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Version 1

Weed Risk Assessment for *Sagittaria sagittifolia* (Alismataceae) - Arrowhead

Top: *Sagittaria sagittifolia* tubers (Creative Commons image; Chang, 2019) Bottom: *Sagittaria sagittifolia* growth habit (Public domain image; Wikipedia, 2020)

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Executive Summary

The result of the weed risk assessment for *Sagittaria sagittifolia* is High Risk of becoming weedy or invasive in the United States. It is a rooted, aquatic, perennial herb that can be a weed of natural, anthropogenic, and agricultural systems. Because the tubers are eaten in China, they are imported to the United States for consumption around the Chinese New Year. *Sagittaria sagittifolia* is a Federal Noxious Weed and is regulated in eight states. It produces many seeds that are dispersed by water, wind, and animals. It can reduce yield in rice, can clog drains and canals, and has been reported to be resistant to sulfonylurea in China. We estimate that 87 percent of the United States is suitable for the species to establish. Although the most likely pathway for entry is the importation of tubers for consumption, *S. sagittifolia* is also sold as a pond plant in some parts of the world and as an ornamental cultivar in a few nurseries in the United States.

Plant Information and Background

PLANT SPECIES: *Sagittaria sagittifolia* L. (Alismataceae) (NPGS, 2020).

SYNONYMS: *Sagittaria japonica* hort. (NPGS, 2020).

COMMON NAMES: Arrowhead (NPGS, 2020; NRCS, 2020), Old World arrowhead (NPGS, 2020).

BOTANICAL DESCRIPTION: *Sagittaria sagittifolia* is a perennial emergent aquatic herb that can grow in the mud of ponds and slow-moving streams across a wide range of temperate latitudes (CISEH, 2018; Holm et al., 1997). The emergent leaves are arrow-shaped and grow on petioles up to 45 cm long (PFAF, 2020). Flowers are unisexual with female flowers on lower whorls and male flowers on upper whorls. Fruits are 4 × 6 mm winged achenes. Plants can also reproduce vegetatively through the production of tubers (Hroudova et al., 1988).

INITIATION: Tubers of *S. sagittifolia* are important cultural foods in Asia, so the federal government allows the importation of tubers for consumption to California, Hawaii, and New York between November and March so that they will be available for the Chinese New Year (Lehtonen, 2003). We conducted this weed risk assessment for *S. sagittifolia* to validate the current import policy.

WRA AREA[1]: United States and Territories.

FOREIGN DISTRIBUTION: *Sagittaria sagittifolia* is native throughout Europe, as well as in China, Russia, Lebanon, and Turkey (NPGS, 2020). It is possibly native to other countries in Asia, but we found no evidence supporting this. It is present throughout southeastern Asia (Moody, 1989) and is a harmful weed in India (Shah and Reshi, 2012). It is naturalized in New Zealand and possibly in Australia, though some reports may represent misidentifications of other species (APS, 2004; Champion, 2004; Champion et al., 2002; Randall, 2007). Scher et al. (2015) list it as present in Mexico and Cuba, and we found a record of it having been cultivated in Cuba by Chinese immigrants (Hammer and Eaquivel, 1989). However, we found no other evidence of its presence is these countries and do not consider it to be naturalized in either country. *Sagittaria sagittifolia* is managed to keep it from spreading in New Zealand (Champion and Clayton, 2001) and is prohibited from being imported (Champion et al., 2008). In China and Japan, it is cultivated for food (Holm et al., 1997) and has been used in traditional Asian medicine (Singh, 2008). It is also sold as an ornamental pond plant (Champion et al., 2008).

U.S. DISTRIBUTION AND STATUS: *Sagittaria sagittifolia* is a Federal Noxious Weed (7 CFR § 360, 2010) and is regulated in Arkansas, Illinois, Indiana, Massachusetts, North Carolina, Oklahoma, Wisconsin, and West Virginia (NPB, 2018). Holm et al. (1997) list it as present in the

[1] The “WRA area” is the area in relation to which the weed risk assessment is conducted (definition modified from that for “PRA area”) (IPPC, 2017).

continental United States, and EDDMapS includes two county records (EDDMapS, 2020). The botanist who verified the record in North Carolina, however, believes that the species is actually the native *S. latifolia*. Because we found no other evidence that this species is currently naturalized in the United States (e.g., Kartesz, 2015; NRCS, 2020), we think the record from Marshall County, MS is most likely also the native species. We found several herbarium records (SERNEC Data Portal, 2020), but the most recent is from 1977, so we do not consider them to be evidence that the species is currently established. Holm et al. (1991) also list it as a principal weed in Hawaii, but this is likely a misidentification of *S. latifolia* (Daehler, 2020), which is naturalized there (CABI, 2010). For these reasons, we believe *S. sagittifolia* is unlikely to be naturalized in the United States. We found it (under the synonym *S. japonica*) sold by two aquatic plant nurseries (Van Ness Water Gardens, 2020; William Tricker Inc, 2020) and expected to be offered soon by one aquatic garden wholesaler (LilyBlooms, 2020), but we found no other evidence of its sale (Greenleaf Nursery Company, 2020; Monrovia, 2020; San Marcos Growers, 2020), and we found little evidence of interest among gardeners (Betrock's Plant Search, 2020; Dave's Garden, 2020).

