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Version 1

Weed Risk Assessment for *Ipomoea aquatica* Forssk. (Convolvulaceae) – Water spinach

Top left: *Ipomoea. aquatica* covering pond (source: Jason Ferrell, Center for Aquatic and Invasive Plants). Bottom: Vine-like growth of plants (source: Jason Ferrell, Center for Aquatic and Invasive Plants). Top right: Flowers (source: Charles Bryson, weedimages.org).

AGENCY CONTACT

Plant Epidemiology and Risk Analysis Laboratory (PERAL)
Science and Technology (S&T)
Plant Protection and Quarantine (PPQ)
Animal and Plant Health Inspection Service (APHIS)
United States Department of Agriculture (USDA)
1730 Varsity Drive, Suite 300
Raleigh, NC 2760

Executive Summary

The result of the weed risk assessment for *Ipomoea aquatica* is High Risk of becoming weedy or invasive in the United States. *Ipomoea aquatica* is a freshwater, semiaquatic herbaceous plant that floats on the water surface. Adventitious roots hang freely from stem nodes, which provide the primary means of dispersal when these nodes break free from the main plant. It grows in ponds, marshes, swamps, very moist soils, ditches, and on stream banks. *Ipomoea aquatica* sometimes produces dense, impenetrable masses of vegetation that obstruct the flow of water, and shades out competing plants. It can also grow as a weed in rice paddies. *Ipomoea aquatica* is naturalized in Florida, Guam, Hawaii, and Puerto Rico, and is cultivated either illegally or, in some states, under permit as a vegetable crop. In Hawaii and Puerto Rico, it does not appear to cause ecological or economic damage as it does in other areas of the world.

While *I. aquatica* is recognized as a federal noxious weed, it is only the State of South Carolina that is known to take a proactive stance against known populations of the plant in the state. Furthermore, we found little evidence of other management activities for *I. aquatica*. Herbicides are reportedly available for use to eradicate *I. aquatica* but may be detrimental to non-target plants and aquatic systems. The efficacy of herbicides, when applied, may prove to be limited in effect.

Plant Information and Background

PLANT SPECIES: *Ipomoea aquatica* Forssk. (NGRP, 2019).

SYNONYM: *Ipomoea reptans* Poir. (NGRP, 2019).

COMMON NAMES: water spinach, swamp morning glory (Austin, 2007).

BOTANICAL DESCRIPTION: *Ipomoea aquatica* is a freshwater, semiaquatic herbaceous vine that grows horizontally with long, hollow stems that branch profusely and float on the water surface, sometimes producing dense masses of vegetation (Edie and Ho, 1969; Mandal et al., 2008; Patnaik, 1976; Prasad et al., 2008). While the plant's main roots are in the soil, its stems produce adventitious roots at the nodes and float (Patnaik, 1976). The leaves are alternate and are either heart- or arrowhead-shaped (Snyder et al., 1981). The plant can grow as an annual or perennial (Prasad et al., 2008). The seed capsule has four valves containing one to four, frequently hairy, seeds (Langeland and Burks, 1998; Patnaik, 1976).

INITIATION: During the development of a pathway-initiated pest risk assessment for global spinach seed for planting, Plant Protection and Quarantine (PPQ) identified *Ipomoea aquatica* as a potential weed seed contaminant of spinach seed. Because this species poses a potential risk to U.S. agricultural and natural resources, PPQ characterized its risk with this analysis.

WRA AREA[1]: United States and Territories.

FOREIGN DISTRIBUTION: *Ipomoea aquatica* is native to China, Bangladesh, India, Nepal, Pakistan, Sri Lanka, Cambodia, Laos, Myanmar, Thailand, Vietnam, Indonesia, Malaysia, the Philippines, Papua New Guinea, most of Africa, and northern Australia (NGRP, 2019). It is naturalized in Costa Rica, Nicaragua, Panama, the Caribbean, and South America (NGRP, 2019). Randall (2017) lists *I. aquatica* as invasive in Bangladesh, India, Israel, and Mexico. It is widely cultivated as a vegetable crop in tropical regions (Austin, 2007; Edie and Ho, 1969; Mandal et al., 2008). *Ipomoea aquatica* is regulated by Guatemala and Honduras (USDA PCIT, 2019).

