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Weed Risk Assessment for *Rotala macrandra* Koehne (Lythraceae) – Giant red Rotala

Rotala macrandra growing submerged (source: Tanaka, 2007).

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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 macrandra* Koehne – Giant red rotala**

Species Family: Lythraceae

Information Synonyms: None found. 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. Consequently, we limited our evaluation to R. macrandra.

Common names: Giant red rotala (Dave's Garden, 2015; Millar, 2010).

Botanical description: *Rotala macrandra* is an aquatic plant that can grow fully submersed, emerged, or as a terrestrial plant (Joseph and Sivarajan, 1989; Kasselmann, 2003). The shoots of *R. macrandra* can grow 60 cm in length. The emerged leaves are green, very broad and ovate, and 2-3 cm long and 1-2 cm wide. The submerged leaves are green to strong brown-red in color, delicate, wavy, and lance shaped, and 2-5 cm long (Clayton et al., 2005; Kasselmann, 2003). Botanical descriptions of *R. macrandra* are available in Benl (1973), Cook (1979), Joseph and Sivarajan (1989) and Kasselmann (2003).

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 the risk of *R. macrandra*.

Foreign distribution: *Rotala macrandra* is native to India (Cook, 1979) and is available for sale globally in the aquarium trade (Champion and Clayton, 2000; Cohen et al., 2007; Martin and Coetzee, 2011). It has escaped from cultivation in Hungary, where the plants survive in thermal water bodies (Botond and Zoltan, 2004).

U.S. distribution and status: *Rotala macrandra* has been cultivated as an aquarium plant in the United States since at least 1977 (Rataj and Horeman, 1977) and is available for sale from online retailers (e.g., Amazon, 2015; AquariumPlants.info, 2016). *Rotala macrandra* has not naturalized in the United States (Kartesz, 2016; NRCS, 2016).

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

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1. *Rotala macrandra* analysis

Establishment/Spread Potential *Rotala macrandra* is an aquatic plant that can grow fully submersed, emerged, or as a terrestrial plant (Joseph and Sivarajan, 1989; Kasselmann, 2003). It is listed as a cultivation escape in Hungary (Botond and Zoltan, 2004). *Rotala macrandra* is easily propagated by cutting and stem fragments (Benl, 1973; Hameeteman, 1979), but we found very little information about

[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).

seed production. Unlike some of the more invasive members of this genus (Holm et al., 1979), *R. macrandra* is slower growing (Rataj and Horeman, 1977) and does not form dense mats. We had very high uncertainty here due to the lack of information about pollination, seed production and dispersal.
Risk score = 2 Uncertainty index = 0.33

Impact Potential We found no evidence that *R. macrandra* has any negative impacts in natural environments, urban and suburban settings, or production systems. It does not compete with other plant species or change habitats and has not been listed as a weed of any systems. Because it has only recently naturalized in thermal pools in Hungary (Botond and Zoltan, 2004), its impact potential is not yet fully known. We had high uncertainty here due to the lack of information about this species in general.
Risk score = 1 Uncertainty index = 0.22

Geographic Potential Based on three climatic variables, we estimate that about 30 percent of the United States is suitable for the establishment of *R. macrandra* (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 macrandra* represents the joint distribution of Plant Hardiness Zones 7-13, areas with 20-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, humid subtropical, marine west coast, humid continental warm summers, and humid continental cool summers. Note that in this weed risk assessment it was not clear if *R. macrandra* occurs in the Mediterranean climate class. For our map, we assumed this environment was suitable for it.

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. macrandra* occurs in streams, temporary ponds, and flooded paddy fields. It mainly occurs in the wet lowlands in the coastal region of India (Joseph and Sivarajan, 1989).

Entry Potential We did not assess the entry potential of *R. macrandra* because it has been present in cultivation in the United States since at least 1977 (Rataj and Horeman, 1977).

