United States Department of Agriculture

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

United States Department of Agriculture

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Version 2

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

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Introduction Plant Protection and Quarantine (PPQ) regulates noxious weeds under the authority of the Plant Protection Act (7 U.S.C. § 7701-7786, 2000) and the Federal Seed Act (7 U.S.C. § 1581-1610, 1939). A noxious weed is defined as "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment" (7 U.S.C. § 7701-7786, 2000). We use the PPQ weed risk assessment (WRA) process (PPQ, 2015) to evaluate the risk potential of plants, including those newly detected in the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

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., Federal 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* Stokes, *Stratiotes aquaticus* Pall., *Stratiotes ensiformis* Gilib., *Stratiotes generalis* E.H.L. Krause (The Plant List, 2015)
	Common names: Water soldier (Forbes, 2000; Smolders et al., 1995a; 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 and Urmi-König, 1983) aquatic species with emergent and submerged growth forms (Erixon, 1979). Submerged leaves are thin and flaccid but brittle, light green, up to 60 cm or rarely 110 cm long and up to 1 cm wide, with somewhat weak spines. Emergent leaves are thick, rigid, brittle, and dark green and are usually less than 40 cm long and 1-4 cm wide, with well-developed spines along leaf margins. The emergent form develops rosettes at the surface of the water (Cook and 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 (MDARD) was tasked with evaluating the aquatic species currently on Michigan's Prohibited and Restricted Species List (MCL 324.41302, 1994). The USDA Plant Epidemiology and Risk Analysis Laboratory's (PERAL) Weed Team worked with MDARD to evaluate 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 and 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 and Urmi-König, 1983; Forbes, 2000). Within Europe, it has naturalized in many areas due to cultivation escapes (Cook and Urmi-König, 1983; Preston and Croft, 1997). Outside of Europe, it is recorded as naturalized and cultivated within Ontario, Canada (OISAP, 2015; Snyder et al., 2016). In Ontario, it has established in 5 separate locations and has become a particular problem in the Trent River waterway (OISAP, 2015; Snyder et al., 2016). Besides Canada, *S. aloides* does not appear to have been naturalized to any other countries outside of Europe (Lansdown, 2014; GBIF, 2015).
	U.S. distribution and status: In the early 1900s, this species was sold in the United States by at least one supplier (Tricker, 1909). Snyder et al. (2016) report that the species is still sold in the United States, which is based upon several assumptions made from the literature (Snyder, 2016a) that may not necessarily be true. During our review of the literature and online sources, we found no evidence indicating that this species is currently present or cultivated in the United States (e.g., GBIF, 2015; NGRP, 2015; NRCS, 2015; Kartesz, 2015; Monrovia, 2016; Lowe's, 2016; Bailey Nurseries, 2011; Greenleaf Nursery Company, 2016; San Marcos Growers, 2001). *Stratiotes aloides* is regulated as an injurious or noxious weed in five states: Alabama (Harden, 2015), Florida (Smith, 2015), Illinois (17 Illinois Administrative Code § 805, 2015), Michigan

(Rosenbaum et al., 2015), Washington (White et al., 2015), and Wisconsin (WDNR, 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 and Urmi-König, 1983; Salisbury, 1961; Bailey and Bailey, 1976). It forms dense mats on the water's surface (Mulderij et al., 2005; OISAP, 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 (Nielsen and Borum, 2008). *Stratiotes aloides* reproduces both vegetatively and by seed (Smolders et al., 1995a), and may be a prolific seed producer (Erixon, 1979; Smolders et al., 1995b). We had high uncertainty here because this species is a recent introduction outside of its native range, and because its reproduction and dispersal mechanisms are not fully understood.

Risk score = 15 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 found within the Trent River in Ontario, Canada (OISAP, 2015). Dense stands exclude native wetland plants (NSW DPI, 2014), and it crowds out native vegetation, resulting in decreased plant biodiversity (OISAP, 2015). The sharp serrated leaves of *S. aloides* can injure swimmers and those who handle the plant (OISAP, 2015). Thick growth could potentially increase the risk of flooding and the cost of water delivery (Oregon Department of Agriculture, 2015), as well as limiting recreational activities such as boating and fishing. We had very high uncertainty here due to the recent introduction of this species and the lack of studies discussing this species' impacts.

Risk score = 2.8 Uncertainty index = 0.29

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 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 water pH, turbidity, 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 often confined to nutrient-rich, loose, muddy substrates, which may be either aerobic or anaerobic

[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).