U.S. DISTRIBUTION AND STATUS: *Ipomoea aquatica* is naturalized in Florida, Guam, Hawaii, and Puerto Rico (Anderson, 2019; IRC, 2016; Snyder et al., 1981; Sosa, 2019; Stone, 1970; Young, 2019). There are additional references reporting it from other areas of the United States (BONAP, 2019; USDA NRCS, 2019), however, many of these citations refer to cultivated plants or transient populations. South Carolina confirms that *I. aquatica* was detected in the state. Action was taken and there are no known escaped or naturalized populations in the state (Lightfoot, 2019). *Ipomoea aquatica* is a Federal Noxious Weed in the United States and is regulated in more than ten states (Chilton II, 2017; USDA NRCS, 2019). Some states allow cultivation under permit but it is cultivated illegally by some (Austin, 2007; Chilton II, 2017; McCoy, 2012). South Carolina destroys *I. aquatica* when it is discovered and does not allow cultivation under permit (Lightfoot, 2019). South Carolina regulates all *Ipomoea* spp. due to its risk of spreading *Cylas formicarius*, sweet potato weevil

[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).

(Lightfoot, 2019). *Ipomoea aquatica* is also present on Midway Atoll, where it was introduced for cultivation (Starr et al., 2008).

Analysis

ESTABLISHMENT/SPREAD POTENTIAL: Because of its long history as a cultivated vegetable, *I. aquatica* is distributed worldwide. It can be invasive in tropical areas where humidity is high (Harwood and Sytsma, 2003; Chilton II, 2017). *Ipomoea aquatica* grows best in full sun; shade is considered a limiting factor (CABI, 2018a). Under ideal conditions, it can grow four inches a day (FOC, 2019). Although it produces water-dispersed seeds (Austin, 2007; Ogunwenmo and Oyelana, 2009), the primary means of reproduction is through vegetative fragmentation (Ogunwenmo and Oyelana, 2009). Stems of *I. aquatica* produce adventitious roots at the nodes (Ogunwenmo and Oyelana, 2009). When broken from the main plant, the stems are dispersed by water to new locations, root from the adventitious roots, and establish new plants (Ogunwenmo and Oyelana, 2009; TexasInvasives.org, 2007; Ugborogho and Ogunwenmo, 1995). Port inspectors have intercepted *I. aquatica* seed in fruit, plants, and seed brought into the United States for propagation (AQAS, 2019). The genus *Ipomoea* contains over 500 species but only *I. aquatica* and *I. carnea* are aquatic (Harwood and Sytsma, 2003; Meira et al., 2012; Ogunwenmo and Oyelana, 2009). *Ipomoea carnea* is one of the "world's 100 most invasive weeds" (Kumar et al., 2018). We had low uncertainty in this risk element.

Risk score = 17 Uncertainty index = 0.12

IMPACT POTENTIAL: *Ipomoea aquatica* forms dense, impenetrable masses of vegetation that float and obstruct the flow of water in drainage systems, and shades out competing plants (Chilton II, 2017; Harwood and Sytsma, 2003; Mandal et al., 2008; MyFWC.com, 2019; Ogunwenmo and Oyelana, 2009). In India, the plant impacts fisheries and 'navigation' (Harwood and Sytsma, 2003). *Ipomoea aquatica* is generally considered as a weed of rice in Cambodia, India, and Thailand (Kamoshita et al., 2014; Kittipong, 1983; Kumar et al., 2013), and may damage the crop in some locations such as Bangladesh (De Datta and Haque, 1982). On the other hand, in Hawaii and Puerto Rico, where *I. aquatica* is naturalized, no ecological or economic damage has been reported (Sosa, 2019; Young, 2019). We had average uncertainty.

Risk score = 3.6 Uncertainty index = 0.19

GEOGRAPHIC POTENTIAL: Based on three climatic variables, we estimate that about 9 percent of the United States is suitable for the establishment of *I. aquatica* (Figure 1, below). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and general areas of occurrence. The map for *I. aquatica* represents the joint distribution of Plant Hardiness Zones 9-13, areas with 0-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, desert, and humid subtropical. The area of the United States shown to be climatically suitable (Figure 1, below) for *I. aquatica* establishment considered only these three climatic variables. Other variables, for example, soil and habitat type, novel climatic conditions, or plant genotypes, may alter the areas in which this species is likely to establish.

Ipomoea aquatica is a tropical plant that grows well when temperatures are above 23.9 °C (GISD, 2006a; Harwood and Sytsma, 2003) but “cannot stand frost or snow” (Edie and Ho, 1969; GISD, 2006a). As an aquatic plant, air temperature is not always a reliable predictor of potential distribution extent (Harwood and Sytsma, 2003). *Ipomoea aquatica* requires “hot, humid conditions for growth” (Harwood and Sytsma, 2003). Pinker et al. (2004) states that for cultivation, humidity should be above 75%. *Ipomoea aquatica* grows best under full sun exposure while shade is considered a limiting factor to its growth (CABI, 2018a).

