Michigan Department of Agriculture and Rural Development

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Version 1

Weed Risk Assessment for *Salvinia molesta* D.S. Mitchell (Salviniaceae) – Giant salvinia

Top left: *Salvinia molesta* dense mats (source: Kenneth Calcote, Mississippi Department of Agriculture and Commerce, Bugwood.org). Bottom left: *Salvinia molesta* growth form, ramet (Leslie J. Mehrhoff, University of Connecticut, Bugwood.org). Right: Close up of *S. molesta* growth (source: Robert Vidéki, Doronicum Kft., Bugwood.org).

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Introduction The Michigan Department of Agriculture and Rural Development (MDARD) regulates aquatic species through a Prohibited and Restricted species list, under the authority of Michigan's Natural Resources and Environmental Protection Act (NREPA), Act 451 of 1994, Part 413 (MCL 324.41301-41305). Prohibited species are defined as species which "(i) are not native or are genetically engineered, (ii) are not naturalized in this state or, if naturalized, are not widely distributed, and further, fulfill at least one of two requirements: (A) The organism has the potential to harm human health or to severely harm natural, agricultural, or silvicultural resources and (B) Effective management or control techniques for the organism are not available." Restricted species are defined as species which "(i) are not native, and (ii) are naturalized in this state, and one or more of the following apply: (A) The organism has the potential to harm human health or to harm natural, agricultural, or silvicultural resources. (B) Effective management or control techniques for the organism are available." Per a recently signed amendment to NREPA (MCL 324.41302), MDARD will be conducting reviews of all species on the lists to ensure that the lists are as accurate as possible.

We use the United States Department of Agriculture's, Plant Protection and Quarantine (PPQ) Weed Risk Assessment (WRA) process (PPQ, 2015) to evaluate the risk potential of plants. The PPQ WRA process includes three analytical components that together describe the risk profile of a plant species (risk potential, uncertainty, and geographic potential; PPQ, 2015). At the core of the process is the predictive risk model that evaluates the baseline invasive/weed potential of a plant species using information related to its ability to establish, spread, and cause harm in natural, anthropogenic, and production systems (Koop et al., 2012). Because the predictive model is geographically and climatically neutral, it can be used to evaluate the risk of any plant species for the entire United States or for any area within it. We then use a stochastic simulation to evaluate how much the uncertainty associated with the risk analysis affects the outcomes from the predictive model. The simulation essentially evaluates what other risk scores might result if any answers in the predictive model might change. Finally, we use Geographic Information System (GIS) overlays to evaluate those areas of the United States that may be suitable for the establishment of the species. For a detailed description of the PPQ WRA process, please refer to the *PPQ Weed Risk Assessment Guidelines* (PPQ, 2015), which is available upon request.

We emphasize that our WRA process is designed to estimate the baseline—or unmitigated—risk associated with a plant species. We use evidence from anywhere in the world and in any type of system (production, anthropogenic, or natural) for the assessment, which makes our process a very broad evaluation. This is appropriate for the types of actions considered by our agency (e.g., State regulation). Furthermore, risk assessment and risk management are distinctly different phases of pest risk analysis (e.g., IPPC, 2015). Although we may use evidence about existing or proposed control programs in the assessment, the ease or difficulty of control has no bearing on the risk potential for a species. That information could be considered during the risk management (decision making) process, which is not addressed in this document.

Salvinia molesta D.S. Groves – Giant salvinia

Species Information

Family: Salviniaceae (Groves et al., 1995)

Synonyms: *Salvinia adnata* Desv. (Gardenal et al., 2008; The Plant List, 2015).

Common names: Kariba weed, African pyle, Australian azolla, water fern, giant azolla (Groves et al., 1995; Julien et al., 2002), floating fern (Julien et al., 2002), giant salvinia (Bhatt et al., 2012).

Botanical description: *Salvinia molesta* is a free-floating aquatic fern which can be distinguished from other *Salvinia* species by “egg-beater” like hairs on the leaf surface which repel water (Oliver, 1993; Australian Natural Heritage Trust, 2003). “Plants” of *S. molesta* are actually phenets (colonies of ramets held together temporarily by a rhizome) (Groves et al., 1995). For a full morphological description, see Oliver (1993).

Initiation: In accordance with the Natural Resources and Environmental Protection Act Part 413, the Michigan Department of Agriculture and Rural Development was tasked with evaluating the aquatic species currently on Michigan’s Prohibited and Restricted Species List (MCL 324.41302). USDA Plant Epidemiology and Risk Analysis Laboratory’s (PERAL) Weed Team worked with MDARD to evaluate and review this species.

Foreign distribution: *Salvinia molesta* is widely naturalized throughout the tropics and subtropics (NGRP, 2015) with naturalized populations throughout Africa, Asia, and Australia (Thomas & Room, 1986). This species was previously cultivated as an aquarium plant (Thomas & Room, 1986; Oliver, 1993).

