Water Spangles (*Salvinia minima*)

Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, February 2023
Revised, August 2023
Web Version, 5/27/2025

Organism Type: Fern
Overall Risk Assessment Category: High

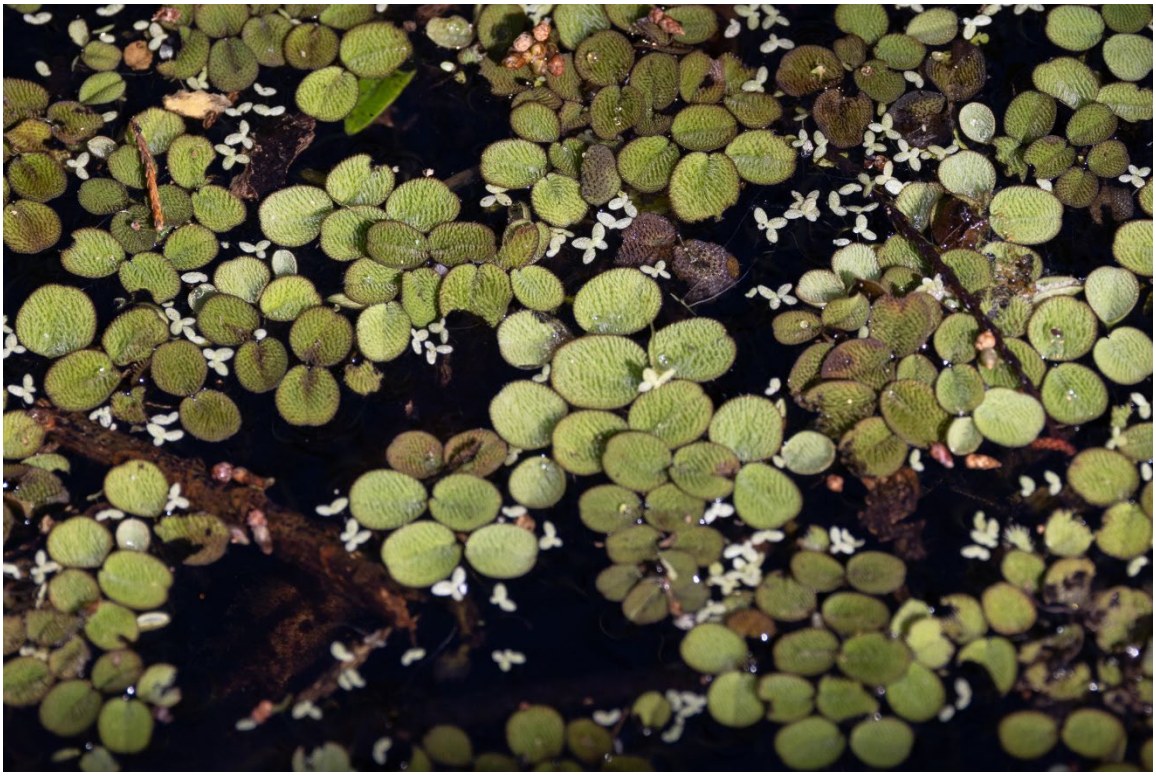

Photo: John Reynolds. Licensed under Creative Commons Attribution 4.0 International. Available: https://inaturalist-open-data.s3.amazonaws.com/photos/253652133/original.jpg (February 2023).

1 Native Range and Status in the United States

Native Range

From Howard Morgan et al. (2023):

"Native Range: Central and South America; common and wide-ranging from southern Mexico to northern Argentina and Brazil (Mickel and Beitel 1988, Stolze 1983). De la Sota (1976)

remarked that, in Argentina, the natural range of *Salvinia minima* could not be precisely determined due to its frequency in the water garden and aquarium trade."

POWO (2023) reports *Salvinia minima* as native in Argentina (Northeast, Northwest), Belize, Bolivia, Brazil (North, Northeast, South, Southeast, West-Central), Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Honduras, Mexico (Gulf, Northeast, Southeast, Southwest), Nicaragua, Panamá, Paraguay, Peru, Uruguay, and Venezuela.

Status in the United States

Howard Morgan et al. (2023) report *Salvinia minima* as established in Alabama, Arkansas, California, Florida, Georgia, Idaho, Louisiana, Mississippi, Ohio, Puerto Rico, South Carolina, Tennessee, and Texas; locally established in Missouri; introduced but with subsequent extirpation in Massachusetts, Minnesota, New Hampshire, and New Mexico; and introduction with unknown status in Hawaii, Illinois, New York, Oklahoma, and Virginia. It is reported as nonindigenous but a cultivated specimen in Washington D.C.

In contrast to Howard Morgan et al. (2023), POWO (2023) lists *Salvinia minima* as native to Puerto Rico.

From Lower (2023):

"Occasional populations rarely reported within the Great Lakes basin, but this species has not been reported to overwinter in the region."

Salvinia minima is available for purchase from vendors in the aquarium trade throughout the United States (e.g., Amazon 2023, Aquaticarts 2023), though no estimates of abundance were available.

Regulations

Salvinia minima is regulated in Texas (Texas Parks and Wildlife 2022). It is regulated at the genus level (*Salvinia*) in Louisiana (Louisiana Department of Agriculture and Forestry 2022), North Carolina (North Carolina Department of Environmental Quality 2022), and Oklahoma (Oklahoma Department of Wildlife Conservation 2022). Please refer back to state agency regulatory documents for details on the regulations, including restrictions on activities involving this species. While every effort has been made to list all applicable State laws and regulations pertaining to this species, this list may not be comprehensive. Notably, it does not include regulations that do not explicitly name this species or its genus or family, for example, when omitted from a list of authorized species with blanket regulation for all unnamed species.

Means of Introductions within the United States

From Howard Morgan et al. (2023):

"First reported in Florida in 1930, probably from ship ballast released into the Saint John River (Schmitz et al. 1998) and cultivated in greenhouses and gardens in the United States since the late 1880's (Weatherby 1921, 1937; Fernald 1950). Early plants in Florida likely entered natural

areas from flooding of cultivated pools or through intentional release (Jacono et al 2001). *Salvinia minima* is still widely available in the water garden trade, either as a sale item or a contaminant. Secondary introductions are likely due to hitchhiking on animals and boats."

From Parys and Johnson (2013):

"Like other aquatic weeds, *S. minima* can easily spread between water bodies if boats and vehicles are not properly cleaned (Johnstone et al. 1985; Miller & Wilson 1989; Jacono 2003). Weather can also contribute to the spread of *Salvinia* spp., as mats fragment when flooding occurs (Harley & Mitchell 1981; Room 1983, 1990)."

Remarks

No additional remarks.

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2023):

Kingdom Plantae
  Subkingdom Viridiplantae
    Infrakingdom Streptophyta
      Superdivision Embryophyta
        Division Tracheophyta
        Subdivision Polypodiophytina
          Class Polypodiopsida
            Subclass Polypodiidae
              Order Salviniales
                Family Salviniaceae
                  Genus *Salvinia*
                    Species *Salvinia minima* Baker

According to WFO (2023), *Salvinia minima* Baker is the current valid name for this species.

Size, Weight, and Age Range

From Howard Morgan et al. (2023):

"Size: 0.4 to 2 centimeters in length"

From CABI (2008):

"Stems can be up to 6 cm and leaves are from 1-1.5 cm long"

From GISD (2023):

"*Salvinia minima* is a free floating, rootless aquatic fern 1 to 4cm long."

