From Thayer et al. (2018):

"*Salvinia molesta* has the potential to alter aquatic ecosystems in several ways. Rapidly expanding populations can overgrow and replace native plants resulting in dense surface cover that prevents light and atmospheric oxygen from entering the water. Decomposing plant material drops to the bottom, consuming dissolved oxygen needed by fish and other aquatic life (Divakaran et al. 1980). Flores and Carlson (2006) noted a 2.5 fold increase in dissolved oxygen by removing 90% of *S. molesta* at five east Texas sites.

"Floating mats of *S. molesta* can be up to one meter thick (Whiteman and Room 1991), impeding navigation, reducing water flow and interfering with fishing and recreational activities (Mitchell and Thomas 1972). This could be significant in areas where economic or subsistence fishing is important (Mitchell et al. 1980). Like dense floating mats of waterhyacinth, dense floating mats of *S. molesta* support secondary colonizing plants, leading to the formation of floating islands or tussocks (McFarland et al. 2004; Mitchell et al. 1980).

From Flores and Carlson (2006):

"Giant salvinia develops dense mats that interfere with rice cultivation, clog fishing nets, and disrupt access to water for humans, livestock, and wildlife (Mitchell and Gopal 1991, Creigh 1991). It damages aquatic ecosystems by overgrowing and replacing native plants that provide food and habitat for native animals and waterfowl (Mitchell 1978, Mitchell and Gopal 1991)."
From GISD (2018):

"*Salvinia molesta* reduces oxygen diffusion into the water reducing the quality of the habitat for fauna and encouraging animals to search for better conditions if possible."

"Near the Sepik river entire villages had to be abandoned because they were entirely dependent on water transport. When the lakes and lagoons beside villages became chocked with Salvinia and water hyachinth villagers could no longer travel to trade, fish or harvest staple foods. Access to schools and hospital care was also blocked (Howard and Harley, 1998; Mitchell et al., 1980, Thomas and Room, 1986a, in McFarland et al., 2003). In parts of Papau New Guinea heavy salvinia infestations have caused a reduction in fish numbers and have made it difficult to use seine, gill and cast nets and long lies."

4 Global Distribution

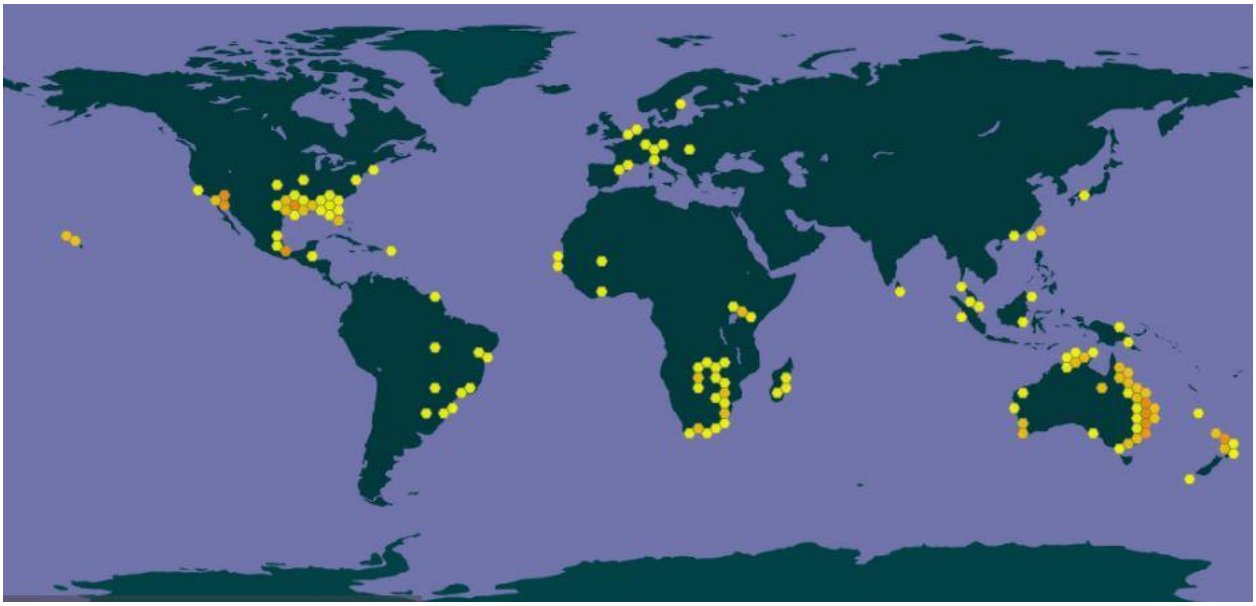

Figure 1. Known global distribution of *Salvinia molesta*. Known locations are found on all continents except for Antarctica. Map from GBIF Secretariat (2018).