(Cook and Urmi-König, 1983). *Stratiotes aloides* is a temperate species (Nielsen and Borum, 2008; Forbes, 2000).

Entry Potential This species has escaped in the Trent River, Ontario, Canada (OISAP, 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 (e.g., Backyard Gardener, 2015).
Risk score = 0.56 Uncertainty index = 0.11

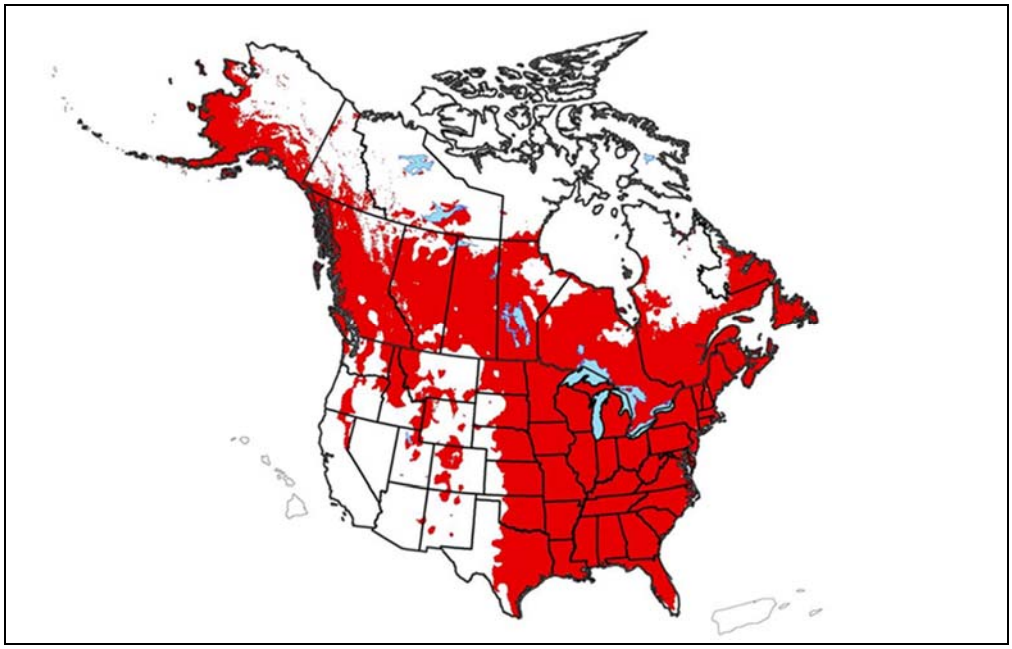

Figure 1. Predicted distribution of *Stratiotes aloides* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 74.7%
P(Minor Invader) = 24.3%
P(Non-Invader) = 1.0%
Risk Result = High Risk
Secondary Screening = Not applicable

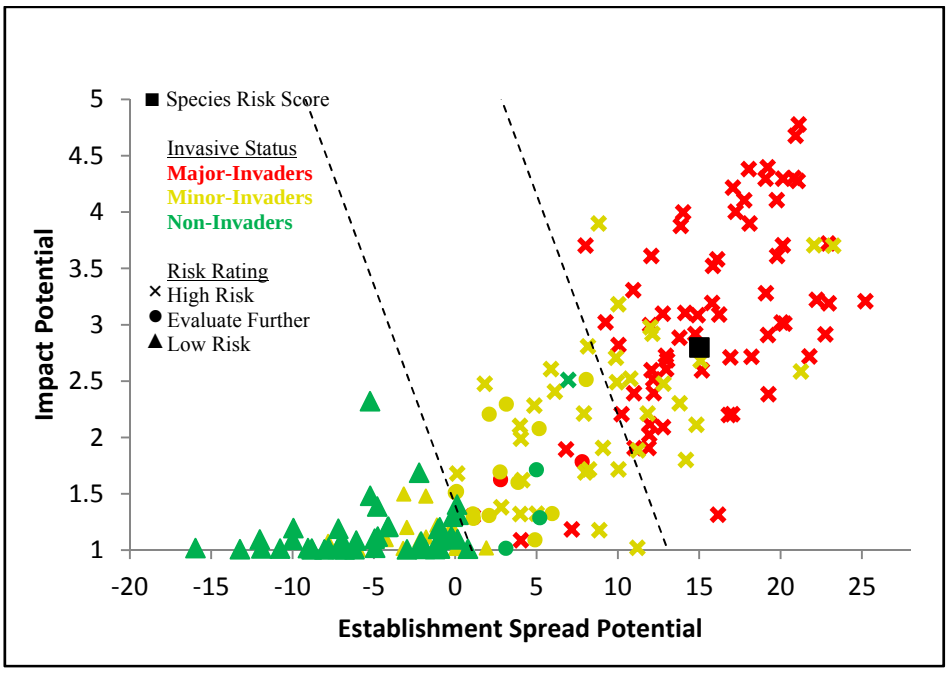

Figure 2. *Stratiotes aloides* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

