Weed Risk Assessment for *Egeria densa* Planch. (Hydrocharitaceae) – Brazilian elodea

Michigan Department of Agriculture and Rural Development

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Version 1

Top left: *Egeria densa* stems and leaves (Robert Vidéki, Doronicum Kft., Bugwood.org). Bottom left: *Egeria densa* double node on stem with vegetative reproductive growth (Robert Vidéki, Doronicum Kft., Bugwood.org). Top right: Underwater view of dense *E. densa* growth (U.S. Geological Survey Archive, U.S. Geological Survey, Bugwood.org). Bottom right: Surface view of flowering *E. densa* infestation (Graves Lovell, Alabama Department of Conservation and Natural Resources, Bugwood.org).

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Introduction The Michigan Department of Agriculture and Rural Development (MDARD) regulates aquatic species through a Prohibited and Restricted species list, under the authority of Michigan's Natural Resources and Environmental Protection Act (NREPA), Act 451 of 1994, Part 413 (MCL 324.41301-41305). Prohibited species are defined as species which "(i) are not native or are genetically engineered, (ii) are not naturalized in this state or, if naturalized, are not widely distributed, and further, fulfill at least one of two requirements: (A) The organism has the potential to harm human health or to severely harm natural, agricultural, or silvicultural resources and (B) Effective management or control techniques for the organism are not available." Restricted species are defined as species which "(i) are not native, and (ii) are naturalized in this state, and one or more of the following apply: (A) The organism has the potential to harm human health or to harm natural, agricultural, or silvicultural resources. (B) Effective management or control techniques for the organism are available." Per a recently signed amendment to NREPA (MCL 324.41302), MDARD will be conducting reviews of all species on the lists to ensure that the lists are as accurate as possible.

We use the United States Department of Agriculture's, Plant Protection and Quarantine (PPQ) Weed Risk Assessment (WRA) process (PPQ, 2015) to evaluate the risk potential of plants. 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.

The PPQ 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., State 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.

Egeria densa **Planch. – Brazilian elodea**

Species Information

Family: Hydrocharitaceae

Synonyms: *Anacharis densa* (Planch.) Vict., and *Elodea densa* (Planch.) Casp.(NGRP, 2015). *Egeria densa* had previously been known by these two synonyms (St. John, 1961; Catling & Wojtas, 1985), but work by St. John (1961) delineated the differences in these three genera and formally placed the species in *Egeria*.

Common names: Brazilian elodea (Curt, Curt, Aguado, & Fernández, 2010), Egeria waterweed (Batianoff & Butler, 2002), Egeria (Roberts, Church, & Cummins, 1999), common waterweed (Curt, Curt, Aguado, & Fernández, 2010).

Botanical description: *Egeria densa* is an emergent plant species with stems that may grow up to 15 ft. long. Stems are 1-3 mm in diameter, and leaves are whorled. The species may be rooted, or found free-floating in mats. (eFloras, 2015; Anderson and Hoshovsky, 2015). For a full botanical description, see CABI (2015).

Initiation: In accordance with the Natural Resources and Environmental Protection Act Part 413, the Michigan Department of Agriculture and Rural Development was tasked with evaluating the aquatic species currently on Michigan's Prohibited and Restricted Species List (MCL 324.41302). The USDA's Plant Epidemiology and Risk Analysis Laboratory (PERAL) Weed Team worked with MDARD to evaluate and review this species.

Foreign distribution: *Egeria densa* is native to South America, specifically Brazil, Uruguay, Paraguay, northern Argentina, and Chile (Kowata et. al, 2014; Cook & Urmi-König, 1984; Catling & Wojtas, 1985). It is naturalized in North America (Canada and Mexico), the British Isles, New Zealand, Australia, southern Africa (South Africa and Ghana), the Caribbean islands (Cuba, Guadeloupe, Martinique, and Jamaica), Central America (Costa Rica, El Salvador, and Nicaragua) and eastern Europe (Italy, Switzerland, France, Germany, Portugal, the Czech Republic, the Netherlands, and Spain), as well as Russia, Japan, and Colombia (Kadono, 2004, GBIF, 2015).

U.S. distribution and status: *Egeria densa* was first detected outside of its native range in the United States, in 1893 in Millneck, Long Island, New York (Yarrow et. al, 2009; Cook & Urmi-König, 1984). Since then, it has spread to Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Hawaii, Illinois, Indiana, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Mississippi, Missouri, Nebraska, New Hampshire, New Jersey, New Mexico, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, and Puerto Rico. *Egeria densa* is a popular aquarium and water garden plant (McLane & Sutton, 2008; AquariumPlants.com, 2015), and is commercially available through nurseries and commercial pet stores (e.g., PetsMart, 2015). This species is also popular for classroom purposes to illustrate photosynthesis and plant cell structure, and is available through major classroom scientific supply companies (Ward's Science, 2015; Carolina Biological Supply Company, 2015). *Egeria densa* is currently regulated as a noxious weed in Alabama, Alaska, Connecticut, Idaho, Illinois, Indiana, Maine, Massachusetts, Michigan, Mississippi, Nebraska, New Hampshire, New York, North Carolina, Oregon, South Carolina, Vermont, Washington, and Wisconsin (USDA, 2015; National Plant Board, 2015).