5 Distribution Within the United States

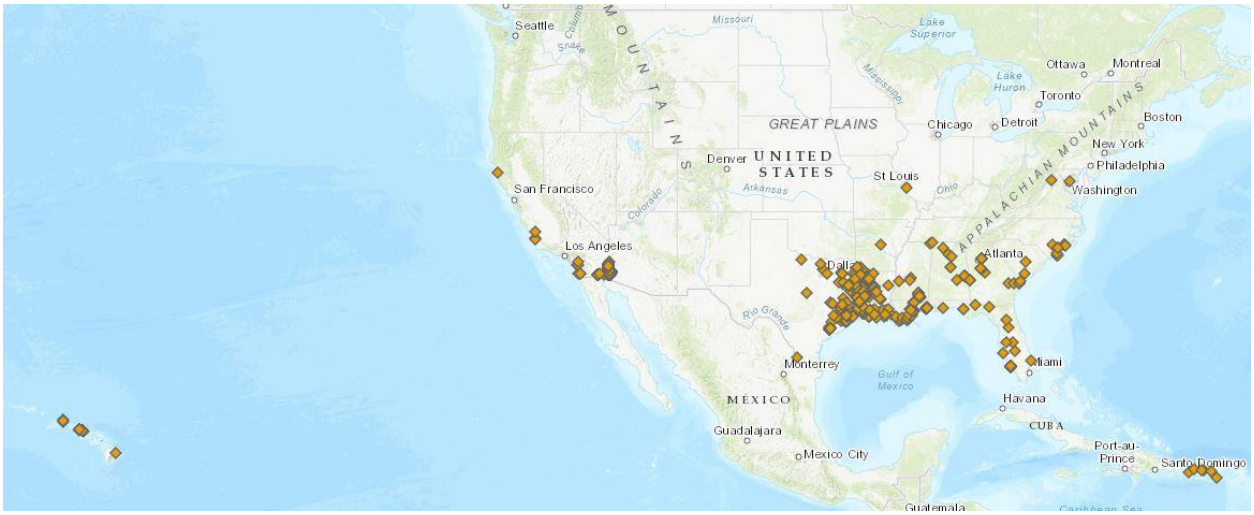

Figure 2. Known distribution of *Salvinia molesta* in the United States. Map from Thayer et al (2018).

6 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Salvinia molesta* was high for most of the eastern contiguous United States as well as the extreme southwest and a small area of the Pacific Northwest. There were areas of low match in the upper Midwest and in small patches in the Great Plains and Pacific Northwest. Everywhere else had a medium climate match. The Climate 6 score (Sanders et al. 2018; 16 climate variables; Euclidean distance) for contiguous United States was 0.614, high (scores 0.103 and greater are classified as high). All States had high individual Climate 6 scores except for Idaho, Minnesota, and Wyoming, which had medium scores, and North Dakota, which had a low score.

