

Weed Risk Assessment for *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae) – Water hyacinth

Michigan Department
of Agriculture and
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Version 1



Top left: water hyacinth blackened rhizomatous roots and bulbous leaf petioles (source: Forest and Kim Starr, CC BY 2.0, via Flickr), Top right: close-up of water lettuce perfect flower (source: badgersportsman.com), Bottom left: *E. crassipes*' long, waxy leaves and full inflorescence spike (source: Wilfredo Robles, Mississippi State University, Bugwood.org). Bottom right: cross section of spongy leaves (source: Florida Department of Agriculture).

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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.

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., 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.

Plant Information and Background

PLANT SPECIES: *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae) (GRIN, 2019).

SYNONYMS: *Pontederia crassipes* Mart., *Eichhornia cordifolia* Gand., *Eichhornia crassicaulis* Schltidl., *Eichhornia speciosa* Kunth, *Heteranthera formosa* Miq., *Piaropus crassipes* (Mart.) Britton, 1893, *Piaropus crassipes* (Mart.) Raf., *Piaropus mesomelas* Raf., *Pontederia crassicaulis* Schltidl., *Pontederia crassipes* Roem. & Schult., *Pontederia elongata* Balf. (GRIN, 2019).

COMMON NAMES: water hyacinth, floating water hyacinth, lilac devil, Nile lily, pickerelweed, water orchid, water violet (CABI, 2019).

BOTANICAL DESCRIPTION: *Eichhornia crassipes* is a free floating mobile macrophyte that grows in nutrient rich freshwaters in tropical and subtropical climates (Coetzee and Telléz, 2008). It forms rosettes of thick, glossy leaves with bulbous petioles and has inflorescence stalks with many purple flowers (CABI, 2019). Water hyacinth is a perennial that reproduces both vegetatively and through seed, with each seed capsule containing up to 450 seeds (CABI, 2019). For a full botanical description see the Environmental Stewardship Abstract from the Nature Conservancy (Batcher, 2000).

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). USDA Plant Epidemiology and Risk Analysis Laboratory's (PERAL) Weed Team worked with MDARD to evaluate and review this species.

WRA AREA¹: United States and Territories.

FOREIGN DISTRIBUTION: *Eichhornia crassipes* is native to the Amazon Basin and most of South America (CABI, 2019). Reports show that it quickly spread to Central America and the Caribbean by the late 1800's. Throughout the late 19th and early 20th centuries, *Eichhornia crassipes* was introduced to other countries in Asia, Africa and Oceania for gardening due to its showy flowers (Julien, 2001; Zhang et al., 2010). It was first introduced as animal feed in China during the 1950's and 1960's (CABI, 2019). Later, *E. crassipes* was introduced to European countries as well. Outside of its native range, *E. crassipes* has become a problematic invasive weed across the globe, flourishing on all continents except for Antarctica (Kriticos and Brunel, 2016). It is regulated as a noxious weed in Australia, Fiji, Kenya, South Africa, and Ontario, Canada, with proposed regulation in other countries (CABI, 2019; BONAP's North American Plant Atlas, 2014).

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

U.S. DISTRIBUTION AND STATUS: *E. crassipes* was introduced to Louisiana in 1884, reaching Florida shortly after (Julien, 2001). It is now present in at least half of the United States and established in the southeast (Adebayo et al., 2011). This species is continually reintroduced through ornamental ponds due to its attractive purple flowers; most spread is attributed to deliberate plantings (GISD, 2022). It is not listed on the Federal Noxious Weed List, though its congener, anchored water hyacinth (*Eichhornia azurea* (Sw.) Kunth), is (USDA APHIS PPQ, 2012). However, it is listed as a noxious weed or regulated in Alabama, Arkansas, California, Connecticut, Florida, South Carolina, and Texas (CABI, 2019; USDA Plants Database) as well as in British Columbia and Manitoba, Canada (CCIPR, 2025). The city of Chicago has also prohibited its sale (Merritt, 2011). *Eichhornia crassipes* is available for sale through multiple retailers (Pond Plants Online).

Analysis

ESTABLISHMENT/SPREAD POTENTIAL: *E. crassipes* rapidly forms dense, floating mats of rosettes and populations can double in 10-60 days (Coetzee & Telléz, 2008; GISD, 2022). It has a short generation time and biomass may double in as little as every 2-34 days (Gutiérrez et al., 2001). This species can reproduce vegetatively through clonal propagation and by seed (Adebayo et al., 2011; Coetzee & Telléz, 2008). Fragmented rosettes become daughter plants that are dispersed by wind and wave action, allowing *Eichhornia crassipes* to proliferate (Coetzee & Telléz, 2008). It benefits from cultivation efforts, and these fragments are spread via machinery, boats, trailers, and animals (GISD, 2022). In addition, *E. crassipes* has a high level of self-compatibility (GISD, 2022) and produces high amounts of seed that can persist 5-20 years (Coetzee & Telléz, 2008; Jacano et al., 2022; USDA Plants Database). However, seed production is low in temperate areas (Barrett, 1980). We had low uncertainty for this risk element.