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

1. *Egeria densa* analysis

Establishment/Spread Potential The ability of *Egeria densa* to spread and form dense thickets (Mony, Koschnick, Haller, & Muller, 2007) strongly contributed to its risk score. This submerged aquatic species is shade tolerant (Bini & Thomaz, 2005) and benefits from fragmentation; fragments with double nodes are able to sprout into new individuals, increasing the potential for dispersal (Curt, Curt, Aguado, & Fernández, 2010; Getsinger & Dillon, 1984). We had average uncertainty in this area for *E. densa*; seed and fruit traits are not well studied, and dispersal methods beyond vegetative reproduction were not explored in the literature reviewed. Thus, it was fairly difficult to ascertain the potential of this species to spread via seed.
Risk score = 14 Uncertainty index = 0.16

Impact Potential *Egeria densa* has very significant natural system impacts; it alters ecosystem parameters substantially. This species depletes available nitrogen, phosphorous, and oxygen, taking nutrients up through its leaves and stems in the water column, as well as through its shoots in the sediment (Suzuki, Fonseca, Esteves, & Chagas, 2015; Cook & Urmi-König, 1984; Weragoda, Tanaka, Jinadasa, & Sasaki, 2009; Chagas, Fonseca, & Suzuki, 2008; Yarrow et. al, 2009). Further, the species outcompetes other macrophytes and phytoplankton by reducing light availability and water temperature beneath its canopy (Chagas, Fonseca, & Suzuki, 2008). In anthropogenic

[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).

systems, the species clogs reservoirs, preventing fishing, boating, swimming, and reducing potable water quality (Mori et. al, 2012; Kadono, 2004; U.S. Army Corps of Engineers, 1976), and may have caused the drowning of at least one person due to entanglement in the long stems (GLANSIS, 2015). *Egeria densa* clogs irrigation canals and lowers water quality for production system purposes (Curt, Curt, Aguado, & Fernández, 2010). We had a low amount of uncertainty for this risk element
Risk score = 4 Uncertainty index = 0.10

Geographic Potential Based on three climatic variables, we estimate that about 77.8 percent of the United States is suitable for the establishment of *Egeria densa* (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 *E. densa* represents the joint distribution of Plant Hardiness Zones 5-13, areas with 0-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, desert, mediterranean, humid subtropical, marine west coast, humid continental warm summers, humid continental cool summers, subarctic, and tundra.

The area of the United States shown to be climatically suitable (Fig. 1) is likely overestimated since our analysis considered only three climatic variables. Other environmental variables, such as stream flow and available nutrients, may further limit the areas in which this species is likely to establish. *Egeria densa* is a freshwater species that prefers slow-moving bodies of water, i.e., ditches, streams, lakes (Yarrow et al., 2009; Curt, Curt, Aguado, & Fernández, 2010), and is able to survive in oligotrophic conditions (Carrillo, Guarín, & Guillot, 2006), notably utilizing a process similar to C_4 metabolism when CO_2 levels are too low for traditional photosynthesis (Yarrow et al., 2009).

Entry Potential We did not assess the entry potential of *Egeria densa* because it is already present in the United States (Yarrow et. al, 2009; Cook & Urmi-König, 1984).