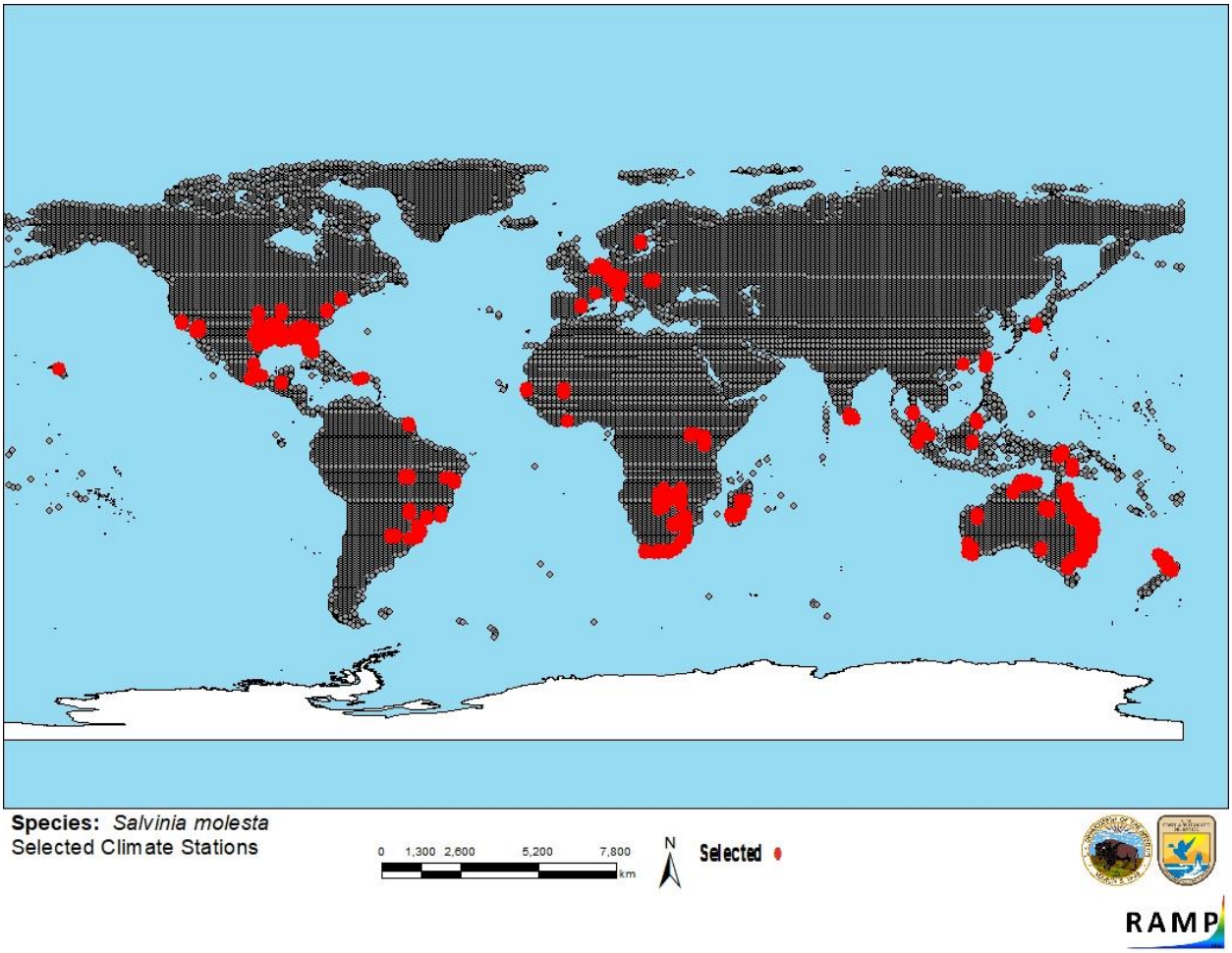

Figure 3. RAMP (Sanders et al. 2018) source map showing weather stations in Africa, Asia, Australia, Europe, North America and South America selected as source locations (red) and non-source locations (gray) for *Salvinia molesta* climate matching. Source locations from GBIF Secretariat (2018). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