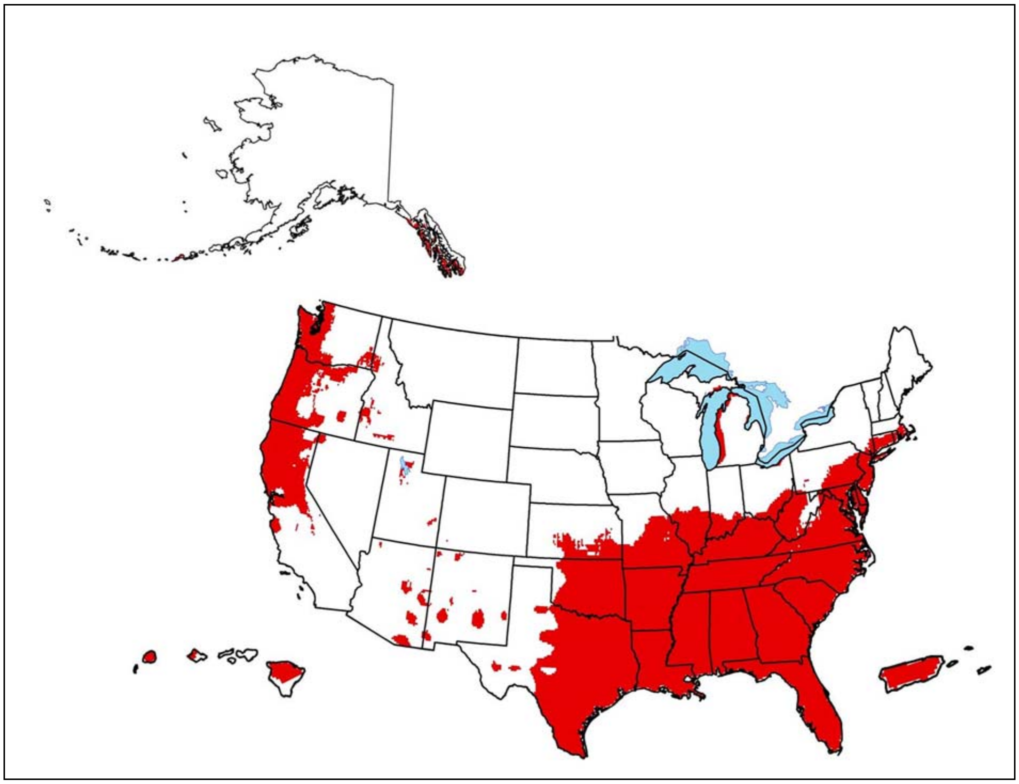

Figure 1. Predicted distribution of *Rotala macrandra* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 4.5%
P(Minor Invader) = 56.3%
P(Non-Invader) = 39.3%