U.S. distribution and status: *Salvinia molesta* was first reported outside of cultivation in the United States in 1995 in a pond in southeastern South Carolina (Julien et al., 2002). Since then, this species has spread to Alabama, Arkansas, Arizona, California, Colorado, Florida, Georgia, Hawaii, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Texas, and Virginia (McFarland et al., 2004; BONAP, 2015). This species is a Federal Noxious Weed (APHIS, 2015b) and is also regulated as a noxious weed in Arizona, Arkansas, Colorado, Connecticut, Illinois, Indiana, Michigan, Mississippi, Nebraska, Nevada, New Mexico, Oklahoma, South Carolina, Tennessee, and Vermont (National Plant Board, 2015). The state of Louisiana undertook aerial herbicide application in the 1990s. When drawdown and biological control were combined, control was much more effective (Savoie, 2004). Biological control with *Cyrtobagous salviniae* has been successful in Florida (Savoie, 2004). *Cyrtobagous salviniae* release field tests in Louisiana and Texas showed "dramatic reductions" in *S. molesta* populations at the studied sites (Tipping et al., 2008).

WRA area[1]: Entire United States, including territories.

1. *Salvinia molesta* analysis

Establishment/Spread Potential *Salvinia molesta* is an aquatic fern (Groves et al., 1995; Parsons & Cuthbertson, 2001) that is capable of growing in shady conditions (Owens et al., 2011). *Salvinia molesta* can double its biomass in 2-3 days (Julien et al., 2002; Room, 1983) and is capable of high growth rates of 0.43 ramets per day (Groves et al., 1995). This high growth rate creates extremely dense mats at the surface of the water (Groves et al., 1995) that become multi-layered with growth and can reach up to 1 m in thickness (Julien et al., 2002; Weber, 2003). Natural vegetative fragmentation (Parsons & Cuthbertson, 2001; Smith, 2008) contributes to both natural dispersal and human-mediated dispersal on boats and trailers (Julien et al., 1995; Owens et al., 2004). We had a very low amount of uncertainty for this risk element.
Risk score = 15 Uncertainty index = 0.05

Impact Potential *Salvinia molesta* has a variety of impacts in natural, anthropogenic, and production systems. In natural systems, thick mats reduce light and oxygen penetration into the water column, and senescing plant material drops to the bottom of the water column consuming dissolved oxygen as it decomposes (Smith, 2008). By preventing photosynthesis, large mats create anoxic conditions (Groves et al., 1995). Further, by diminishing light availability to lower strata, *S. molesta* can outcompete many native species of submersed and floating plants, consequently reducing community diversity (McFarland et al., 2004; IUCN, 2015). In anthropogenic systems, thick mats interfere with the operation of engineering structures and prolong flooding by blocking drains. It contributes to fences and other structures being swept away in floods and degrade potable water by causing anaerobic conditions which generate unpleasant tastes and odors and favor the spread of certain diseases (Groves et al., 1995; Julien et al., 2002). Large mats interfere with fishing, transport and recreation, degrade the aesthetic appeal and recreational value of lakes and rivers (Groves et al., 1995), prevent access to fishing grounds, and deplete habitat for game birds (Julien et al., 2002). Large mats obstruct or prevent the use of water for irrigation, impede the

[1] "WRA area" is the area in relation to which the weed risk assessment is conducted [definition modified from that for "PRA area"] (IPPC, 2012).

access of stock to water (Groves et al., 1995), and may establish in rice fields during irrigation and subsequently compete directly with the crop for water (Parsons & Cuthbertson, 2001). *Salvinia molesta* is controlled in all three systems via biocontrol (Savoie, 2004; Tipping et al., 2008; Sullivan et al., 2011). We had a low amount of uncertainty for this risk element.
Risk score = 4.5 Uncertainty index = 0.08

Geographic Potential Based on three climatic variables, we estimate that about 62 percent of the United States is suitable for the establishment of *Salvinia molesta* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence. The map for *S. molesta* represents the joint distribution of Plant Hardiness Zones 6-13, areas with 0-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, desert, Mediterranean, humid subtropical, marine west coast, humid continental warm summers, and humid continental cool summers. Note that in this weed risk assessment it was not clear if *Salvinia molesta* occurs in areas of 90-100 inches of precipitation. For this evaluation, we assumed these environments are climatically suitable since it occurs in wetter and drier precipitation bands.

The area of the United States shown to be climatically suitable (Fig. 1) is likely overestimated since our analysis considered only three climatic variables. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish. *Salvinia molesta* prefers tropical, sub-tropical or warm temperate areas of the world and grows best in still or slow-moving water bodies including ponds, lakes, slow rivers, canals, and ditches (Global Invasive Species Database, 2005).

Entry Potential We did not assess the entry potential of *Salvinia molesta* because it is already present in the United States (Julien et al., 2002; McFarland et al., 2004).

