Weed Risk Assessment for *Stratiotes aloides* L. (Hydrocharitaceae) – Water soldier

Michigan Department of Agriculture and Rural Development

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Version 1

Top left: hand harvesting in the Trent River (source: Francine MacDonald, Ontario Ministry of Natural Resources and Forestry). Bottom left: Dense emergent growth form (source: Francine MacDonald, Ontario Ministry of Natural Resources and Forestry). Right: Submergent growth form (source: Francine MacDonald, Ontario Ministry of Natural Resources and Forestry)

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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.

Stratiotes aloides L. – Water soldier

Species Information

Family: Hydrocharitaceae

Synonyms: *Stratiotes aculeatus*, *Stratiotes aquaticus*, *Stratiotes ensiformis*, *Stratiotes generalis* (The Plant List, 2015)

Common names: Water soldier (Forbes, 2000; Smolders et al., 1995b; Erixon, 1979), water aloe (Dave's Garden, 2015; Oregon Department of Agriculture, 2015), pineapple plant (Oregon Department of Agriculture, 2015).

Botanical description: *Stratiotes aloides* is a loosely rooted (Cook & Urmi-König, 1983) aquatic species with emergent and submerged growth forms (Erixon, 1979). Submerged leaves are thin, flaccid but brittle, light green, up to 60 cm or rarely 110 cm long, up to 1 cm wide, with somewhat weak spines; emergent leaves are thick, rigid, brittle, dark green, usually less than 40 cm long, 1-4 cm wide, with well-developed spines, and the emergent growth forms rosettes at the surface of the water (Cook & Urmi-König, 1983). For a full botanical description, see Cook and Urmi-König (1983).

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: *Stratiotes aloides* is native to Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, Finland, Holland, Hungary, Italy, Sweden, Romania, the United Kingdom, Yugoslavia, and possibly Germany/Poland (Cook & Urmi-König, 1983). This species may be native to other countries in Europe, but its original native range is difficult to determine due to cultivation (Cook & Urmi-König, 1983; Forbes, 2000). Within Europe, it has naturalized in many areas due to cultivation escapes (Cook & Urmi-König, 1983; Preston & Croft, 1997) Outside of Europe, its only record of escape is within the Trent River in Ontario, Canada (Ontario's Invading Species Awareness Program, 2015). *Stratiotes aloides* it does not appear to have been introduced to any other countries outside of Europe, besides Canada (Lansdown, 2014; GBIF, 2015).

U.S. distribution and status: This species is not known to be present in the United States (GBIF, 2015; ISSG, 2015; NGRP, 2015; USDA, 2015; BONAP, 2015). It is regulated as a noxious weed in four states: Alabama, Florida, Michigan, and Washington (National Plant Board, 2015).

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

1. *Stratiotes aloides* analysis

Establishment/Spread Potential

Stratiotes aloides is a shade tolerant aquatic species (PFAF, 2015; Cook & Urmi-König, 1983; Salisbury, 1961; Bailey & Bailey, 1976). It forms dense mats on the water's surface (Mulderij et al., 2005; Ontario's Invading Species Awareness Program, 2015). When present in small water bodies, the species completely covers the water surface with a dense stand of floating rosettes up to 50 cm tall (Nielson & Borum, 2008). *Stratiotes aloides* reproduces both vegetatively and by seed (Smolders et al., 1995b), and may be a prolific seed producer (Erixon, 1979; Smolders et al., 1995a). We had high uncertainty here because this species is a recent introduction outside of its native range, and reproduction and dispersal mechanisms are not fully understood.

Risk score = 17 Uncertainty index = 0.24

Impact Potential

Very little is known about the impacts of *S. aloides*. This species was first discovered to have escaped beyond its native range in 2008 when it was discovered within the Trent River in Ontario (Ontario's Invading Species Awareness Program, 2015). Dense stands can exclude native wetland plants (NSW DPI, 2015), and it crowds out native vegetation resulting in decreased plant biodiversity (Ontario's Invading Species Awareness Program, 2015). The sharp serrated leaves of *S. aloides* can injure swimmers and those who handle the plant (Ontario's Invading Species Awareness Program, 2015). Thick growth could potentially increase the risk of flooding and the cost of water delivery (Oregon Department of Agriculture, 2015), as well as recreational activities such as boating and fishing. We had very high uncertainty here due to the recent introduction of this species and lack of studies discussing this species' impacts.