Environment

From GISD (2023):

"*Salvinia minima* grow in still waters of ponds, small lakes, canals, and slow streams. It can also be found in shallow backwaters of bayous, oxbows, ditches, cypress swamps and marshes inhabiting water bodies with salinity levels as high as 4-7ppt."

Climate

From POWO (2023):

"It grows primarily in the wet tropical biome."

From CABI (2008):

"*S. minima* occurs […] in warm temperate areas (Jacono et al., 2001)."

Distribution Outside the United States

Native

From Howard Morgan et al. (2023):

"Native Range: Central and South America; common and wide-ranging from southern Mexico to northern Argentina and Brazil (Mickel and Beitel 1988, Stolze 1983). De la Sota (1976) remarked that, in Argentina, the natural range of *Salvinia minima* could not be precisely determined due to its frequency in the water garden and aquarium trade."

POWO (2023) reports *Salvinia minima* as native in Argentina (Northeast, Northwest), Belize, Bolivia, Brazil (North, Northeast, South, Southeast, West-Central), Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Honduras, Mexico (Gulf, Northeast, Southeast, Southwest), Nicaragua, Panamá, Paraguay, Peru, Uruguay, and Venezuela.

Introduced

From Tipping and Center (2005):

"It is adventive in Bermuda (Weatherby 1937), […] and Spain (Lawalree 1964)."

POWO (2023) reported *Salvinia minima* as introduced to the Leeward Islands of the Caribbean.

From Coetzee et al. (2022):

"A previously unrecorded alien species of *Salvinia* was discovered in South Africa at the Hartbeespoort Dam, North-West Province. […] It was confirmed that the Hartbeespoort Dam

plants were neither *Salvinia molesta* D. Mitch (giant salvinia), which has long been invasive in southern Africa, nor *Salvinia hastata* Desv., which is indigenous to east and west Africa (Henderson 2012). The species was subsequently identified as *Salvinia minima* Baker (Salviniaceae) […]"

"Here we document for the first time the establishment and spread of *S. minima* in southern Africa, […]"

From Onwuka et al. (2020):

"The results of this study [in Paya Indah Wetland Reserve, Malaysia] show that Lesser Whistling Duck prefered [sic] to utilize the lake area dominated with aquatic vegetation, such as; […], common duckweed (*Salvinia minima*), […]"

Means of Introduction Outside the United States

From GISD (2023):

"*S. minima* is still widely available in the water garden trade, either as a sale item or a contaminant (Jacono, 2003)."

Short Description

From CABI (2008):

"*S. minima* is a deep-green, free-floating, rootless, aquatic fern (ISSG, 2006). Stems can be up to 6 cm and leaves are from 1-1.5 cm long and almost round to elliptic. They are obtuse or notched at the apex and round to heart-shaped at the base. The upward surfaces of the fronds are covered with stiff hairs, with four separated branches. The under surface of the leaves are brown and pubescent with slender and unbranched hairs (Flora of North America Editorial Committee, 1993). The stiff hairs on the fronds serve to trap air, thus providing buoyancy (Dickinson and Miller, 1998). Obscure veins are areolate and do not quite reach to the leaf edges. Sporocarps occur in groups of four to eight, with up to 25 megasporangia (Flora of North America Editorial Committee, 1993)."

Biology

From Howard Morgan et al. (2023):

"Life history: *Salvinia minima* has three separate growth stages. In the primary stage, a small number of fern buds are introduced to a new environment, where they lie flat on the surface of the water. As the ferns grow into their secondary stage, their leaves being [sic] begin to curl upwards when the plants crowd against each other as they spread, while in the final tertiary stage, the leaves can become almost vertical due to crowding as the plants form a mat covering the water surface (Tewari and Johnson 2011)."

"The continuous branching and fragmentation of rhizomes turns out large volumes of vegetative daughter plants throughout the growing season. Copious hairy coverings minimize the

desiccation of plants spotted on boats, trailers, alligators, turtles, and even dogs leaving the water. Lateral buds deeply imbedded in the rhizome, may lie dormant during periods of reduced moisture and cold temperature. Small rhizome fragments, commonly sheltered in associating vegetation, provide material for reintroduction on the return of favorable growing conditions."

Human Uses

From Parys and Johnson (2013):

"*Salvinia minima* has a history of being sold in the nursery trade, and is still widely available on the internet in spite of its invasive nature (Forno et al. 1983; Kay & Hoyle 2001)."

From GISD (2023):

"*S. minima* is still widely available in the water garden trade, either as a sale item or a contaminant (Jacono, 2003).

Diseases

No information was found on diseases associated with *Salvinia minima*.

Threat to Humans

From Parys and Johnson (2013):

"Persistence of these mats also raises human health issues, as *Salvinia* spp. provides ideal habitat for *Mansonia* spp. (Diptera: Culicidae) which have been identified as vectors in the spread of West Nile Virus, St. Louis Encephalitis and Venezuelan Equine Encephalitis (Chow et al. 1955; Ramachandran 1960; Lounibos et al. 1990). Several species of biting midges (Diptera: Ceratopogonidae) have also associated with *Salvinia* infestations (Buckingham & Balciunas 1994; Borkent & Craig 2001)."

3 Impacts of Introductions

From Wersal and Madsen (2010):

"Waterhyacinth (*Eichhornia crassipes* [Mart.] Solms) and common salvinia (*Salvinia minima* Baker) are two floating aquatic plants that can cause wide-spread problems in the southern United States. These species can cause reductions in ecosystem function as well as the abundance of native plant species."

"In Louisiana, common salvinia biomass reached 1.02 kg m-2 and caused reductions in native plant abundance (Walley 2007)."

From Parys and Johnson (2013):

"Uncontrolled *S. minima* forms dense mats of plant material that decrease aesthetic value and limit use of aquatic areas (Montz 1989). Infestations obstruct waterways, decrease light

availability, reduce available dissolved oxygen, and alter pH levels (Hatch 1995; Flores & Carlson 2006)."

From Dickinson and Miller (1998):

"In the summer competition experiment, *Salvinia minima* grew rapidly and had negative effects on the relative change in cover of both *Azolla caroliniana* and *Spirodela punctata*. Relative change in cover of *Salvinia minima* increased when it was grown with *Spirodela punctata*, but only when *A. caroliniana* was not present. A negative correlation in the swamp between cover of *Salvinia minima* and *Spirodela punctata*, the two most abundant species during the summer, was consistent with the strong competitive effects of *Salvinia minima* in the summer competition experiment. During the autumn competition experiment, *S. minima* had a negative effect on the relative increase in *A. caroliniana* cover. This effect, however, was not competitive and was caused by a herbivore of *S. minima* that switched to *A. caroliniana* as the growth of *S. minima* slowed in the autumn."

From Howard Morgan et al. (2023):

"In Texas and Louisiana, *S. minima* typically occurs in dense, expansive populations and is known as a very troublesome weed. At Lacassine Bayou, southwestern Louisiana, plants completely blanket a waterway measuring 19.3 km long and 110 m wide (Jacono et al. 2001). Mats in Louisiana have been measured as thick as 20 - 25 cm (Montz 1989)."

"An eight-year study at Jean Lafitte National Historic Park, Louisiana, found complete displacement of native *Lemna* species by *Salvinia minima*. (T. Doyle, LA, pers. comm.). The Lemnaceae (duckweeds) contain high protein content and are important food sources for waterfowl."