Risk Result = Evaluate Further
Secondary Screening = Evaluate Further

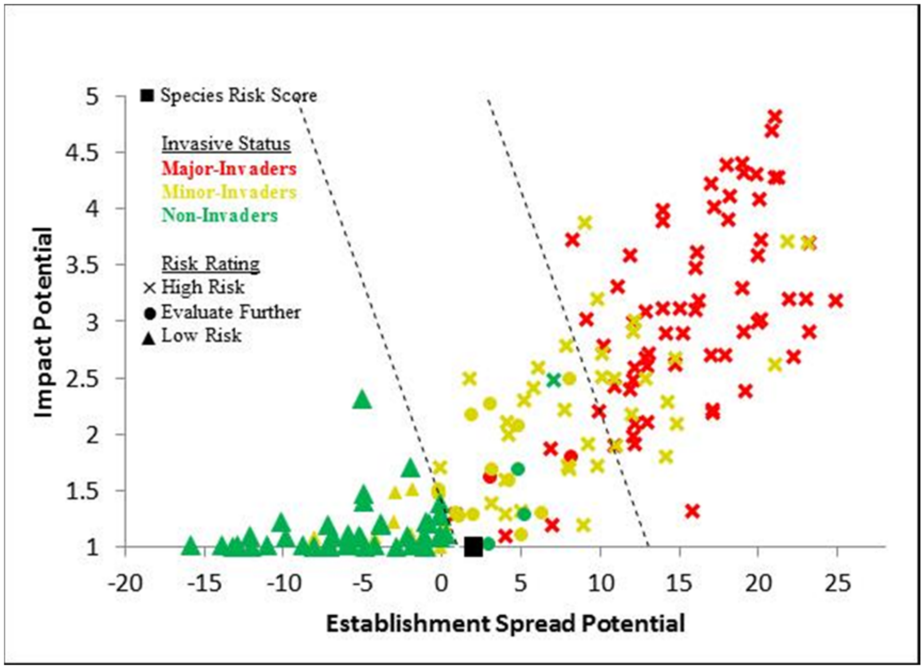

Figure 2. *Rotala macrandra* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

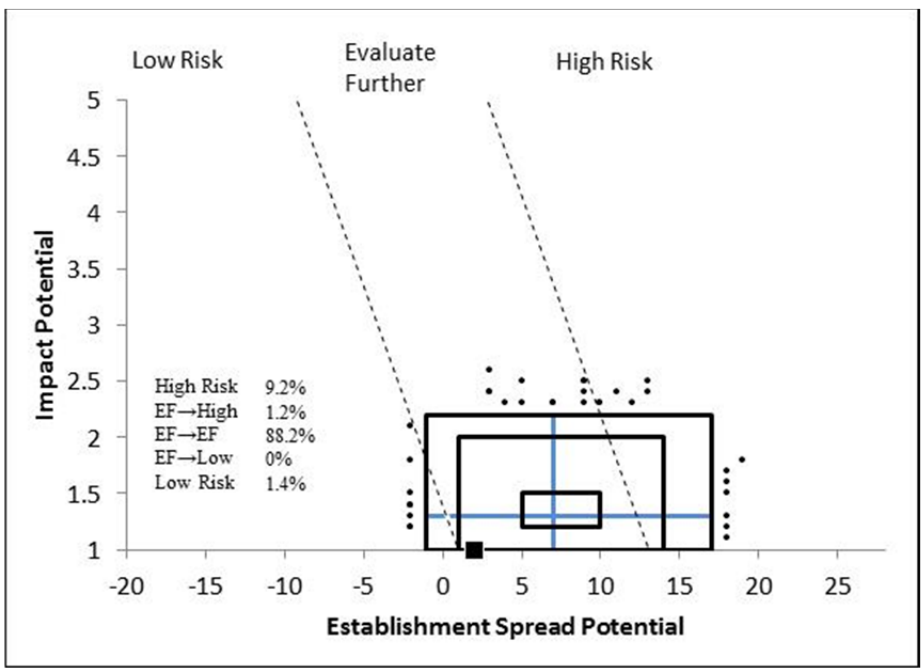

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Rotala macrandra*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Rotala macrandra* is Evaluate Further, even after secondary screening. *Rotala macrandra* has traits similar to plant species that are non-invaders and minor invaders in the United States (Fig. 2). We had a very large amount of uncertainty in our risk assessment (Fig. 3) due to the lack of information about the biology of this species outside of cultivation.

Rotala macrandra is popular in the global aquarium trade (Champion and Clayton, 2000; Cohen et al., 2007; Martin and Coetzee, 2011) and has been cultivated in the United States since at least 1977 (Rataj and Horeman, 1977). The National Centre of Aquatic Biodiversity and Biosecurity in New Zealand lists *R. macrandra* as a low-risk, environmentally friendly aquarium/pond plant (Clayton et al., 2005). *Rotala macrandra* is able to survive as a cultivation escape in thermal water bodies in Hungary (Botond and Zoltan, 2004), but has not become established anywhere else outside of its native range. This may be because *R. macrandra* is slower growing than the more invasive *R. rotundifolia* (Rataj and Horeman, 1977). In aquariums, *R. macrandra* is considered to be a demanding, delicate plant that is very difficult to grow (Benedict, 2007; Benl, 1973; Kasselmann, 2003; Windeløv, 2004).