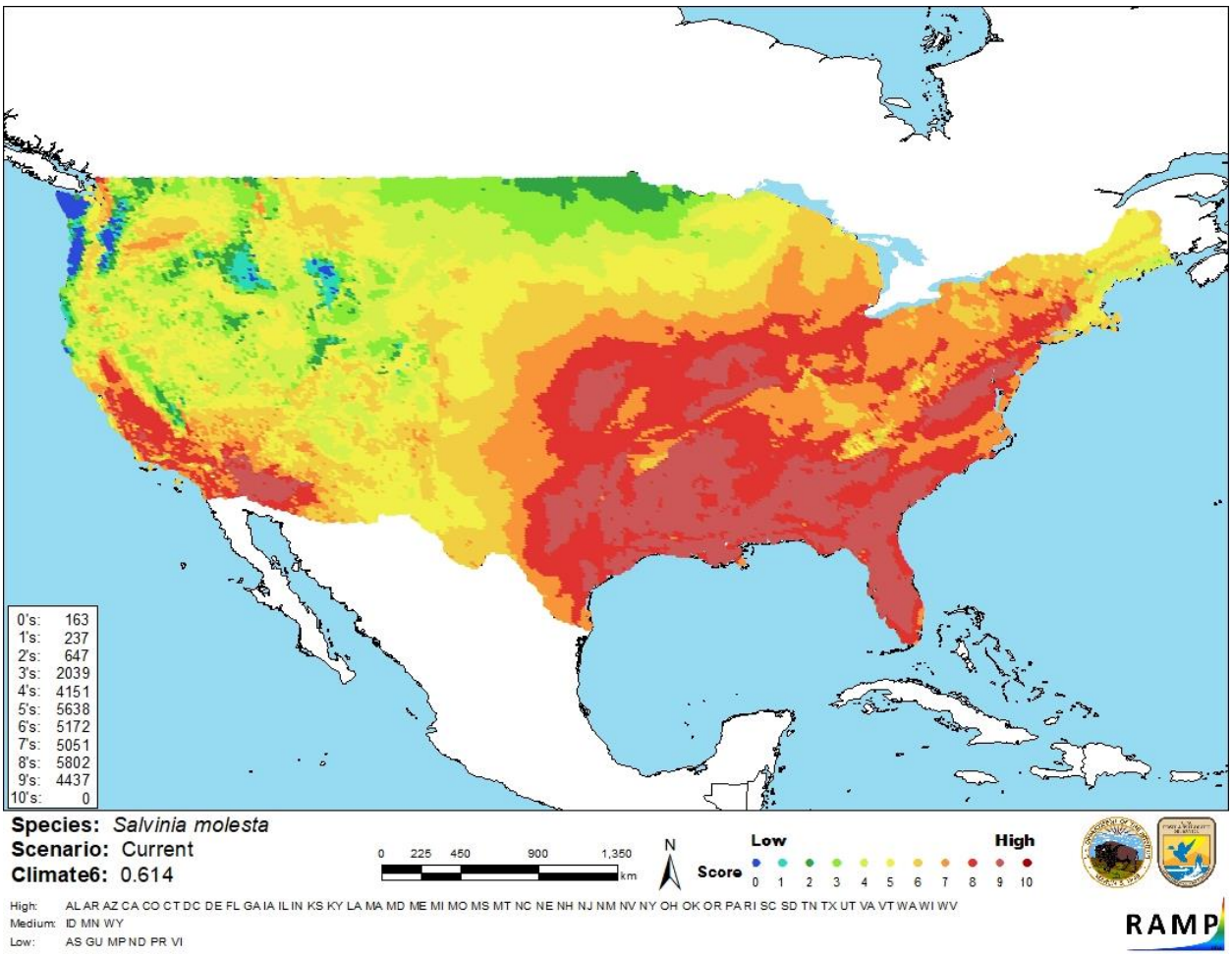

Figure 4. Map of RAMP (Sanders et al. 2018) climate matches for *Salvinia molesta* in the contiguous United States based on source locations reported by GBIF Secretariat (2018). Counts of climate match scores are tabulated on the left. 0 = Lowest match, 10 = Highest match.

The High, Medium, and Low Climate match Categories are based on the following table:

Climate 6: Proportion of (Sum of Climate Scores 6-10) / (Sum of total Climate Scores)	Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

7 Certainty of Assessment

Due to its invasiveness, information is readily available on *Salvinia molesta*. Having spread to multiple continents, *S. molesta* and its impacts have been highly observed. Information on the biology, invasion history and impacts of this species is substantial, including considerable peer-reviewed literature. There is enough information available to describe the risks posed by this species. Certainty of this assessment is high.

8 Risk Assessment

Summary of Risk to the Contiguous United States

Salvinia molesta is a free floating aquatic fern that is highly invasive. When in the proper climate, *S. molesta* becomes a dense mat that interferes and alters with the aquatic ecosystem. Native to only four countries in South America, established non-native populations of *S. molesta* exist in Africa, Asia, Australia, Europe, North America and South America. It was first introduced to the United States as an ornamental plant. It is listed as a U.S. Federal Noxious Weed. A high climate match score and proof of invasion within the contiguous United States (and multiple other countries) allows for high certainty of this assessment. The overall risk assessment for *Salvinia molesta* is high.

Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): High**
- **Certainty of Assessment (Sec. 7): High**
- **Remarks/Important additional information:** No additional remarks.
- **Overall Risk Assessment Category: High**

9 References

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 10.

CABI. 2018. *Salvinia molesta* (Kariba weed) [original text by K. Parysand, and A. Mikulyuk]. *In* Invasive Species Compendium. CAB International, Wallingford, U.K. Available: https://www.cabi.org/ISC/datasheet/48447. (October 2018).