Analysis

ESTABLISHMENT/SPREAD POTENTIAL: *Sagittaria sagittifolia* is managed to prevent its spread in New Zealand (Champion and Clayton, 2001), and we found no evidence that it is spreading. It is an aquatic plant that produces many seeds, which are dispersed primarily on water (Holm et al., 1997; Hroudova et al., 1988; NPPA, n.d.) but also through wind (Holm et al., 1997), externally on mammals (Holm et al., 1997; Hroudova et al., 1988), and internally by fish (Boedeltje et al., 2016; Holm et al., 1997; Pollux, 2017). It has been reported to be resistant to the herbicide sulfonylurea in China (Lang et al., 2015). Several congeners of this species are considered to be weedy and invasive (Champion et al., 2008; Moody, 1989). We had very high uncertainty for this risk element due to the lack of clear information about its seed fecundity, generation time, and dispersal by people.

Risk score = 13.0 Uncertainty index = 0.31

IMPACT POTENTIAL: *Sagittaria sagittifolia* is considered to be a weed of natural, anthropogenic, and agricultural systems (Holm et al., 1997; Randall, 2007), but we found relatively little direct evidence for its impact. It is reported to suppress native plant populations in New Zealand (Greater Welllingon Regional Council, n.d.) and is managed to prevent its spread (Champion and Clayton, 2001). We found no other evidence of its impact in natural areas. It can block water passage in anthropogenic systems such as drains and canals, often requiring its removal (Holm et al., 1997). Furthermore, we found evidence that it reduces yield in rice (Saha et al., 2005) but no information about control methods that specifically target this weed. We had average uncertainty for this risk element.

Risk score = 3.0 Uncertainty index = 0.18

GEOGRAPHIC POTENTIAL: Using the PPQ climate-matching model for weeds (Magarey et al., 2017), we estimate that about 22 to 87 percent of the United States is suitable for the establishment of *S. sagittifolia*, depending on the certainty of the climate match (Fig. 1). The maximum area where we estimate that climate is potentially suitable represents the joint distribution of Plant Hardiness Zones 2-10, areas with 10-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, Mediterranean, humid subtropical, marine west coast, humid continental warm summers, humid continental cool summers, subarctic, and tundra. The area of the United States shown to be climatically suitable was determined using only these three climatic variables. Other factors, such as soil, hydrology, disturbance regime, and species interactions may alter the areas in which this species is likely to establish. Because *S. sagittifolia* is a rooted aquatic herb and grows in the mud of ponds and slow-moving streams, ditches, and canals (PFAF, 2020; Stace, 2010), as well as in marshes and rice paddies (Zhirong, 1990), it would be limited to aquatic and wetland habitats.

ENTRY POTENTIAL: The edible tubers of *S. sagittifolia* are imported into California, Hawaii, and New York for Chinese New Year (Lehtonen, 2003), so we did not assess its entry potential any further. The species has been cultivated for food in China and Japan, used in traditional Asian medicine, and sold as an ornamental pond plant (Champion et al., 2008; Holm et al., 1997; Scher et al., 2015; Singh, 2008).

Risk Model Results

Model Probabilities: P(Major Invader) = 67.6%
P(Minor Invader) = 31.0%
P(Non-Invader) = 1.4%