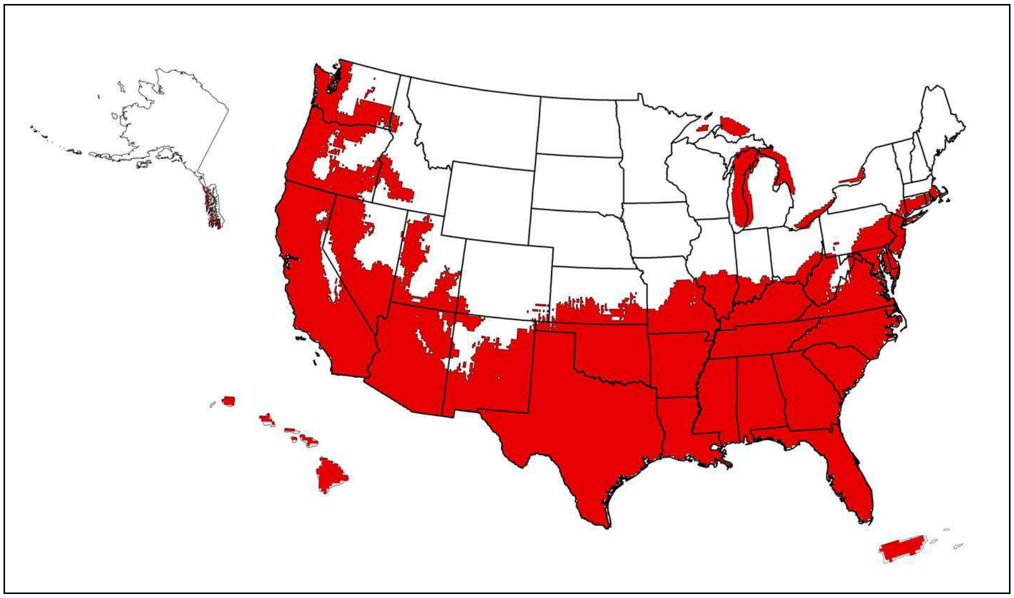

Figure 1. Predicted distribution of *Salvinia molesta* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

<u>2. Results</u>

Model Probabilities: P(Major Invader) = 89.2%
P(Minor Invader) = 10.5%
P(Non-Invader) = 0.4%

Risk Result = High Risk

Secondary Screening = Not Applicable

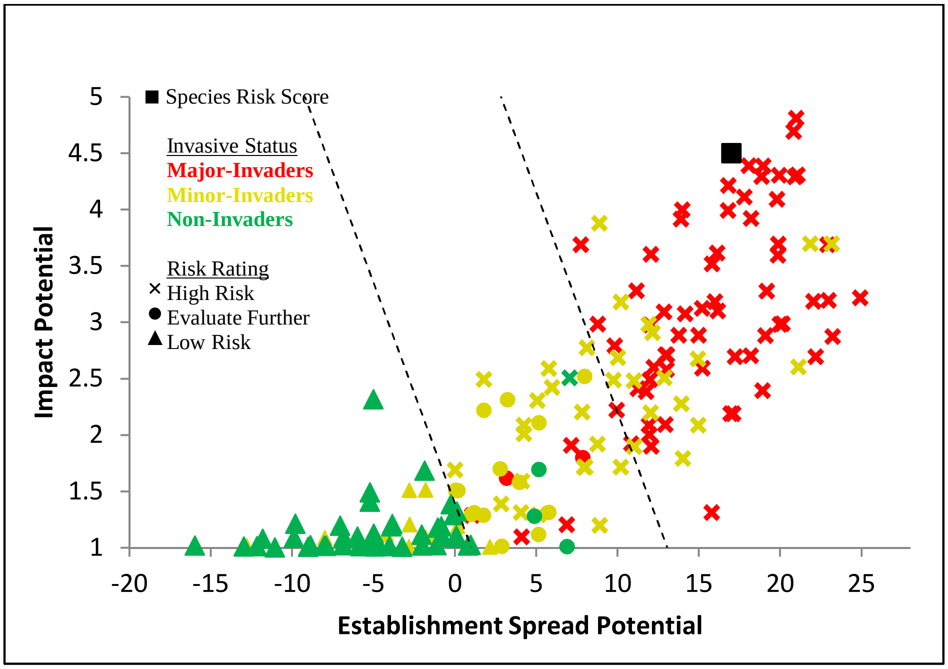

Figure 2. *Salvinia molesta* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

