United States Department of Agriculture

Weed Risk Assessment for *Rotala rotundifolia* (Buch.-Ham. ex Roxb.) Koehne (Lythraceae) – Roundleaf toothcup

United States Department of Agriculture

Animal and Plant Health Inspection Service

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Version 1

Top left: *Rotala rotundifolia* is named after its round, emergent leaves. Bottom left: The pink, emerged flowers of *R. rotundifolia*. Right: A mat of *R. rotundifolia* dense enough to support the weight of several ducks (Photographs by Robert Vidéki. Source: Bugwood, 2015).

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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.

***Rotala rotundifolia* (Buch.-Ham. ex Roxb.) Koehne – Roundleaf toothcup**

Species Information

Family: Lythraceae

Synonyms: *Ammannia rotundifolia* Buch.-Ham. ex Roxb. (basionym) (NGRP, 2016). Some authors have treated *R. rotundifolia* and *R. macrandra* as conspecific. However, Cook (1979) and Joseph and Sivarajan (1989) argued that these were indeed two different species based on the exserted stamens of *R. macrandra* as well as the different bracteole lengths, extent of calyx lobing, and very different appearance of the submerged leaves in these two species.

Common names: Roundleaf toothcup (Jacono and Vandiver Jr., 2007; NGRP, 2016), dwarf rotala (Burks et al., 2003), pink sprites (Dave's Garden, 2015).

Botanical description: *Rotala rotundifolia* is a water-loving plant that can grow fully submerged (Cook, 1979; Joseph and Sivarajan, 1989), as an emerged aquatic plant, and as a terrestrial plant in dry gravel (Ervin and White, 2007). Its stems can be creeping or floating and can grow to 70 cm long. The emersed leaves are round, 1-2 cm in size, and green, while submerged leaves are lance-shaped, up to 2.2 cm in length, and green to red in color (Kasselmann, 2003). Several botanical descriptions of this species are available (Cook, 1979; Ohwi, 1984; Joseph and Sivarajan, 1989; Kasselmann, 2003; and Zhengyi et al., 2016).

Initiation: PPQ received a market access request for *Rotala macrandra*, *R. rotundifolia*, and *R. wallichii* aquatic plants for propagation from the Ministry of Food, Agriculture and Fisheries of the Danish Plant Directorate (MFAF, 2009). These *Rotala* species are not native to the United States (Kasselmann, 2003) and may pose a threat to the United States. In this assessment, we evaluate one of these species, *R. rotundifolia*.

Foreign distribution: *Rotala rotundifolia* is native to South and Southeast Asia from Japan to India (Cook, 1979; Joseph and Sivarajan, 1989; Rataj and Horeman, 1977). It is widely grown as an aquarium plant (Csurhes and Edwards, 1998). *Rotala rotundifolia* has become naturalized in Australia in Queensland and New South Wales (Csurhes and Edwards, 1998; Hosking et al., 1997) and in thermal water bodies in Hungary (Lukács et al., 2014; Mesterházy et al., 2009). *Rotala rotundifolia* is a prohibited species in Western Australia, Tasmania (Gettys and Tipping, 2014) and Honduras (APHIS, 2015).

U.S. distribution and status: *Rotala rotundifolia* is available for sale in the United States from a large pet store chain (PetSmart, 2015). It has become naturalized in four counties in Florida (Burks et al., 2003; Gettys and Della Torre II, 2014). A population of *R. rotundifolia* was also found in a pond on the University of Alabama campus (Reese and Haynes, 2002), but this population was eradicated by draining the pond (Ervin and Madsen, 2009; Gettys et al., 2015).

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

1. *Rotala rotundifolia* analysis

Establishment/Spread Potential

Rotala rotundifolia is an aquatic plant that has become naturalized in Australia (Csurhes and Edwards, 1998; Hosking et al., 1997), Hungary (Lukács et al., 2014; Mesterházy et al., 2009), and the United States (Burks et al., 2003; Gettys and Della Torre II, 2014; Reese and Haynes, 2002). In Florida, *R. rotundifolia* can grow at a rate of 4 to 5 inches per week, which allows it to quickly spread across water surfaces (UF/IFAS, 2015). Populations of *R. rotundifolia* create dense submerged and floating mats (Gettys and Della Torre II, 2014) and reproduce by both seed (Jacono and Vandiver Jr., 2007) and floating stem fragments (Burks et al., 2003; Jacono and Vandiver Jr., 2007; Rataj and Horeman, 1977). We had very high uncertainty here because while *R. rotundifolia* is known to disperse by water (Ervin and White, 2007; Graham et al., 2011), we found little information about other dispersal methods for this species.
Risk score = 14 Uncertainty index = 0.25