Risk Result = High Risk

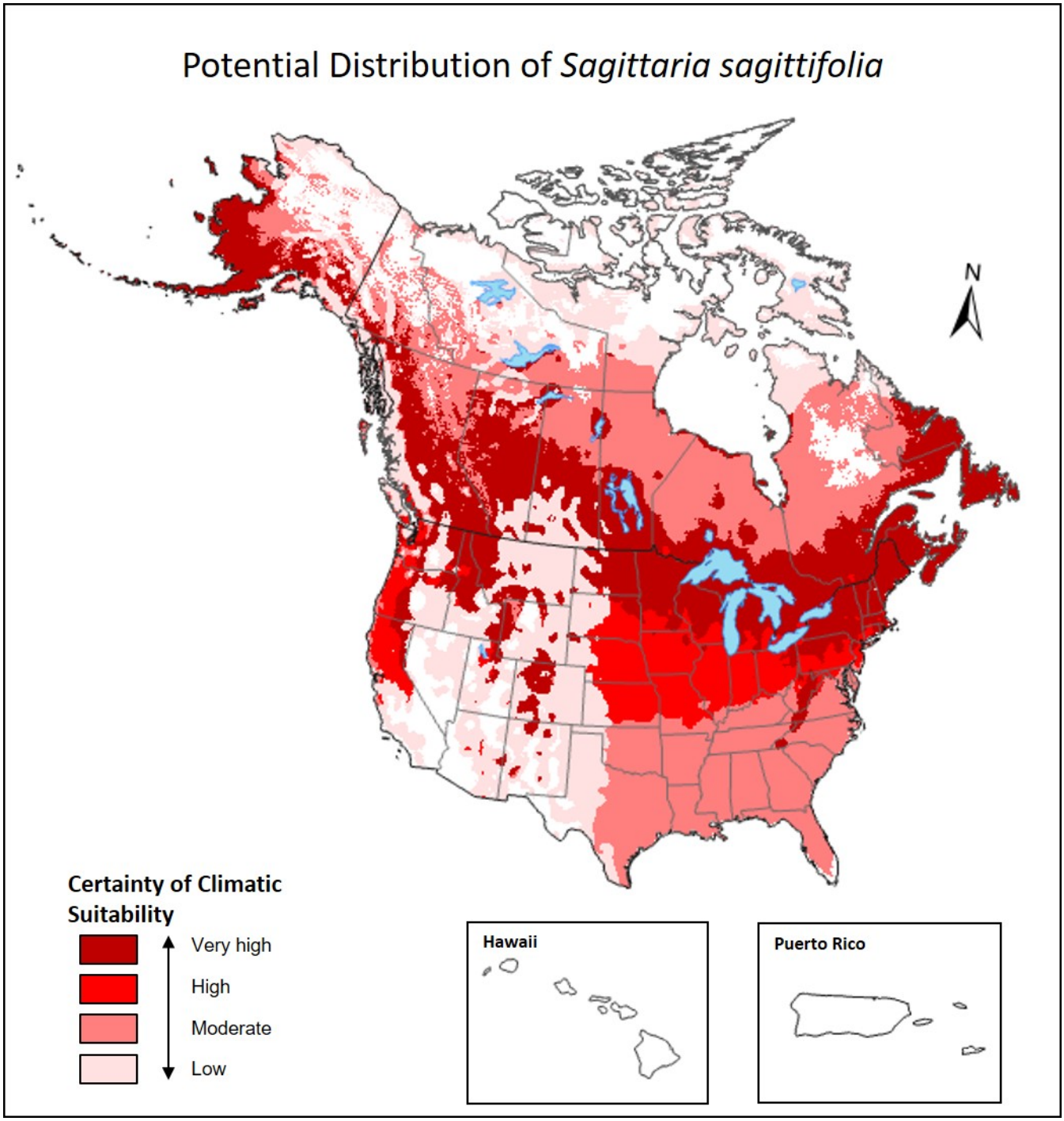

Figure 1. Potential distribution of *Sagittaria sagittifolia* in the United States. Climatic suitability was determined using the APHIS-PPQ climate matching tool for invasive plants (Magarey et al., 2017). Variation in climatic suitability is based on the uncertainty ratings assigned to climate levels (App. A). Thus, very high climate suitability corresponds to areas where the uncertainty rating for all three climate variables was negligible. In contrast, low climatic suitability corresponds to areas where the uncertainty for one or more of the climate variables was high.