Risk score = 2.4 Uncertainty index = 0.36

Geographic Potential

Based on three climatic variables, we estimate that about 58 percent of the United States is suitable for the establishment of *Stratiotes aloides* (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 *Stratiotes aloides* represents the joint distribution of Plant Hardiness Zones 3-10, areas with 20-100+ inches of annual

[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).

precipitation, and the following Köppen-Geiger climate classes: humid subtropical, marine west coast, humid continental warm summers, humid continental cool summers, and subarctic.

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. *Stratiotes aloides* is found in sheltered bays or inlets of large lakes, but it is a more characteristic species of backwaters, ponds, ditches and sluggish canals. It is almost confined to nutrient-rich, loose, muddy substrates which may be either aerobic or anaerobic (Cook & Urmi-König, 1983). *Stratiotes aloides* is a temperate species (Nielson & Borum, 2008; Forbes, 2000).

Entry Potential This species has escaped in the Trent River, Ontario (Ontario's Invading Species Awareness Program, 2015), a waterway that is connected to Lake Ontario in the United States. *Stratiotes aloides* is cultivated in Europe as an ornamental, where it frequently escapes (Forbes, 2000). It is available from internet retailers in its native range in Europe (Backyard Gardener, 2015).
Risk score = 0.5 Uncertainty index = 0.08

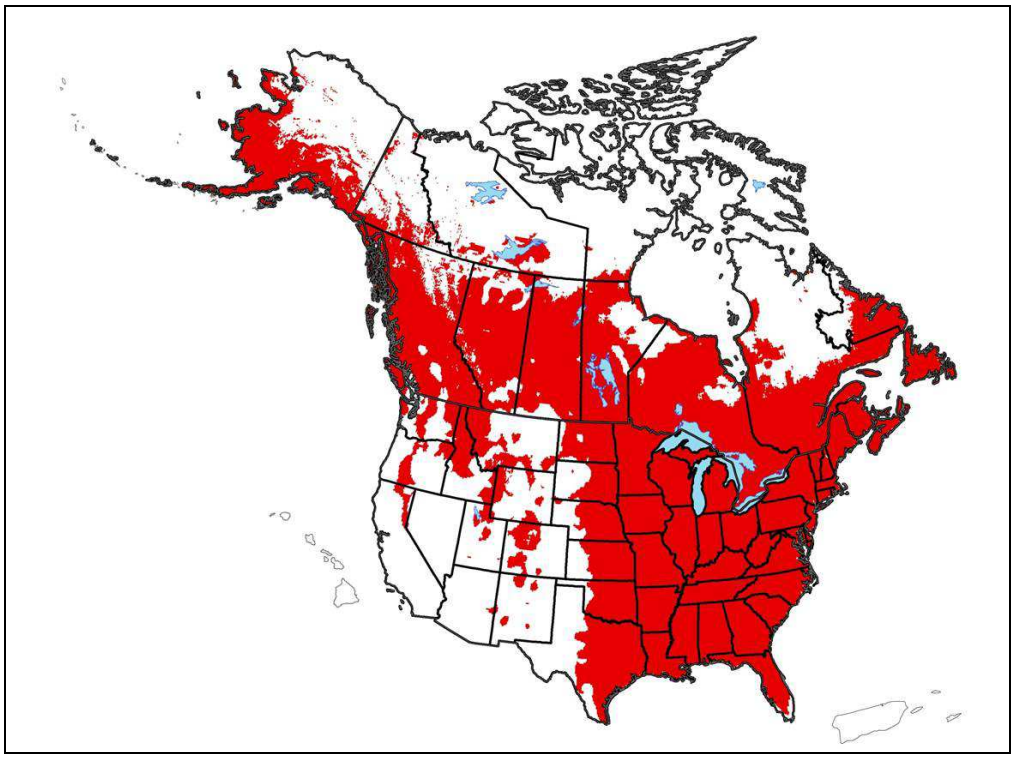

Figure 1. Predicted distribution of *Stratiotes aloides* in the United States. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 78.8%
P(Minor Invader) = 20.4%
P(Non-Invader) = 0.8%