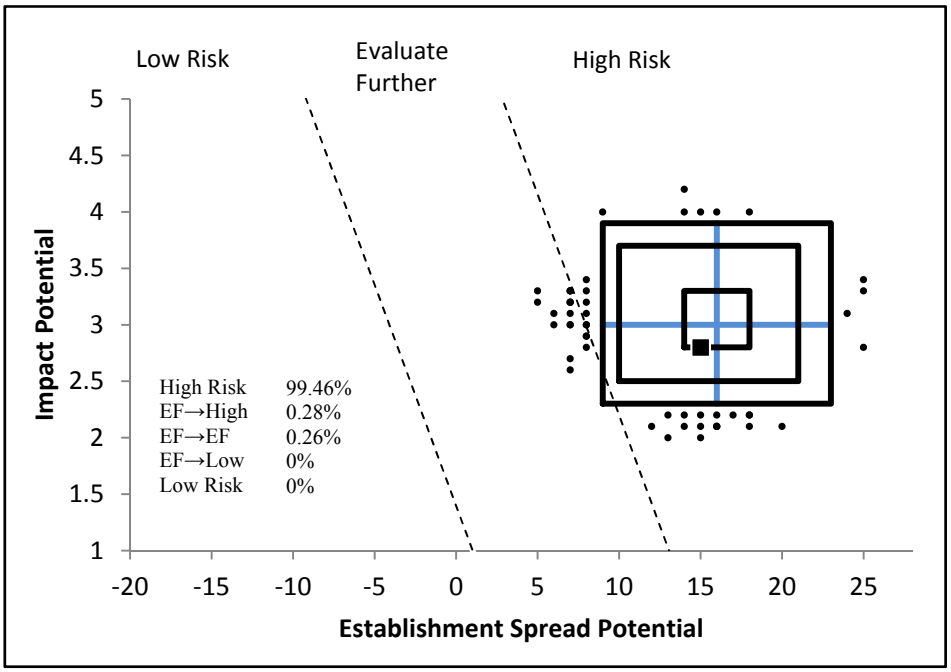

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Stratiotes aloides*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Stratiotes aloides* is High Risk (Figure 2). Our uncertainty analysis shows that 99.4 percent of all possible outcomes of the simulation were high risk, indicating that our conclusion is robust despite the high levels of uncertainty (Figure 3). Relative to other weed risk assessments, our uncertainty was higher in this assessment because this species' biology and impacts are not well characterized.

In Europe, *Stratiotes aloides* has spread and naturalized outside its native range. Cultivation escapes resulting in naturalized populations of *S. aloides* have made it difficult to precisely delimit the native and introduced ranges of this species (Cook and Urmi-König, 1983; Forbes, 2000). Despite this spread into new areas, there are several areas in Europe, largely considered native, where *S. aloides* appears to be declining. In Spain, it is considered extinct (Aedo et al., 2015). In certain localities of Germany it is considered endangered (Cook and Urmi-König, 1983), and in the Netherlands it has also significantly declined (Smolders et al., 2003). These authors attribute the decline of *S. aloides* in Europe to habitat destruction and to changes in water quality (Cook and Urmi-König, 1983; Smolders et al., 2003; Sugier et al., 2010; Aedo et al., 2015). Sulphate-induced eutrophication in natural areas resulting in a series of nutrient alterations in the water column may lead to increased competition by free-floating species and the decline of *S. aloides* populations (Smolders et al., 2003; Sugier et al., 2010). Since many of the areas where *S. aloides* appears to be declining in Europe can be considered disturbed areas, *S. aloides* is still likely to be of concern to more natural areas of the United States.