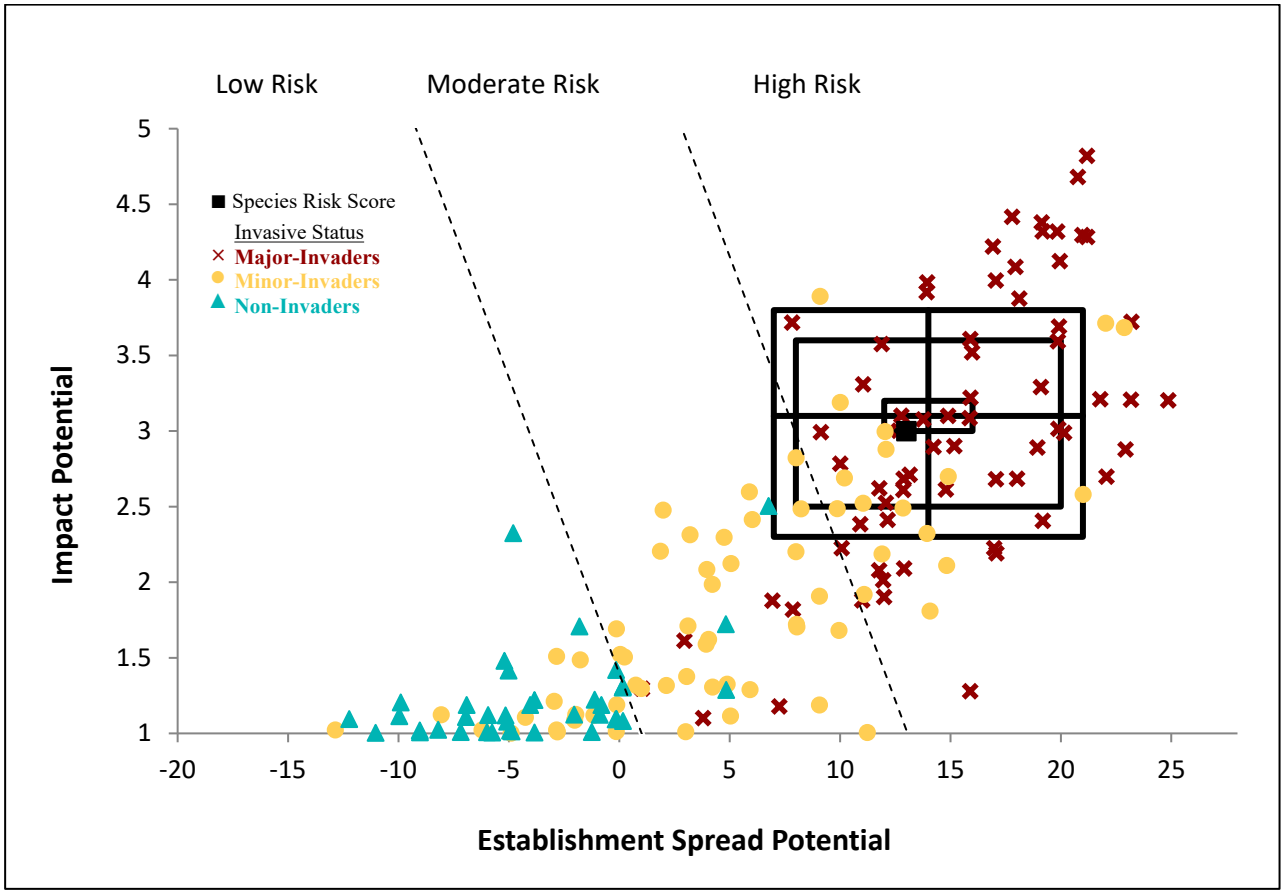

Figure 2. Risk and uncertainty results for *Sagittaria sagittifolia*. The risk score for this species (solid black symbol) is plotted relative to the risk scores of the species used to develop and validate the PPQ WRA model (Koop et al., 2012). The results from the uncertainty analysis are plotted around the risk score for *S. sagittifolia*. The smallest, black box contains 50 percent of the simulated risk scores, the second is 95 percent, and the largest is 99 percent. The black vertical and horizontal lines in the middle of the boxes represent the medians of the simulated risk scores (N=5000). For additional information on the uncertainty analysis used, see Caton et al. (2018).

Discussion

The result of the weed risk assessment for *Sagittaria sagittifolia* is High Risk of becoming weedy or invasive in the United States. It is naturalized in New Zealand and possibly Australia. It is widely considered to be a weed of natural, anthropogenic, and agricultural systems, but we found little information about its specific impact. About half of its impact score was derived from questions about perceived impact. Although we had moderate to high uncertainty in this assessment, about 97 percent of the simulated risk scores (Fig. 2) resulted in an outcome of High Risk, suggesting that additional information is not likely to change the qualitative outcome of this assessment. *Sagittaria sagittifolia* is extremely similar to the U.S. native *S. latifolia*, differing primarily in fruit size and flower color (Stace, 2010).

The tuber of *S. sagittifolia* is a cultural food in China and is imported into California, Hawaii, and New York for Chinese New Year (Lehtonen, 2003). Typically, it is sliced thin and fried (Grossman, 2015; Shaw, 2017) for consumption. We also found web pages describing how to grow it as an ornamental for Chinese New Year, but these were based in Singapore (Kiat and Wong, 2006; Wong, 2013), and we do not know if planting it is part of the celebration in the United States. We did, however, find a post on a gardening forum from an individual who purchased the tubers at an Asian market and planted them, despite knowing that *S. sagittifolia* is a FNW (GardenWeb, 2012). Tubers of *S. latifolia*, which is native to the continental United States and introduced in Hawaii (NRCS, 2020), were also used as food by indigenous peoples of North America (Kuhnlein and Turner, 1991; Mason, 1957) and have been cultivated by Chinese communities in California (Mason, 1957). Both Native Americans and other foragers in the Pacific Northwest currently use this species (Flatt, 2011; Lloyd, 2012; Shaw, 2017).

Suggested Citation

PPQ. 2020. Weed risk assessment for *Sagittaria sagittifolia* L. (Alismataceae) – Arrowhead. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (PPQ), Raleigh, NC. 22 pp.

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Appendix A. Weed risk assessment for *Sagittaria sagittifolia* L. (Alismataceae)

The following table includes 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.