Risk Result = High Risk

Secondary Screening = Not applicable

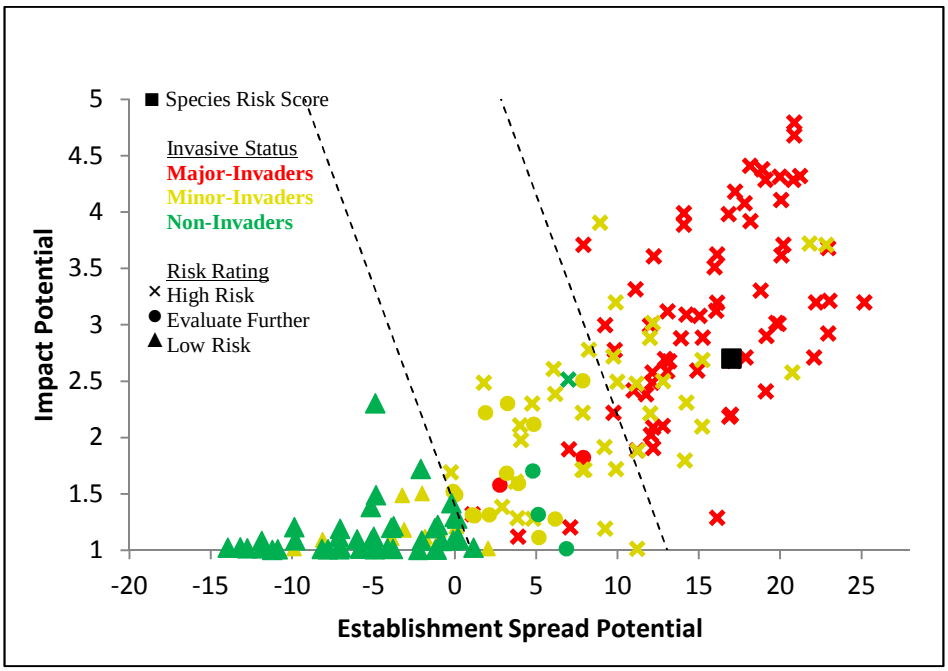

Figure 2. *Stratiotes aloides* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

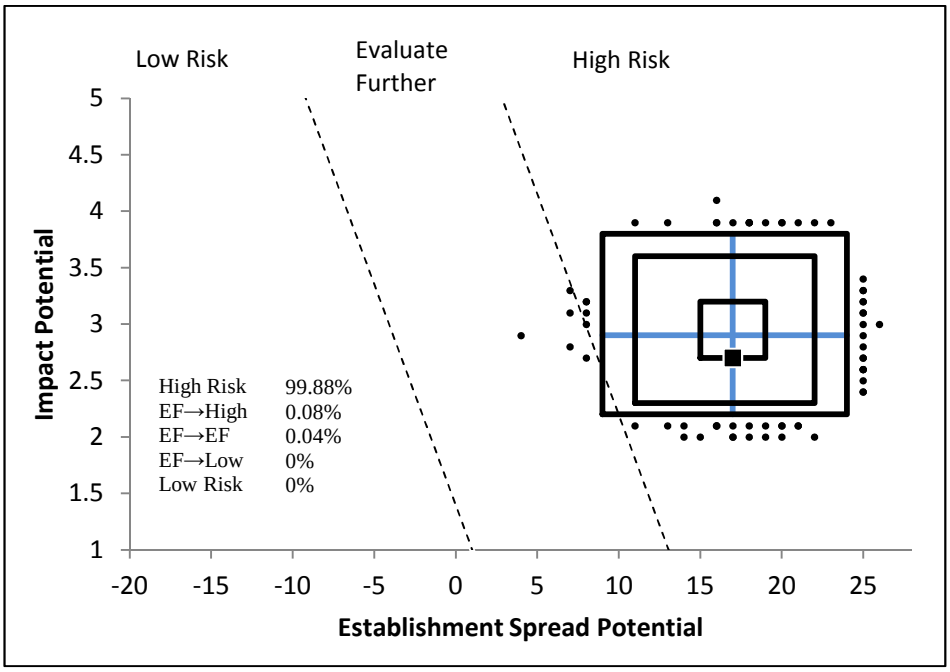

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Stratiotes aloides*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Stratiotes aloides* is High Risk (Figure 2). Our uncertainty anlysis shows that 99.6 of all possible outcomes of the risk anlysis are high risk, indicating that our conclusion is robust despite the high levels of uncertainty relative to other weed risk assesments, uncertainty was higher in this assessment because this species' biology and impacts are not well characterized.

Because the precise native and introduced ranges of this species in Europe are not well understood, it is difficult to determine where the species is native (Cook & Urmi-König, 1983; Forbes, 2000). The only place that *S. aloides* has been confirmed as naturalized is Ontario, Canada (Ontario's Invading Species Awareness Program, 2015). The Ontario Ministry of Natural Resources and Forestry has partnered with several organizations[1] to monitor and control *S. aloides* establishment and spread in the Trent River, implemented in the fall of 2014 (Ontario's Invading Species Awareness Program, 2015). Control includes herbicidal treatment of designated areas of the Trent River. In addition, a pilot program designed to test the efficacy of mechanical removal of the species went underway in the summer of 2015, and monitoring is currently in place to determine the outcome of the program (Ontario's Invading Species Awareness Program, 2015).