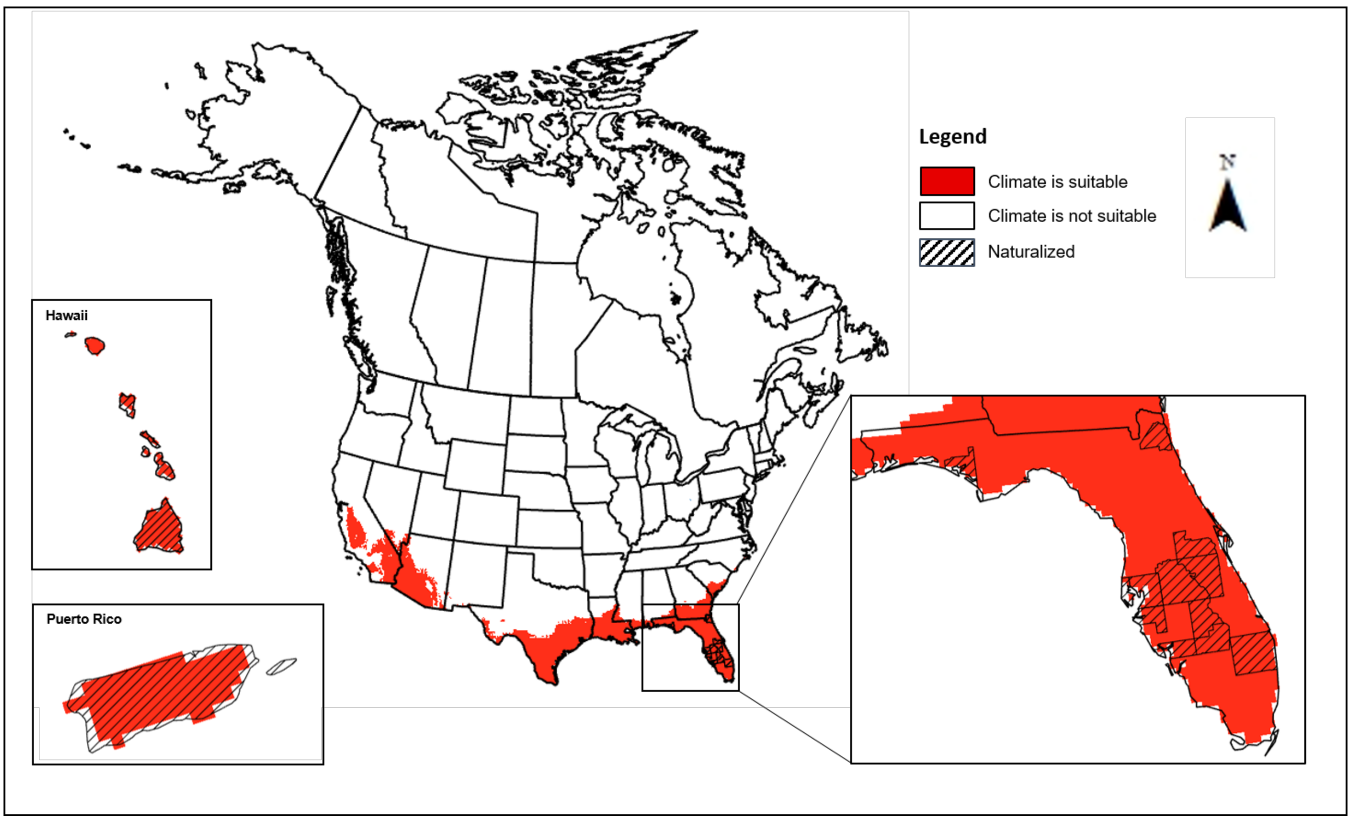

Figure 1. Current and potential distribution of *Ipomoea aquatica* in the United States. Climatic suitability was determined using the APHIS-PPQ climate matching tool for invasive plants (Magarey et al., 2017). The known distribution of *I. aquatica* was based on county distribution records from online databases and other sources (see text for sources). While there are more records of *I. aquatica* in the United States, this map only shows records of naturalized populations and excludes records of cultivated plants Map components are shown at different scales.

ENTRY POTENTIAL: We did not assess *I. aquatica*’s entry potential because this species is already present in the United States (Kartesz, 2019; Wagner et al., 1999).

Risk Model Results

Model Probabilities: P(Major Invader) = 88.5%
P(Minor Invader) = 11.1%
P(Non-Invader) = 0.4%