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]	e - high	2	*Sagittaria sagittifolia* is native throughout Europe, as well as in Russia, China, Lebanon and Turkey (NPGS, 2020). Champion (2004; 2002) lists it as naturalized in New Zealand, and it is managed to prevent its spread in Auckland, (Champion and Clayton, 2001). It is reported as naturalized in Australia (Randall, 2007), but this may be a misidentification of another *Sagittaria* species (APS, 2004). We used high uncertainty because it is not described as spreading in New Zealand, and we do not know how much management inhibits its spread. Alternate choices for the uncertainty simulation were both "d".
ES-2 (Is the species highly domesticated)	n - negl	0	Although it is cultivated for food in China (Holm et al., 1997), it also grows in the wild (NPGS, 2020), and we found no evidence that it has been bred for traits that would reduce its weed potential.
ES-3 (Significant weedy congeners)	y - negl	1	Of the 35 *Sagittaria* spp. worldwide (Mabberley, 2008), *S. montevidensis* and *S. platyphylla* are major weeds of water channels where they have established in Australia and are banned from sale in Tasmania, New South Wales, South Australia, and Western Australia (Champion et al., 2008). *Sagittaria platyphylla* blocks irrigation channels, impedes water flow, and chokes natural watercourses and wetlands (NSW WeedWise, 2018). *Sagittaria aginashi*, *S. guayanensis*, *S. platyphylla*, and *S. pygmaea* are weeds of rice (Moody, 1989). We have low uncertainty since several Australian states list congeners as weeds.
ES-4 (Shade tolerant at some stage of its life cycle)	? - max		*Sagittaria sagittifolia* seems to prefer full sun (Backyard Gardener, 2020; Dave's Garden, 2020), but while Holm et al. (1997) and Waterside Nursery (2020b) describe it as tolerating moderate or partial shade, Plants for a Future says that it cannot grow in shade (PFAF, 2020). We answered unknown because we found conflicting evidence.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	*Sagittaria sagittifolia* is not a vine; it is an aquatic herb (NPGS, 2020). The leaves form rosettes but are not described as tightly appressed (Dorken and Barrett, 2003; Hroudova et al., 1988).
ES-6 (Forms dense thickets, patches, or populations)	? – max	0	Unknown. Hroudova et al. (1988) indicate that it can quickly overgrow an entire pond in some conditions, but it is not clear whether overgrowth would be at high density. The fact that it can interfere with water flow in anthropogenic systems (Biosecurity New Zealand, 2016; Holm et al., 1991; MPI, 2012), suggests that it may form dense stands, but we found no direct evidence.
ES-7 (Aquatic)	y - negl	1	*Sagittaria sagittifolia* is a rooted, emergent aquatic herb (Holm et al., 1997; Khuroo et al., 2007; NPGS, 2020; Shah and Reshi, 2012).
ES-8 (Grass)	n - negl	0	This species is not a grass, it is an herb in the family Alismataceae (NPGS, 2020).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen. Furthermore, it is not a member of a plant family that is known to contain nitrogen fixing species (Santi et al., 2013)
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Many sources describe it as producing seed (CISEH, 2018; Dave's Garden, 2020; Holm et al., 1997), and Hay et al. (2000) report a germination rate of 76 percent.
ES-11 (Self-compatible or apomictic)	y - high	1	We found no information specific to *S. sagittifolia.* Because the congener *S. latifolia* is self-compatible (Perl-Treves and Rajagopalan, 2006), we answered yes with high uncertainty.
ES-12 (Requires specialist pollinators)	n - mod	0	Plants for a Future indicates that it is pollinated by insects but does not list specific pollinators (PFAF, 2020). Waterside Nursery lists it as a good plant for pollinators and describes it as attracting, bees, butterflies, and hoverfiles (Waterside Nursery, 2020a, 2020b). Since it attracts a variety of insects, and particular pollinator species are not mentioned, it seems unlikely to require specialist 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 years; (d) more than 3 years; or (?) unknown]	b - high	1	We did not find any information on whether a plant grown from seed will flower in its first year. The Natural Resources Conservation Service reports that seeds *of Sagittaria* spp. take two years to germinate (NRCS, 2003), but Pollux (2017) indicates that fruit of *S. sagittifolia* falls in autumn and that seeds are dormant through winter and germinate in spring. Because this is a perennial herb, it is unlikely to require more than three years to produce seed or to produce multiple generations per year. It also produces vegetative tubers on long