Impact Potential

Rotala rotundifolia is targeted for control in natural systems because this species forms a dense layer on the water surface (Gettys and Della Torre II, 2014) that shades out native vegetation (UF/IFAS, 2015) and restricts water flow (Gettys and Della Torre II, 2014). It is prohibited in Western Australia, Tasmania (Gettys and Tipping, 2014) and Honduras (APHIS, 2015). *Rotala rotundifolia* is also controlled in residential areas because dense populations interfere with drainage, preventing water control canals from working properly (Gettys et al., 2015). This species is listed as a weed of rice throughout Asia (Holm et al., 1979; Moody, 1989), but we did not find any information about it being specifically targeted for control in production systems. We had high uncertainty here due to the lack of information about the impacts *R. rotundifolia* has in production systems.
Risk score = 3.5 Uncertainty index = 0.22

Geographic Potential

Based on three climatic variables, we estimate that about 42 percent of the United States is suitable for the establishment of *R. rotundifolia* (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 *Rotala rotundifolia* represents the joint distribution of Plant Hardiness Zones 6-13, areas with 20-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, Mediterranean, humid subtropical, marine west coast, humid continental warm summers, and humid continental

[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).

cool summers.

The area of the United States shown to be climatically suitable (Fig. 1) is likely overestimated since our analysis considered only three climatic variables. Other environmental variables, such as soil, habitat type, turbidity, and water pH, may further limit the areas in which this species is likely to establish. In its native range, *R. rotundifolia* grows in marshes, swamps, and shallow ponds at high altitudes (Cook, 1979; Joseph and Sivarajan, 1989). It grows well on shorelines as well as in open water (Ervin and Madsen, 2009).

Entry Potential We did not assess the entry potential of *R. rotundifolia* because it is already present in the United States in four counties in Florida (Burks et al., 2003; Gettys and Della Torre II, 2014; Kartesz, 2016).

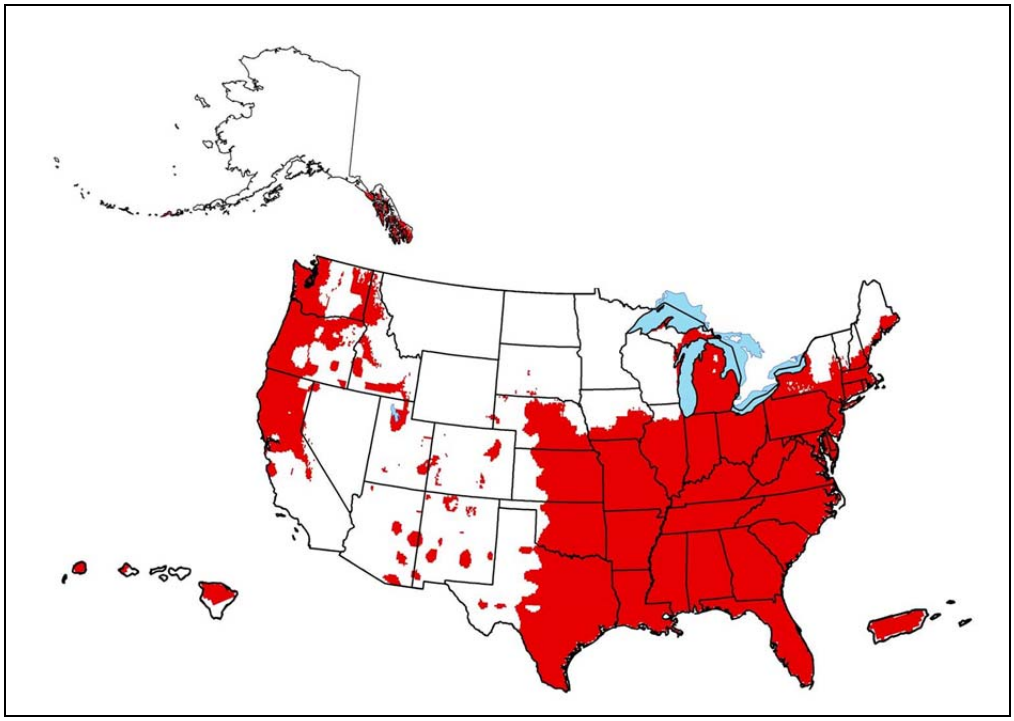

Figure 1. Predicted distribution of *Rotala rotundifolia* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 78.1%
P(Minor Invader) = 21.1%
P(Non-Invader) = 0.8%
Risk Result = High Risk
Secondary Screening = Not Applicable