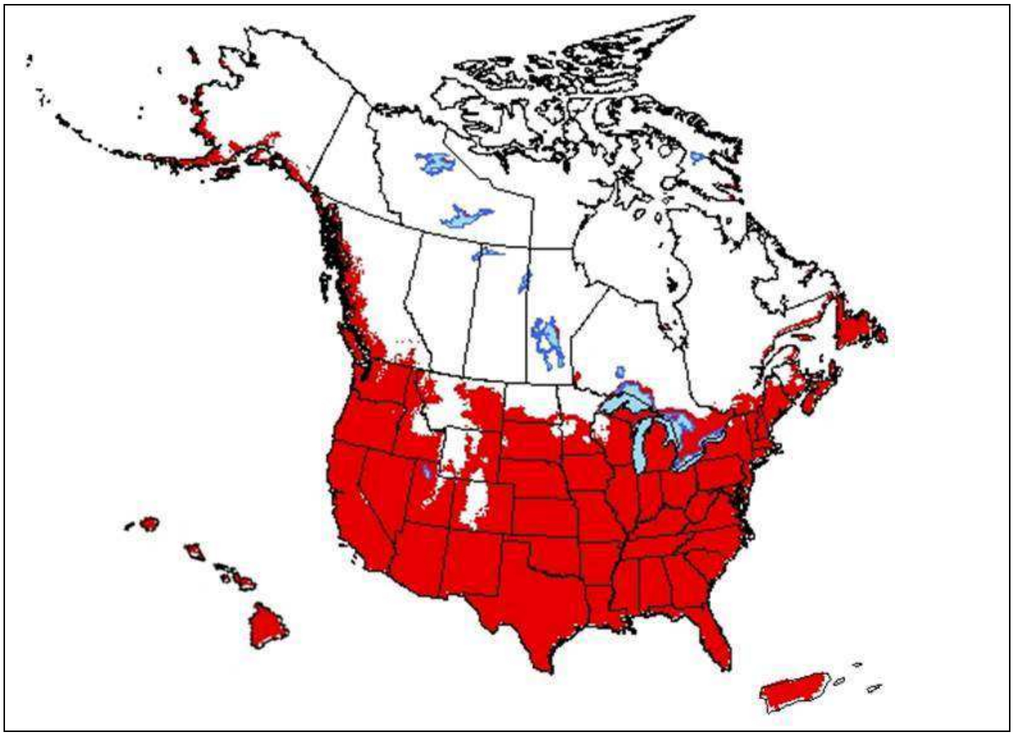

Figure 1. Predicted distribution of *Egeria densa* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 82.8%
P(Minor Invader) = 16.6%
P(Non-Invader) = 0.6%