Question ID	Answer - Uncertainty	Score	Notes (and references)
			rhizomes; these can be dispersed (Caffrey and Monahan, 2006; Hroudova et al., 1988). The tubers form soon after the above-ground parts of the plant. The parent part dies back in the autumn, while the tubers overwinter and sprout the following spring. (Hroudova et al., 1988). Therefore, the generation time for vegetative reproduction is one year. Alternate choices for the uncertainty simulation were both "c."
ES-14 (Prolific seed producer)	y - mod	1	Hroudova et al. (1988) record observations of 410-4300 seeds per plant and 1800-25,000 seeds per square meter. Holm et al. (1997) have similar records of 400-9000 seeds per plant, and Champion et al. (2008) list the species as having very high seed production. Hay et al. (2000) report a seed germination rate of 76 percent. Based on these values, individual plants are producing up to 6750 viable seeds, and plant populations up to 18,750 viable seeds per square meter. Because these upper values exceed our threshold of 5000 viable seeds per square meter, we answered yes with moderate uncertainty.
ES-15 (Propagules likely to be dispersed unintentionally by people)	n - high	-1	Although the species was apparently introduced to India unintentionally (Khuroo et al., 2007) and the propagules are sticky (Hroudova et al., 1988), we have no evidence that it is dispersed on clothes, shoes, or vehicles. The National Plant Pest Accord for New Zealand indicates that the species is not accidentally dispersed (NPPA, n.d.). We have high uncertainty because we do not know how the introduction to India occurred.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	n - mod	-1	The National Plant Pest Accord for New Zealand indicates that the plant is only spread by deliberate human planting and dispersal on water (NPPA, n.d.). We found no evidence that it has been intercepted as a contaminant (AQAS, 2020).
ES-17 (Number of natural dispersal vectors)	4	4	Propagule traits for questions ES-17a through ES-17e: The seeds are 2 x 1 mm, enclosed in 6 x 4 mm achenes with membranous wings (Reed, 1977).
ES-17a (Wind dispersal)	y - negl		Wings on the achenes facilitate wind-dispersal (Holm et al., 1997).
ES-17b (Water dispersal)	y - negl		Seeds float on the water (Hroudova et al., 1988; NPPA, n.d.) for 6-12 months (Holm et al., 1997). Tubers can also be dispersed on water if disturbance brings them to the surface (Hroudova et al., 1988). We have low uncertainty since several sources indicate that

Question ID	Answer - Uncertainty	Score	Notes (and references)
			the seeds float, and seeds falling from emergent aquatic plants would readily come into contact with water.
ES-17c (Bird dispersal)	y - high		Holm et al. (1997) report that seeds are more likely to germinate if eaten by ducks or shore birds and could be carried up to 1600 km, but Pollux et al. (2005) found that seeds were less likely to germinate if eaten by mallards (*Anas platyrhynchos*) or teals (*Anas crecca*) than if they were not ingested. Soons et al. (2008) found that few seeds experimentally fed to mallards were retrieved and none germinated, though the germination conditions in the experiment may have been too dry for *S. sagittifolia*. The achenes can also stick to feathers (Hroudova et al., 1988). DeVlaming and Proctor (DeVlaming and Proctor, 1968) found evidence of bird dispersal for the congener *S. longiloba*.
ES-17d (Animal external dispersal)	y - mod		The achenes can stick to fur (Holm et al., 1997; Hroudova et al., 1988).
ES-17e (Animal internal dispersal)	y - mod		Holm et al. (1997) report that seeds eaten by fish are viable after 48 hours in the digestive tract, and Pollux (2017) estimated a dispersal distance of about 8 km, with wide variation among individual fish. Experiments with carp (*Cyprinus carpio*) and tilapia (*Oreochromis mossambicus*) had relatively low germination rates for ingested seeds, partly because carp digest many of the seeds (Boedeltje et al., 2016; 2015; Pollux et al., 2006). We have moderate uncertainty because, although a low percentage of seeds ingested by fish may germinate, the high volume of seed production would seem to increase the chance of at least some seeds being dispersed this way.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	Seeds can survive 10 years in storage (Royal Botanic Gardens Kew, 2020) and can tolerate drying (Hay et al., 2000; Royal Botanic Gardens Kew, 2020). Crocker (1938) reports that seeds are actually more likely to germinate after three to four months of drying. We have high uncertainty because we found no evidence of seed banks forming in nature, and seeds falling from an emergent aquatic plant seem unlikely to experience drying.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	n - mod	-1	Although *S. sagittifolia* often becomes dominant soon after dredging (Holm et al., 1997), regular cutting back of the plant reduces production of tubers (Sukhodolova, 2017), so it seems more likely that the dominance after dredging is related to an ability to quickly colonize an area