Outside Europe, the only region where *S. aloides* has become naturalized is Ontario, Canada (OISAP, 2015). The Ontario Ministry of Natural Resources and Forestry partnered with several organizations[2] in the fall of 2014 to monitor and control *S. aloides'* establishment and spread in the Trent River (OISAP, 2015). One control strategy used herbicides in designated areas of the Trent River. These applications knocked the species back, but it is uncertain whether the herbicides can prevent the plant from spreading downstream (Snyder et al., 2016). A pilot program was also implemented to test the efficacy of mechanical removal of the species and was started in the summer of 2015 (OISAP, 2015). Monitoring is currently in place to determine the outcome of the program (OISAP, 2015). Despite efforts to control *S. aloides*, the species continues to spread in Ontario (OISAP, 2015). The close proximity of *S. aloides* populations to the U.S. border and the documented impacts the species has on natural systems and recreational activities makes *S. aloides* a High Risk plant species.

[2] 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 and Urmi-König, 1983). Within Europe, this species has naturalized in many areas due to cultivation escapes (Cook and Urmi-König, 1983; Preston and Croft, 1997), to the point where it is now difficult to determine which countries this species is native to and to which it has been introduced (Cook and Urmi-König, 1983; Forbes, 2000). Its only naturalization outside its native range is within Ontario, Canada, where it has been found in five locations including the Trent River (OISAP, 2015; Snyder et al., 2016). *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 where it has affected 11 km of the river system (OISAP, 2015; Snyder et al., 2016). Besides Canada, this species is not known to have escaped or been introduced anywhere outside of Europe (Lansdown, 2014; GBIF, 2015). With the Ontario introduction standing as the only verifiable introduction of *S. aloides* outside of its native range, we are answering "f," based on the spread and distribution in the Trent River (OISAP, 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). When listed for sale, the plant occurs under its species name and not under variety or cultivar names (The Manic Botanic, 2016; Water Garden Plants, 2016), which does not suggest any specific breeding or domestication.
ES-3 (Weedy congeners)	n - low	0	*Stratiotes aloides* is the only surviving member of its genus; all congeners have become extinct (Cook and Urmi-König, 1983). We found no evidence that any other members of the family Hydrocharitaceae (Cook and Urmi-König, 1983) are related closely enough to *S. aloides* to be considered for this question. Thus, we answered no, with low uncertainty.
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	*Stratiotes aloides* grows in semi-shade (PFAF, 2015). It is able to grow as either emergent or submerged (Erixon,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			1979). The submerged form easily persists in water 2-5 m deep (Cook and 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 percent to less than 1 percent of incident light (Riemer, 1993).
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 and 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 (OISAP, 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 (Nielsen and Borum, 2008). One study in Ireland noted that "Mill Lough, [which is 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 and 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 and Urmi-König, 1983; Efremov and 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 nitrogen-fixing capabilities (Martin and Dowd, 1990). *Stratiotes aloides* is an herbaceous aquatic plant (Bailey and Bailey, 1976; PFAF, 2015)
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Seventy percent of collected seeds germinated in a laboratory, and seedlings were found in the wild (Smolders et al., 1995b). Successful germination in the lab has also been observed by Cook and 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 and Urmi-König, 1983). The dioecy of *Stratiotes* is not absolute and some individual plants can be hermaphroditic (Forbes, 2000). “[F]lowers of both sexes contain whorls of staminodes [and] … [a]lthough the staminodes are normally sterile, rarely the female flowers contain a few apparently fertile stamen” (Forbes, 2000). However, we found no information regarding the viability of seeds of hermaphroditic individuals. We therefore answered unknown.
ES-12 (Requires specialist pollinators)	n - mod	0	Most likely, *Diptera* species pollinate this species, as they are frequent visitors in an area with natural seed set (Cook and Urmi-König, 1983). Abundant insect pollinators were present within *S. aloides* stands observed in the field by Smolders et al. (1995b). These authors do not treat these pollinators as specialist pollinators, suggesting that they are generalist pollinators.
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	b - low	1	New rosettes are produced consistently throughout the summer (Preston and Croft, 1997). During the summer, lateral shoots bearing terminal rosettes develop. These rosettes become detached at a relatively late stage in development or while bud-like (Cook and Urmi-König,