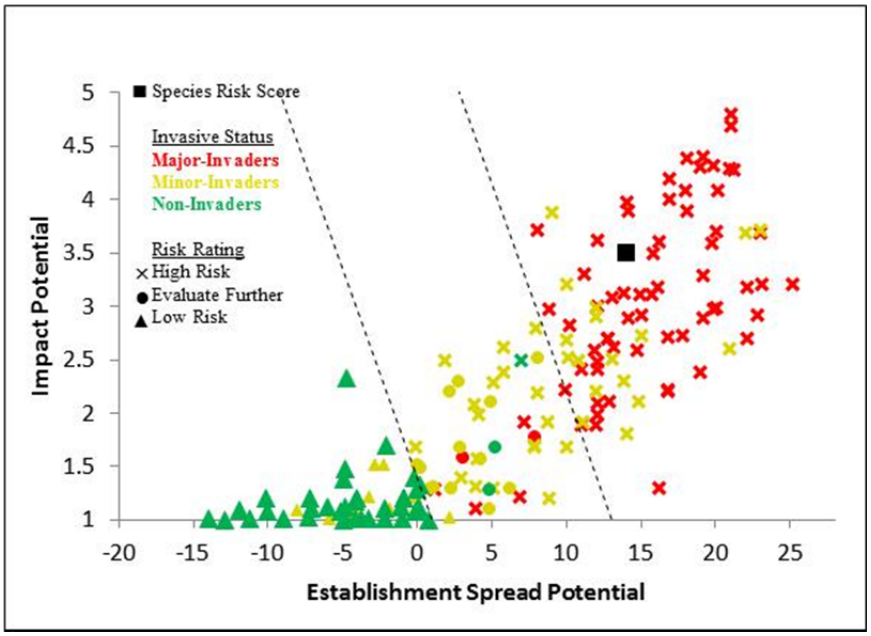

Figure 2. *Rotala rotundifolia* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

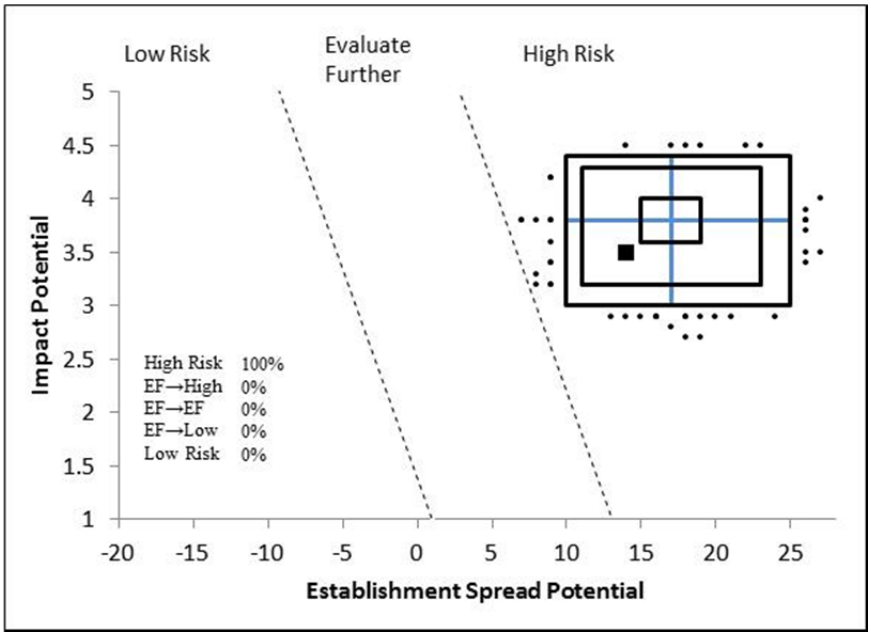

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Rotala rotundifolia*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Rotala rotundifolia* is High Risk. *Rotala rotundifolia* has traits similar to plant species that are major invaders (Fig. 2). Ervin and White (2007) determined that *R. rotundifolia* had a growth rate similar to the invasive plant *Alternanthera philoxeroides* (alligator weed), and shoot growth of *R. rotundifolia* was actually higher than shoot growth of *A. philoxeroides* across a broad temperature gradient. In our uncertainty analysis, 100 percent of the simulated risk scores resulted in a rating of high risk, indicating our results are very robust (Fig. 3). Our result is also in agreement with the Australian Quarantine and Inspection Service (AQIS) pre-entry weed risk assessment model, in which *R. rotundifolia* received a score of "reject" (Champion and Clayton, 2000).

Where possible, draining water bodies infested with *R. rotundifolia* can be an effective control method (Ervin and Madsen, 2009; Gettys et al., 2015). Submersed applications of triclopyr and 2,4-D are effective at managing *R. rotundifolia* populations, but there are limits to applying these herbicides in areas where sensitive, non-target plant species are located. Other herbicides have been tested and do not provide good control (Gettys and Della Torre II, 2014). Mechanical harvesting is challenging because *R. rotundifolia* is heavier than other submersed weeds, which puts extra stress on machinery. Care must also be taken during mechanical harvesting to avoid dispersing this plant species downstream through broken stem fragments. Additionally, because this species grows well in dry soil, off-loading harvested plants onto the shore line may result in *R. rotundifolia* becoming established along the edges of waterways; harvested plants should be disposed at a landfill (Gettys and Della Torre II, 2014).