From Tewari and Johnson (2011):

"Thick mats of common salvinia prevent sunlight from reaching submerged plants, whereas floating plant species such as antler fern (*Ceratopteris pteridoides* [Hooker]) and duckweed (*Lemna* spp.) are also displaced (USGS 2005b). Common salvinia can lower the dissolved oxygen of infested water and provide safe haven to pest species such as mosquitoes (USGS 2005b). Motor crafts used for recreational activities such as boating and fishing get tangled in thick floating mats of common salvinia, making it extremely difficult to navigate, and these infestations may hinder the ability of law enforcement agencies to carry out their duties effectively (USGS 2005b). Commercial activities such as rice and crawfish farming, water drainage, and electrical power generation can also be negatively impacted by common salvinia (Charles Dugas, Louisiana Department of Wildlife and Fisheries, retired, pers. comm.)."

"The cost of controlling common salvinia using herbicides by state and contract workers may range from $198 to $297/ha, depending on herbicide used, and the cost to private land owners is much higher (Charles Dugas, Louisiana Department of Wildlife and Fisheries, retired, pers. comm.)."

Salvinia minima has been regulated in four U.S. States: Louisiana (Louisiana Department of Agriculture and Forestry 2022), North Carolina (North Carolina Department of Environmental Quality 2022), Oklahoma (Oklahoma Department of Wildlife Conservation 2022), and Texas (Texas Parks and Wildlife 2022).

4 History of Invasiveness

The History of Invasiveness for *Salvinia minima* is classified as High. Established populations of *S. minima* have been found outside of its native range, primarily within the southeastern United States. Documented negative impacts include exclusion of native plants, changes in water chemistry, interference in recreational activities, high financial cost for control, and impacts to energy production.

5 Global Distribution

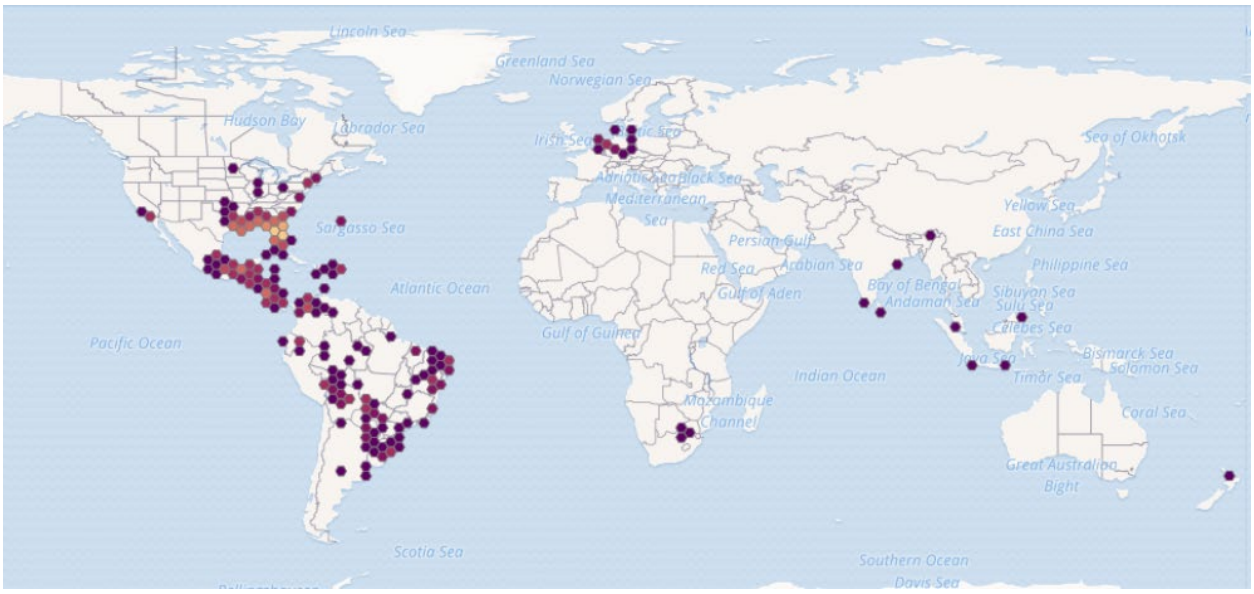

Figure 1. Known global distribution of *Salvinia minima*. Observations are reported from North America, Africa, Europe, and Asia. Points outside of North America, South America, South Africa, and peninsular Malaysia were excluded from the climate match as they were not found to represent established populations. Northern points in North America were not used to select source locations for the climate match, see section 6.

6 Distribution Within the United States

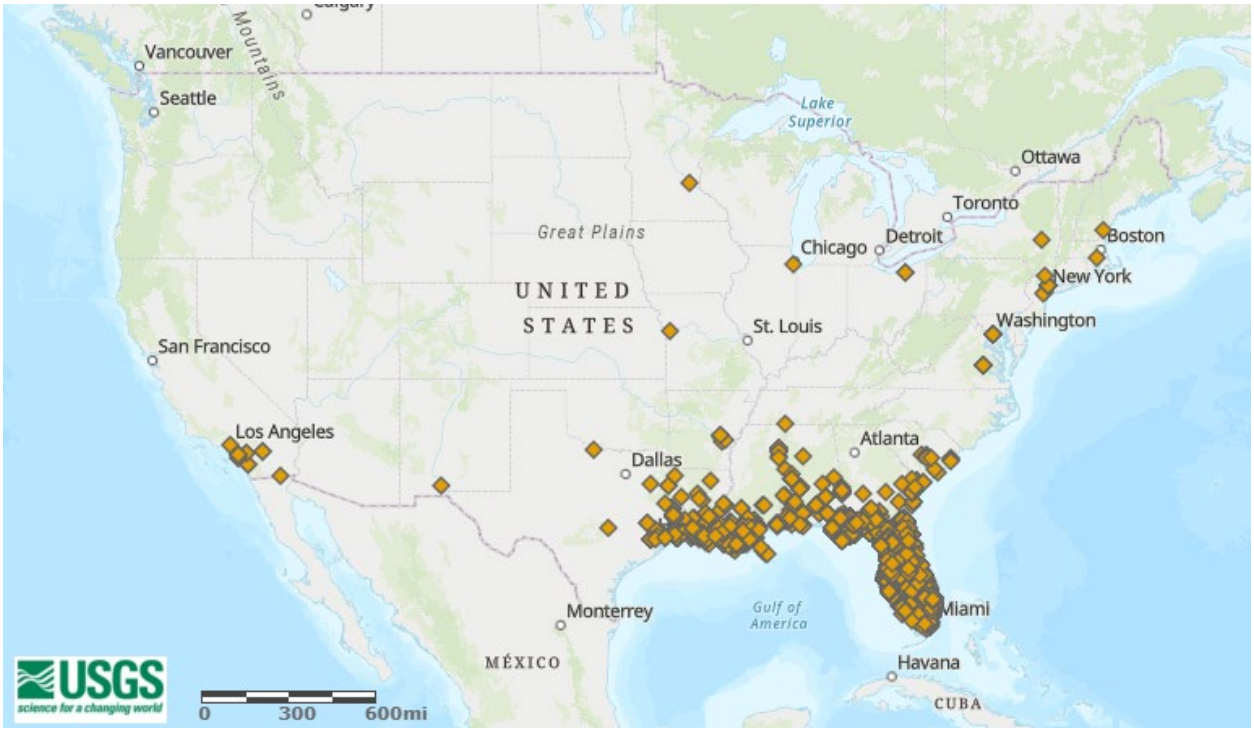

Figure 2. Reported observations of *Salvinia minima* in the contiguous United States. Map from USGS (2025). Points in Illinois, Massachusetts, Minnesota, New Hampshire, New Mexico, New York, Oklahoma, Virginia, District of Columbia, Ohio, and Kansas were excluded from the climate match as they were not found to represent established populations.