Risk Result = High Risk

Secondary Screening = Not Applicable

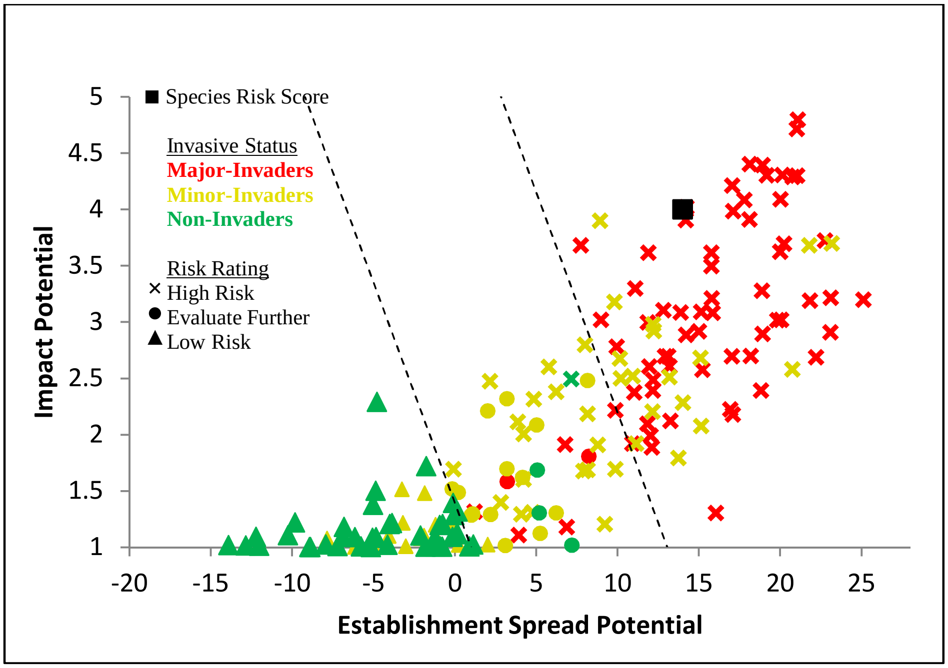

Figure 2. *Egeria densa* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

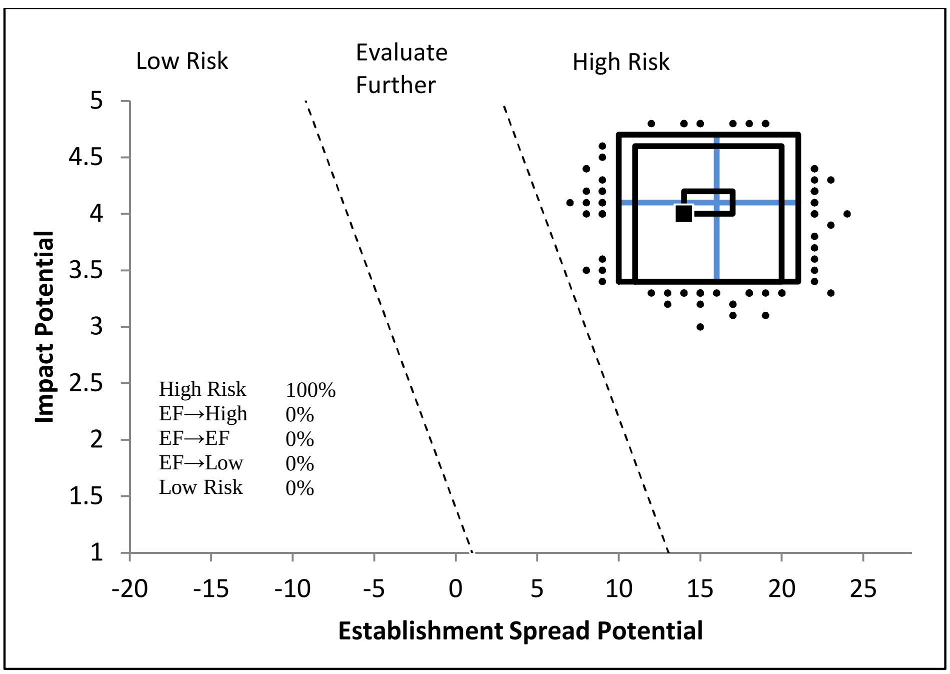

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Egeria densa*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Egeria densa* is High Risk. When compared with the species used to validate this WRA model, *Egeria densa* had traits similar to major invaders (Figure 2). *Egeria densa* is able to establish in nine different Plant Hardiness Zones, as well as 11 of the 12 Köppen-Geiger climate classes and precipitations bands of 0-100+ inches. This wide geographic range, coupled with the *E. densa*'s vegetative spread and reproduction potential, implicates much of the United States as at risk for the establishment of *E. densa*. *Egeria densa* is a threat to natural, anthropogenic, and production systems because it grows densely and alters habitat dynamics such as light availability, temperature, and nutrient limitation. Further, this species is commonly sold in the aquarium trade, and is used in educational settings to study plant cell growth and structure (Cook & Urmi-König, 1984), making it easily accessible for dispersal. This categorization of "High Risk" is supported by the uncertainty analysis; all 5000 iterations of the analysis resulted in a score of "High Risk." (Figure 3). Work done by the U.S. Army Corps of Engineers in 1976 studying herbicide effectiveness on *Egeria densa* populations concluded that amine-salt endothall and diquat were both effective in the chemical control of *E. densa*, with diquat+copper being the most effective, and a diquat+endothall mix used in the treatment of the Walker Dam in Virginia with great success in reducing the *E. densa* infestation.

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Appendix A. Weed risk assessment for *Egeria densa* Planch. (Hydrocharitaceae). Below is all of the evidence and associated references used to evaluate the risk potential of this taxon. We also include the answer, uncertainty rating, and score for each question. The Excel file, where this assessment was conducted, is available upon request.