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Appendix A. Weed risk assessment for *Rotala rotundifolia* (Buch.-Ham. ex Roxb.) Koehne (Lythraceae). 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 - low	5	Native to South and Southeast Asia from Japan to India (Cook, 1979; Joseph and Sivarajan, 1989; Rataj and Horeman, 1977). In Australia, *R. rotundifolia* was cultivated as early as 1974 and "escaped from water gardens to become naturalised in several areas in Queensland and New South Wales" (Csurhes and Edwards, 1998). Naturalized populations were first recorded in Queensland in 1974 and in New South Wales in 1992 (Hosking et al., 1997). Naturalized in Australia, "but not common" (Richardson et al., 2006). *Rotala rotundifolia* was first detected growing outside of cultivation in the United States in 1996, when populations were found in Florida along a canal (Jacono and Vandiver Jr., 2007). In 2001, a population was found in a pond on the University of Alabama campus (Reese and Haynes, 2002). This pond was drained in 2005, and *R. rotundifolia* was subsequently found growing along a stream connecting the pond to the Black Warrior river; all these individual plants were then removed (Ervin and White, 2007). By 2003, *R. rotundifolia* had naturalized in three counties in Florida. In one Florida location, it was described as being a "robust stand...spreading along the edge of a flood-control canal," and in another location there was "significant spread" (Burks et al., 2003). *Rotala rotundifolia* has now naturalized in a fourth county in Florida, and in Florida the populations are described as being "large - but mostly isolated" (Gettys and Della Torre II, 2014). In Florida, *R. rotundifolia* can grow at a rate of 4 to 5 inches per week and can quickly spread across water surfaces (UF/IFAS, 2015). *Rotala rotundifolia* has naturalized in Hungary around thermal water bodies including thermal baths, springs, and streams (Lukács et al., 2014; Mesterházy et al., 2009). Because *R. rotundifolia* has been characterized as spreading at several locations, we answered "f" but used low uncertainty because several references describe this plant as only naturalized. The alternate answers for the Monte Carlo simulation are both "e."
ES-2 (Is the species highly domesticated)	n - low	0	We found no evidence that *R. rotundifolia* has been bred for reduced weediness. In the plant trade, it is primarily sold under just the species name *R. rotundifolia* (PetSmart, 2015; Windeløv, 2004).
ES-3 (Weedy congeners)	y - low	1	There are over 40 species in the genus *Rotala* (Graham et al., 2011; Joseph and Sivarajan, 1988). Of these, Holm et al. (1979) list *R. indica* as a serious weed in Afghanistan, Japan, Korea, the Philippines, and Taiwan; *Rotala*

Question ID	Answer - Uncertainty	Score	Notes (and references)
			mexicana as a principal weed in Japan; and *Rotala uliginosa* as a principal weed in Korea. "Many [*Rotala* species] are found as weeds in rice fields and irrigation channels" (Rataj and Horeman, 1977).
ES-4 (Shade tolerant at some stage of its life cycle)	y - mod	1	Submerged *R. rotundifolia* plants can grow in water as deep as 2 meters, but plants produce the most biomass when grown in terrestrial environments in wet soil conditions (Gettys et al., 2015). Submerged aquatic plants growing 2 meters deep may receive as much as 30 percent to less than 5 percent of incident light (Riemer, 1993). Requires high sunlight for optimum growth (UF/IFAS, 2015). This plant is "less particular as to light" than other aquarium plants cultivated under similar conditions (Rataj and Horeman, 1977). Requires "good light [medium to very high] to produce red leaves," although this red color is mainly aesthic (Windeløv, 2004). Because *R. rotundifolia* can grow submerged at a depth of 2 meters, we answered yes, but we used moderate uncertainty because the majority of our references indicated that this species prefers strong sunlight.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	*Rotala rotundifolia* is not a vine, nor does it form basal rosettes; *Rotala rotundifolia* has erect, "loosely leafy" stems (Ohwi, 1984).
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	*Rotala rotundifolia* forms dense, floating mats in Florida (Jacono and Vandiver Jr., 2007). In the pond on the University of Alabama campus, *R. rotundifolia* "was observed growing in a dense mat on the pond surface, extending more than one meter from shore around most of the pond perimeter" (Ervin and White, 2007). "*Rotala* produces extremely dense submersed populations and large thick mats" on the water surface (Gettys and Della Torre II, 2014). Described as growing in "small patches or mats" in Florida (Burks et al., 2003). "It forms side shoots willingly, becoming compact and bushy" (Windeløv, 2004).
ES-7 (Aquatic)	y - negl	1	*Rotala rotundifolia* is an aquatic plant (Joseph and Sivarajan, 1989). All *Rotala* species are aquatic (Cook, 1979; Rataj and Horeman, 1977). This species can persist in dry gravel, as an emerged aquatic plant, and fully submerged (Ervin and White, 2007).
ES-8 (Grass)	n - negl	0	*Rotala rotundifolia* is not a grass; it is an aquatic plant in the family Lythraceae (Cook, 1979; NGRP, 2016).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	The stem of *R. rotundifolia* can be woody at the base (Joseph and Sivarajan, 1989). However, *R. rotundifolia* is in the family Lythraceae, which is not known to contain nitrogen-fixing species (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Spreads by seed (Zhang and Hirota, 2000; Zhirong, 1990). Plants germinated from seeds collected from Florida populations (Jacono and Vandiver Jr., 2007). Produces viable seed (UF/IFAS, 2015).
ES-11 (Self-compatible or	n - mod	-1	*Rotala rotundifolia* is genetically self-incompatible