Risk Result = High Risk

Secondary Screening = Not Applicable

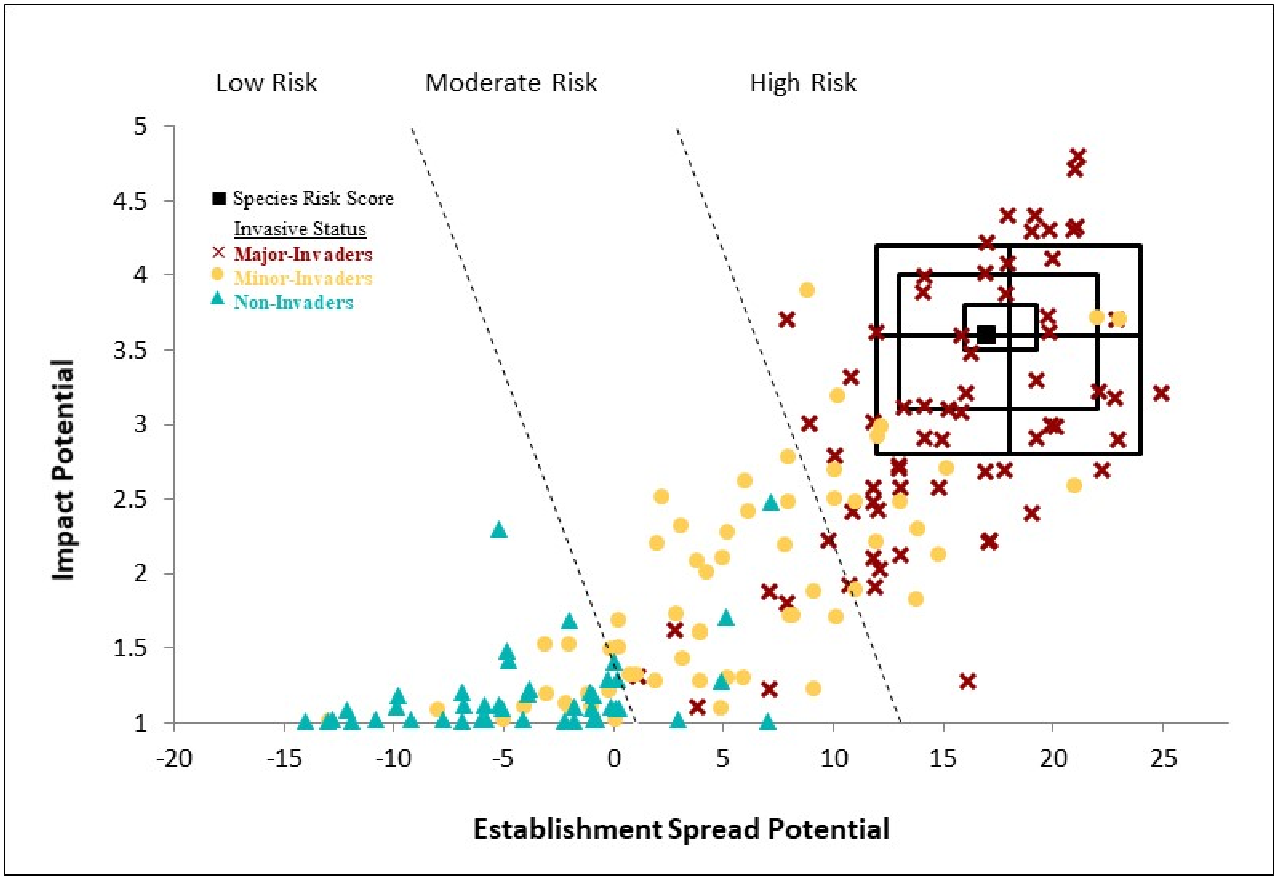

Figure 2. Risk and uncertainty results for *Ipomoea aquatica*. The species' risk score (solid black symbol) is plotted relative to the risk scores of the species used to develop and validate the PPQ WRA model (Koop, 2012). The results from the uncertainty analysis are plotted around the risk score for *Ipomoea aquatica*. The smallest, black box contains 50 percent of the simulated risk scores, the second 95 percent, and the largest 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 this weed risk assessment for *Ipomoea aquatica* is High Risk (Figure 2, above). *Ipomoea aquatica* grows quickly and can overgrow ponds, resulting in the disappearance of competing plants "due to the shading and choking effect of the over-running branches" (Patnaik, 1976; Van and Madeira, 1998). Its dense mats of vegetation can inhibit water flow in irrigation canals, ditches, dams, and is reported to obstruct 'navigation' and impact fisheries (Harwood and Sytsma, 2003; TexasInvasives.org, 2007). *Ipomoea aquatica* is regulated as a U.S. federal noxious weed (USDA APHIS, 2017) and as a State Noxious Weed in over ten states (Chilton II, 2017; USDA NRCS, 2019). However, the conditions and locations where *I. aquatica* have become a problem are specific and limited in the United States.