It is interesting to note that this species appears to be declining in its native range. Aedo et al. (2015) state that *S. aloides* has become extinct within its native range of Spain, most likely due to habitat loss. Smolders et al. (2003) have noted that it has significantly declined within its native range in the Netherlands. *Stratiotes aloides* has almost completely disappeared from shallow peaty lakes, but is still abundant in ditches and some agricultural areas. Sulphate induced eutrophication in natural areas, a product of human interactions, results in a series of nutrient alterations in the water column, leading to increased competition of free-floating species and the decline of *S. aloides* populations (Smolders et al., 2003). Sugier et al. (2010) also indicate that this species has been declining throughout its native range in Europe due to eutrophication.

[1]Organizations include: the Ontario Federation of Anglers and Hunters, Ontario Ministry of Environment and Climate Change, Trent University, Lower Trent Conservation, United States Army Engineer Research and Development Center, Parks Canada, and Ontario Invasive Plant Council.

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Appendix A. Weed risk assessment for *Stratiotes aloides* L. (Hydrocharitaceae). 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 - high	5	Native to Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, Finland, Holland, Hungary, Italy, Sweden, Romania, the United Kingdom, Yugoslavia, and possibly Germany/Poland (Cook & Urmi-König, 1983). Within Europe, this species has naturalized in many areas due to cultivation escapes (Cook & Urmi-König, 1983; Preston & Croft, 1997) and it is difficult to determine which countries this species is native to, and to which it has been introduced (Cook & Urmi-König, 1983; Forbes, 2000). Within North America, its only record of escape is within the Trent River in Ontario, Canada (Ontario's Invading Species Awareness Program, 2015). *Stratiotes aloides* distribution maps for 2014 and 2015 show that, despite aggressive control measures, *S. aloides* is still spreading within some areas of the Trent River (Ontario's Invading Species Awareness Program, 2015). This species is not known to have escaped anywhere outside of Europe besides Ontario, and does not appear to have been introduced to any other countries outside Europe (Lansdown, 2014; GBIF, 2015). With the Ontario introduction standing as the only verifiable introduction of *S. aloides* outside its native range, we are answering f, based on the spread and distribution in the Trent River (Ontario's Invading Species Awareness Program, 2015). This species appears to be a recent escape within the Trent River, and immediate control efforts may have curbed much of the potential establishment/spread of this species, so spread status is somewhat difficult to assess. Consequently, we used high uncertainty, and our alternate answers were both "e."
ES-2 (Is the species highly domesticated)	n - low	0	We found no evidence that *S. aloides* is highly domesticated. It has been grown as an aquatic ornamental in Europe for nearly three centuries (Forbes, 2000) and has escaped so frequently that it has become difficult to distinguish between its native and introduced ranges in Europe (Cook & Urmi-König, 1983; Preston & Croft, 1997)
ES-3 (Weedy congeners)	n - low	0	*Stratiotes aloides* is the only surviving member of its genus; all congeners have become extinct (Cook & Urmi-König, 1983). We found no evidence that any other members of the family Hydrocharitaceae, where *S. aloides* is placed (Cook & Urmi-König, 1983), are closely related enough to *S. aloides* to be considered for this question. Thus, we answered no, with low uncertainty, as there may be some closely related species that were not discovered during our literature review.
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	*Stratiotes aloides* grows in semi-shade (PFAF, 2015). It grows in two different forms, either emergent or totally