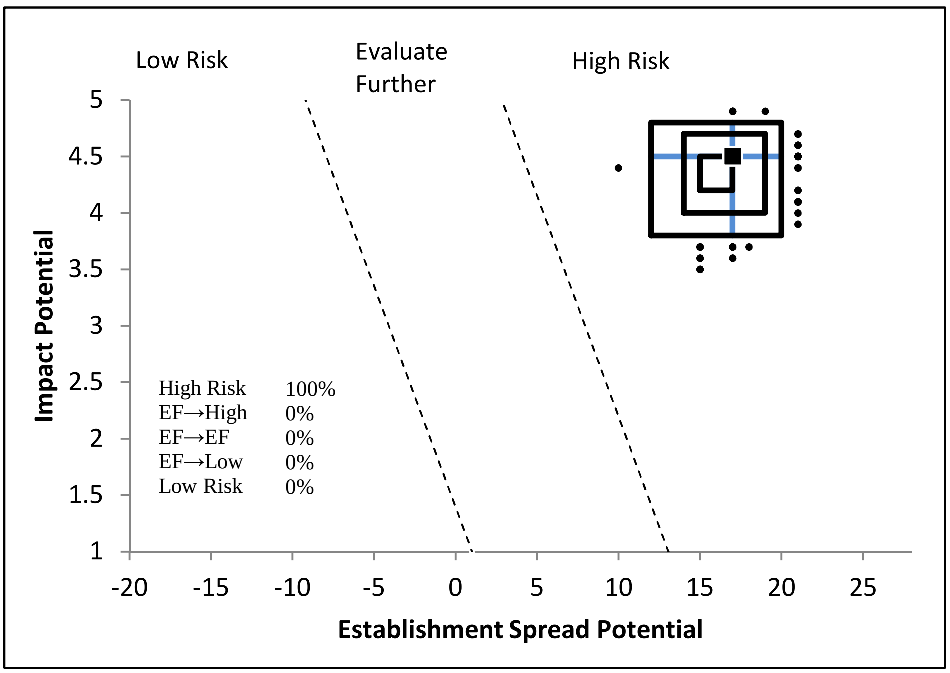

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Salvinia molesta*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Salvinia molesta* is High Risk (Figure 2). Because all of the simulated risk scores from our uncertainty analysis also resulted in high risk determination (Figure 3), we believe our result is robust. Our conclusion of high risk is supported by two other weed risk assessment models used to assess the species' risk in Spain (Andreu & Vilà, 2010). The Australian model (Pheloung et al., 1999) resulted in a score of 23 (high risk), and the European model (Weber & Gut, 2004) resulted in a score of 32 and a risk class ranking of III (high risk).

A successful biocontrol agent for *S. molesta*, *Cyrtobagous salviniae*, was discovered after researchers identified that *S. molesta* is native to Brazil, where this insect is found (Thomas & Room, 1986). Field tests of natural pests showed that an undescribed insect, *C. salviniae*, was able to destroy a 200 hectare infestation in Lake Moondarra, Australia in 14 months (Thomas & Room, 1986). Mukherjee et al. (2014) showed that populations of *C. salviniae* introduced to the United States were unable to withstand temperate temperatures; however, populations of the insect introduced to Australia were more cold tolerant. The authors conjectured that this may be due to the more extensive breeding program in Australia (Mukherjee et al., 2014). To apply *C. salviniae* control to more temperate regions of the United States where *S. molesta* may establish, further selective breeding may be necessary to successfully establish *C. salviniae* populations.

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Appendix A. Weed risk assessment for *Salvinia molesta* D.S. Mitchell (Salviniaceae). Below is all of the evidence and associated references used to evaluate the risk potential of this taxon. We also include the answer, uncertainty rating, and score for each question. The Excel file, where this assessment was conducted, is available upon request.