Question ID	Answer - Uncertainty	Score	Notes (and references)
apomictic)			(Cook, 1979). Based on this evidence, we answered no.
ES-12 (Requires specialist pollinators)	n - high	0	*Rotala rotundifolia* plants have "showy flowers, [show] a tendency towards having a distinct inflorescence and they flower during a distinct season; they are presumably insect pollinated" (Cook, 1979). *Rotala rotundifolia* produces seed in its introduced range in Florida (Jacono and Vandiver Jr., 2007; UF/IFAS, 2015). Because this evidence indicates that *R. rotundifolia* does not appear to need specialized pollinators, we answered no, but used high uncertainty because none of these authors indicated exactly which insect species might be pollinating these plants.
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	Perennial species (Ohwi, 1984). "Perennial or perhaps occasionally annual" (Cook, 1979). "Usually perennial habit" (Burks et al., 2003). Annual or perennial plants (Joseph and Sivarajan, 1989). Flowers and fruits from September to March in India (Joseph and Sivarajan, 1989) and flowers during spring and early summer in the United States (Ervin and Madsen, 2009). In laboratory experiments, Ervin and White (2007) observed that *R. rotundifolia* stem fragments can quickly produce shoots, nodes, and roots within a 12-day period. Based on this evidence, we answered "b" but used moderate uncertainty because the evidence was so variable. The alternate answers for the Monte Carlo simulation were "a" and "c."
ES-14 (Prolific reproduction)	? - max	0	*Rotala rotundifolia* plants "produce many small seeds within capsules" (UF/IFAS, 2015). Fifteen to twenty seeds are produced per capsule (Joseph and Sivarajan, 1989). The overall percentage of germination was low for seeds collected from Florida *R. rotundifolia* populations (Jacono and Vandiver Jr., 2007). We answered unknown because there is very little information about the number of seeds produced by *R. rotundifolia*.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	When using mechanical harvesters to remove plant populations, "offloading harvested material onto the canal bank [which is done for many aquatic weeds] may...actually spread populations of *Rotala* along the canal bank because the species grows quite well as a shoreline plant. As a result, plant material should be transported far from the water or hauled to a landfill" (Gettys and Della Torre II, 2014). "Along with the cultivation of rice it has been dispersed over a wide area [from India], reaching as far as the Caspian Sea" (Rataj and Horeman, 1977). In the aquatic plant trade, *R. rotundifolia* has been confused with *R. macrandra* and *R. indica* (Burks et al., 2003; NaturalAquariums.com, 2009).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	? - max	0	We found no evidence that *R. rotundifolia* is a contaminant of trade, but aquatic plants in general are often unintentionally dispersed through the aquarium trade (Kay and Hoyle, 2001; Keller and Lodge, 2007;

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Maki and Galatowitsch, 2004). Thus, we answered unknown.
ES-17 (Number of natural dispersal vectors)	1	-2	Fruit and seed descriptions used to answer ES-17a-e: "capsules dehiscent, 4- or rarely 3-valved" (Ohwi, 1984). "Capsule sub-globose, 1-5 mm across, 4-valved. Seeds 15-20, semi-ellipsoidal, 0.5 mm" (Joseph and Sivarajan, 1989).
ES-17a (Wind dispersal)	n - mod		We found no evidence that *R. rotundifolia* disperses in this manner. The seeds have no adaptations for wind dispersal.
ES-17b (Water dispersal)	y - negl		In a discussion about *R. rotundifolia* and other aquatic plants in general, Ervin and White (2007) state that "[plant fragments] can be dispersed easily in water bodies, providing rapid distribution purely by vegetative means." *Rotala* species have boat-shaped seeds that are buoyant due to their aerenchymatous float tissue (Graham et al., 2011). We answered yes with negligible uncertainty based on these adaptations and because *R. rotundifolia* is an aquatic plant.
ES-17c (Bird dispersal)	? - max		Waterfowl disperse many aquatic plant species (Brochet et al., 2009; Figuerola and Green, 2002) and there are pictures of ducks sitting on dense mats of *R. rotundifolia* (Bugwood, 2015). Howevever, because we did not find any direct evidence of *R. rotundifolia* being spread by birds, we answered unknown.
ES-17d (Animal external dispersal)	? - max		Animals can spread the vegetative fragments of aquatic plants (RI DEM, 2014), but we did not find any evidence of *R. rotundifolia* being spread this way. Thus, we answered unknown.
ES-17e (Animal internal dispersal)	n - high		We found no evidence that *R. rotundifolia* disperses in this manner. It is unknown whether these small seeds could survive gut passage.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	Unknown. It is not known whether *R. rotundifolia* produces persistent seed banks in Florida (Jacono and Vandiver Jr., 2007).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - low	1	Because *R. rotundifolia* spreads by floating stem and branch fragments, which take root easily (Burks et al., 2003; Jacono and Vandiver Jr., 2007; Rataj and Horeman, 1977), the "fragments produced during mechanical harvesting may result in downstream spread of the species" (Gettys and Della Torre II, 2014). Aquatic plants in general are easily spread to new areas by vegetative fragmenting (Pieterse and Murphy, 1990).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - high	0	Submersed applications of triclopyr and 2,4-D are effective at managing *R. rotundifolia* populations, but there are limits to applying these herbicides in areas where sensitive, non-target plant species are located. Other herbicides have been tested and do not provide good control (Gettys and Della Torre II, 2014). Herbicide treatments greatly reduce the growth of *R. rotundifolia* (Jacono and Vandiver Jr., 2007) and have been effective at reducing Florida populations of *R. rotundifolia* (Burks et al., 2003). While *R. rotundifolia* is not listed by the