Question ID	Answer - Uncertainty	Score	Notes (and references)
years; (d) more than 3 years; or (?) unknown]			1983). Detached rosettes sink in the autumn and overwinter as rosettes with green leaves, and in the spring they float to the surface (Cook and Urmi-König, 1983). We are answered "b" as it is likely that these rosettes produce new rosettes individually after detaching from the parent plant and overwintering. The alternate answers for our Monte Carlo simulation were both "a."
ES-14 (Prolific reproduction)	n - 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 three fruit per plant, with up to 30 seeds per fruit (Smolders et al., 1995b). Though these are possible maximums, the average seed production is 1.5-11.8 seeds per plant on seed bearing plants, with 39-46% of plants not bearing any seed (Smolders et al., 1995b). This results in an average seed production of 135-1,062 seeds/m^2 to a maximum possible seed production of 8,100 seeds/m^2. Natural seed set, however, is somewhat rare (Cook and Urmi-König, 1983), most likely due to single-gender stands not occurring closely enough to male plants for pollination (Smolders et al., 1995b). We answered no because even though prolific seed production is possible, it would be extremely rare when this would occur naturally.
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 (OISAP, 2015). As detached rosettes can regenerate at a rate of 84 percent (Sarneel, 2013) and form new individuals (Renman, 1989), any human activity which leads to fragmentation may contribute 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. Although some aquatic plants have been known to contaminate other aquatic plants in trade (Maki and Galatowitsch, 2004), because this is a large, sharp plant, this seems like an unlikely pathway.
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 30 seeds (Smolders et al., 1995b), ovoid or somewhat barrel-shaped, tapering to a cone-like structure, 12-34 mm long and 9-15 mm diameter (Cook and 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 they are round or irregularly compressed, 5.8–10.6 mm long, 2.3–3.0 mm wide (Cook and Urmi-König, 1983).
ES-17a (Wind dispersal)	n - low		We found no evidence of wind dispersal. Fruit and seeds do not appear to have any adaptations for wind dispersal.
ES-17b (Water dispersal)	y - negl		The ripe fruit often break 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 and Urmi-König, 1983). Propagules are readily distributed by wave action and currents (Erixon, 1979). Overwintering rosette shoots are

Question ID	Answer - Uncertainty	Score	Notes (and references)
			temporarily rootless and are highly dispersible during spring floods (Efremov and Sviridenko, 2008).
ES-17c (Bird dispersal)	? - max		We found no direct evidence, but suspect seeds may be dispersed in this manner as fresh seeds are covered in a gelatinous mass that may allow seeds to stick to feet or feathers. However, 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 as fresh seeds are covered in a gelatinous mass that may allow seeds to stick to feet or fur. However, 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 and Urmi-König, 1983). Smolders et al. (1995a) found that seeds that had passed through the human digestive system germinated at higher rates than seeds that did not. It is also worth noting that fossil seed was sometimes found in coprolites (fossilized dung) (Cook and 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 and 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., 1995a). Seeds tend to germinate about four months after being shed, but irregular germination has been observed for seeds stored for up to three years in water at room temperature. (Cook and Urmi-König, 1983). We answered 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 rosettes can create new individuals (Renman, 1989). Even rosettes that have not fully matured still produce new individuals (Cook and 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 percent (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 (2015) 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, Canada (OISAP, 2015).
ES-21 (Number of cold hardiness zones suitable for its survival)	8	0	
ES-22 (Number of climate types suitable for its survival)	5	2	
ES-23 (Number of precipitation bands suitable for its survival)	9	1	
IMPACT POTENTIAL			
General Impacts			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-G1 (Allelopathic)	y - mod	0.1	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 artificial conditions (i.e., light and nutrient overloading) inhibited the studied phytoplankton species (i.e., *Microcystis aeruginosa*, *Nannochloropsis limnetica*, and *Scenedesmus obliquus*). We answered yes as there is clear evidence of allelopathic behavior occurring under natural conditions.
Imp-G2 (Parasitic)	n - negl	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 and 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 (OISAP, 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 limits light and changes 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	0.2	*Stratiotes aloides* creates a new dominate layer of vegetation on the surface of small water bodies (Nielsen and Borum, 2008) and is known for creating dense mats that limit light to submerged macrophytes (Kufel et al., 2010).
Imp-N3 (Changes species diversity)	y - low	0.2	Dense stands can exclude native wetland plants (NSW DPI, 2014). Crowds out native vegetation resulting in decreased plant biodiversity (OISAP, 2015). The aquatic macrophyte population in Lake Seymour (within the Trent Severn Waterway), where *S. aloides* is currently 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 the 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 (MacDonald, 2015).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - low	0.1	*Stratiotes aloides* causes system wide changes within ecosystems, including altering the structure and the species diversity in shallow water systems (Nielsen and Borum, 2008;MacDonald, 2015). Therefore, it seems likely that *S. aloides* is likely to impact floating and submergent threatened and endangered species.