Question ID	Answer - Uncertainty	Score	Notes (and references)
			submerged (Erixon, 1979). Submerged plants are more adapted to shade conditions (Riemer, 1993). The submerged form easily persists in water 2-5 m deep (Cook & Urmi-König, 1983). A study of light intensity in natural lakes in Wisconsin showed that plants at a depth of 5 m receive anywhere between 17% to less than 1% of the incident light (Riemer, 1993). For this reason, we are answering yes.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	*Stratiotes aloides* is not a vine, nor does it form tightly appressed basal rosettes. This species is an herbaceous aquatic species (Bailey & Bailey, 1976; PFAF, 2015).
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	*Stratiotes aloides* forms very dense stands (Mulderij et al., 2005) and dense mats on the surface of the water (Ontario's Invading Species Awareness Program, 2015). When present in small water bodies, the species completely covers the water surface with a dense stand of floating rosettes up to 50 cm tall (Nielson & Borum, 2008). One observational study in Ireland noted that "Mill Lough, approximately [6 ha], was so overgrown with *S. aloides* that it was difficult to row a boat through it" (Forbes, 2000).
ES-7 (Aquatic)	y - negl	1	*Stratiotes aloides* is an herbaceous aquatic plant (Salisbury, 1961; Bailey & Bailey, 1976) that may grow as either an emergent or submerged plant (Erixon, 1979).
ES-8 (Grass)	n - negl	0	*Stratiotes aloides* is a member of the family Hydrocharitaceae (Cook & Urmi-König, 1983; Efremov & Sviridenko, 2008) 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). *Stratiotes aloides* is an herbaceous aquatic plant (Bailey & Bailey, 1976; PFAF, 2015)
ES-10 (Does it produce viable seeds or spores)	y - negl	1	70% of collected seeds germinated in a laboratory, and seedlings were found in the wild (Smolders et al., 1995b). Successful germination has also been observed by Cook & Urmi-König (1983).
ES-11 (Self-compatible or apomictic)	? - max	0	*Stratiotes aloides* is primarily dioecious, with male and female flowers on different plants (Cook & Urmi-König, 1983). The dioecy of *Stratiotes* is not absolute. Some individual plants are hermaphroditic, with receptive female staminoides on flowers of individuals with both sexes of flowers (Forbes, 2000). However, we found no information regarding the viability of seeds of hermaphroditic individuals. We are therefore answering unknown.
ES-12 (Requires specialist pollinators)	n - mod	0	Most likely *Diptera* pollinate, as they are frequent visitors in an area with natural seed set (Cook & Urmi-König, 1983). Abundant insect pollinators were present within *S. aloides* stands observed in the field by Smolders et al. (1995a). These authors do not treat these pollinators as specialist pollinators, suggesting that these are generalist pollinators, and so we are answering no.
ES-13 [What is the taxon's minimum generation time? (a) less than a year with multiple	b - low	1	New rosettes are produced consistently throughout the summer (Preston & Croft, 1997). Throughout the summer, lateral shoots are developed which bear terminal rosettes.

Question ID	Answer - Uncertainty	Score	Notes (and references)
generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) unknown]			These rosettes become detached at a relatively late stage in development or they become detached while bud-like (Cook & Urmi-König, 1983). Detached rosettes sink in the autumn and overwinter as a rosette with green leaves, and in the spring they float to the surface (Cook & Urmi-König, 1983). We are answering b, as it is likely that these rosettes produce new rosettes individually after detaching from the parent plant and overwintering. Alternate answers, however, are both a, as it is not entirely clear if this is the case.
ES-14 (Prolific reproduction)	y - mod	1	Field observations have shown that within its native range, *Stratiotes aloides* can grow at densities of 90 individuals/m^2 (Erixon, 1979) and produce up to 3 fruit per plant, with up to 30 seeds per fruit (Smolders et al., 1995a). This results in a maximum possible seed production of up to 8,100 seeds/m^2. Although natural seed set is somewhat rare (Cook & Urmi-König, 1983), which is most likely due to single gender stands not occurring closely enough to male plants for pollination (Smolders et al., 1995a), because prolific seed production is clearly possible, we are answered yes.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - low	1	Fragments are easily spread by recreational boaters (FOCA, 2015) and boat wake can dislodge plants and offsets and allow them to spread to new areas (Ontario's Invading Species Awareness Program, 2015). As detached rosettes can regenerate at a rate of 84% (Sarneel, 2013) and form new individuals (Renman, 1989) any human activity which leads to this fragmentation may lead to dispersal.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	n - mod	-1	We found no evidence that this species contaminates agricultural, forestry, or horticultural products. This species is cultivated as an ornamental for outdoor water gardens (Forbes, 2000) so it seems unlikely that it may contaminate aquarium species.
ES-17 (Number of natural dispersal vectors)	2	0	Fruit and seed traits considered in questions ES-17a through ES-17e: Fruit a berry-like capsule containing up to 24 seeds, ovoid or somewhat barrel-shaped, tapering to a cone-like structure, 12-34 mm long and 9-15 mm diameter (Cook & Urmi-König, 1983). Seeds are cylindrical, but often curved at the micropylar end with a more or less pronounced beak that may or may not have a neck, in transverse section round or irregularly compressed, 5.8--10.6 mm long, 2.3--3.0 mm wide (Cook & Urmi-König, 1983)
ES-17a (Wind dispersal)	n - low		This species does not appear to have any adaptations for wind dispersal.
ES-17b (Water dispersal)	y - negl		The ripe fruits often become torn off at their bases and sink; those that remain attached eventually begin to decay and the seeds are released in a gelatinous mass and sink to the bottom of the water column (Cook & Urmi-König, 1983). Propagules are readily distributed by wave action and currents (Erixon, 1979). Also notable, overwintering rosette shoots are temporarily rootless, and are highly dispersible during spring floods. (Efremov & Sviridenko, 2008).
ES-17c (Bird dispersal)	? - max		We found no direct evidence but suspect seeds may be