Question ID	Answer - Uncertainty	Score	Notes (and references)
			International Survey of Herbicide Resistant Weeds as having developed herbicide resistance, the related species *R. indica* var. *uliginosa* and *R. pusilla* have developed resistance to herbicides used in rice crops (Heap, 2016). It is unknown whether these species can interbreed with *R. rotundifolia*. Based on this evidence, we answered no with high uncertainty.
ES-21 (Number of cold hardiness zones suitable for its survival)	8	0	
ES-22 (Number of climate types suitable for its survival)	8	2	
ES-23 (Number of precipitation bands suitable for its survival)	9	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - mod	0	We found no evidence that *R. rotundifolia* is allelopathic.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that *R. rotundifolia* is a parasitic plant. The family Lythraceae is not known to contain parasitic plants (Heide-Jørgensen, 2008; Nickrent, 2009).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	y - mod	0.4	The large, thick growth of *Rotala rotundifolia* "greatly reduces ecosystem services, because oxygen level and light penetration are hampered. In addition, water flow is restricted because of the species' excessive growth" (Gettys and Della Torre II, 2014).
Imp-N2 (Changes habitat structure)	y - low	0.2	*Rotala rotundifolia* produces "large thick mats that dominate the surface of the water" (Gettys and Della Torre II, 2014). *Rotala rotundifolia* rapidly "grows across the water surface" (UF/IFAS, 2015). Because *R. rotundifolia* creates a layer to the surface of water bodies where there wasn't one previously, we answered yes with low uncertainty.
Imp-N3 (Changes species diversity)	y - mod	0.2	By producing dense mats at the water surface, *R. rotundifolia* "quickly shades out other aquatic vegetation" (UF/IFAS, 2015). "*Rotala* is listed as a FLEPPC [Florida Exotic Pest Plant Council] Category II plant, meaning the species has increased in abundance or frequency but has not yet drastically altered Florida plant communities" (Gettys and Della Torre II, 2014).We answered yes, but with moderate uncertainty because this plant has only been in Florida for a few years and its impacts may not be fully known.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - low	0.1	Hosking et al. (1997) list *R. rotundifolia* as being a "potential invader of wetlands" in Australia. "The plant could naturalise in wetlands [in Australia], perhaps at the expense of native aquatic and semi-aquatic plants" (Csurhes and Edwards, 1998). We answered yes because *R. rotundifolia* can establish in natural areas and has impacts that would affect other species (see Imp-N1 and Imp-N2).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	y - low	0.1	Based on their research comparing growth rates of *R. rotundifolia* to the known invader *Alternanthera philoxeroides* (alligator weed), Ervin and White (2007)

Question ID	Answer - Uncertainty	Score	Notes (and references)
			state, "These experimental results, in combination with observations from field and greenhouse grown *Rotala rotundifolia* indicate that this species may indeed pose a serious threat to wetlands of the southeastern US."
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon a weed but no evidence of control; (c) taxon a weed and evidence of control efforts]	c - negl	0.6	*Rotala rotundifolia* plants were removed from a stream connected to the Black Warrior river in Alabama (Ervin and White, 2007). Herbicide trials have been conducted on *R. rotundifolia* to determine the best control methods for this species in natural areas (Jacono and Vandiver Jr., 2007). Randall (2007) reports that *R. rotundifolia* is a weed of natural systems in Australia. Listed as a weed of natural areas by the Florida Exotic Pest Plant Council (Swearingen, 2015; UF/IFAS, 2015). In 2011, the University of Florida Institute of Food and Agricultural Sciences (IFAS) assessed *R. rotundifolia* and gave it a rating of "Caution," which means this species may be recommended for regulation by IFAS faculty in the future, should currently be managed to prevent escape, and will be reassessed in the future (IFAS, 2011). Because *R. rotundifolia* is being controlled in natural areas, we answered "c." The alternate choices for the Monte Carlo simulation were both "b."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	y - low	0.1	"Because the rapid and vigorous growth of *Rotala* inhibits water flow, the ability of infested canals to function properly in flood events is greatly hindered" (Gettys and Della Torre II, 2014). Dense *R. rotundifolia* infestations interfere with water flow and navigation in flood-control canals (Gettys et al., 2015).
Imp-A2 (Changes or limits recreational use of an area)	? - max		While it is conceivable that *R. rotundifolia* could have this impact, due to the dense mats it forms that restrict water flow (Gettys and Della Torre II, 2014), we found no evidence of this. Thus, we answered unknown.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	"Once [*R. rotundifolia*] has been established cultivation in the paludarium or greenhouse is so rapid that the species can become a real weed" (Kasselmann, 2003). "[I]ts high growth rates...cause it to outgrow aquaria in short periods of time" (Ervin and Madsen, 2009). Many aquatic plant enthusiasts find *R. rotundifolia* desirable (NaturalAquariums.com, 2009), so we answered no, but used moderate uncertainty based on the quote from Kasselmann.
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 - negl	0.4	In Florida, herbicides and grass carp have been evaluated for the control of *R. rotundifolia* in canals in residential areas (Burks et al., 2003; Gettys and Della Torre II, 2014). A pond on the University of Alabama campus was drained to kill the *R. rotundifolia* population that had become established there (Jacono and Vandiver Jr., 2007). We answered "c" based on these control efforts in residential areas. The alternate answers for the Monte Carlo simulation were both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product	? - high		Even though *R. rotundifolia* is listed as a weed of rice in