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Appendix A. Weed risk assessment for *Rotala macrandra* 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]	d - low	0	Native to India (Cook, 1979). Listed as a casual escape in Hungary (Botond and Zoltan, 2004). Based on this evidence, we answered "d." The alternate answers for the Monte Carlo simulation are "e" and "b."
ES-2 (Is the species highly domesticated)	n - low	0	We found no evidence that *R. macrandra* has been bred for reduced weediness. In the aquarium trade, this plant is primarily sold under the species name *R. macrandra* (Windeløv, 2004), but different colored varieties exist, including variegated, narrow leaf, and green varieties (AquariumDomain.com, 2015; Millar, 2010). However, some of these varieties may actually be other species or hybrids (NaturalAquariums.com, 2009).
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 mexicana* as a principal weed in Japan; *Rotala rotundifolia* as a principal weed in Taiwan; and *Rotala uliginosa* as a principal weed in Korea. *Rotala rotundifolia* has naturalized and become problematic in canals in southern Florida (Gettys and Della Torre II, 2014; Graham et al., 2011) and is a prohibited species in Western Australia and Tasmania (Gettys and Tipping, 2014). "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)	n - high		Common "in streams, temporary ponds and flooded paddy fields" (Joseph and Sivarajan, 1989). Requires very high amounts of light in aquariums to turn a red/pink color (Benedict, 2007; Hameeteman, 1979; Windeløv, 2004). "It is cultivated in half-shade" (Rataj and Horeman, 1977). Light deprivation in aquariums will cause its leaves to drop (Benedict, 2007). "Will not tolerate shading" in aquariums (Millar, 2010). "Under inadequate lighting [in aquariums], the lower leaves of *Rotala macrandra* have been known to disintegrate" (AquariumDomain.com, 2015). *Rotala macrandra* can grow as a submerged plant (Aquatic Plant Central, 2015; Joseph and Sivarajan, 1989), and less light is available to submerged plants (Riemer, 1993). We answered no because *R. macrandra* has a negative growth response to shady conditions, but used high uncertainty

Question ID	Answer - Uncertainty	Score	Notes (and references)
			because this plant is able to grow submerged.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	*Rotala macrandra* has erect stems (Joseph and Sivarajan, 1989); it is not a vine or a plant that forms basal rosettes.
ES-6 (Forms dense thickets, patches, or populations)	n - high	0	If well-cared for in aquariums, *R. macrandra* can "form a dense grouping that will need regular pruning" (AquariumDomain.com, 2015). However, we found no evidence that *R. macrandra* growth is dense outside of aquariums or that this species forms mats or thickets. *Rotala macrandra* does not grow as fast as the mat-forming *R. rotundifolia* (Rataj and Horeman, 1977). Thus, we answered no, but used high uncertainty.
ES-7 (Aquatic)	y - negl	1	This is an aquatic species that can grow submersed, emerged, or as a terrestrial plant (Aquatic Plant Central, 2015; Joseph and Sivarajan, 1989). "It usually grows in more or less permanent water and is often found in swiftly flowing water" (Cook, 1979). All *Rotala* species are aquatic (Cook, 1979; Rataj and Horeman, 1977).
ES-8 (Grass)	n - negl	0	*Rotala macrandra* is not a grass; it is an aquatic plant in the family Lythraceae (Cook, 1979).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	*Rotala macrandra* is in the family Lythraceae, which is not known to contain nitrogen-fixing species (Martin and Dowd, 1990). Thus, we answered no.
ES-10 (Does it produce viable seeds or spores)	? - max	0	Cook (1979) and Joseph and Sivarajan (1989) provide descriptions of *R. macrandra* seeds. However, we did not find any information about seed reproduction or propagation by seeds. *Rotala macrandra* likely reproduces vegetatively; it is easily propagated by cuttings (AquariumDomain.com, 2015; Benl, 1973; Hameeteman, 1979) and has thin, easily broken stems (Benl, 1973; Hameeteman, 1979) that may facilitate vegetative dispersal. Thus, we answered unknown.
ES-11 (Self-compatible or apomictic)	n - mod	-1	*Rotala macrandra* is genetically self-incompatible (Cook, 1979). Based on this evidence, we answered no.
ES-12 (Requires specialist pollinators)	? - max		*Rotala macrandra* 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). Because we did not find any information about *R. macrandra* producing viable seeds, we were unable to determine if specialized pollinators were required for sexual reproduction of this species. Thus, we answered unknown.
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 (Clayton et al., 2005; Cook, 1979). "Perennial or perhaps occasionally annual" (Cook, 1979). Annual plant that does not grow attractively after it flowers (Benl, 1973). "[A]nnuals or perennials" that flower and fruit from September through January in India (Joseph and Sivarajan, 1989). *Rotala macrandra* is easily propagated vegetatively (AquariumDomain.com, 2015; Benl, 1973; Hameeteman, 1979) and has thin, easily broken stems (Benedict, 2007; Hameeteman, 1979) that likely facilitate vegetative dispersal. However, we did not find any descriptions about the length of time for vegetative