Flores, D., and J. W. Carlson. 2006. Biological control of giant salvinia in East Texas waterways and the impact on dissolved oxygen levels. Journal of Aquatic Plant Management 44:115–121.

GBIF Secretariat. 2018. GBIF backbone taxonomy: *Salvinia molesta* (D. Mitch.). Global Biodiversity Information Facility, Copenhagen. Available: https://www.gbif.org/species/5274863. (October 2018).

GISD (Global Invasive Species Database). 2018. Species profile: *Salvinia molesta*. Invasive Species Specialist Group, Gland, Switzerland. Available: http://www.iucngisd.org/gisd/speciesname/Salvinia+molesta. (October 2018).

ITIS (Integrated Taxonomic Information System). 2018. *Salvinia molesta,* (D.S. Mitch.). Integrated Taxonomic Information System, Reston, Virginia. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=181823#null. (October 2018).

Sanders, S., C. Castiglione, and M. Hoff. 2018. Risk assessment mapping program: RAMP, version 3.1. U.S. Fish and Wildlife Service.

Swearingen, J., and C. Bargeron. 2016. Invasive Plant Atlas of the United States. University of Georgia Center for Invasive Species and Ecosystem Health. Available: http://www.invasiveplantatlas.org/. (October 2018).

Thayer, D. D., I. A. Pfingsten, C. C. Jacono, M. M. Richerson, and V. Howard. 2018. *Salvinia molesta* (Mitchell). U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, Florida. Available: https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=298. (September 2018).

10 References Quoted But Not Accessed

Note: The following references are cited within quoted text within this ERSS, but were not accessed for its preparation. They are included here to provide the reader with more information.

Agriculture and Resource Management Council of Australia and New Zealand, Australian and New Zealand Environment and Conservation Council and Forestry Ministers. 2000. Weeds of national significance salvinia (*Salvinia molesta*) strategic plan. National Weeds Strategy Executive Committee, Launceston, Australia.

Ashraf, M. A., M. J. Maah, and I. Yusoff. 2011. Heavy metals accumulation in plants growing in ex tin mining catchment. International Journal of Environmental Science and Technology 8(2):401–416.

Chow, C. Y., E. S. Thevasagayam, and E. G Wambeek. 1955. Control of Salvinia-a host plant of *Mansonia* mosquitos. Bulletin of the World Health Organization 12(3):365–9.

Creigh, C. 1991. A marauding weed in check. Australia. Ecos 70:26–29.

Divakaran, O., M. Arunachalam, and N. Balakrishnan Nair. 1980. Growth rates of *Salvinia molesta* Mitchell with special reference to salinity. Proceedings of the Indian Academy of Sciences Plant Sciences 89(3):161–168.

EPPO (European and Mediterranean Plant Protection Organization). 2012. *Salvinia molesta* (Salviniaceae).

Finlayson, C. M., T. P. Farrell, and D. J. Griffiths. 1982. Treatment of sewage effluent using the water fern salvinia. Water Research Foundation of Australia, Kingsford, New South Wales.

Forno, I. W. 1983. Native distribution of the *Salvinia auriculata* complex and keys to species identification. Aquatic Botany 17:71–83.

Fuller, P. L., M. G. Pursley, D. Diaz, and W. Devers. 2010. Effects of Hurricane Katrina on an incipient population of giant salvinia *Salvinia molesta* in the lower Pascagoula River, Mississippi. Gulf and Caribbean Research 22:63–66.

Holm, L. G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. The world's worst weeds distribution and biology. University Press of Hawaii, Honolulu.

Howard, G. W., and K. L. S. Harley. 1998. How do floating aquatic weeds affect wetland and conservation and development? How can these effects be minimised? Wetlands Ecology and Management 5:215–225.

Jacono, C. C. 1999. *Salvinia molesta* (Salviniaceae) new to Texas and Louisiana. SIDA Contributions to Botany 18(3):927–928.

Jacono, C. C. 2003. *Salvinia molesta* D.S. Mitchell. U.S. Geological Survey.

Julien, M. H., T. D. Center, and P. W. Tipping. 2002. Floating fern (Salvinia). *In* R. Van Driesche, et al. [Source material did not give full list of editors.] Biological control of invasive plants in the eastern United States. USDA Forest Service Publication.