Question ID	Answer - Uncertainty	Score	Notes (and references)
yield)			many areas of the world (Holm et al., 1979; Moody, 1989), we found no evidence of this specific impact. Thus we answered unknown.
Imp-P2 (Lowers commodity value)	y - high	0.2	Zhirong (1990) reports that *R. rotundifolia* damages rice crops in China. Because we only found a single report of this impact without any clear information on how the plant actually causes this damage, we used high uncertainty.
Imp-P3 (Is it likely to impact trade?)	? - max		Prohibited species in Western Australia, Tasmania (Gettys and Tipping, 2014) and Honduras (APHIS, 2015). Because it is unclear if this species moves as a contaminant (see ES-16), we answered unknown.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	? - max		While it is conceivable that *R. rotundifolia* could have this impact, we found no evidence of this. Thus, we answered unknown.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - mod	0	"[H]erbivorous fish [such as grass carp] apparently are not inclined to eat this species; they have been observed nibbling at submersed foliage of *R. rotundifolia* and immediately spitting it out" (Burks et al., 2003). The genus *Rotala* is not listed in Toxic Plants of North America (Burrows and Tyrl, 2001). Based on this evidence, we answered no, but with moderate uncertainty.
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 - low	0.2	Holm et al. (1979) list *R. rotundifolia* as a principal weed of agriculture in Taiwan. Moody (1989) reports *R. rotundifolia* to be a weed of rice in Bangladesh, India, Laos, Nepal, and Thailand. Weed of rice in India (Galinato et al., 1999). Zhang and Hirota (2000) say *R. rotundifolia* is a common noxious weed of paddy fields in China. "[F]ound mainly in rice fields" (Rataj and Horeman, 1977). Randall (2007) lists *R. rotundifolia* as a weed of agriculture. Because we found no evidence of control for *R. rotundifolia* in production systems we answered "b" with low uncertainty. The alternate answers for the Monte Carlo simulation were both "c" because it seems likely that some form of undocumented control is occurring in rice fields.
GEOGRAPHIC POTENTIAL			Note: Below "p.s." refers to a specific, geo-referenced point source (latitude/longitude) data; "occur." refers to a regional or country-level occurrence.
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that *R. rotundifolia* occurs in this Plant Hardiness Zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence that *R. rotundifolia* occurs in this Plant Hardiness Zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence that *R. rotundifolia* occurs in this Plant Hardiness Zone.
Geo-Z4 (Zone 4)	n - low	N/A	We found no evidence that *R. rotundifolia* occurs in this Plant Hardiness Zone.
Geo-Z5 (Zone 5)	n - mod	N/A	We found no evidence that *R. rotundifolia* occurs in this Plant Hardiness Zone.
Geo-Z6 (Zone 6)	y - high	N/A	One point in this Plant Hardiness Zone in Japan and one