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
			reproduction outside of cultivation. Based on this evidence, we answered "b." Our alternate answers were both "a" based on the potential of this species to reproduce vegetatively.
ES-14 (Prolific reproduction)	n - high	-1	Because we found very little information about this species producing seeds in general, we answered no, but used high uncertainty.
ES-15 (Propagules likely to be dispersed unintentionally by people)	? - max	0	We found no specific evidence for this species. However, because aquarium plants are sometimes inappropriately disposed by their owners in ponds and streams (Pieterse and Murphy, 1990), we answered unknown.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	? - max	0	We found no evidence that *R. macrandra* has been found as a contaminant, but aquatic plants in general are often unintentionally dispersed through the aquarium trade (Kay and Hoyle, 2001; Keller and Lodge, 2007; Maki and Galatowitsch, 2004). In the aquatic plant trade, *R. macrandra* can be confused with *R. rotundifolia* (Burks et al., 2003).Thus, we answered unknown.
ES-17 (Number of natural dispersal vectors)	1	-2	Fruit and seed descriptions used to answer ES-17a through ES-17e: "Capsule globose, 1-5 mm across, 4-valved. Seeds semi-ellipsoidal, about 0.05 mm long" (Joseph and Sivarajan, 1989).
ES-17a (Wind dispersal)	n - mod		We found no evidence that *R. macrandra* disperses in this manner. The seeds have no adaptations for wind dispersal.
ES-17b (Water dispersal)	y - negl		*Rotala* species have boat-shaped seeds that are buoyant due to their aerenchymatous float tissue (Graham et al., 2011). Additionally, the stems of *R. macrandra* break easily (Benedict, 2007), which likely contributes to propagule dispersal in water. We answered yes with negligible uncertainty based on these adaptations and because *R. macrandra* is an aquatic plant.
ES-17c (Bird dispersal)	? - max		Waterfowl disperse many aquatic plant species (Brochet et al., 2009; Figuerola and Green, 2002), but we did not find any evidence of *R. macrandra* being spread this way. Thus, 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. macrandra* being spread this way. Thus, we answered unknown.
ES-17e (Animal internal dispersal)	n - high		We found no evidence that *R. macrandra* disperses in this manner. We used high uncertainty because very little information was available on *R. macrandra* seed production and dispersal in general.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	n - high	-1	We found no evidence that *R. macrandra* has a persistent seed bank. We used high uncertainty because we found very little information about seeds in general for this species.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - low	1	Easily propagated and multiplied from cuttings (AquariumDomain.com, 2015; Benl, 1973; Hameeteman, 1979). *Rotala macrandra* has thin, easily broken stems (Benedict, 2007; Hameeteman, 1979) that likely facilitate vegetative dispersal. Mechanical control of the related species *R. rotundifolia* can disperse vegetative propagules