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 [What is the taxon's establishment and spread status outside its native range? (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown]	f - negl	5	*Egeria densa* is native to South America, specifically Brazil, Uruguay, Paraguay, northern Argentina, and Chile (Kowata et. al, 2014; Cook & Urmi-König, 1984; Catling & Wojtas, 1986). *Egeria densa* is naturalized in North America (Canada and Mexico), the British Isles, New Zealand, Australia, southern Africa (South Africa and Ghana), the Caribbean islands (Cuba, Guadeloupe, Martinique, and Jamaica), Central America (Costa Rica, El Salvador, and Nicaragua) eastern Europe (Italy, Switzerland, France, Germany, Portugal, the Czech Republic, the Netherlands, and Spain), as well as Russia, Japan, and Colombia (Kadono, 2004, GBIF, 2015). In Japan, *E. densa* is considered a "serious weed" and spreading in distribution, which is attributed to "explosive expansion" (Kadono, 2004; Kadono, Nakamura, & Suzuki, 1997). In New Zealand, *Egeria densa* spread rapidly from a small infestation in Lake Rotorua in July 1983 to become the most abundant macrophyte in the lake by December 1988, occupying about 475 ha (Wells & Clayton, 1991). In the United States, spreading infestations have been reported in California, Florida, Oregon, Virginia, Louisiana, Alabama, and South Carolina (Blackburn, 1974). Flooding is thought to be responsible for dispersing fragments downstream and establishing new populations (U.S. Army Corps of Engineers, 1976). Alternate answers for the Monte Carlo simulation were both "e".
ES-2 (Is the species highly domesticated)	n - low	0	This species is cultivated for the aquarium trade (Catling & Wojtas, 1986), but we found no evidence in the literature that it has been bred to reduce weed potential.
ES-3 (Weedy congeners)	n - low	0	The genus *Egeria* contains two species: *Egeria densa* and *Egeria najas* (Cook & Urmi-König, 1984). Only *Egeria densa* is considered a weed (Randall, 2012).
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	*Egeria densa* is a submerged aquatic plant that is able to grow under low-light conditions (Bini & Thomaz, 2005; Yarrow et. al, 2009). *Egeria densa* shoot length continued to grow at levels of 73% shading, reaching a maximum shade tolerance of 93% shading (Tanner, Clayton, & Wells, 1993).
ES-5 (Climbing or smothering growth form)	n - negl	0	Although this plant has long submerged stems (Yarrow et. al, 2009), it is not a vine, nor does it form tightly appressed basal rosettes.
ES-6 (Forms dense thickets)	y - negl	2	*Egeria densa* forms vast, dense mats (Getsinger & Dillon, 1984), develops a canopy (Mony, Koschnick, Haller, & Muller, 2007) and produces large, nearly pure stands (Cook & Urmi-König, 1984).
ES-7 (Aquatic)	y - negl	1	*Egeria densa* is a submersed aquatic macrophyte (Getsinger & Dillon, 1984; Kadono, Nakamura, & Suzuki, 1997; Yarrow et. al, 2009).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-8 (Grass)	n - negl	0	This plant is a member of the family Hydrocharitaceae and is therefore not a grass (Getsinger & Dillon, 1984).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen. Further, this species is not in a plant family known to have N-fixing capabilities (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	? - max	0	Under laboratory controlled conditions, pollen transferred within species yielded viable seed, however in the native range of *E. densa*, in a pool where both sexes were present, fruit was not observed (Cook & Urmi-König, 1984). We answered unknown, as seed viability for this species has not been well-studied, and literature focuses on vegetative reproduction as the primary means of reproduction.
ES-11 (Self-compatible or apomictic)	n - negl	-1	Plants are dioecious (i.e., there are separate male and female plants; CABI, 2015; Cook & Urmi-König, 1984; Catling & Wojtas, 1986) and only male plant colonies exist beyond the plant's native range (Foret, Barry, Langlinais, Solymosy, & Viator, 1976; Lambertini et. al, 2010; Kadono, Nakamura, & Suzuki, 1997).
ES-12 (Requires special pollinators)	? - max		Within its native range, *E. densa* is visited by Diptera, however, pollen transfer was not been observed (Cook & Urmi-König, 1984). Seed set in nature and in cultivation is rare (Cook & Urmi-König, 1984), however, *E. densa* has been cited as being entomophilous (Yarrow et. al, 2009).
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 - low	1	Stems become brittle and naturally fragment in autumn (Cook & Urmi-König, 1984). Stems of *Egeria densa* have segments or areas which readily break, while the double nodes and sections needed for reproduction are very flexible and not easily broken (Jacobs, 1946). Fragments or shoot pieces that have detached by December and contain a double node have the ability to develop into a new plant in the spring (Haramoto & Ikusima, 1988; Getsinger & Dillon, 1984). We answered "b" with low uncertainty. Due to the possibility of human-mediated fragmentation earlier in the season, leading to the growth of new individuals, alternate answers for the Monte-Carlo simulation were both "a".
ES-14 (Prolific reproduction)	n - mod	-1	Sexual propagation of *E. densa* is rare, even in nature (Haramoto & Ikusima, 1988). No pistillate flowers, seed, or fruit have been observed in its introduced range (Getsinger & Dillon, 1984), and *E. densa* very rarely sets seed (Cook & Urmi-König, 1984). The literature focuses primarily on vegetative fragmentation as this species' means of reproduction, and discussion of sexual propagation only mentions how rare it is in nature. Therefore, we answered no, given the lack of observed seed, but with moderate uncertainty, as few sources fully discuss sexual reproduction.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	Spread of plant fragments through boating and other recreational activities is likely (Rothlisberger, Chadderton, McNulty & Lodge, 2010; Johnson, Ricciardi and Carlton, 2001). Boat propellers may cut plants, and fragments can become entangled on propellers and trailers. (Rothlisberger, Chadderton, McNulty & Lodge, 2010). The spread of *E. densa* is probably more directly the result of human's activity than any other "natural" dispersal agent (Cook & Urmi-König, 1984).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	? - max	2	A Minnesota study of the movement of invasive aquatic species found a "3% incidental receipt rate" of *E. densa* for plants purchased (Maki & Galatowitsch, 2004), where *E. densa* individuals were mislabeled as other species. Curt et al. (2010) state that the accidental introduction of *E. densa* into a reservoir was as a contaminant of *Eichhornia crassipes*, which was being used for ornamental purposes, indicating that *E. densa* can be a contaminant. Additional evidence supporting movement as trade contaminants may exist, because Indonesia and Korea require phytosanitary certificates declaring shipments free of *E. densa* (APHIS, 2015). However, due to the speculative nature of the evidence, we answered “unknown” with maximum uncertainty.
ES-17 (Number of natural dispersal vectors)	2	0	Information relevant for ES-17a through ES-17e: Fruit: berry-like (Thorne, Hellquist, & Haynes 2013), ovoid, thin-walled, translucent, an irregularly dehiscent capsule (Cook & Urmi-König, 1984), 6.8 to 7.8 mm long and 2.8 to 3.0 mm in diameter (Anonymous, 2010) Seeds: ellipsoidal, slightly bent at the chalazal end, testa tough and covered with elongated or swollen cells; micropyle elongate and beak-like (Cook & Urmi-König, 1984), 7.3 to 8.3 mm long (Anonymous, 2010).
ES-17a (Wind dispersal)	n - low		We found no evidence of this type of dispersal, and seeds and fruit appear to possess no adaptations for wind dispersal, thus making it highly unlikely to be dispersed via wind.
ES-17b (Water dispersal)	y - negl		Floating plant fragments provide the major means of dispersal (Blackburn, 1974; Cook & Urmi-König, 1984; Haramoto & Ikusima, 1988; Jacobs, 1946).
ES-17c (Bird dispersal)	? - max		Ducks have been observed eating *E. densa* tips and leaves, while also pulling apart stems to detach leaves (Curt, Curt, Aguado, & Fernández, 2010). Native birds in Florida were observed using the dense mats as forage ground (Yarrow et. al, 2009), and *E. densa* stands are a primary component of the diet of the black-necked swan as well as a primary breeding area (Lovengreen et. al, 2008). Seeds could get stuck between wings/on mud in feet, and birds could potentially eat seeds/fruits during feeding/breeding, or facilitate fragmentation of the plant. Vegetative fragments can also be transported via waterfowl (IPANE, 2015). A study conducted by Coughlan et al. (2015) concluded that the high humidity of waterfowl plumage prevented dessication for the studied species, *Lemna minor*, a submerged aquatic species, for at least six hours, and could be retained in feathers of mallard ducks for at least two hours when traveling at speeds of up to 65 km/hour. *Egeria densa* can withstand dessication at high humidity levels for at least three hours (Barnes et. al, 2013). However, the reproductive double nodes are significantly larger than *Lemna minor* fragments. We answered “unknown” with maximum uncertainty, because although there has been no direct observation of this type of transport, research indicates that it is possible.
ES-17d (Animal external dispersal)	? - max		We found no evidence, however the methods of dispersal of *E. densa*'s seeds and fruit are not well studied, therefore we answered "unknown".