Ipomoea aquatica has been in the United States for over 60 years (Ochse, 1951) but is only naturalized in Florida, Guam, Hawaii, and Puerto Rico (Figure 1). Hawaii and Puerto Rico, with naturalized populations of *I. aquatica,* do not report any ecological or economic damage resulting from the presence of *I. aquatica* (Sosa, 2019; Young, 2019). Risk assessments conducted for Oregon and Texas concluded that *I. aquatica* is low risk. There was “no evidence that it will grow outside of tropical areas naturally” (Chilton II, 2017; Harwood and Sytsma, 2003). Texas allows the cultivation of *I. aquatica* inside greenhouses and under permit (Dao, 2017). In 2017, Hurricane Harvey flooded and severely damaged greenhouses where *I. aquatica* was being grown commercially (Dao, 2017; Wang, 2017); however, it is not clear if any plants escaped and established beyond the greenhouses.

Suggested Citation

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Appendix A. Weed risk assessment for *Ipomoea aquatica* Forssk. (Convolvulaceae)

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]	f - low	5	*Ipomoea aquatica* is native to southern Asia (NGRP, 2019; Van and Madeira, 1998). It can be invasive in some tropical and temperate regions (EDDMapS, 2019; Harwood and Sytsma, 2003; Chilton II, 2017). Randall (2017) lists *I. aquatica* as invasive in Bangladesh, India, Israel, and Mexico. Because it grows rapidly, it can overgrow a "site and render it useless for domestic purposes" (Gangstad et al., 1976; GISD, 2006b). The alternate answers for the uncertainty simulation were 'e' and 'd.'
ES-2 (Is the species highly domesticated)	n - mod	0	*Ipomoea aquatica* has been cultivated for consumption over thousands of years (Austin, 2007; Edie and Ho, 1969; Mandal et al., 2008). It is still widely cultivated (Van and Madeira, 1998), especially in Asia (CABI, 2018a; Edie and Ho, 1969). Cultivars are present and breeding continues in order to produce more desirable traits (Palada and Crossman, 1999; Pinker et al., 2004). We found no information describing breeding efforts for reduced weediness or invasiveness.
ES-3 (Significant weedy congeners)	y - low	1	The genus *Ipomoea* contains over 500 species but only *I. aquatica* and *I. carnea* are aquatic (Harwood and Sytsma, 2003; Meira et al., 2012; Ogunwenmo and Oyelana, 2009). *Ipomoea carnea* is one of the "world's 100 most invasive weeds" (Kumar et al., 2018).
ES-4 (Shade tolerant at some stage of its life cycle)	n - mod	0	*Ipomoea aquatica* grows best in full sun and shade is considered a limiting factor (CABI, 2018a). Plants grown in shade are weak (Tiwari and Chandra, 1985).
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	y - low	1	*Ipomoea aquatica* is a "trailing vine" that can produce stems 70 feet long (FLEPPC, 2019; MyFWC.com, 2019). Other adjectives used to describe *I. aquatica* include "creeper" (Ugborogho and Ogunwenmo, 1995), "scrambler" (Ugborogho and Ogunwenmo, 1995), and "vine-like species" (McCann et al., 1996). Because this is not a typical terrestrial vine, we used low uncertainty instead of negligible.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	*Ipomoea aquatica* can form dense, impenetrable masses that float (Harwood and Sytsma, 2003; Mandal et al., 2008; MyFWC.com, 2019).
ES-7 (Aquatic)	y - negl	1	*Ipomoea aquatica* is an aquatic or semiaquatic herbaceous plant (Edie and Ho, 1969; Snyder et al., 1981).
ES-8 (Grass)	n - negl	0	*Ipomoea aquatica* is not a grass. *Ipomoea aquatica* is an herbaceous vine in the Convolvulaceae family (NGRP, 2019; Van and Madeira, 1998).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	*Ipomoea aquatica* is not a woody species. It is in the Convolvulaceae family which is not known known to contain nitrogen-fixing species (NGRP, 2019; Santi et al., 2013).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	*Ipomoea aquatica* produces viable seed and can be direct seeded for cultivation (Chilton II, 2017; Palada and Crossman, 1999; Snyder et al., 1981). The seeds do not germinate well under water (Edie and Ho, 1969; Palada and Crossman, 1999).
ES-11 (Self-compatible or apomictic)	y - negl	1	In a pollination experiment, Kaewsorn et al., (Kaewsorn et al., 2008) showed that I. *aquatica* is self-compatible. While white-stemmed cultivars always set seed when pollinated with pollen from the same plant, red-stemmed cultivars only set seed 61.5% of the time (Kaewsorn et al., 2008). In an experiment where unopened flowers were bagged, Ogunwenmo and Oyelana (2009) determined that the upland biotype was able to set seed, but not the wild type. Thus, while there is some variation in self-compatibility within the species, some biotypes of *I. aquatica* are self-compatible
ES-12 (Requires specialist pollinators)	n - low	0	We found no evidence suggesting that *I. aquatica* requires specialist pollinators. Because bagged flowers will produce seed (Ogunwenmo and Oyelana, 2009), this species does not require specialist pollinators. Kaewsorn et al. (2008) report that small insects visited the flowers in a greenhouse experiment.
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 - mod	1	*Ipomoea aquatica* is usually a perennial plant, but occasionally it behaves as an annual (Holm et al., 1997; Ogunwenmo and Oyelana, 2009; Prasad et al., 2008). Flowering starts 48-63 days after sowing (Westphal, 1992 in CABI, 2018b). It also reproduces through vegetative fragmentation, but we found no evidence about how often that occurs. We used moderate uncertainty due to a lack of specific information. Alternate answers for the