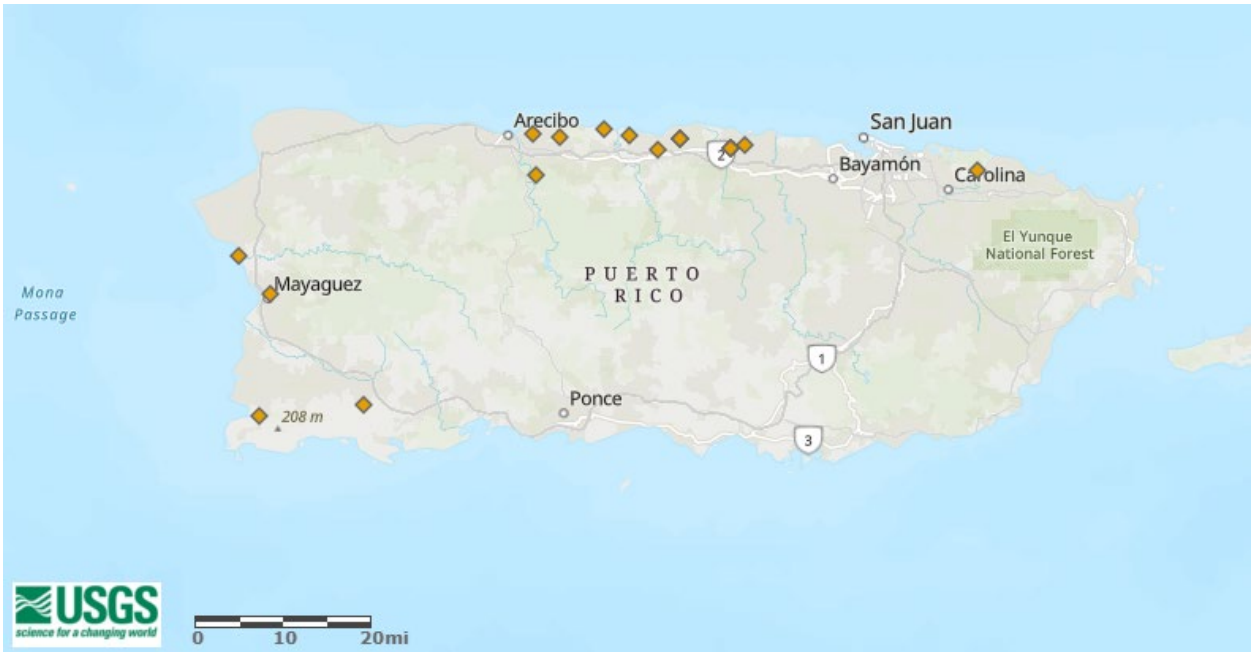

Figure 3. Reported observations of *Salvinia minima* in Puerto Rico. Map from USGS (2025).

Figure 4. Reported observation of *Salvinia minima* in Hawaii. Map from USGS (2025). This observation was not used in the climate matching analysis as the establishment status is unknown.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Salvinia minima* in the contiguous United States was high in the Southeast, portions of the Desert Southwest, southern California, and in pockets of the Midwest and southern Great Lakes. Areas of low match were found in the Cascade-Sierra Mountains and coastal Pacific Northwest, Intermountain West, and patches in the Northeast. Medium matches were found in the remaining regions. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) for the contiguous United States was 0.734, indicating that Yes, there is establishment concern for this species. Establishment concern is warranted for Climate 6 scores greater than or equal to 0.002 based on an analysis of the establishment success of 356 nonnative aquatic species introduced to the United States (USFWS 2024).

Projected climate matches in the contiguous United States under future climate scenarios are available for *Salvinia minima* (see Appendix). These projected climate matches are provided as additional context for the reader; future climate scenarios are not factored into the Overall Risk Assessment Category.