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 [What is the taxon's establishment and spread status outside its native range? (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown]	f - negl	5	*Salvinia molesta* is native to a relatively small area (20,000 km^2) (Julien et al., 2002) in southeastern Brazil (Groves et al., 1995), which includes the states of Sao Paulo, Paraná, Santa Catarina and Rio Grande do Sul (Julien et al., 2002). *Salvinia molesta* is widely naturalized throughout the tropics and subtropics (NGRP, 2015) with naturalized populations throughout Africa, Asia, and Australia (Thomas & Room, 1986). Under ideal growth conditions, biomass and numbers of ramets typically double in two to three days (Julien et al., 2002; Room, 1983). *Salvinia molesta* has a high reproductive potential which greatly contributes to localized spread (Parsons & Cuthbertson, 2001; Finlayson, 1984) and regional spread (Sullivan et al., 2011). For example, a few plants were introduced to a floodplain in Papua New Guinea, and in ten years *S. molesta* spread to cover over 500 km^2 of the floodplain, and over 250 km2 of surface cover of open water (Thomas & Room, 1986). *Salvinia molesta* was first found outside cultivation in the United States in 1995 in South Carolina (Julien et al., 2002) and has since spread to 16 states (McFarland et al., 2004; BONAP, 2015).
ES-2 (Is the species highly domesticated)	n - low	0	This species has been cultivated for the aquarium trade (Global Invasive Species Database, 2005), but we found no evidence in the literature that it is highly domesticated or has been bred to reduce weed potential.
ES-3 (Weedy congeners)	y - low	1	There are about 10 species in the genus *Salvinia* (The Plant List, 2015), 7 of which have been reported as weeds (Randall 2012). *Salvinia molesta* is a member of the *Salvinia auriculata* complex (Mora-Olivo & Yatskievych, 2009; McFarland et al., 2004), all of which are on the United States Federal Noxious Weed List (i.e. *Salvinia herzogii*, *S. biloba*, and *S. auriculata*) (APHIS, 2015b). In areas of high nutrient concentration, submerged vegetation is replaced by S. auriculata (Bini et al., 1999).
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	In a 3 week study conducted by Owens et al. (2011), *S. molesta* specimens were grown in tanks with 0%, 30%,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			57%, and 80% shade. Plants growing in 30% and 57% shade completely covered the surface of their containers and were represented by a mixture of primary and secondary growth forms. *Salvinia molesta* plants in the 80% shade treatment containers remained in the primary growth form and loosely covered the surface. These results indicate although plant growth rates in high shade conditions are slower, the species is capable of surviving under these conditions.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	This species is not a vine, nor does it form basal rosettes. Rather, this species is a free-floating aquatic fern (Groves et al., 1995; Parsons & Cuthbertson, 2001).
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	*Salvinia molesta* forms dense mats (Groves et al., 1995); mats become multi-layered and can reach up to 1 m in thickness (Julien et al., 2002; Weber, 2003).
ES-7 (Aquatic)	y - negl	1	*Salvinia molesta* is a free-floating aquatic fern (Groves et al., 1995; Parsons & Cuthbertson, 2001).
ES-8 (Grass)	n - negl	0	This species is a member of the family Salviniaceae (Groves et al., 1995; Julien et al., 2002) and is therefore not a grass.
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen. Further, this species is not in a plant family known to have N-fixing capabilities (Martin and Dowd, 1990; Groves et al., 1995; Julien et al., 2002) and is not a woody plant. *Salvinia molesta* is a free-floating aquatic fern (Groves et al., 1995; Parsons & Cuthbertson, 2001).
ES-10 (Does it produce viable seeds or spores)	n - negl	-1	*Salvinia molesta* is a sterile (Julien et al., 2002; Weber, 2003; Everitt et al., 2007) pentaploid hybrid (Parsons & Cuthbertson, 2001) that in mature dense stands, forms spore sacs containing abortive spores (Parsons & Cuthbertson, 2001; Gardenal et al., 2008). Thus, reproduction is entirely by vegetative means (Parsons & Cuthbertson, 2001; Smith, 2008).
ES-11 (Self-compatible or apomictic)	n - low	-1	This species does not appear to be capable of sexual reproduction (Julien et al., 2002; Weber, 2003; Everitt et al., 2007; Parsons & Cuthbertson, 2001; Smith, 2008). *Salvinia molesta* is a sterile (Julien et al., 2002; Weber, 2003; Everitt et al., 2007) pentaploid hybrid (Parsons & Cuthbertson, 2001)
ES-12 (Requires specialist pollinators)	n - low	0	Ferns are spore producing plants and do not undergo pollination (Ramawat et al., 2014).
ES-13 [What is the taxon's minimum generation time? (a) less than a year with multiple generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) unknown]	a - negl	2	*Salvinia molesta* is a perennial (Julien et al., 2002). Because this species does not reproduce sexually, we evaluated this question based on its ability to reproduce vegetatively. Individual plants (ramets) of *S. molesta* produce vegetative offshoots that are connected by rhizomes. As these plants grow over time, they form colonies (or phenets) that are temporarily held together by a rhizome (Groves et al., 1995). In the absence of damage, extension of existing branches is largely determined by temperature and the availability of nitrogen and has a maximum value near 0.43 ramets per day (Groves et al., 1995). Under ideal growth conditions, biomass and