Question ID	Answer - Uncertainty	Score	Notes (and references)
			uncertainty simulation were 'a' and 'c.' We selected 'a' as an alternate as it seems likely that vegetative fragmentation may lead to several generations in a year.
ES-14 (Prolific seed producer)	n - high	-1	For a wetland community in Africa, Olubode et al. (2011) reported that there are between 44 and 76 plants per square meter; however it is not clear how many of these were reproductive adults. Patnaik (1976) found that *I. aquatica* can produce 174-245 seeds per plant in one season, but these plants ranged between 1.7 and 22.5 meters long. Li et al. (2009) recorded a 70% germination rate in experimental controls. Without additional information it is impossible to estimate the number of seeds produced per square meter. However, we answered no with high uncertainty because compared to other plants that readily produce thousands of seeds per plant, per plant seed production in *I. aquatica* is rather low.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - low	1	When fragments break away from the main plant, they can be transported unintentionally by humans and start new populations (Lin et al., 2012; Patnaik, 1976). In general, aquatic weeds get entangled on boats (e.g., propellers, trailers, etc.), and inadvertently get transported to new locations (Rothlisberger et al., 2010; Willby and Eaton, 1993).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - low	2	Port inspectors have intercepted *I. aquatica* seed in fruit, plants, and seed brought into the United States for propagation (AQAS, 2019).
ES-17 (Number of natural dispersal vectors)	1	-2	Description of propagules for questions ES-17a through ES-17e: "Fruit an oval or spherical capsule, woody at maturity, about 1 cm (1/2 in) wide, holding 1-4 grayish seeds, these often short-hairy" (Langeland and Burks, 1998). Seeds are 4-8 mm long and 4-6 mm in diameter, slightly pubescent (Ogunwenmo, 2006).
ES-17a (Wind dispersal)	n - negl		We found no evidence suggesting *I. aquatica* propagules are wind dispersed. Because the seeds are "large" (Ogunwenmo, 2006), and possess no traits that would aid in wind-dispersal, we answered no with negligible uncertainty.
ES-17b (Water dispersal)	y - negl		Seeds of *I. aquatica* contain air pockets, allowing them to float for long periods (Austin, 2007; Ogunwenmo and Oyelana, 2009). The primary means of reproduction is through vegetative fragmentation (Ogunwenmo and Oyelana, 2009). The stems float and when broken from the main plant can travel by water to new locations and grow new plants by roots