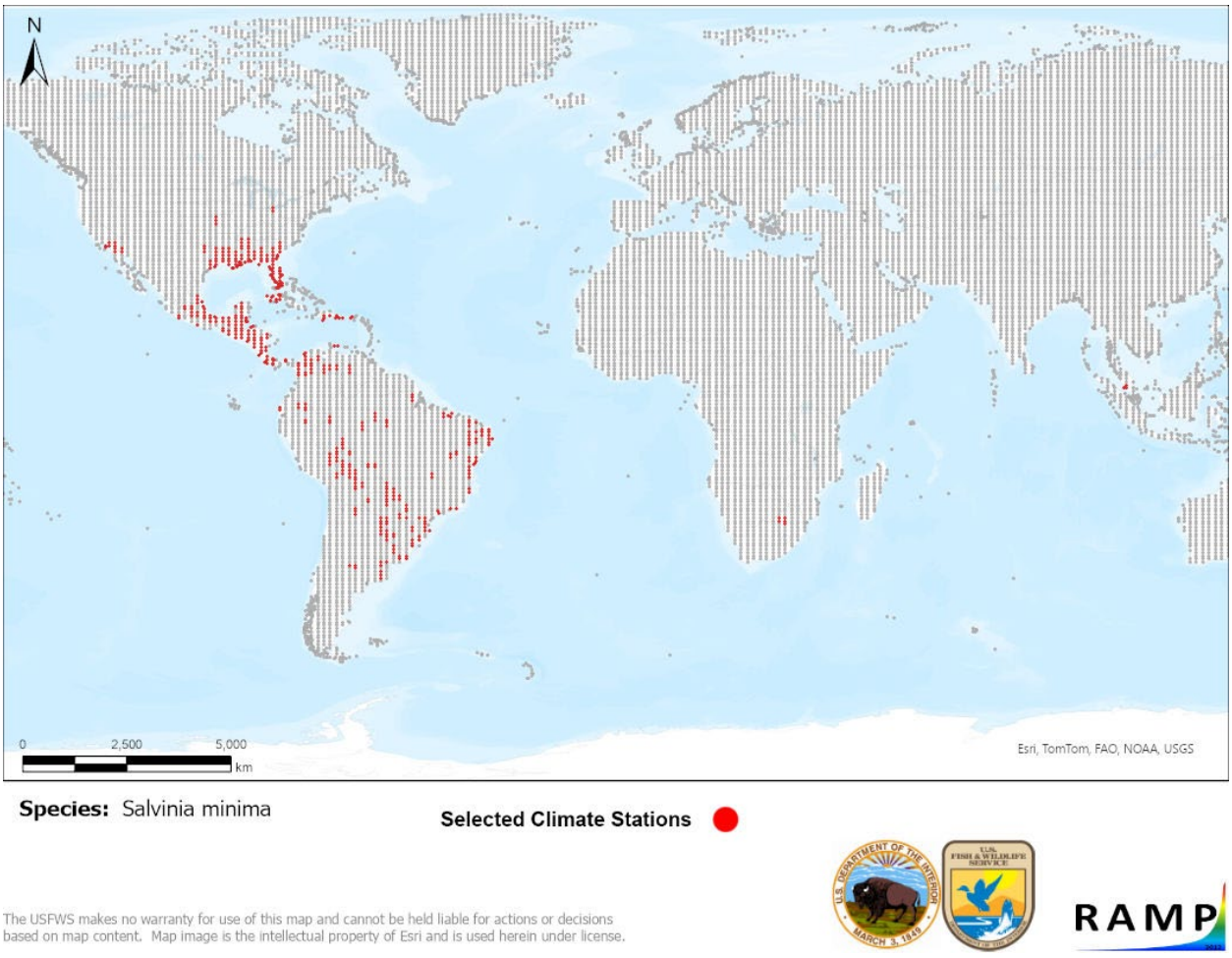

Figure 5. RAMP (Sanders et al. 2023) source map showing weather stations in North America, Central America, South America, Africa, and Asia selected as source locations (red; United States, Mexico, Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Cuba, Dominican Republic, Colombia, Venezuela, Ecuador, Peru, Brazil, Bolivia, Paraguay, Uruguay, Argentina, South Africa, Malaysia) and non-source locations (gray) for *Salvinia minima* climate matching. Source locations from GBIF Secretariat (2023) and USGS (2025). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

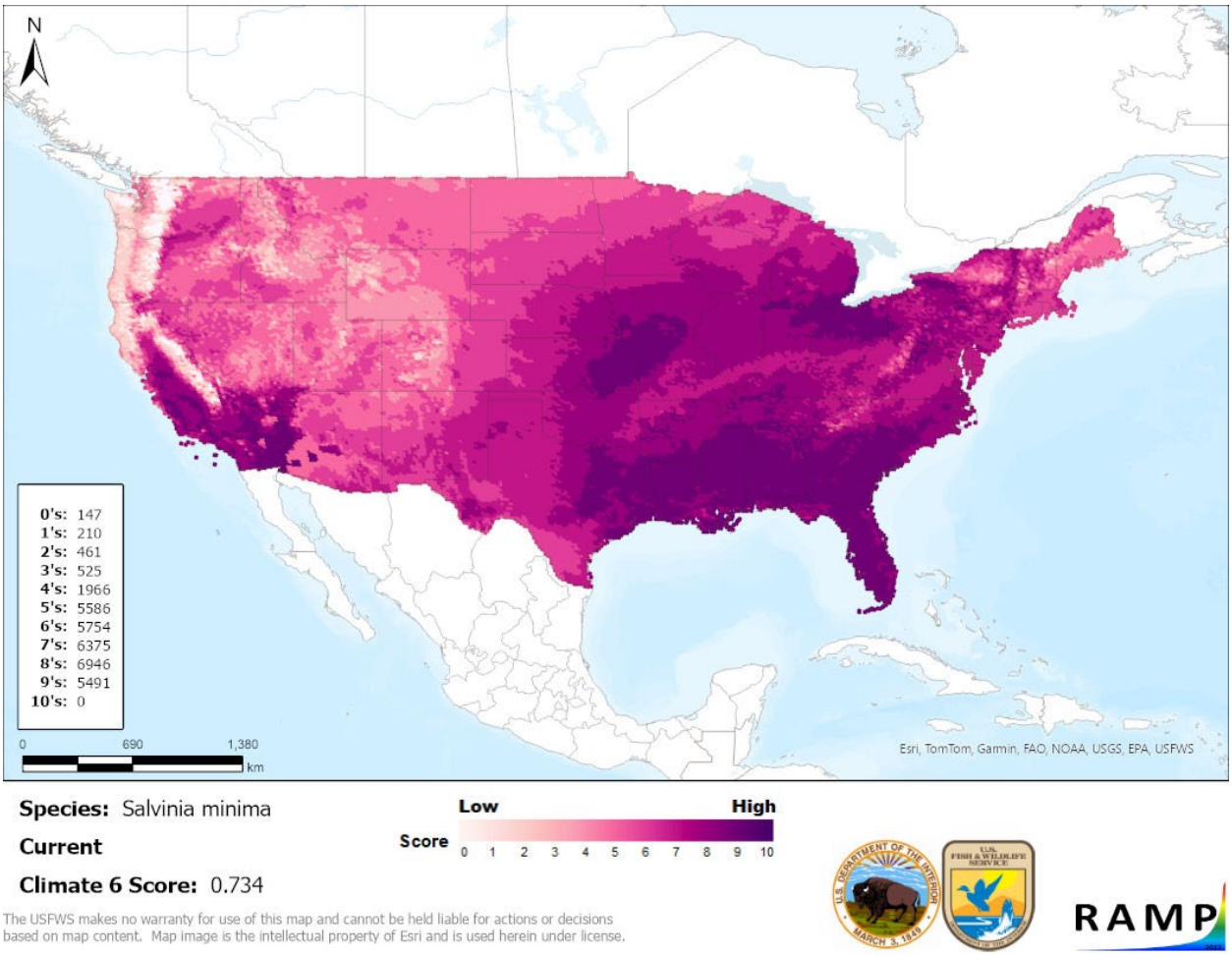

Figure 6. Map of RAMP (Sanders et al. 2023) climate matches for *Salvinia minima* in the contiguous United States based on source locations reported by GBIF Secretariat (2023) and USGS (2025). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

8 Certainty of Assessment

The Certainty of Assessment for *Salvinia minima* is classified as High. Information is available on the biology, ecology, and distribution of *S. minima*. Additionally, there is information available on actual impacts of introduction from multiple peer-reviewed studies.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Salvinia minima, water spangles, is a free floating aquatic plant native to Central and South America. *S. minima* is commonly found in calm waters such as marshes, ponds, lakes, and backwaters of rivers and streams. This species is commonly sold in the garden and aquarium trade and has been introduced and established outside of its native range, mainly in the United States. *S. minima* is regulated in at least four States. The History of Invasiveness for *S. minima* is classified as High due to several established populations with documented negative impacts

including reductions in native plant species, water chemistry alteration, interference with recreational activities, and high economic cost to localities for control and management. The climate matching analysis for the contiguous United States indicates establishment concern for this species. Areas of high match were found in the Southeast, Southwest, and in patches in the Midwest and Great Lakes. The Certainty of Assessment for this ERSS is classified as High due to the availability of information on the biology, ecology, distribution, and negative impacts of introduction. The Overall Risk Assessment Category for *S. minima* in the contiguous United States is High.

Assessment Elements

- **History of Invasiveness (see section 4): High**
- **Establishment Concern (see section 7): Yes**
- **Certainty of Assessment (see section 8): High**
- **Remarks, Important additional information: None**
- **Overall Risk Assessment Category: High**

10 Literature Cited

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in section 11.

Amazon. 2023. *Salvinia minima*. Amazon. Available: https://www.amazon.com/s?k=salvinia+minima&i=lawngarden&crid=3O7RA9XMZBBF6&sprefix=salvinia+minima%2Clawngarden%2C110&ref=nb_sb_noss_2 (February 2023).

Aquaticarts. 2023. Water spangles (*Salvinia minima*). Aquaticarts. Available: https://aquaticarts.com/products/water-spangles (February 2023).

[CABI] CABI International. 2008. *Salvinia minima*. CABI Invasive Species Compendium. Wallingford, United Kingdom: CAB International. Available: https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.107785 (February 2023).