Question ID	Answer - Uncertainty	Score	Notes (and references)
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 evidence of control efforts]	c - low	0.6	Weed of natural areas in Ireland (Stokes et al., 2006). 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 (OISAP, 2015). For the Monte Carlo simulation, our 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 (OISAP, 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 the sharp, serrated leaves of this plant may deter swimmers (SLELO PRISM, 2015; OISAP, 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 in Ontario, Canada, 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 (Handley, 2014; 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 that this species is a weed of or even establishes in production systems, we answered all questions as no.
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 contaminate traded goods.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - high	0	Snyder et al. (2016) indicate that it causes sedimentation to build up in drainage ditches but provide no direct evidence for this in their analysis (Snyder, 2016b). We found no other 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 and Urmi-König, 1983).

Question ID	Answer - Uncertainty	Score	Notes (and references)
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]	a - mod	0	We found no evidence that this species is a weed in production systems. Our 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 - 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), and Canada (OISAP, 2015).
Geo-Z6 (Zone 6)	y - negl	N/A	Germany, Austria, Sweden, Finland, Latvia, Belarus, and Poland.
Geo-Z7 (Zone 7)	y - negl	N/A	France, Germany, Austria, Norway, Sweden, Poland, and Hungary.
Geo-Z8 (Zone 8)	y - negl	N/A	The United Kingdom, France, Belgium, the Netherlands, Germany, Norway, Denmark, and Sweden.
Geo-Z9 (Zone 9)	y - negl	N/A	The United Kingdom, Ireland, France, the Netherlands, Denmark, and 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, and 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

Question ID	Answer - Uncertainty	Score	Notes (and references)
			continental warm summers region fall below -3 °C (Arnfield, 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.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Germany, Austria, Denmark, Sweden, Norway, Latvia, Belarus, Poland, Hungary (GBIF, 2015), and Canada (OISAP, 2015).
Geo-C10 (Subarctic)	y - negl	N/A	Germany, Sweden, and 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, and Hungary.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	The United Kingdom, France, Belgium, the Netherlands, Germany, Denmark, Sweden, Norway, and 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), and Canada (OISAP, 2015).
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Ireland, France, and 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 and Austria.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	The United Kingdom and Germany.
Geo-R10 (90-100 inches; 229-254 cm)	y - mod	N/A	We answered yes for this precipitation band given that this is an aquatic species and higher precipitation levels are unlikely to limit it.
Geo-R11 (100+ inches; 254+ cm)	y - mod	N/A	We answered yes for this precipitation band given that this is an aquatic species and higher precipitation levels are unlikely to limit it.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - mod	0	In 1909, this species was reported to be available by at least one retailer (Tricker, 1909). However, we found no recent evidence that this species is present in the United States (GBIF, 2015; NGRP, 2015; NRCS, 2015; Kartesz, 2015).
Ent-2 (Plant proposed for entry, or entry is imminent)	n - low	0	We found no evidence.
Ent-3 (Human value & cultivation/trade status)	d - low	0.5	European ornamental that escapes (Forbes, 2000). Available for online purchase in native countries (The Manic Botanic, 2016).
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central	y - negl		Canada (Trent River, Ontario) (OISAP, 2015).

Question ID	Answer - Uncertainty	Score	Notes (and references)
America, the Caribbean or China)			
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)	? - max		Unknown. This is a freshwater species (Cook & Urmi-König, 1983) but it seems possible that it could spread in the ballast of freshwater ships.
Ent-4e (Contaminant of aquarium plants or other aquarium products)	n - mod	0	We found no evidence.
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 and 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 and Urmi-König, 1983); however, we found no evidence that this species is a contaminant.
Ent-5 (Likely to enter through natural dispersal)	y - high	0.06	This species is currently present in the Trent River, Ontario, Canada (OISAP, 2015). This waterway is connected to Lake Ontario and feeds into U.S. waters; however, a joint effort by various organizations within Ontario has created an aggressive control and monitoring program for *S. aloides* in the Trent River (OISAP, 2015). Although the species spread has been contained outside the Trent River system in Canada (OISAP, 2015) the close proximity of the *S. aloides* populations in Canada to the U.S. border suggest that it seems possible for the plant to disperse naturally into the United States.