Question ID	Answer - Uncertainty	Score	Notes (and references)
			dispersed in this manner. Fresh seeds are covered in a gelatinous mass that may allow seeds to stick to feet or feathers, but this mass only becomes sticky when dry (Forbes, 2000).
ES-17d (Animal external dispersal)	? - max		We found no direct evidence but suspect seeds may be dispersed in this manner. Fresh seeds are covered in a gelatinous mass that may allow seeds to stick to feet or fur, but this mass only becomes sticky when dry (Forbes, 2000).
ES-17e (Animal internal dispersal)	y - mod		*Stratiotes aloides* is fed upon by a range of herbivores (Cook & Urmi-König, 1983). Smolders et al. (1995b) found that seeds which had passed through the human digestive system germinated at higher rates than seeds which did not. It is also worth noting that fossil seed was sometimes found in coprolites (fossilized dung) (Cook & Urmi-König, 1983). Here we answered yes, with moderate uncertainty, as internal dispersal seems likely and beneficial to the species.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - high	1	No long-term dormancy mechanism has been identified in any overwintering rosettes (Cook & Urmi-König, 1983). *Stratiotes aloides* seeds do not germinate until after the seed coat has been removed; however seeds that do not germinate within the first three years may not survive as seedlings (Smolders et al., 1995b). Seeds tend to germinate about 4 months after being shed, but irregular germination has been observed for seeds stored for up to three years in water at room temperature. (Cook & Urmi-König, 1983). We are answering yes because even though rosettes do not overwinter, seeds may persist for three years.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	Detached ramets can create new individuals (Renman, 1989). Even rosettes that have not fully matured still produce new individuals (Cook & Urmi-König, 1983). Thus, if a rosette is separated from the parent plant, it will contribute to lateral expansion of the species (Renman, 1989). Buds removed from the parent plant have a resprouting rate of 84% (Sarneel, 2013).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	This species is not listed by Heap (2013) as a weed that is resistant to herbicides. Herbicides containing diquat as the main ingredient have been utilized for control of *S. aloides* in the Trent River in Ontario (Ontario's Invading Species Awareness Program, 2015).
ES-21 (Number of cold hardiness zones suitable for its survival)	9	0	
ES-22 (Number of climate types suitable for its survival)	4	2	
ES-23 (Number of precipitation bands suitable for its survival)	8	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	y - mod	0	Brammer (1979) found that very dense stands of *S. aloides* in natural areas alter the water chemistry in a way that inhibits phytoplankton growth, by increasing pH and decreasing carbon alkalinity. Mulderij et al. (2005) found that water in which *S. aloides* had been grown under

Question ID	Answer - Uncertainty	Score	Notes (and references)
			artificial conditions (i.e. light and nutrient overloading) inhibited the studied phytoplankton species (i.e. *Microcystis aeruginosa*, *Nannochloropsis limnetica*, and *Scenedesmus obliquus*). We are answering yes to this question as there is clear evidence of alleopathic behavior occurring under natural conditions.
Imp-G2 (Parasitic)	n - low	0	We found no evidence that this species is parasitic. Furthermore, *S. aloides* does not belong to a family known to contain parasitic plants (Heide-Jorgensen, 2008; Cook & Urmi-König, 1983).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	? - max		Has the potential to alter surrounding water chemistry, which may harm phytoplankton and other aquatic organisms (Ontario's Invading Species Awareness Program, 2015). The ecosystem effects of this species as a non-native plant have not been well-studied; we suspect that this species will change ecosystem processes due to its dense growth. Dense growth of surface species often limit light and change dissolved oxygen concentrations (Zhu et al., 2014; Tall et al., 2011; Groth et al., 1996). Because further studies of this species as a non-native taxon are necessary to determine its effects on ecosystem parameters, we answered unknown.
Imp-N2 (Changes habitat structure)	y - mod		Because of light limitation under dense mats of floating S. aloides, the species is rarely accompanied by submerged macrophytes (Kufel et al., 2010). The aquatic macrophyte population in Lake Seymour (within the Trent Severn Waterway) where S. aloides is most abundant, was composed of a diverse mix of both native and non-native submergent aquatic vegetation including Eurasian milfoil, curly leaf pondweed, Chara, white water lily, and Vallisneria spp. prior to te introduction of S. aloides. The new community is dominated by a mix of both emergent/submergent forms of S. aloides, which appear to outcompete other forms of aquatic vegetation (Francine MacDonald, personal communication).
Imp-N3 (Changes species diversity)	y - mod	0.2	Dense stands can exclude native wetland plants (NSW DPI, 2015). Crowds out native vegetation resulting in decreased plant biodiversity (Ontario's Invading Species Awareness Program, 2015). We are answering yes, with moderate uncertainty, as further studies are necessary to determine the extent of this species' effects on diversity.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	? - max		Without better knowledge of the species' impact on natural systems, it is unknown if *S. aloides* will affect T&E species.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	? - max		Without better knowledge of the species' impact on natural systems, it is unknown if *S. aloides* will affect globally outstanding ecoregions.
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	c - low	0.6	Weed of natural areas in Ireland (Stokes et al., 2004). Control efforts are being undertaken in the Trent River, a natural waterway. The eradication plan involves mechanical removal of individual plants by hand pulling, and application with the herbicide diquat (Ontario's Invading