Coetzee JA, Paper MK, Miller BE, Kinsler D, Cilliers CJ, Hill MP. 2022. Into Africa: *Salvinia minima* Baker (Salviniaceae) invades South Africa. BioInvasions Records 11:1011–1018.

Dickinson MB, Miller TE. 1998. Competition among small, free-floating, aquatic plants. American Midland Naturalist 140:55–67.

GBIF Secretariat. 2023. GBIF backbone taxonomy: *Salvinia minima* Baker. Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/5274860 (May 2025).

[GISD] Global Invasive Species Database. 2023. Species profile: *Salvinia minima*. Invasive Species Specialist Group, Gland, Switzerland. Available: http://www.iucngisd.org/gisd/speciesname/Salvinia+minima (February 2023).

Lower E. 2023. *Salvinia minima* Baker. Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database, and Ann Arbor, Michigan: NOAA Great Lakes Aquatic Nonindigenous Species Information System. Available: https://nas.er.usgs.gov/queries/greatlakes/FactSheet.aspx?Species_ID=297&Potential=Y&Type=2&HUCNumber=DGreatLakes (February 2023).

Howard Morgan V, Anemaet E, Lower E. 2023. *Salvinia minima* Baker. Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database. Available: https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=297 (February 2023).

[ITIS] Integrated Taxonomic Information System. 2023. *Salvinia minima* Baker. Reston, Virginia: Integrated Taxonomic Information System. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=181822#null (February 2023).

Louisiana Department of Agriculture and Forestry. 2022. List of noxious weeds and limitations on noxious weed seed. Louisiana Administrative Code Title 7, Section 109.

North Carolina Department of Environmental Quality. 2022. Noxious aquatic weed list. 15A North Carolina Administrative Code 02G .0602.

Oklahoma Department of Wildlife Conservation. 2022. Restriction on aquatic species introduction. 800 Oklahoma Administrative Code 20.

Onwuka MC, Rajpar MN, Zakaria M. 2020. Food variety of lesser whistling duck in Malaysian lakes. Science & Technology 28:1329–1343.

Parys KA, Johnson SJ. 2013. Biological control of common salvinia (*Salvinia minim*) in Louisiana using *Cyrtobagous salviniae* (Coleptera: Curculionidae). Florida Entomologist 96:10–18.

[POWO] Plants of the World Online. 2023. *Salvinia minima* Baker. Plants of the World Online. London: Royal Botanic Gardens, Kew. Available: https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:227109-2 (February2023).

Sanders S, Castiglione C, Hoff M. 2023. Risk Assessment Mapping Program: RAMP. Version 5.0. U.S. Fish and Wildlife Service.

Tewari S, Johnson J. 2011. Impact of two herbivores, *Samea multiplicalis* (Lepidoptera: Crambidae) and *Cyrtobagous salviniae* (Coleoptera: Curculionidae), on *Salvinia minima* in south Louisiana. Journal of Aquatic Plant Management 49:36–43.

Texas Parks and Wildlife. 2022. Invasive, prohibited and exotic species. Austin: Texas Parks and Wildlife. Available: https://tpwd.texas.gov/huntwild/wild/species/exotic/prohibited_aquatic.phtml (October 2022).

Tipping PW, Center TD. 2005. Population dynamics of *Cyrtobagous salviniae* on Common Salvinia in South Florida. Journal of Aquatic Plant Management 43:47–50.

[USFWS] U.S. Fish and Wildlife Service. 2024. Standard operating procedure: how to prepare an "Ecological Risk Screening Summary." Version 3. Available: https://www.fws.gov/media/standard-operating-procedures-how-prepare-ecological-risk-screening-summary-2024 (May 2025).

[USGS] U.S. Geological Survey. 2025. Point distribution map: *Salvinia minima*. Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database. Available: https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=297 (May 2025).

Wersal RM, Madsen JD. 2010. Combinations of penoxsulam and diquat as foliar applications for control of waterhyacinth and common salvinia: evidence of herbicide antagonism. Journal of Aquatic Plant Management 48:21–25.

[WFO] World Flora Online. 2023. *Salvinia minima* Baker. The World Flora Online. Available: http://www.worldfloraonline.org/taxon/wfo-0001109618 (February 2023).

11 Literature Cited in Quoted Material

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.

Borkent A, Craig DA. 2001. Submerged *Stilobezzia rabelloi* Lane (Diptera: Ceratopogonidae) pupae obtain oxygen from the aquatic fern *Salvinia minima* Baker. Proceedings of the Entomological Society of Washington 103:655–665.

Buckingham GR, Balciunas JK. 1994. Biological studies of *Bagous hydrillae*. Vicksburg, Mississippi: U.S. Army Corps of Engineers, Waterways Experiment Station. Technical report A-94-6.

Chow CY, Thevasagayam ES, Wambeek EG. 1955. Control of *Salvinia* as host of *Mansonia* mosquitos. Bulletin of the World Health Organization 12:365–369.

De la Sota ES. 1976. Sinopsis de las especies Argentinas del genero *Salvinia* Adanson (Salviniaceae - Pteridophyta). The Bulletin of the Botanical Society of Argentina 17(1–2):47–50.

Dickinson MB, Miller TE. 1998. Competition among small, free-floating, aquatic plants. American Midland Naturalist 140:55–67.

Fernald ML. 1950. Gray's manual of botany a handbook of the flowering plants and ferns of the central and northeastern United States and adjacent Canada. 8th edition. New York: American Book Company.

Flores D, Carlson JW. 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.

Flora of North America Editorial Committee. 1993. Flora of North America. Oxford, UK: Oxford University Press.

Forno IW, Sands DPA, Sexton W. 1983. Distribution, biology, and host specificity of *Cyrtobagous singularis* Hustache (Coleoptera: Curculionidae) for the biological control of *Salvinia molesta*. Bulletin of Entomological Research 73:85–95.

Harley KLS, Mitchell DS. 1981. The biology of Australian weeds: 6. *Salvinia molesta*. The Journal of the Australian Institute of Agricultural Science 47:67–76.

Hatch SL. 1995. *Salvinia minima* new to Texas. Sida 16:595.

Henderson L. 2012. A new aquatic invader in South Africa. South African Plant Invader Atlas News 24:1–2.

[ISSG] Invasive Species Specialist Group. 2006. Auckland, New Zealand: University of Auckland. Available: http://www.issg.org/database.

Jacono CC. 2003. Salvinia: *Salvinia minima* - common salvinia nonindigenous aquatic ferns in the United States (*Salvinia molesta* - *Salvinia minima*) and their biological control, *Cyrtobagous salviniae*, the salvinia weevil. U.S. Geological Survey.

Jacono CC, Davern TR, Center TD. 2001. The adventive status of *Salvinia minima* and *S. molesta* in the southern United States and the related distribution of the weevil *Cyrtobagous salviniae*. Castanea 66(3):214–226.

Johnstone IM, Coffey BT, Howard-Williams C. 1985. The role of recreational boat traffic in interlake dispersal of macrophytes: a New Zealand case study. Journal of Environmental Management 20:263–279.

Kay SH, Hoyle ST. 2001. Mail order, the internet, and invasive aquatic weeds. Journal of Aquatic Plant Management 39:88–91.

Lawalree A. 1964. Salviniaceae. Pages 24–25 in Tutin TG, Ball PW, Chater AO, editors. Flora Europaea. Cambridge, UK: University Press.