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17e (Animal internal dispersal)	? - max		We found no evidence, however the methods of dispersal of *E. densa*'s seeds and fruit are not well studied, therefore we answered "unknown".
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	n - mod	-1	We found no evidence of a persistent seed bank for this species. *Egeria densa* overwinters vegetatively before rooting in the spring (Catling & Wojtas, 1986).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	This species spreads primarily vegetatively (Foret, Barry, Langlinais, Solymosy, & Viator, 1976). Fragmentation enhances population growth (Curt, Curt, Aguado, & Fernández, 2010), and stem fragments that contain double nodes can develop into new plants, but the fragments must be at least 7.5 mm long (Getsinger & Dillon, 1984).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - negl	0	Diquat has been reported as effective in controlling *Egeria densa*, although multiple initial applications are required, followed by annual applications to maintain control (U.S. Army Corps of Engineers, 1976). Further, it is not listed by Heap (2013) as a weed that is resistant to herbicides.
ES-21 (Number of cold hardiness zones suitable for its survival)	9	0	
ES-22 (Number of climate types suitable for its survival)	11	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - high	0	Studies conducted by Nakai et al. (1999) on the allelopathy of freshwater macrophytes indicated inhibition of growth of two blue-green algae (*Anabena flos-aquae* and *Microcystis aeruginosa*) by *E. densa*. However, these experiments were conducted in a flask in a laboratory environment with macrophyte culture solutions and carefully constructed macrophyte concentrations of whole vegetation. These conditions are extremely unrepresentative of the natural environment. Because we did not find any direct evidence of allelopathy under natural conditions, we answered no, but with high uncertainty.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this species is parasitic. Furthermore, *Egeria densa* does not belong to a family known to contain parasitic plants (Heide-Jorgensen, 2008; Getsinger & Dillon, 1984; Nickrent, 2009).
Impacts to Natural Systems			
Imp-N1 (Change ecosystem processes and parameters that affect other species)	y - negl	0.4	*Egeria densa* degrades faster than other macrophytes, and this degradation increases nitrogen in the water column, decreases then increases phosphorus in the water column, quickly releases nutrients (Suzuki, Fonseca, Esteves, & Chagas, 2015), and often depresses oxygen levels (Cook & Urmi-König, 1984). Canopy forming macrophytes such as *E. densa* restrict dissolved oxygen exchange with the atmosphere, resulting in anoxic conditions at the sediment-water interface (Weragoda, Tanaka, Jinadasa, & Sasaki, 2009). *Egeria densa* reduces competition mainly by limiting phosphorus in the water column (Chagas, Fonseca, & Suzuki, 2008). *Egeria densa* sequesters