Question ID	Answer - Uncertainty	Score	Notes (and references)
			in China (GBIF, 2015, p.s.).
Geo-Z7 (Zone 7)	y - mod	N/A	Multiple points in or on the border of this Plant Hardiness Zone in China (GBIF, 2015, p.s.).
Geo-Z8 (Zone 8)	y - negl	N/A	The United States (Alabama) and multiple points in China (GBIF, 2015, p.s.).
Geo-Z9 (Zone 9)	y - negl	N/A	Multiple points in China (GBIF, 2015, p.s.).
Geo-Z10 (Zone 10)	y - negl	N/A	The United States (Florida) (Burks et al., 2003, occur.) and multiple points in China (GBIF, 2015, p.s.).
Geo-Z11 (Zone 11)	y - negl	N/A	West Bengal, India (Makhopadhyay et al., 2007, occur.) and multiple points in Taiwan (GBIF, 2015, p.s.).
Geo-Z12 (Zone 12)	y - negl	N/A	Multiple points in Taiwan (GBIF, 2015, p.s.).
Geo-Z13 (Zone 13)	y - low	N/A	Thailand (NGRP, 2016, occur.). "*Rotala rotundifolia* grows better at or slightly below 20 °C" (Cook, 1979). 18-30 °C is recommended for growth in aquariums (Windeløv, 2004).
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - low	N/A	One point in Laos and one point in China (GBIF, 2015, p.s.).
Geo-C2 (Tropical savanna)	y - low	N/A	A couple points in China, Vietnam, Laos, Bangladesh, and Thailand (GBIF, 2015, p.s.).
Geo-C3 (Steppe)	y - low	N/A	One point in China (GBIF, 2015, p.s.) and a few points in India (Cook, 1979, p.s.).
Geo-C4 (Desert)	n - mod	N/A	GBIF lists one point in Libya (GBIF, 2015, p.s.), but we found no other evidence in the literature about *R. rotundifolia* being established in Libya. Thus, we answered no with moderate uncertainty for this climate class.
Geo-C5 (Mediterranean)	y - negl	N/A	Multiple points in China (GBIF, 2015, p.s.).
Geo-C6 (Humid subtropical)	y - negl	N/A	The United States (Alabama) and multiple points in Taiwan (GBIF, 2015, p.s.).
Geo-C7 (Marine west coast)	y - negl	N/A	Multiple points in China (GBIF, 2015, p.s.).
Geo-C8 (Humid cont. warm sum.)	y - low	N/A	A population found growing in this climate class in China (Cook, 1979, p.s.). A couple points in Japan (Cook, 1979, p.s.; GBIF, 2015, p.s.).
Geo-C9 (Humid cont. cool sum.)	y - high	N/A	One point in China (GBIF, 2015, p.s.). Occurs in thermal waters in Hungary (Hussner, 2012; Mesterházy et al., 2009, occur.).
Geo-C10 (Subarctic)	n - low	N/A	We found no evidence that *R. rotundifolia* occurs in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence that *R. rotundifolia* occurs in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that *R. rotundifolia* occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - mod	N/A	GBIF lists one point in Libya (GBIF, 2015, p.s.), but we found no other evidence in the literature about *R. rotundifolia* being established in Libya. Thus, we answered no with moderate uncertainty for this precipitation band.
Geo-R2 (10-20 inches; 25-51 cm)	n - high	N/A	We found no evidence that *R. rotundifolia* occurs in this precipitation band.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Several points in Australia (GBIF, 2015, p.s.) and a

Question ID	Answer - Uncertainty	Score	Notes (and references)
			population in China (Cook, 1979, p.s.).
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	The United States (Florida) (Burks et al., 2003; Gettys and Della Torre II, 2014, occur.), a few points in Australia, and one point in Taiwan (GBIF, 2015, p.s.).
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	The United States (Florida) (Burks et al., 2003; Gettys and Della Torre II, 2014, occur.) and a few points in China (GBIF, 2015, p.s.).
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	The United States (Alabama) and several points in China and Australia (GBIF, 2015, p.s.).
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Several points in China (GBIF, 2015, p.s.).
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Several points in China (GBIF, 2015, p.s.).
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	Several points in China (GBIF, 2015, p.s.).
Geo-R10 (90-100 inches; 229-254 cm)	y - negl	N/A	Several points in China (GBIF, 2015, p.s.).
Geo-R11 (100+ inches; 254+ cm)	y - negl	N/A	Multiple points in China and Taiwan (GBIF, 2015, p.s.).
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	*Rotala rotundifolia* has naturalized in four counties in Florida (Burks et al., 2003; Gettys and Della Torre II, 2014; Kartesz, 2016). Cultivated as an aquarium plant in the United States since at least 1977 (Rataj and Horeman, 1977). Available in the international aquarium trade since the 1960s (Burks et al., 2003). *Rotala rotundifolia* had previously also naturalized in a pond on the University of Alabama campus (Reese and Haynes, 2002), but this population (and the plants growing along the Black Warrior River) has since been extirpated (Ervin and White, 2007; Ervin and Madsen, 2009; Gettys et al., 2015).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	Introduced to Australia as an ornamental plant (Hosking et al., 1997). In Australia and the United States, "the plant is widely used by aquarists and sold through the pet industry" (Csurhes and Edwards, 1998). Rixon et al. (2005) say this species is commonly sold by aquarium retailers located near the Great Lakes region of the United States, but this reference lists *R. rotundifolia* as a synonym of *R. indica*, so it is unclear which species is actually being discussed. Naturalized populations in the United States were introduced through the aquatic plant trade (Reese and Haynes, 2002). *Rotala rotundifolia* has also been evaluated as a plant that could be used to clean up wastewater contaminated by heavy metals (Yang and Ye, 2015).
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	-	N/A	

Question ID	Answer - Uncertainty	Score	Notes (and references)
seeds))			
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	Dried *R. rotundifolia* plants are used in floral crafts (Raj and Gupta, 2005).
Ent-5 (Likely to enter through natural dispersal)	-	N/A	