Lounibos LP, Larson VL, Morris CD. 1990. Parity, fecundity, and body size of *Mansonia dyari* in Florida. Journal of the American Mosquito Control Association 6:121–126.

Mickel JT, Beitel JM. 1988. Pteridophyte flora of Oaxaca, Mexico. New York: New York Botanical Garden.

Miller IL, Wilson CG. 1989. Management of *Salvinia* in the Northern Territory. Journal of Aquatic Plant Management 27:40–46.

Montz GN. 1989. Distribution of *Salvinia minima* in Louisiana. Pages 14–17 in Proceedings of the 23rd Annual Meeting, Aquatic Plant Control A-89-1. Vicksburg, Mississippi: U.S. Army Corps of Engineers, Waterways Experiment Station.

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

Room PM. 1983. 'Falling apart' as a lifestyle. The rhizome architecture and population growth of *Salvinia molesta*. Journal of Applied Ecology 71:349–365.

Room PM. 1990. Ecology of a simple plant-herbivore system: biological control of *Salvinia*. Trends in Ecology and Evolution 5:74–79.

Schmitz et al. 1998. [Source material did not give full citation for this reference.]

Stoltze RG. 1983. Ferns and fern allies of Guatemala. Marsileaceae, Salviniacaea, and the fern allies. Fieldiana Botany 12:10–13.

[USGS] United States Geological Survey. 2005. Biological control of common salvinia (*Salvinia minima*) at Jean Lafitte National Historical Park and Preserve, Louisiana. Available: http://salvinia.er.usgs.gov/html/salvinia_minima.html.

Walley. 2007. [Source material did not give full citation for this reference.]

Weatherby CA. 1921. Other records of *Salvinia natans* in the United States. American Fern Journal 11(2):50–53.

Weatherby CA. 1937. A further note on *Salvinia*. American Fern Journal 27:98–102.

Appendix

Summary of Future Climate Matching Analysis

Future climate projections represent two Shared Socioeconomic Pathways (SSP) developed by the Intergovernmental Panel on Climate Change (IPCC 2021): SSP5, in which emissions triple by the end of the century; and SSP3, in which emissions double by the end of the century. Future climate matches were based on source locations reported by GBIF Secretariat (2023) and USGS (2025).

Under the future climate scenarios (figure A1), on average, high climate match for *Salvinia minima* was projected to occur in the Appalachian Range, Great Lakes, Mid-Atlantic, Southeast, Southern Atlantic Coast, and Southern Florida regions of the contiguous United States. The areas of high match decrease in size from time step 2055 to time step 2085. Areas of low match were found in the Northern Pacific Coast and Western Mountains. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.706 (model: MPI-ESM1-2-HR, SSP5, 2085) to a high of 0.833 (model: IPSL-CM6A-LR, SSP5, 2055). All future scenario Climate 6 scores were above the Establishment Concern threshold, indicating that Yes, there is establishment concern for this species under future scenarios. The Climate 6 score for the current climate match (0.734, figure 6) falls within the range of scores for future projections. The time step and climate scenario with the most change relative to current conditions was SSP5, 2085, the most extreme climate change scenario. Under one or more time step and climate scenarios, areas within the Northeast and Southwest saw a large increase in the climate match relative to current conditions. Additionally, areas within the Appalachian Range, Colorado Plateau, Great Basin, Great Lakes, Northern Pacific Coast, Northern Plains, and Western Mountains saw a moderate increase in the climate match relative to current conditions. Under one or more time step and climate scenarios, areas within the Southern Plains saw a large decrease in the climate match relative to current conditions. Additionally, areas within the Appalachian Range, California, Great Lakes, Gulf Coast, Southeast, Southern Atlantic Coast, Southern Florida, and Southwest saw a moderate decrease in the climate match relative to current conditions. Additional, very small areas of large or moderate change may be visible on the maps (figure A3). The areas of moderate and large changes had a larger geographic extent under SSP5 than SSP3 in the 2085 time step.

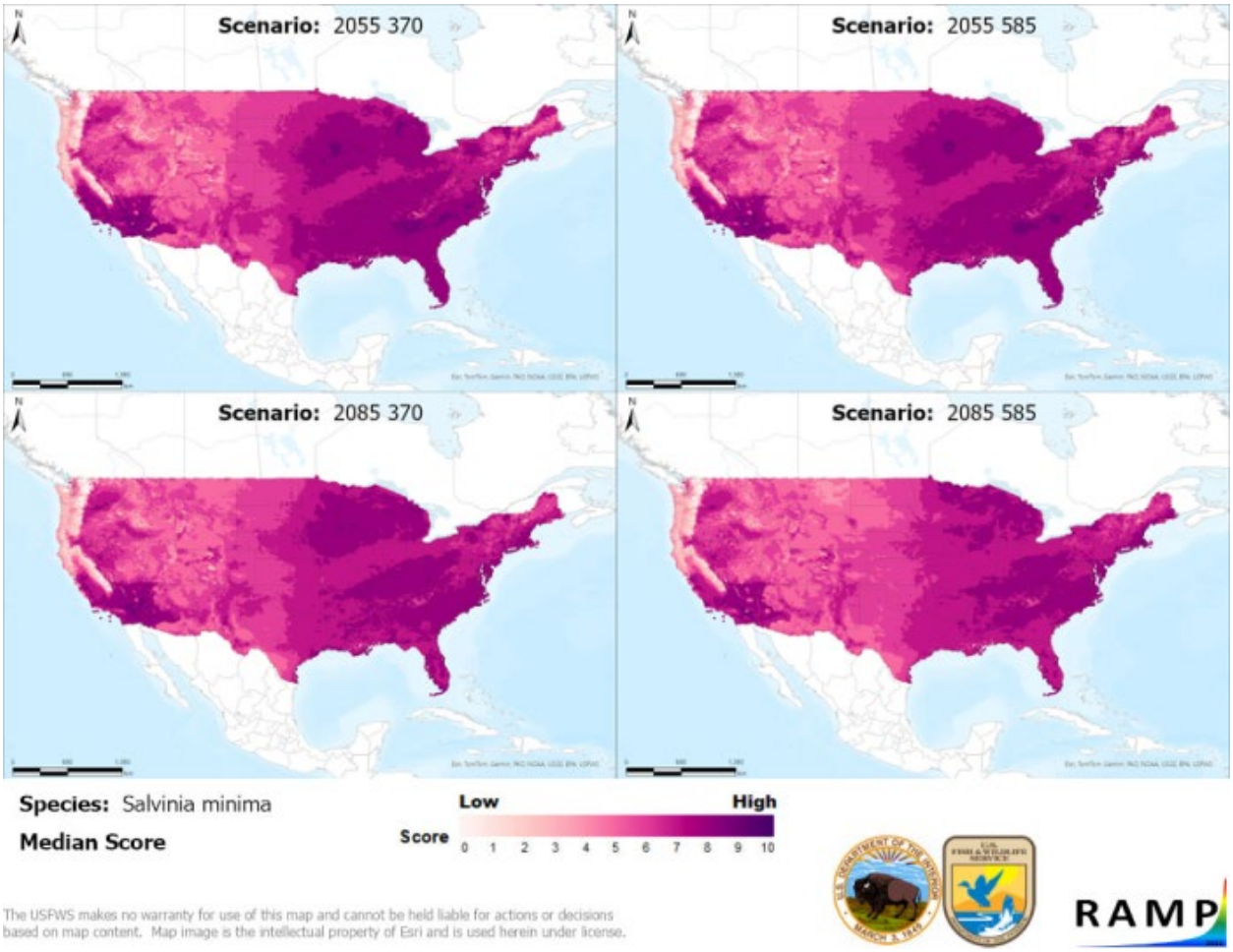

Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Salvinia minima* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2023) and USGS (2025). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global climate models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