Question ID	Answer - Uncertainty	Score	Notes (and references)
evidence of control efforts]			Species Awareness Program, 2015). For the Montecarlo 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 - mod	0.1	Sharp serrated leaves can injure swimmers and those who handle the plant (Ontario's Invading Species Awareness Program, 2015). Thick growths of aquatic plants could potentially increase the risk of flooding and the cost of water delivery by slowing the passage of water through canals, marshes and streams (Oregon Department of Agriculture, 2015).
Imp-A2 (Changes or limits recreational use of an area)	y - low	0.1	Dense mats hinder recreational activities such as boating and fishing, and sharp, serrated leaves may deter swimmers (SLELO PRISM, 2015; Ontario's Invading Species Awareness Program, 2015; Oregon Department of Agriculture, 2015)
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	We found no evidence that this species affects ornamental plants.
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 - high	0.4	Considered a weed by residents along the Trent River, Ontario, due to its adverse impacts on swimming, boating, and fishing (Campbell, 2009). There are several companies in the United Kingdom who offer control services for S. aloides to homeowners and landscapers (Pitchcare Ireland, 2015; Aquatic Solutions UK, 2015). We answered c, and alternate answers were both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - mod	0	We found no evidence that this species reduces crop or commodity yield. Because we found no evidence this species is a weed of or even establishes in production systems, we answered all questions as no with moderate uncertainty.
Imp-P2 (Lowers commodity value)	n - mod	0	We found no evidence that this species reduces commodity value.
Imp-P3 (Is it likely to impact trade?)	n - mod	0	We found no evidence that this species is likely to impact trade. Phytosanitary certificates for this species are required for the countries of Australia and Nauru, but we found no evidence that this species is likely to follow a pathway of trade.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	We found no evidence that this species affects the quality or availability of irrigation.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - mod	0	We found no evidence that this species is toxic to animals. In Germany and Russia it is reported to have been used as food for pigs (Cook & Urmi-König, 1983).
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	a - mod	0	We found no evidence that this species is a weed in production systems. Alternate answers are both b.