Question ID	Answer - Uncertainty	Score	Notes (and references)
			numbers of ramets typically double in two to three days (Julien et al., 2002; Room, 1983). Given the ability for ramets to produce new ramets within a matter of days, we answered "a". Alternate answers for the Monte Carlo simulation are both "b."
ES-14 (Prolific reproduction)	n - negl	-1	This species does not reproduce sexually (Julien et al., 2002; Weber, 2003; Everitt et al., 2007; Parsons & Cuthbertson, 2001; Smith, 2008) as it is a sterile (Julien et al., 2002; Weber, 2003; Everitt et al., 2007) pentaploid hybrid (Parsons & Cuthbertson, 2001). While vegetative reproduction is not directly considered in this question, it is important to note that carrying capacity for this species ranges from 2,500 large ramets per square meter in nutrient-poor waters to 30,000 small ramets per square meter in nutrient-rich waters (Groves et al., 1995).
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	*Salvinia molesta* may be spread within and between water-bodies by contaminated boats, boat trailers, motors and recreation and fishing gear (Julien et al., 1995; Global Invasive Species Database, 2005). Buds are fragmented and dispersed when disturbed by human activities (Owens et al., 2004). The movement of boats to and from Lake Kariba in Zimbabwe may have been responsible for the spread of *S. molesta* into inland waterways (Global Invasive Species Database, 2005).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	*Salvinia molesta* has been spread around the world as a contaminant of shipments of various aquatic goods such as tropical fish and aquatic plants (CABI, 2015). Its introduction into the United States is linked to the importation of other aquarium plants (FWC, 2015); specimens). For example a specimen found growing in a Florida nursery were imported via contaminated nursery stock from Sri Lanka (Oliver, 1993). *Salvinia molesta* may also have been brought in to the United States as packing with fresh, iced fish (Donaldson & Rafferty, 2015).
ES-17 (Number of natural dispersal vectors)	3	0	Propagule information for ES-17a through ES-17e: This species does not reproduce sexually, but rather, through natural vegetative fragmentation (Parsons & Cuthbertson, 2001; Smith, 2008). Natural fragmentation is promoted in nutrient-rich communities, with several buds forming successively at each node. As the new bud develops into a branch, the older one is abscissed and moves away from the parent (Parsons & Cuthbertson, 2001).
ES-17a (Wind dispersal)	n - negl		We found no evidence of wind dispersal. Furthermore, it seems highly unlikely that vegetative offsets would normally be dispersed by wind.
ES-17b (Water dispersal)	y - negl		*Salvinia molesta* fragments are dispersed within water bodies mainly by water currents (Groves et al., 1995), but also via flooding (Parsons & Cuthbertson, 2001).
ES-17c (Bird dispersal)	y - high		Water birds are a significant means of dispersal (NSW WeedWise, 2015), and birds have been documented as spreading *S. molesta* between waterways (CABI, 2015). We are answering yes, with high uncertainty, without further evidence.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17d (Animal external dispersal)	y - low		There are records of *S. molesta* being carried for short distances by large animals, such as cattle after drinking from infested sites (Groves et al., 1995) or as they move from infested water bodies (Julien et al., 2002). Hippos in Africa and water buffalo in Australia have been recorded to carry *S. molesta* both within and between water-bodies (Global Invasive Species Database, 2005).
ES-17e (Animal internal dispersal)	n - low		We found no evidence to support this kind of dispersal. It seems unlikely that vegetative parts would survive digestion in animals if they are consumed.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	n - mod	-1	We found no evidence regarding dormancy or the production of a propagule bank, and this plant does not produce any seeds or other perennating structures, so we are answering no.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	New plants are formed when mechanical interference severs pieces of the rhizomes (Parsons & Cuthbertson, 2001). Small fragments are viable propagules that are easily spread by boats and when used as a pond or water garden plant (Smith, 2008). Buds must be at least 0.3 in. in length to produce new growth when separated from the parent plant (Owens et al., 2004).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	We found no evidence that this species is resistant to herbicides. Furthermore, it is not listed by Heap (2013). Herbicides shown to be effective in *S. molesta* control include: anhydrous ammonia, dinoseb, formalin, pentachlorophenol, diquat, paraquat, sodium arsenite, ametryn, dimethametryn + piperophos, terbutryn, hexazinone, 90% a.i. powdered Velpar + surfactant, and fluridone (Groves et al., 1995).
ES-21 (Number of cold hardiness zones suitable for its survival)	8	0	
ES-22 (Number of climate types suitable for its survival)	9	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - low	0	We found no evidence that this species is allelopathic.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this species is parasitic. Furthermore, *S. molesta* does not belong to a family known to contain parasitic plants (Heide-Jorgensen, 2008; Groves et al., 1995; Julien et al., 2002).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	y - negl	0.4	Large mats prevent photosynthesis (Groves et al., 1995). High plant growth rates and slow decomposition rates reduce the concentration of nutrients in the water column (Julien et al., 2002; Koutika & Rainey, 2015; McFarland et al., 2004). Light penetration and oxygen levels are adversely affected, pH is reduced (Parsons & Cuthbertson, 2001). Light and oxygen are prevented from entering the water at the same time as decomposing material drops to the bottom consuming dissolved oxygen (Smith, 2008),