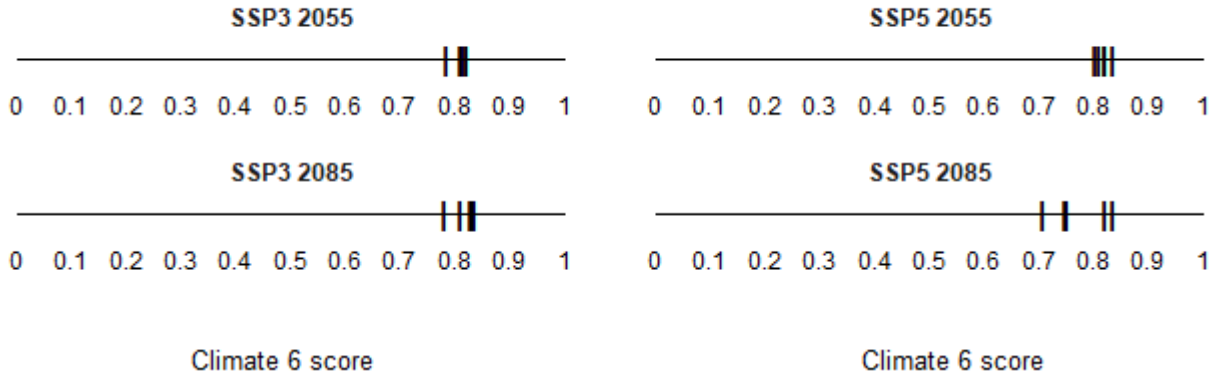

Figure A2. Comparison of projected future Climate 6 scores for *Salvinia minima* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 2018; IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global climate models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0.

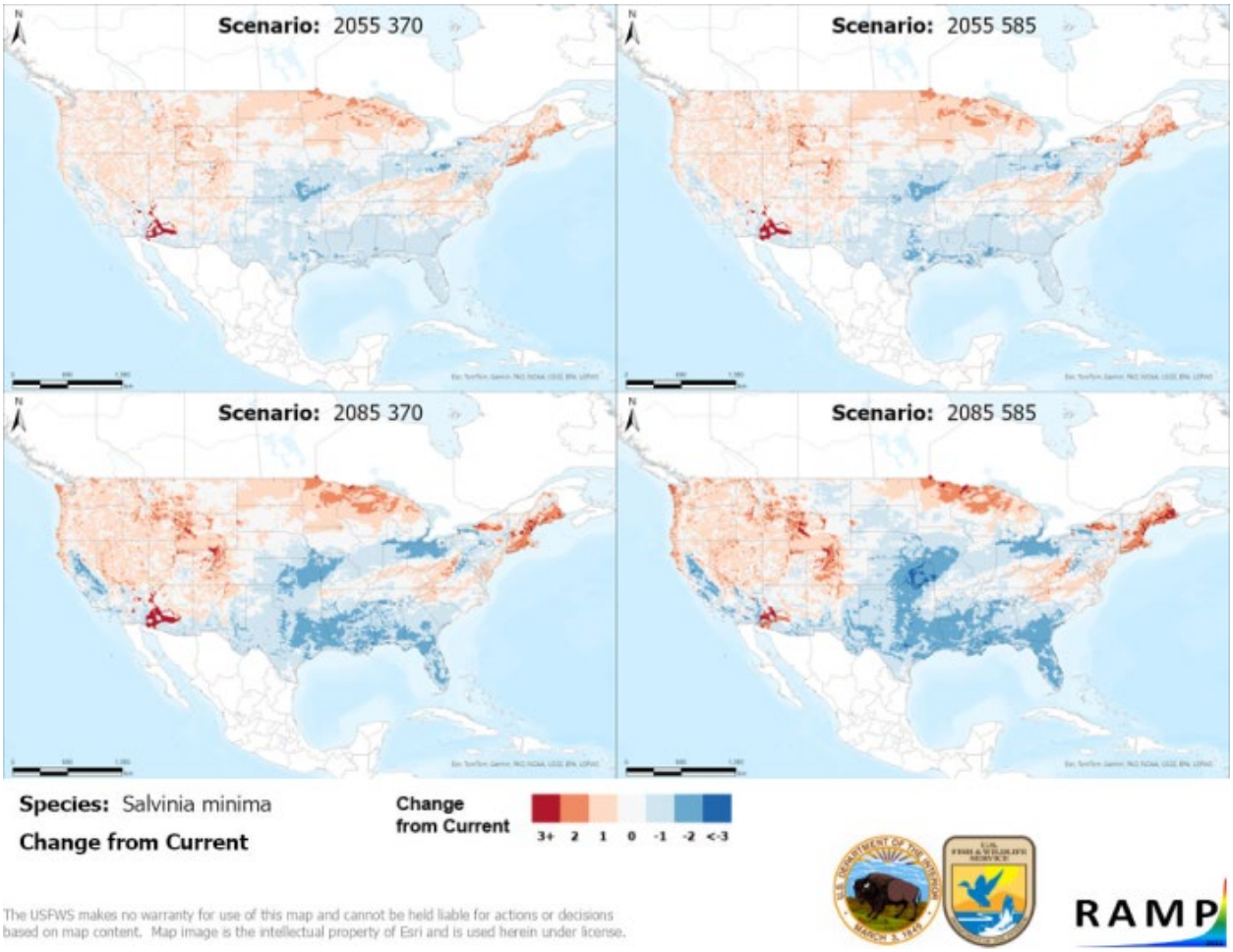

Figure A3. RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 6) and the median target point score for future climate scenarios (figure A1) for *Salvinia minima* based on source locations reported by GBIF Secretariat (2023) and USGS (2025). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. Shades of blue indicate a lower target point score under future scenarios than under current conditions. Shades of red indicate a higher target point score under future scenarios than under current conditions. Darker shades indicate greater change.

Literature Cited

GBIF Secretariat. 2023. GBIF backbone taxonomy: *Salvinia minima* Baker. Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/5274860 (May 2025).

[IPCC] Intergovernmental Panel on Climate Change. 2021. Climate change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Karger DN, Conrad O, Böhner J, Kawohl T, Kreft H, Soria-Auza RW, Zimmermann NE, Linder P, Kessler M. 2017. Climatologies at high resolution for the Earth land surface areas. Scientific Data 4:170122.

Karger DN, Conrad O, Böhner J, Kawohl T, Kreft H, Soria-Auza RW, Zimmermann NE, Linder HP, Kessler M. 2018. Data from: Climatologies at high resolution for the earth's land surface areas. EnviDat. Available: https://doi.org/10.16904/envidat.228.v2.1.

Sanders S, Castiglione C, Hoff M. 2023. Risk Assessment Mapping Program: RAMP. Version 5.0. U.S. Fish and Wildlife Service.

[USGS] U.S. Geological Survey. 2025. Point distribution map: *Salvinia minima*. Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database. Available: https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=297 (May 2025).