Question ID	Answer - Uncertainty	Score	Notes (and references)
			without competition than due to benefit from mutilation.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	y - mod	1	*Sagittaria sagittifolia* is not listed in the International Survey of Herbicide Resistant Weeds (Heap, 2020), but resistance to sulfonylurea has been reported in Yanbian, China (Lang et al., 2015). Taylor (1995) reports that arrowhead has shown some resistance to Londax (bensulfuron-methyl), but the species of arrowhead is not listed. We have moderate uncertainty because we found only a few references to herbicide resistance, and one of them does not specify *S. sagittifolia*.
ES-21 (Number of cold hardiness zones suitable for its survival)	9	0	
ES-22 (Number of climate types suitable for its survival)	8	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - high		We found studies reporting effects from *S. sagittifolia* extracts on wheat (*Triticum aestivum*), wild oat (*Avena fatua*), and milk thistle (*Silybum marianum*) (Gul and Ijaz, 2015) and on the cyanobacteria *Aphanizomenon flos-aquae* and *Anabaena flosaquae* (Zhang et al., 2015; Zhang et al., 2016). Kurbatova et al. (2019), however, did not observe allelopathy from growing plants. We found no evidence of allelopathic effects in natural populations.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this species is parasitic. Furthermore, the plant family Alismataceae is not known to contain any parasitic plants (Heide-Jorgensen, 2008).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - mod	0	Although patches of *S. sagittifolia* decrease water flow speed in the patches and increase it outside the patches, causing seasonal variation in trapping of sediment and organic material (Kleeberg et al., 2010), we expect that would be true of any rooted, emergent aquatic plant. We therefore answered no, but with moderate uncertainty.
Imp-N2 (Changes habitat structure)	n - mod	0	We found no evidence of this impact.
Imp-N3 (Changes species diversity)	y - low	0.2	It is reported to suppress native plant populations in New Zealand (Greater Welllingon Regional Council, n.d.).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	? - max	0	Unknown; it is reported to suppress native plant populations in New Zealand (Greater Wellington Regional Council, n.d.), but we found no other evidence for this impact.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - low	0	Since *S. sagittifolia* does not appear to significantly affect ecosystem processes or habitat structure, it is unlikely that it would impact U.S. 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 - mod	0.6	*Sagittaria sagittifolia* is listed as a weed of the natural environment (Randall, 2007). It is managed to prevent its spread at a field site near Auckland, New Zealand (Champion and Hofstra, 2013; Champion and Clayton, 2001). Alternate answers for the uncertainty simulation were "b" and "a."
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	y - negl	0.1	*Sagittaria sagittifolia* can interfere with water flow and form large stands in and along drains, reservoirs, and canals (Biosecurity New Zealand, 2016; Holm et al., 1997; MPI, 2012). It affects potable water supplies in India (Holm et al., 1997).
Imp-A2 (Changes or limits recreational use of an area)	n - high	0	We found no specific evidence of *S. sagittifolia* limiting recreational use of an area, but we have some uncertainty because its ability to block waterways could potentially interfere with boating or swimming.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	We found no evidence of this impact.
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	*Sagittaria sagittifolia* is a serious weed of waterways in Argentina, Australia, the United Kingdom (England), Germany, Italy, Russia, Sweden and Taiwan and a principal weed in Germany (Holm et al., 1997). Holm et al. (1997) also note that the weed must often be removed from drains and canals. We interpret this to refer to control efforts such as dredging. We have low uncertainty because it is described as a weed in many areas. Alternate answers for the uncertainty simulation were both "b".
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - mod	0.4	*Sagittaria sagittifolia* is reported as damaging rice crops (Zhirong, 1990). It was of the top five weeds in experimental rice fields, and rice yield was lower in the non-treated control field than in the herbicide, hand-weeded, or weed-free fields (Saha et al., 2005). We have moderate uncertainty because the damage is not quantified and we do not know how much