Loyal, D. S., and R. K. Grewal. 1966. Cytological study on sterility in *Salvinia auriculata* Aublet with a bearing on its reproductive mechanism. Cytologia 31(3):330–338.

Lounibos, L. P., V. L. Larson, and C. D. Morris. 1990. Parity, fecundity and body size of *Mansonia dyari* in Florida. Journal of the American Mosquito Control Association 6(1):121–126.

McFarland, et al. 2003. [Source material did not give full citation for this reference.]

McFarland, D. G., L. S. Nelson, M. J. Grodowitz, R. M. Smart, and C. S. Owens. 2004. *Salvinia molesta* D. S. Mitchell (giant salvinia) in the United States: a review of species ecology and approaches to management. U.S. Army Corps of Engineers Aquatic Plant Control Research Program, Jacksonville, Florida.

Miller and Wilson. 1989. [Source material did not give full citation for this reference.]

Mitchell, D. S. 1972. The Kariba weed: *Salvinia molesta*. British Fern Gazette 10:251–252.

Mitchell, D. S. 1979. The incidence and management of *Salvinia molesta* in Papua New Guinea. FAO Report to the Office of the Environment and Conservation, Papua New Guinea.

Mitchell, D. S., and B. Gopal. 1991. Invasion of tropical freshwater by alien aquatic plants. Pages 139–154 in Ecology of biological invasion of the tropics. International Scientific Publications, New Delhi.

Mitchell, D. S., T. Petr, and A. B. Viner. 1980. The water-fern *Salvinia molesta* in the Sepik River, Papua New Guinea. Environmental Conservation 7(2):115–122.

Mitchell, D. S., and P. A. Thomas. 1972. Ecology of water weeds in neotropics. An ecological survey of the aquatic weeds *Eichhornia crassipes* and *Salvinia* species, and their natural enemies in the Neotropics. UNESCO, Technical papers in Hydrology 12, Paris.

Mitchell, D. S., and N. M. Tur. 1975. The rate of growth of *Salvinia molesta* (*S. Auriculata* Auct.) in laboratory and natural conditions. The Journal of Applied Ecology 12(1):213–225.

Nelson, B. 1984. *Salvinia molesta* Mitchell does it threaten Florida? Aquatics 6(3):6–8.

Oliver, J. D. 1993. A review of the biology of giant salvinia (*Salvinia molesta* Mitchell). Journal of Aquatic Plant Management 31:227–231.

Pancho, J. V, and M. Soerjani. 1978. Aquatic weeds of Southeast Asia. A systematic account of common Southeast Asian aquatic weeds.

Parsons, W. T., and E. G. Cuthbertson. 1992. Noxious weeds of Australia. Inkata Press Melbourne, Australia.

PIER (Pacific Island Ecosystems at Risk). 2003. *Salvinia molesta*. [Source material did not give full citation for this reference.]

Prasad, M. N. V. 2010. Exploring the potential of wetland plants for cleanup of hazardous waste. Journal of Basic and Applied Biology 4(3):18–28.

Ramachandran, C. P. 1960. The culture of *Mansonia* using an aquatic plant - Salvinia. Transactions of the Royal Society of Tropical Medicine and Hygiene 54:6–7.

Room, P. M. 1990. Ecology of a simple plant-herbivore system: biological control of salvinia. Tree 5(3):74–79.

Shimada, N., S. Yajima, and Y. Watanabe. 1988. Improvement of water quality using *Salvinia molesta* - absorption of nitrogen and phosphorus by *Salvinia molesta*. Technical Bulletin, Faculty of Horticulture, Chiba University 41:15–21.

Storrs and Julien. 1996. [Source material did not give full citation for this reference.]

Sukumaran, D. 2013. Phytoremediation of heavy metals from industrial effluent using constructed wetland technology. Applied Ecology and Environmental Services 1(5):92–97.

Thomas, P. A., and P. M. Room. 1986. Taxonomy and control of *Salvinia molesta*. Nature 320(6063):581–584.

Western Aquatic Plant Management Society. 2003. *Salvinia molesta*. [Source material did not give full citation for this reference.]

Whiteman, J. B., and P. M. Room. 1991. Temperatures lethal to *Salvinia molesta* Mitchell. Aquatic Botany 40:27–35.

Wunderlin, R. P., and B. F. Hansen. 2011. Guide to the vascular plants of Florida, 3rd edition. University Press of Florida, Gainesville.

Yang and Chen. 1994. [Source material did not give full citation for this reference.]