Question ID	Answer - Uncertainty	Score	Notes (and references)
			(Gettys and Tipping, 2014). Based on this evidence, we answered yes with low uncertainty.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - high	0	We found no evidence that *R. macrandra* has been targeted for control by chemical herbicides. While *R. macrandra* is not listed by the 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). Based on this evidence, we answered no with high uncertainty.
ES-21 (Number of cold hardiness zones suitable for its survival)	7	0	
ES-22 (Number of climate types suitable for its survival)	7	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. macrandra* is allelopathic.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that *R. macrandra* 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)	n - mod	0	We found no evidence that *R. macrandra* has this impact.
Imp-N2 (Changes habitat structure)	n - mod	0	We found no evidence that *R. macrandra* has this impact.
Imp-N3 (Changes species diversity)	n - mod	0	We found no evidence that *R. macrandra* has this impact.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	n - mod	0	We found no evidence that *R. macrandra* has any impacts in natural systems. Thus, it seems unlikely that *R. macrandra* would affect Threatened and Endangered species.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - mod	0	We found no evidence that *R. macrandra* has any impacts in natural systems. Thus, it seems unlikely that *R. macrandra* would affect globally outstanding ecoregions in the United States.
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]	a - low	0	We found no evidence that *R. macrandra* impacts natural systems. The National Centre of Aquatic Biodiversity and Biosecurity in New Zealand lists *R. macrandra* as a low-risk, environmentally friendly aquarium/pond plant (Clayton et al., 2005). Thus we answered "a" with low uncertainty. The alternate answers 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)	n - mod	0	We found no evidence that *R. macrandra* has this impact.
Imp-A2 (Changes or limits recreational use of an area)	n - mod	0	We found no evidence that *R. macrandra* has this impact.
Imp-A3 (Affects desirable and	n - low	0	We found no evidence that *R. macrandra* has this impact.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ornamental plants, and vegetation)			This *Rotala* species is considered "very difficult" to grow; "*Rotala macrandra* is an unusually beautiful aquarium plant, but unfortunately it makes such big demands that it only thrives in a few aquariums" (Windeløv, 2004) and "a demanding and difficult aquarium plant which will only rarely display optimum growth" (Kasselmann, 2003). One author even wrote, "Past experience...reveals that *R. macrandra* is a delicate foster child in home aquariums" (Benl, 1973). Thus, it seems unlikely to aggressively compete with other aquarium plants. We used low uncertainty.
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 - mod	0	Champion and Clayton (2000) say *R. macrandra* has not been reported to be a weed. There are three references in The Global Compendium of Weeds for *R. macrandra*; these references all cite *R. macrandra* being a cultivation escape in Hungary (Randall, 2012). However, none of these references list *R. macrandra* as having impacts in natural, anthropogenic, or production systems. Thus, we answered "a." We used moderate uncertainty because this species is surviving where it has been introduced to thermal water bodies in Hungary (Botond and Zoltan, 2004). The alternate choices for the Monte Carlo simulation were both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - mod	0	We found no evidence that *R. macrandra* has this impact.