Question ID	Answer - Uncertainty	Score	Notes (and references)
			decreasing the available oxygen throughout the water column and increasing levels of carbon dioxide and hydrogen sulfide (Thomas & Room, 1986).
Imp-N2 (Changes habitat structure)	y - negl	0.2	Thick mats on the water surface kill submerged plants by preventing light from entering the water (Groves et al., 1995). Any habitat with submerged vegetation will lose this layer (Koutika & Rainey, 2015; McFarland et al., 2004). As the plants die, organic debris accumulates at the bottom of the water column and can threaten fisheries by creating a shallow-water environment less suited to fish breeding (McFarland et al., 2004).
Imp-N3 (Changes species diversity)	y - negl	0.2	Native aquatic plants are eliminated (Weber, 2003) and it shades out submerged plants (Koutika & Rainey, 2015). Mats reduce the amount of light and oxygen penetrating the water surface, preventing submerged aquatic plants from photosynthesizing efficiently (IUCN, 2015). Migrating birds, for example, find it difficult to access resources in water bodies covered with *Salvinia* (IUCN, 2015). By curtailing the availability of light, *S. molesta* can outcompete many native species of submersed and floating plants, consequently reducing community diversity (McFarland et al., 2004).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - negl	0.1	The impacts described above in Imp-N1 through Imp-N3, and below in Imp-N5 are significant and can directly affect T&E species. For example, a rapidly expanding infestation was documented in April of 1999, when *Salvinia molesta* in Enchanted Lake, Kailua, Hawaii, threatened the habitat of three endangered water bird species, i.e., the Hawaiian coot (*Fulica alai*), Hawaiian gallinule (*Gallinula chloropus sandivicensis*), and Hawaiian stilt (*Himantopus mexicanus knudseni*) (McFarland et al., 2004).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	y - low	0.1	*Salvinia molesta* is already present in the southeastern and western regions of the United States (BONAP, 2015), as well as Hawaii (McFarland et al., 2004), that are listed as globally outstanding ecoregions (Ricketts et al., 1999) may be a catalyst of habitat alteration. The buildup of vegetation and decaying matter reduces water flow and increases siltation, which further reduces the water flow. The vegetation mats provide a suitable substrate for non-aquatic plants to take root in, increasing the buildup of vegetative matter. *Salvinia molesta* causes more water to be lost due to evapotranspiration than would be lost from an open water body of the same size. This problem is more serious in areas where water is scarce or infrequently replenished. Shallow open water-bodies may be converted into marshes (IUCN, 2015).
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon a weed but no evidence of control; (c) taxon a weed and evidence of control efforts]	c - negl	0.6	*Salvinia molesta* is a weed in Africa (Macdonald et al., 2003) and India (Rao & Sagar, 2012); and is a serious weed of rivers, streams, and lakes in Australia (Parsons & Cuthbertson, 2001). In 2013, *S. molesta* was elected as one of the '100 of the World's Worst Invasive Alien Species' (Global Invasive Species Database, 2005). This species is controlled by numerous groups. For example,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			the state of Louisiana undertook aerial herbicide application in the 1990s. When drawdown and biological control were combined, control was much more effective (Savoie, 2004). Biological control with *Cyrtobagous salviniae* has been successful in Florida (Savoie, 2004). *Cyrtobagous salviniae* release field tests in Louisiana and Texas showed "dramatic reductions" in *S. molesta* populations at the studied sites (Tipping et al., 2008). For the Monte Carlo simulation, alternate answers were both "b."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	y - negl	0.1	Large mats of *S. molesta* interfere with the operation of engineering structures (e.g. floodgates, locks and weirs), prolong flooding by blocking drains, and damage fences and other structures during floods (Groves et al., 1995). While not formally considered for this question, we think it is important to note that these mats also degrade potable water by causing anaerobic conditions which produces unpleasant tastes and odors; and favor the spread of certain diseases (Groves et al., 1995; Julien et al., 2002), and provide ideal habitat for mosquitoes that transmit encephalitis, dengue fever, and malaria (Julien et al., 2002).
Imp-A2 (Changes or limits recreational use of an area)	y - negl	0.1	Large mats interfere with fishing, transport and recreation, and they degrade the aesthetic appeal and recreational value of lakes and rivers (Groves et al., 1995). They also prevent access to fishing grounds and deplete habitat for game birds (Julien et al., 2002). Dense growth of the plant forms a physical barrier on the water surface that prevents or impedes water use for recreational activities, such as swimming, boating, water skiing, and fishing (McFarland et al., 2004).
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	We found no evidence that this species affects ornamental vegetation.
Imp-A4 [What is the taxon's weed status in anthropogenic systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	c - low	0.4	*Salvinia molesta* is a major aquatic weed that is a major obstacle to the enjoyment and use of water (Australian Natural Heritage Trust, 2003). *Cyrtobagous salviniae* biocontrol was used to control a *S. molesta* population in Papua New Guinea. This population was preventing villagers from fishing and accessing local markets and schools, and so entire villages were abandoned. Biocontrol in this area was specifically undertaken to allow villagers to regain the ability to fish and travel by boat (Sullivan et al., 2011). For the Monte Carlo simulation, alternate answers are both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - high	0.4	Thick mats accumulate sediments, which strongly contribute to flooding events. Flooding causes the loss of crops and agricultural operations (McFarland et al., 2004).