Question ID	Answer - Uncertainty	Score	Notes (and references)
			produced at the nodes (Ogunwenmo and Oyelana, 2009; TexasInvasives.org, 2007; Ugborogho and Ogunwenmo, 1995).
ES-17c (Bird dispersal)	n - mod		We found no evidence indicating that plants are bird-dispersed.
ES-17d (Animal external dispersal)	n - mod		Because the plants fragment and root easily, dispersal can occur by animals (Ogunwenmo and Oyelana, 2009; Patnaik, 1976; Riis and Sand-Jensen, 2006). However, because we found no evidence of specific adaptations for external dispersal we answered no with moderate uncertainty.
ES-17e (Animal internal dispersal)	n - mod		We found no evidence suggesting *I. aquatica* propagules are dispersed by animals internally.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	While we found evidence that seeds are forced into dormancy due to a thick or impermeable seed coat (CABI, 2018a; Ebert and Wu, 2019; Ogunwenmo, 2006), we found no information about how long the seeds may persist in the soil.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	Cultivation of *I. aquatica* is by seed or stem cuttings (Edie and Ho, 1969; Mandal et al., 2008). Naturally, *I. aquatica* primarily spreads as stems break and disperse (Ogunwenmo and Oyelana, 2009).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	*Ipomoea aquatica* can be controlled with non-specific spectrum herbicides (Chilton II, 2017; WI DNR, 2017). We found no evidence that *I. aquatica* has developed herbicide resistance (Heap, 2013).
ES-21 (Number of cold hardiness zones suitable for its survival)	5	0	
ES-22 (Number of climate types suitable for its survival)	5	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - mod	0	Although *Ipomoea aquatica* extracts inhibited growth of *Pennisetum typhoideum* (pearl millet) (Singhvi and Sharma, 1984), I chose an answer of ‘n’ with moderate uncertainty due to lack of additional evidence.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence suggesting that *I. aquatica* is parasitic (Heide-Jorgensen, 2008; Nickrent, 2009; Walker, 2012).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - low	0	We found no evidence suggesting that *I. aquatica* changes ecosystem processes.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-N2 (Changes habitat structure)	y - mod	0.2	*Ipomoea aquatica* forms mats on the water surface (Holm et al., 1997). It can spread, "choking the entire surface of the pond" (Patnaik, 1976).
Imp-N3 (Changes species diversity)	y - low	0.2	Dense masses of vegetation float on the water and may develop into an impenetrable mass that shades out competing species (Mandal et al., 2008; Patnaik, 1976).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - high	0	Although we found no direct evidence that *I. aquatica* has impacted protected species, because it forms dense mats on the water surface, it may cause harm to Threatened and Endangered aquatic species.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - mod	0	We found no evidence that *I. aquatica* might threaten any 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	*Ipomoea aquatica* is found in natural systems such as wetlands, lakes, and stream/ river banks (Langeland and Burks, 1998; TexasInvasives.org, 2007; Van and Madeira, 1998). The Florida Exotic Pest Council classifies *I. aquatica* as a Category 1 species for having "documented ecological damage" (FLEPPC, 2019). The Florida Department of Environmental Protection has attempted eradication several times with limited success (Langeland and Burks, 1998; Simberloff et al., 1997).
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	y - negl	0.1	*Ipomoea aquatica* is reported as obstructing water flow in drainage, dams, and flood control canals (Chilton II, 2017; Joshi, 2012).
Imp-A2 (Changes or limits recreational use of an area)	y - mod	0.1	Dense growth of *I. aquatica* obstructs 'navigation' (Chia et al., 2012; Harwood and Sytsma, 2003). It is reported as being a "hindrance to movement of canoes and light boats" (Ugborogho and Ogunwenmo, 1995). Due to lack of specific information on the effects of *I. aquatica* in recreational areas, we used moderate uncertainty.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	We found no evidence that *I. aquatica* affects ornamentals.
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]	a - high	0	Although *I. aquatica* is reported to obstruct drainage, and hinder navigation. We did not find any direct evidence that it is considered a weed of anthropogenic systems. The species was introduced to Midway Atoll for cultivation, and was later found in a seep by a field (Starr et al., 2008). The plants at this site were removed (Starr et al., 2008). Without additional evidence, we answered "a" with high uncertainty. Alternate