Imp-P2 (Lowers commodity value)	n - mod	0	We found no evidence that *R. macrandra* has this impact.
Imp-P3 (Is it likely to impact trade?)	? - max		*Rotala macrandra* is considered a quarantine pest for South Africa, but is not specifically listed in any regulations (Martin and Coetzee, 2011). Because we did not find any direct evidence that *R. macrandra* is moved as trade contaminant, we answered unknown.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	? - max		We found no evidence that *R. macrandra* has this impact. We answered unknown because populations of the related species *R. rotundifolia* interfere with drainage and prevent water control canals from working properly (Gettys et al., 2015).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - mod	0	The genus *Rotala* is not listed in Toxic Plants of North America (Burrows and Tyrl, 2001). We found no evidence that this species is toxic. Thus, we answered no 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]	a - mod	0	While several other *Rotala* species are reported to be weeds of rice production (Holm et al., 1979; Moody, 1989), we found no evidence that *R. macrandra* is a weed of production systems. We answered "a" but used moderate uncertainty because Joseph and Sivarajan (1989) report that *R. macrandra* occurs in flooded paddy fields. The alternate answers for the Monte Carlo simulation were both "b."
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			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that *R. macrandra* occurs in this Plant Hardiness Zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence that *R. macrandra* occurs in this Plant Hardiness Zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence that *R. macrandra* occurs in this Plant Hardiness Zone.
Geo-Z4 (Zone 4)	n - low	N/A	We found no evidence that *R. macrandra* occurs in this Plant Hardiness Zone.
Geo-Z5 (Zone 5)	n - low	N/A	We found no evidence that *R. macrandra* occurs in this Plant Hardiness Zone.
Geo-Z6 (Zone 6)	n - mod	N/A	We found no evidence that *R. macrandra* occurs in this Plant Hardiness Zone.
Geo-Z7 (Zone 7)	y - high	N/A	Hungary (Botond and Zoltan, 2004; Hussner, 2012, occur.).
Geo-Z8 (Zone 8)	y - high	N/A	We did not find any occurrences of *R. macrandra* in this Plant Hardiness Zone. We answered yes with high uncertainty because *R. macrandra* is able to survive in Plant Hardiness Zones 7 and 10, so it follows that this species could survive in Zones 8 and 9.
Geo-Z9 (Zone 9)	y - high	N/A	We did not find any occurrences of *R. macrandra* in this Plant Hardiness Zone. We answered yes with high uncertainty because *R. macrandra* is able to survive in Plant Hardiness Zones 7 and 10, so it follows that this species could survive in Zones 8 and 9.
Geo-Z10 (Zone 10)	y - mod	N/A	India [Tamil Nadu (GBIF, 2015, occur.) and Andhra Pradesh (Kulkarni and Sharma, 1984, occur.)].
Geo-Z11 (Zone 11)	y - low	N/A	India (Karnataka, Maharashtra, and Andhra Pradesh) (Kulkarni and Sharma, 1984, occur.).
Geo-Z12 (Zone 12)	y - low	N/A	India (Tamil Nadu) (GBIF, 2015, occur.).
Geo-Z13 (Zone 13)	y - negl	N/A	India (Kerala) (Cook, 1979, p.s.; Joseph and Sivarajan, 1989, occur.). *Rotala macrandra* "grows best with a water temperature of 25-28°C" (Cook, 1979). 22-28 °C is recommended for growth in aquariums (Windeløv, 2004).
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - negl	N/A	India (Kerala) (Cook, 1979, p.s.; Joseph and Sivarajan, 1989, occur.).
Geo-C2 (Tropical savanna)	y - low	N/A	India [Tamil Nadu (GBIF, 2015, occur.), Karnataka, Maharashtra, and Andhra Pradesh (Kulkarni and Sharma, 1984, occur.)].
Geo-C3 (Steppe)	y - low	N/A	India (Karnataka, Maharashtra, and Andhra Pradesh) (Kulkarni and Sharma, 1984, occur.).
Geo-C4 (Desert)	n - low	N/A	We found no evidence that *R. macrandra* occurs in this climate class.