Question ID	Answer - Uncertainty	Score	Notes (and references)
			We found no other evidence regarding crop yield, and so we used high uncertainty, as flooding is not guaranteed to happen at every location with *S. molesta* populations, but it may occur.
Imp-P2 (Lowers commodity value)	n - mod	0	We found no evidence that this species lowers commodity value.
Imp-P3 (Is it likely to impact trade?)	y - low	0.2	Plant fragments may be introduced as contaminants of the aquaria trade (CABI, 2015; FWC, 2015) or the import of fish (CABI, 2015; Donaldson & Rafferty, 2015). Currently, French Polynesia, Honduras, Morocco, New Zealand, Republic of Korea, and Thailand require phytosanitary certificates declaring shipments free of *S. molesta* (APHIS, 2015a). The pathway of movement combined with the requirements of phytosanitary certificates indicate that *S. molesta* is likely to impact international trade.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - low	0.1	Large mats obstruct or prevent the use of water for irrigation and can impede the access of livestock to water (Groves et al., 1995). *Salvinia molesta* may establish in rice fields during irrigation and subsequently compete directly with the crop for water (Parsons & Cuthbertson, 2001). Mats block access to drinking water for livestock, wildlife, and people; and clog irrigation and drainage canals (Thomas & Room, 1986).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	We found no evidence that this species is toxic to animals.
Imp-P6 [What is the taxon's weed status in production systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	c - negl	0.6	Major weed of rice and harbors (Thomas & Room, 1986). Weed of rice in Indonesia, India, Malaysia, the Philippines, Sri Lanka, and Thailand (Moody, 1989). Chemical control undertaken in Sri Lanka in rice paddies, but this control was prohibitively expensive, as regrowth from survivors will again increase plant density to pre-spraying levels (Thomas & Room, 1986). Good control of *S. molesta* in farm dams was achieved by biological control using *Cyrtobagous salviniae* (Sullivan et al., 2011). Alternate answers for the Monte Carlo simulation were both "b."
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2015).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z5 (Zone 5)	n - low	N/A	We found no evidence that it occurs in this hardiness zone.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z6 (Zone 6)	y - low	N/A	The United States (CT, KS, MO).
Geo-Z7 (Zone 7)	y - negl	N/A	The United States (MD) and Sweden.
Geo-Z8 (Zone 8)	y - negl	N/A	The United States (AL, GA, LA, TX), the Netherlands, and Australia.
Geo-Z9 (Zone 9)	y - negl	N/A	The United States (CA, FL, GA, LA), the Netherlands, France, South Africa, Japan, and New Zealand.
Geo-Z10 (Zone 10)	y - negl	N/A	The United States (CA), Brazil, Kenya, Zambia, Botswana, Namibia, South Africa, and New Zealand.
Geo-Z11 (Zone 11)	y - negl	N/A	The United States (CA), Mexico, Guatemala, Zambia, Zimbabwe, South Africa, Papua New Guinea, and New Zealand.
Geo-Z12 (Zone 12)	y - negl	N/A	Brazil, New Zealand, and Australia.
Geo-Z13 (Zone 13)	y - negl	N/A	The United States, Brazil, Senegal, Cote d'Ivoire, Malaysia, Thailand, Indonesia, and Papua New Guinea.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - negl	N/A	Brazil, Guatemala, Cote d'Ivoire, Malaysia, Thailand, Indonesia, and Papua New Guinea.
Geo-C2 (Tropical savanna)	y - negl	N/A	The United States (HI), Brazil, Mexico, Cote d'Ivoire, Zambia, Papua New Guinea, and Australia.
Geo-C3 (Steppe)	y - negl	N/A	The United States (CA), Senegal, Zambia, Namibia, Botswana, Australia.
Geo-C4 (Desert)	y - mod	N/A	The United States (CA).
Geo-C5 (Mediterranean)	y - negl	N/A	The United States (CA), France, Kenya, South Africa, and Australia.
Geo-C6 (Humid subtropical)	y - negl	N/A	The United States (AL, FL, GA, LA, MD, MO, TX), Brazil, Zambia, Zimbabwe, South Africa, and Japan.
Geo-C7 (Marine west coast)	y - negl	N/A	The Netherlands, Zimbabwe, South Africa, New Zealand, and Australia.
Geo-C8 (Humid cont. warm sum.)	y - negl	N/A	The United States (KS).
Geo-C9 (Humid cont. cool sum.)	y - low	N/A	The United States (CT), and Sweden.
Geo-C10 (Subarctic)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that it occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - negl	N/A	The United States (CA), Senegal, South Africa, and Australia.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	The United States (CA, HI), Mexico, Namibia, Zambia, Zimbabwe, Botswana, South Africa, and Australia.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	The United States (HI, KS), Brazil, Sweden, France, Kenya, Namibia, Zambia, Zimbabwe, and South Africa.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	The United States (MO), the Netherlands, South Africa, and Australia.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	The United States (CT, LA, MD, TX), Brazil, Japan, Papua New Guinea, New Zealand, and Australia.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	The United States (AL, GA, LA, TX), Papua New Guinea, and Australia.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	The United States (LA), Brazil, Cote d'Ivoire, New Zealand, and Australia.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	The United States (FL), Cote d'Ivoire, and Australia.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	Guatemala, Japan, and Indonesia.
Geo-R10 (90-100 inches; 229-254 cm)	y - low	N/A	We found no specific evidence that it occurs in this precipitation band. However, because it occurs in areas receiving 89-90 inches and 100+ inches of rainfall (GBIF, 2015), it is likely to also occur in this precipitation band.
Geo-R11 (100+ inches; 254+ cm)	y - negl	N/A	Brazil, Malaysia, Thailand, Indonesia, and Papua New Guinea.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	*Salvinia molesta* was first reported outside of cultivation in the United States in 1995 in a pond in southeastern South Carolina (Julien et al., 2002) and has since spread to 16 states (McFarland et al., 2004; BONAP, 2015).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	
Ent-4c (Contaminant of seeds for planting)	-	N/A	
Ent-4d (Contaminant of ballast water)	-	N/A	
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	
Ent-4f (Contaminant of landscape products)	-	N/A	
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	
Ent-4i (Contaminant of some other pathway)	-	N/A	
Ent-5 (Likely to enter through natural dispersal)	-	N/A	