Question ID	Answer - Uncertainty	Score	Notes (and references)
			nutrients rapidly from the water column and sediments. (Yarrow et. al, 2009).
Imp-N2 (Change habitat structure)	y - low	0.2	*Egeria densa* eliminates native species through nutrient limitation and shading (Chagas, Fonseca, & Suzuki, 2008), and may affect seed banks of native macrophytes by preventing germination (Yarrow et. al, 2009). It has become the second most common species in Japanese waterways, due to the prevalence of monospecific stands (Kadono, 2004). *Egeria densa* was identified in Lake Biwa, Japan, in 1969, and by the 1970s, the submerged plant zone in the southern and western basins, which previously consisted of the native species *Vallisneria denseserrulata*, *V. asiatica*, *Hydrilla verticillata*, *Potamogeton maachianus*, *P. crispus*, *Najas major*, and *N. minor*, was inhabited exclusively by *E. densa* (Tanimizu & Miura, 1976).
Imp-N3 (Change species diversity)	y - negl	0.2	*Egeria densa* reduces species diversity (Chagas, Fonseca, & Suzuki, 2008) of native plant species. While they overwinter, *Egeria densa* plants and fragments can cover the bottom of lakes from winter to spring (Jacobs, 1946; Kadono, 2004), and hinder the growth of native plants which are dormant in winter (Kadono, 2004). Biomass of native plants in Japanese waterways has declined drastically since the introduction of *E. densa* (Kadono, 2004). Reduced light, temperature, and oxygen under *E. densa* stands are limiting to many species, and reduce their occurrence (Cook & Urmi-König, 1984).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species)	y - low		*Egeria densa* invades natural systems such as streams, lakes, and the basins of river systems (Yarrow et al., 2009). As reviewed under Imp-N1 and Imp-N3, *Egeria densa* negatively impacts native species species diversity through several mechanisms, including the formation of dense monospecific stands at or just below the water's surface (Getsinger & Dillon, 1984; Mony, Koschnick, Haller, & Muller, 2007). While there is no direct evidence of it affecting T&E species, the formation of monospecific stands is likely to impact T&E species. .
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	y - negl	0.1	*Egeria densa* is already present as a noxious weed in the United States in areas in Oregon, Washington, Alabama, Mississippi, and South Carolina (BONAP, 2014) that are listed as globally outstanding ecoregions (Ricketts et. al, 1999). This species alters nutrient regimes within areas it becomes established in, and outcompetes native species to shade out benthic plants and phytoplankton (Chagas, Fonseca, & Suzuki, 2008; Suzuki, Fonseca, Esteves, & Chagas, 2015; Cook & Urmi-König, 1984).
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	*Egeria densa* is a widely distributed aquatic weed (Carrillo, Guarín, & Guillot, 2006) which invades natural systems such as streams, lakes, and the basins of river systems (Yarrow et al., 2009). It is considered a pest plant in Australia (Curt, Curt, Aguado, & Fernández, 2010), is listed on New Zealand's environmental weed list (Howell, 2008), and has been noted as a weed of natural systems in California, where the California Department of Boating and Waterways has spent between \$6.2 million and \$7.9 million per year during the years of 2001-2005 to control the *E. densa* population, using aquatic herbicides (California Department of Boating and Waterways, 2015).