Question ID	Answer - Uncertainty	Score	Notes (and references)
efforts]			
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 - low	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z3 (Zone 3)	y - low	N/A	Finland
Geo-Z4 (Zone 4)	y - negl	N/A	Finland
Geo-Z5 (Zone 5)	y - negl	N/A	Sweden, Finland (GBIF, 2015). Canada (Ontario's Invading Species Awareness Program, 2015)
Geo-Z6 (Zone 6)	y - negl	N/A	Germany, Austria, Sweden, Finland, Latvia, Belarus, Poland.
Geo-Z7 (Zone 7)	y - negl	N/A	France, Germany, Austria, Norway, Sweden, Poland, Hungary.
Geo-Z8 (Zone 8)	y - negl	N/A	The United Kingdom, France, Belgium, the Netherlands, Germany, Norway, Denmark, Sweden.
Geo-Z9 (Zone 9)	y - negl	N/A	The United Kingdom, Ireland, France, the Netherlands, Denmark, Sweden.
Geo-Z10 (Zone 10)	y - mod	N/A	The United Kingdom.
Geo-Z11 (Zone 11)	n - high	N/A	A few points in Spain, however, Aedo et al. (2015) report that *S. aloides* is extinct in natural areas of Spain, so these are likely erroneous or purposefully cultivated.
Geo-Z12 (Zone 12)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z13 (Zone 13)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C2 (Tropical savanna)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C3 (Steppe)	n - high	N/A	A few points in Spain, however, Aedo et al. (2015) report that *S. aloides* is extinct in natural areas of Spain, so these are likely erroneous or purposefully cultivated.
Geo-C4 (Desert)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C5 (Mediterranean)	n - high	N/A	A few points in Spain, however, Aedo et al. (2015) report that *S. aloides* is extinct in natural areas of Spain, so these are likely erroneous or purposefully cultivated.
Geo-C6 (Humid subtropical)	y - mod	N/A	Some points in France.
Geo-C7 (Marine west coast)	y - negl	N/A	Ireland, the United Kingdom, France, Belgium, the Netherlands, Germany, Denmark
Geo-C8 (Humid cont. warm sum.)	y - low	N/A	The climate qualifications for the humid subtropical region and the marine west coast region are identical to those of the humid continental warm summers region, with one difference: the coldest months of the humid subtropical region and the marine west coast region fall between -3°C and 18°C, while the coldest months of the humid continental warm summers region fall below -3°C (Koppen climate classification, 2015). Given that *S. aloides* is known to occur in areas where the coldest temperatures fall between -40.0 °C and -34.4 °C (GBIF, 2015) we believe it is likely that this species can occur in humid continental warm summer regions.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Germany, Austria, Denmark, Sweden, Norway, Latvia, Belarus, Poland, Hungary (GBIF, 2015). Canada (Ontario's Invading Species Awareness Program, 2015).
Geo-C10 (Subarctic)	y - negl	N/A	Germany, Sweden, Finland.
Geo-C11 (Tundra)	n - low	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)	n - negl	N/A	We found no evidence that it occurs in this precipitation band.
Geo-R2 (10-20 inches; 25-51 cm)	n - mod	N/A	A few points in Spain, however, Aedo et al. (2015) report that *S. aloides* is extinct in natural areas of Spain, so these are likely erroneous or purposefully cultivated.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	The United Kingdom, France, Belgium, Germany, Sweden, Poland, Belarus, Hungary.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	The United Kingdom, France, Belgium, the Netherlands, Germany, Denmark, Sweden, Norway, Finland.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Ireland, the United Kingdom, France, the Netherlands, Germany, Denmark, Sweden(GBIF, 2015). Canada (Ontario's Invading Species Awareness Program, 2015).
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Ireland, France, Germany.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Germany.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Germany, Austria.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	The United Kingdom, Germany.
Geo-R10 (90-100 inches; 229-254 cm)	y - mod	N/A	We are answering yes for this precipitation band given that this is an aquatic species.
Geo-R11 (100+ inches; 254+ cm)	y - mod	N/A	We are answering yes for this precipitation band given that this is an aquatic species.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - mod	0	Does not appear to be present in the United States (GBIF, 2015; ISSG, 2015; NGRP, 2015; USDA, 2015; BONAP, 2015)
Ent-2 (Plant proposed for entry, or entry is imminent)	n - low	0	
Ent-3 (Human value & cultivation/trade status)	d - low	0.5	European ornamental that escapes (Forbes, 2000). Available for online purchase in native countries.
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	y - negl		Trent River, Ontario (Ontario's Invading Species Awareness Program, 2015).
Ent-4b (Contaminant of plant propagative material (except seeds))	n - mod	0	We found no evidence.
Ent-4c (Contaminant of seeds for planting)	n - mod	0	We found no evidence.
Ent-4d (Contaminant of ballast water)	n - low	0	We found no evidence. This is a freshwater species (Cook & Urmi-König, 1983).
Ent-4e (Contaminant of	n - mod	0	We found no evidence.

Question ID	Answer - Uncertainty	Score	Notes (and references)
aquarium plants or other aquarium products)			
Ent-4f (Contaminant of landscape products)	n - mod	0	We found no evidence.
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	n - mod	0	We found no evidence.
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	n - high	0	In Finland it is used as an auxiliary fodder for cattle; in Germany and Russia it is reported to have been used as food for pigs (Cook & Urmi-König, 1983). However, we found no evidence that this species is a contaminant.
Ent-4i (Contaminant of some other pathway)	a - mod	0	*Stratiotes aloides* is widely used as a green fertilizer or compost in fields and market gardens (Cook & Urmi-König, 1983); however, we found no evidence that this species is a contaminant.
Ent-5 (Likely to enter through natural dispersal)	n - high	0	This species is currently present in the Trent River, Ontario (Ontario's Invading Species Awareness Program, 2015). This waterway is connected to Lake Ontario, and feeds into United States waters; however, a joint effort by various organizations within Ontario have created an aggressive control and monitoring program for *S. aloides* in the Trent River (Ontario's Invading Species Awareness Program, 2015). Given this intense scrutiny and level of management efforts, it does not seem likely that this species will enter the United States naturally. Spread of the species outside of the Trent River has been contained since it was first reported (Ontario's Invading Species Awareness Program, 2015).