Question ID	Answer - Uncertainty	Score	Notes (and references)
			reduction in yield is due to *S. sagittifolia* compared to other weeds. In addition, Liang (2014) found that intentional intercropping of *S. sagittifolia* with rice reduced rice disease incidence and increased yield.
Imp-P2 (Lowers commodity value)	n - mod	0	We found no evidence of this impact.
Imp-P3 (Is it likely to impact trade?)	n - low	0	*Sagittaria sagittifolia* is prohibited in New Zealand (Champion et al., 2008; Lehtonen, 2003) but is unlikely to be a contaminant (Lehtonen, 2003). Because it is unlikely to be a contaminant, we answered no with low uncertainty.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - mod	0.1	It is a common weed of irrigation systems in Italy and India (Holm et al., 1997). We have moderate uncertainty because we found no other sources listing this impact.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	We found no evidence that this species or the genus is toxic (e.g., Bruneton, 1999; Burrows and Tyrl, 2013). Furthermore, Holm et al (Holm et al., 1997) report that *S. sagittifolia* is fed to livestock.
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]	b - mod	0.2	*Sagittaria sagittifolia* is listed as a weed of agriculture (Randall, 2007). It is a principal weed of rice in India, Italy, and Taiwan. (Holm et al., 1997) and a weed of rice throughout southeastern Asia (Moody, 1989). We have moderate uncertainty because we found no information on control efforts specifically targeting *S. sagittifolia*, but we did find references to the use of herbicides against weed assemblages that include *S. sagittifolia*. Alternate answers for the uncertainty simulation were both "c."
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF Secretariat, 2019).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - high	N/A	One point in Russia, about 110 miles from Zone 2. We answered no because it is possible this record is erroneous and does not reflect the species' ability to survive in this Zone.
Geo-Z2 (Zone 2)	y - mod	N/A	A few points in Russia.
Geo-Z3 (Zone 3)	y - negl	N/A	Some points in Russia and a few in Finland.
Geo-Z4 (Zone 4)	y - negl	N/A	Many points in Finland and Russia, three in Sweden.
Geo-Z5 (Zone 5)	y - negl	N/A	Three points in Germany, one in Romania, some in Russia, some in Estonia, and many in Finland.
Geo-Z6 (Zone 6)	y - negl	N/A	Some points in Czech Republic and Austria, and many points in Germany.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z7 (Zone 7)	y - negl	N/A	Many points in Germany, some in Poland and Sweden.
Geo-Z8 (Zone 8)	y - negl	N/A	Many points in France and the United Kingdom, some in Denmark.
Geo-Z9 (Zone 9)	y - negl	N/A	Many points in the United Kingdom, some in France and China.
Geo-Z10 (Zone 10)	y - mod	N/A	Four points in China, one in Laos, one in Vietnam, a few in the United Kingdom and France; all points are on the coast or close to Zone 9.
Geo-Z11 (Zone 11)	n - high	N/A	One point in Laos and one in Vietnam; both points are on the edge of Zone 10.
Geo-Z12 (Zone 12)	n - mod	N/A	We found no evidence of the species in this Zone.
Geo-Z13 (Zone 13)	n - low	N/A	One point in French Polynesia, but based on the overall distribution, this identification seems doubtful.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - mod	N/A	One point in Laos, but this is primarily a temperate species, so the point may be a misidentification
Geo-C2 (Tropical savanna)	n - mod	N/A	One point in Thailand, one in Laos, but this is primarily a temperate species, so these points may be misidentifications.
Geo-C3 (Steppe)	y - high	N/A	Two points in Russia, one in China, one in Australia. The species may only be able to survive in suitable microhabitats in this climate class.
Geo-C4 (Desert)	n - low	N/A	We found no evidence of the species in this climate class.
Geo-C5 (Mediterranean)	y - low	N/A	Some points in Italy, France, and Spain.
Geo-C6 (Humid subtropical)	y - mod	N/A	A few points in Italy, some in China, four in Vietnam, one in Russia, one in Australia.
Geo-C7 (Marine west coast)	y - negl	N/A	Many points in the United Kingdom, Germany, and France.
Geo-C8 (Humid cont. warm sum.)	y - low	N/A	Four points in China, seven in Russia.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Many points in Germany, Czech Republic, Poland, and Sweden.
Geo-C10 (Subarctic)	y - negl	N/A	Many points in Finland, Sweden, and Norway.
Geo-C11 (Tundra)	y - high	N/A	One point in Norway, close to the subarctic region; 11 points in the Alps.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence of the species in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - mod	N/A	We found no evidence of the species in this precipitation band.
Geo-R2 (10-20 inches; 25-51 cm)	y - high	N/A	Some points in Spain and Italy (Sardinia), one in Romania, three in Russia, one in Australia, and five in China.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Many points in France, Germany, Poland, Russia, and Sweden.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Many points in France, Germany, the United Kingdom, and Sweden.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Many points in Norway; the species is distributed throughout Europe in areas that receive 40-90 inches of annual precipitation.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	The species is distributed throughout Europe in areas that receive 40-90 inches of annual precipitation.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Many points in the United Kingdom; the species is distributed throughout Europe in areas that receive 40-90 inches of annual precipitation.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	A few points in China; the species is distributed throughout Europe in areas that receive 40-90 inches of annual precipitation.
Geo-R9 (80-90 inches; 203-229 cm)	y - mod	N/A	A few points in China; the species is distributed throughout Europe in areas that receive 40-90 inches of annual precipitation.
Geo-R10 (90-100 inches; 229-254 cm)	y - high	N/A	One point in Taiwan, a few points in China.
Geo-R11 (100+ inches; 254+ cm)	y - high	N/A	Three points in Taiwan, a few points in China.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - low	0	As discussed under U.S. status and distribution, this species does not appear to be established in the United States; however, it may be cultivated to a minor extent.
Ent-2 (Plant proposed for entry, or entry is imminent)	y - negl	1	The edible tubers are imported into California, Hawaii, and New York for Chinese New Year (Lehtonen, 2003). Since the importation of the tubers is the reason for this assessment, we have negligible uncertainty.
Ent-3 [Human value & cultivation/trade status: (a) Neither cultivated or positively valued; (b) Not cultivated, but positively valued or potentially beneficial; (c) Cultivated, but no evidence of trade or resale; (d) Commercially cultivated or other evidence of trade or resale]	-	N/A	It has been cultivated for food in China and Japan and is sold as an ornamental pond plant (Champion et al., 2008; Holm et al., 1997). It is also used in traditional Asian medicine (Singh, 2008). We have low uncertainty about its presence in trade, but the volume of trade is probably low.
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	It is native to China (Holm et al., 1991; NPGS, 2020; Scher et al., 2015) and present in Mexico and Cuba (Scher et al., 2015).
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	We found no evidence of this.
Ent-4c (Contaminant of seeds for planting)	-	N/A	We found no evidence of this.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Ent-4d (Contaminant of ballast water)	-	N/A	We found no evidence of this.
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	We found no evidence of this, but it is sometimes sold as an ornamental pond plant (Champion et al., 2008).
Ent-4f (Contaminant of landscape products)	-	N/A	We found no evidence of this.
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	We found no evidence of this.
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	We found no evidence of this.
Ent-4i (Contaminant of some other pathway)	-	N/A	We found no evidence of any other pathways.
Ent-5 (Likely to enter through natural dispersal)	-	N/A	We found no evidence to support this.