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Diquat has been used as an effective herbicide, with native fish being largely unaffected by the diquat, and shoreline vegetation remaining unaffected, as diquat is inactivated by soil. However, diquat also eliminated native species, so special care must be taken to aid in the re-establishment of those native species (U.S. Army Corps of Engineers, 1976). Alternate answers for the Monte Carlo simulation are both "b".
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	y - negl	0.1	During the rainy season, enormous quantities of *E. densa* branches block turbines at a hydroelectric facility in Brazil (Mori et. al, 2012). Dense communities hinder ship navigation in Japan (Kadono, 2004). *Egeria densa* in the Walker Dam Impoundment in Virginia was responsible for increasing eutrophication and trapping of sediments, leading to filling in of the reservoir (U.S. Army Corps of Engineers, 1976). and a reservoir in Virginia used for water supply (U.S. Army Corps of Engineers, 1976).
Imp-A2 (Changes or limits recreational use of an area)	y - negl	0.1	Dense communities of *E. densa* hinder fisheries (Kadono, 2004), and thick mats clog vessel propellers and rudders. *Egeria densa* infestations in the Walker Dam Impoundment in Virginia restrict much of the recreational use of the reservoir in the spring, summer, and fall months and *E. densa*-free fishing areas could not be located in the reservoir (U.S. Army Corps of Engineers, 1976). The US Army Corps of Engineers research for control of *E. densa* focused on lakes in Louisiana commonly used for fishing. Further, *E. densa* may have caused the drowning of at least one person due to entanglement in the long stems (GLANSIS, 2015).
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	n - mod	0	We found no evidence that this species affects ornamental plants and vegetation.
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	*Egeria densa* is an "obnoxious water weed" of major economic significance which invades navigable waters and causes problems in the navigation of water (U.S. Army Corps of Engineers, 1976), primarily reservoirs (Yarrow et al., 2009). Mechanical harvesting may perpetuate growth of new individuals, but herbicides have been used successfully to control the species (Blackburn, 1974). Residents of Lake Limerick in Washington spend up to $25,000 per year to control *E. densa* (Washington Department of Ecology, 2015). The herbicide diquat was found to be effective with a reservoir used for fishing in Virginia, with minimal impacts. Recreational access to the bodies of water being treated was blocked for five days (U.S. Army Corps of Engineers, 1976). Alternate answers for the Monte Carlo simulation are both "b".
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - mod	0	We found no evidence that this species affects crop or commodity yield.
Imp-P2 (Lowers commodity value)	n - mod	0	We found no evidence that this species lowers commodity value.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-P3 (Is it likely to impact trade)	y - low	0.2	It is currently prohibited to transport, import, or sell *Egeria densa* in Alabama, Connecticut, Maine, Massachusetts, Michigan, New Hampshire, New York, South Carolina, Vermont, and Wisconsin (USDA, 2015). Internationally, Indonesia and Korea require phytosanitary certificates declaring shipments free of *E. densa* (APHIS, 2015). Maki and Galatowitsch (2004), in a study identifying aquatic plant shipments in Minnesota, reported receiving *E. densa* labeled as other species, indicating that the species is moved through the aquatic plant trade. The inspections necessary to prevent seizures/refusal of shipments within these areas due to *E. densa* present an impact to trade.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - low	0.1	Dense growth of *E. densa* can clog irrigation canals (GLANSIS, 2015; Roberts, Church, & Cummins, 1999). A serious invasion of an irrigation canal in Spain affected both the quality of the water and the functioning of the pumps and sprinklers (Curt, Curt, Aguado, & Fernández, 2010).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	We found no evidence that this species is toxic to animals.
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 - mod	0.6	The unwanted growth in irrigation canals (GLANSIS, 2015) indicates that this species is a weed of production systems. It appears as though infestations of canals have attempted to be controlled through biological and chemical means (Curt, Curt, Aguado, & Fernández, 2010; U.S. Army Corps of Engineers, 1976). Nursery owners in Spain mechanically removed *E. densa* from an irrigation canal once per year, and Peking ducks were observed eating tips and leaves of the plants and controlling the population biologically, but not reducing it (Curt, Curt, Aguado, & Fernández, 2010). We answered "c", given these attempts at control, but with moderate uncertainty, as few sources outline issues and control efforts specifically within production systems. The alternate answers for the Monte Carlo simulation were both "b".
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically-referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2015).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z2 (Zone 2)	n - mod	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z3 (Zone 3)	n - high	N/A	Two points in Canada, but we answered no without additional information as these may be misidentifications. Furthermore, this is a tropical species and seems unlikely to occur in such a cold climate.
Geo-Z4 (Zone 4)	n - high	N/A	One point in the United States, but we answered no without additional information or evidence (same reasoning as in Geo-Z3).
Geo-Z5 (Zone 5)	y - mod	N/A	A few points in the United States. One point in Iceland, in a geothermal pond (Wasowicz et al., 2014).
Geo-Z6 (Zone 6)	y - negl	N/A	Some points in the United States. Two points in Germany. One point each in the Czech Republic and Japan.
Geo-Z7 (Zone 7)	y - negl	N/A	Some points in the United States. A few in Germany and Japan.
Geo-Z8 (Zone 8)	y - negl	N/A	France, the Netherlands, and the United States.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z9 (Zone 9)	y - negl	N/A	Australia, Spain, the United Kingdom, and the United States.
Geo-Z10 (Zone 10)	y - negl	N/A	Australia. Some points in the United States and Mexico. A few points in Brazil and New Zealand.
Geo-Z11 (Zone 11)	y - negl	N/A	A few points in Australia, Brazil, Colombia, and New Zealand. Some in Mexico.
Geo-Z12 (Zone 12)	y - negl	N/A	Brazil. Two points in Mexico, one in Nicaragua, and one in Ghana.
Geo-Z13 (Zone 13)	y - high	N/A	A few points in Brazil near zone 12, and one point in Costa Rica.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - high	N/A	Three points in Colombia.
Geo-C2 (Tropical savanna)	y - negl	N/A	Brazil. One point each in Costa Rica, Ghana, and Guatemala.
Geo-C3 (Steppe)	y - negl	N/A	Brazil. Some points in the United States. A few in Australia, Mexico, and Spain.
Geo-C4 (Desert)	y - high	N/A	One point in the United States. Although there may not be too many aquatic habitats in deserts, this species would be able to survive in any area that impounds water, natural or artificial.
Geo-C5 (Mediterranean)	y - negl	N/A	The United States.
Geo-C6 (Humid subtropical)	y - negl	N/A	Brazil and the United States.
Geo-C7 (Marine west coast)	y - negl	N/A	France, Germany, Mexico, and the United Kingdom.
Geo-C8 (Humid cont. warm sum.)	y - low	N/A	Some points in the United States, two in Japan.
Geo-C9 (Humid cont. cool sum.)	y - low	N/A	Some points in Germany and the United States.
Geo-C10 (Subarctic)	y - high	N/A	One point in Iceland (GBIF, 2015; Wasowicz et al., 2014).
Geo-C11 (Tundra)	y - high	N/A	One point in Iceland (GBIF, 2015; Wasowicz et al., 2014)
Geo-C12 (Icecap)	n - mod	N/A	We found no evidence that it occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - low	N/A	Some points in Brazil. One point in the United States, near to the next precipitation band.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Australia, Brazil, and the United States.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Brazil, Mexico, and the United States.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	France, Mexico, the United Kingdom, and the United States.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Brazil, Mexico, the United Kingdom, and the United States.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Brazil, Mexico, Nicaragua, the United Kingdom, and the United States.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Brazil, Ireland, Mexico, and the United States.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Japan and Mexico.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	Brazil, Japan, and Mexico.
Geo-R10 (90-100 inches; 229-254 cm)	y - negl	N/A	Japan and Mexico.
Geo-R11 (100+ inches; 254+ cm)	y - negl	N/A	Brazil, Colombia, Costa Rica, Japan, and Mexico.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	The first record of *E. densa* outside of its native range was found in Long Island, NY in 1893 (Yarrow et. al, 2009; Cook & Urmi-König, 1984).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	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	
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	