Question ID	Answer - Uncertainty	Score	Notes (and references)
			answers for the uncertainty simulation were ‘b’ and ‘c.’
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - low	0.4	*Ipomoea aquatica* causes unspecified damage on rice production (De Datta and Haque, 1982). Kittipong (1983) lists *I. aquatica* as causing "moderate yield or quality losses and is economically troublesome in certain rice cultures in rice-producing countries of the world." In addition, *I. aquatica* is reported as negatively impacting fisheries (Harwood and Sytsma, 2003; Holm et al., 1997).
Imp-P2 (Lowers commodity value)	? - max		Kittipong (1983) states that it reduces yield OR causes quality losses in rice. However, because the reference used "or" and because we considered that evidence above, we did not want to over inflate the value of that information by using it to support a yes response here.
Imp-P3 (Is it likely to impact trade?)	y - mod	0.2	*Ipomoea aquatica* is regulated in Guatemala and Honduras (USDA PCIT, 2019). Port inspectors have intercepted *I. aquatica* seed in fruit, plants, and seed brought into the United States for propagation (AQAS, 2019). South Carolina regulates all *Ipomoea* spp. due to its risk of spreading *Cylas formicarius*, sweet potato weevil (Lightfoot, 2019).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - low	0.1	*Ipomoea aquatica* can inhibit water flow of irrigation canals and ditches (Harwood and Sytsma, 2003; TexasInvasives.org, 2007).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	Extracts of *I. aquatica* were experimentally shown to be toxic to Nile tilapia (Ayoola et al., 2011). However, *I. aquatica* is often used as feed for other animals (Edie and Ho, 1969; Mandal et al., 2008) and grown along with fish in aquaculture (Ayoola et al., 2011). We chose a low uncertainty because we did not find field-based evidence of toxicity.
Imp-P6 [What is the taxon’s weed status in production systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	c - low	0.6	*Ipomoea aquatica* is a weed in several production systems, including bananas, cocoa, maize, papaya, peanuts, rice, soybeans, and sugarcane (Holm et al., 1997; Kamoshita et al., 2014; Kumar et al., 2013). Control of *I. aquatica* is often by manual labor (Caton, 2010). Alternate answers for the uncertainty simulation were ‘b’ and ‘a.’
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2018).
Plant hardiness zones			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z1 (Zone 1)	n - negl	N/A	No evidence *I. aquatica* occurs in this hardiness zone.
Geo-Z2 (Zone 2)	n - negl	N/A	No evidence *I. aquatica* occurs in this hardiness zone.
Geo-Z3 (Zone 3)	n - negl	N/A	No evidence *I. aquatica* occurs in this hardiness zone.
Geo-Z4 (Zone 4)	n - negl	N/A	No evidence *I. aquatica* occurs in this hardiness zone.
Geo-Z5 (Zone 5)	n - negl	N/A	No evidence *I. aquatica* occurs in this hardiness zone.
Geo-Z6 (Zone 6)	n - negl	N/A	No evidence *I. aquatica* occurs in this hardiness zone.
Geo-Z7 (Zone 7)	n - mod	N/A	Two points in China in mountains near Zones 8 and 9.
Geo-Z8 (Zone 8)	n - high	N/A	Four points in China, most near Zone 9. We answered no because *I. aquatica* is intolerant of frost and snow, and grows poorly in cold temperatures (Holm et al., 1997).
Geo-Z9 (Zone 9)	y - high	N/A	One point in Australia near edge of Zone 10. Some points in China. Few points in Florida. Two points in Japan, one point in Namibia, and point one in South Korea.
Geo-Z10 (Zone 10)	y - negl	N/A	Many points in Australia. Few points in China, Namibia, Botswana, Angola. Three points in Florida.
Geo-Z11 (Zone 11)	y - negl	N/A	Many points in Australia and Niger. Few points in Taiwan. Some points in Mauritania.
Geo-Z12 (Zone 12)	y - negl	N/A	Many points in Australia and Taiwan. Some points in Ghana. Few points in Thailand. Two points in Cambodia. Some in Côte d'Ivoire.
Geo-Z13 (Zone 13)	y - negl	N/A	Some points in Australia and Malaysia. Many points in Benin. Few points in Ghana and Colombia.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - negl	N/A	Some points in Indonesia and Malaysia.
Geo-C2 (Tropical savanna)	y - negl	N/A	Many points in Australia and West Africa. Some points in Thailand.
Geo-C3 (Steppe)	y - negl	N/A	Many points in Australia and West Africa. One point in India.
Geo-C4 (Desert)	y - negl	N/A	Some points in Australia. Most points near Steppe. Some points in Mauritania. Few points in Niger. Two points in Sudan.
Geo-C5 (Mediterranean)	n - high	N/A	Two points in Ethiopia. We answered no because it is not clear if these points represent naturalized or cultivated plants.
Geo-C6 (Humid subtropical)	y - negl	N/A	Some points in Australia, China, and Florida. Many points in Taiwan. Some points in Florida. One point in Texas.
Geo-C7 (Marine west coast)	n - high	N/A	One point in Madagascar and Colombia.
Geo-C8 (Humid cont. warm sum.)	n - high	N/A	One point in South Korea.
Geo-C9 (Humid cont. cool sum.)	n - low	N/A	One point in South Korea on the coast.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C10 (Subarctic)	n - negl	N/A	We found no evidence that this species occurs in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence that this species occurs in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that this species occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - high	N/A	Some points in Senegal, Mauritania, Mali, Burkina Faso, and Niger.
Geo-R2 (10-20 inches; 25-51 cm)	y - mod	N/A	Few points in Australia next to wetter bands. Some points in Burkina Faso and Niger.
Geo-R3 (20-30 inches; 51-76 cm)	y - low	N/A	Some points in Australia. Few points in Benin.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Some points in Australia. Many points in Benin. Few points in Ghana.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Some points in Australia. Many points in Benin.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Many points in Australia.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Many points in Australia. Present throughout South East Asia where precipitation ranges from 60-100 inches +.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Some points in Australia. Present throughout South East Asia where precipitation ranges from 60-100 inches +.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	One point in Australia. Present throughout South East Asia where precipitation ranges from 60-100 inches +.
Geo-R10 (90-100 inches; 229-254 cm)	y - negl	N/A	Present throughout South East Asia where precipitation ranges from 60-100 inches +.
Geo-R11 (100+ inches; 254+ cm)	y - negl	N/A	Few points in Malaysia, Thailand. Some points in Taiwan. Present throughout South East Asia where precipitation ranges from 60-100 inches +.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	*Ipomoea aquatica* is already present in the United States (Figure 1).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
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	
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	

Question ID	Answer - Uncertainty	Score	Notes (and references)
Ent-4c (Contaminant of seeds for planting)	-	N/A	
Ent-4d (Contaminant of ballast water)	-	N/A	
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	
Ent-4f (Contaminant of landscape products)	-	N/A	
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	
Ent-4i (Contaminant of some other pathway)	-	N/A	
Ent-5 (Likely to enter through natural dispersal)	-	N/A	