Geo-C5 (Mediterranean)	? - max	N/A	Unknown. In the areas where *R. macrandra* is known to occur, this climate class only occurs in a very small region of Tamil Nadu in India, so we did not have enough information to determine if *R. macrandra* would be able to survive in this climate class. Thus, we answered unknown. However, in our geographic potential analysis, where we are forced to answer yes or no for each climate class, we assumed that Mediterranean habitat was suitable because we had evidence that *R. macrandra* is able to survive in all the other warmer climate classes in our model (with the exception of desert).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C6 (Humid subtropical)	y - low	N/A	India (Tamil Nadu) (GBIF, 2015, occur.).
Geo-C7 (Marine west coast)	y - low	N/A	India (Tamil Nadu) (GBIF, 2015, occur.).
Geo-C8 (Humid cont. warm sum.)	y - high	N/A	Hungary (Botond and Zoltan, 2004; Hussner, 2012, occur.). This climate class only occurs in a small area of Hungary, but it is warmer than other regions of Hungary. Because *R. macrandra*, like the related species *R. rotundifolia* (Mesterházy et al., 2009), may be surviving in warmer areas in Hungary we answered yes, but used high uncertainty.
Geo-C9 (Humid cont. cool sum.)	y - high	N/A	Hungary (Botond and Zoltan, 2004; Hussner, 2012, occur.).
Geo-C10 (Subarctic)	n - negl	N/A	We found no evidence that *R. macrandra* occurs in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence that *R. macrandra* occurs in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that *R. macrandra* occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - mod	N/A	We found no evidence that *R. macrandra* occurs in this precipitation band.
Geo-R2 (10-20 inches; 25-51 cm)	n - high	N/A	We found no evidence that *R. macrandra* occurs in this precipitation band.
Geo-R3 (20-30 inches; 51-76 cm)	y - low	N/A	Hungary (Botond and Zoltan, 2004; Hussner, 2012, occur.).
Geo-R4 (30-40 inches; 76-102 cm)	y - low	N/A	Hungary (Botond and Zoltan, 2004; Hussner, 2012, occur.) and India (Karnataka, Maharashtra, and Andhra Pradesh) (Kulkarni and Sharma, 1984, occur.).
Geo-R5 (40-50 inches; 102-127 cm)	y - low	N/A	India (Karnataka, Maharashtra, and Andhra Pradesh) (Kulkarni and Sharma, 1984, occur.).
Geo-R6 (50-60 inches; 127-152 cm)	y - low	N/A	India [Tamil Nadu (GBIF, 2015, occur.), Karnataka, Maharashtra, and Andhra Pradesh (Kulkarni and Sharma, 1984, occur.)].
Geo-R7 (60-70 inches; 152-178 cm)	y - low	N/A	India [Tamil Nadu (GBIF, 2015, occur.) and Andhra Pradesh (Kulkarni and Sharma, 1984, occur.)].
Geo-R8 (70-80 inches; 178-203 cm)	y - low	N/A	India [Tamil Nadu (GBIF, 2015, occur.), Karnataka, Maharashtra, and Andhra Pradesh (Kulkarni and Sharma, 1984, occur.)].
Geo-R9 (80-90 inches; 203-229 cm)	y - low	N/A	India (Tamil Nadu) (GBIF, 2015, occur.).
Geo-R10 (90-100 inches; 229-254 cm)	y - low	N/A	India (Maharashtra) (Kulkarni and Sharma, 1984, occur.).
Geo-R11 (100+ inches; 254+ cm)	y - negl	N/A	India (Kerala) (Cook, 1979, p.s.; Joseph and Sivarajan, 1989, occur.).
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	Cultivated as an aquarium plant in the United States since at least 1977 (Rataj and Horeman, 1977).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	Cultivated in New Zealand (Champion and Clayton, 2000) and Canada (Cohen et al., 2007) and available in the global aquarium trade (Martin and Coetzee, 2011). "Although it is difficult to grow, this plant is well-established in the hobby. It is not too difficult to obtain through trading or through the various internet plant stores" (Aquatic Plant Central,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			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 seeds))	-	N/A	
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	