Risk score = 22.0

Uncertainty index = 0.09

IMPACT POTENTIAL: *E. crassipes* is considered a weed in natural, anthropogenic and production systems. In natural systems, it threatens native vegetation by outcompeting for resources, forming dense mats that shade out other plants, altering the water conditions and depleting algal populations (Rojas-Sandoval & Acevedo-Rodríguez, 2013). It has been shown to be allelopathic and its decomposition creates anoxic conditions in the water (Robinson, 2003; Shanab et al., 2010). In addition to harming plants, the anoxic conditions can negatively affect fish, birds and invertebrates mostly due to loss of habitat, but also because algae are a major food source (Rojas-Sandoval & Acevedo-Rodríguez, 2013). Biodiversity is negatively affected by *E. crassipes*. In the Delta region, it has caused significant ecological alterations in the surrounding community (Toft et al., 2003). In anthropogenic systems, *E. crassipes* clogs water ways reducing recreational use, affects municipal water, and negatively impacts hydroelectric power. The mats provide breeding grounds for disease-carrying mosquitoes. Fishery productivity is directly impacted by *E. crassipes*, and it is a weed in rice

paddies. Infestations can deplete irrigation water needed for crop or cattle production. This species is regulated as a noxious weed in places around the world and within the U.S., notably, the state of Wisconsin, the city of Chicago, and Ontario, Canada (BONAP's North American Plant Atlas, 2014; Merritt, 2011; Wisconsin Department of Natural Resources). We had Low uncertainty for this risk element.

Risk score = 4.6

Uncertainty index = 0.10

GEOGRAPHIC POTENTIAL: Using the PPQ climate-matching model for weeds (Magarey et al., 2017), we estimate that about 44.9% percent of the United States is suitable for the establishment of *E. crassipes* (Fig. 1). This area represents the joint distribution of Plant Hardiness Zones 5a-14b, areas with 0-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical monsoon, tropical savanna, hot arid desert, hot arid steppe, cold arid steppe, temperate dry-summer hot and warm-summer, temperate dry season hot and warm-summer, cold dry winter hot summer, and cold no dry season hot and warm summer (app. A). The area of the United States shown to be climatically suitable was determined using only these three climatic variables. Other factors, such as hydrology, disturbance regime, and species interactions may alter the areas in which this species is likely to establish. *Eichhornia crassipes* is known to establish and cause problems in Michigan (Michigan Flora Online, 2011).

Reported Occurrences and Climatic Suitability for *Eichhornia crassipes* (Mart.)

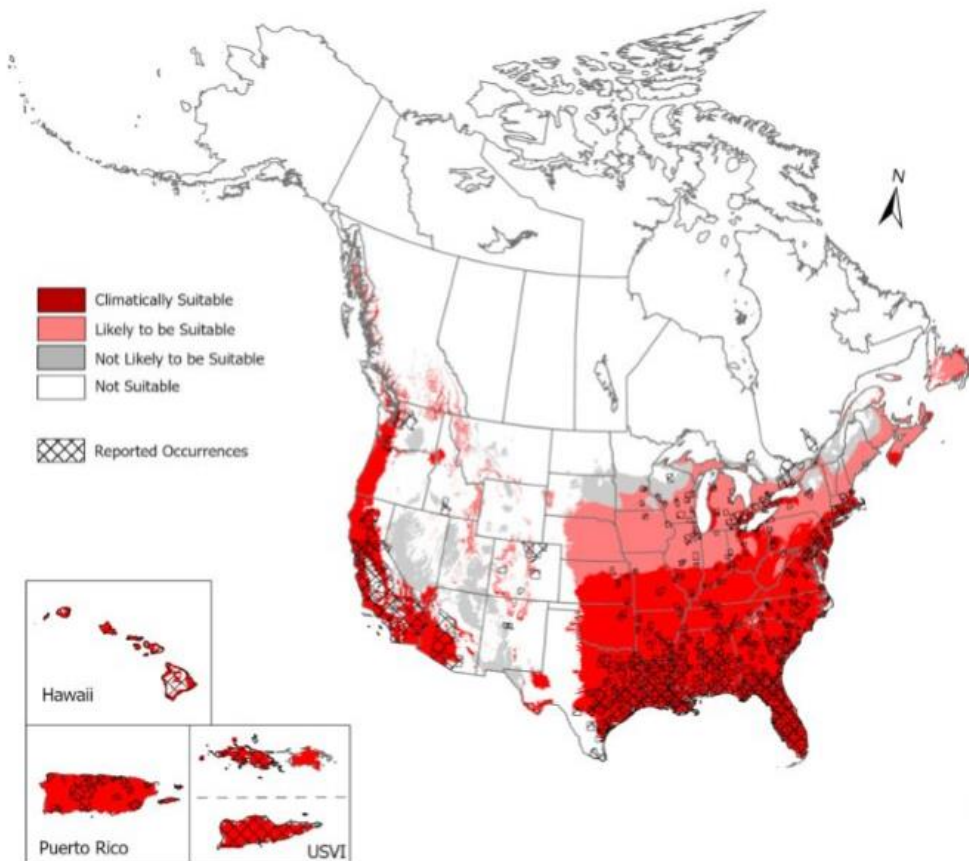


Figure 1. Current and potential distribution of *Eichhornia crassipes* in the United States. Climatic suitability was determined using the APHIS-PPQ climate matching tool for invasive plants (Magarey et al., 2017). The known distribution of *E. crassipes* was based on county distribution records from online databases and other sources (see text). Map components are shown at different scales.

ENTRY POTENTIAL: We did not assess the entry potential of *Eichhornia crassipes* because it is already present in the United States (Fig. 1).

Risk Model Results

Model Probabilities: P(Major Invader) = 97.8%
P(Minor Invader) = 2.1%
P(Non-Invader) = 0.4%

Risk Result = High Risk

Risk Result after Secondary Screening = Not Applicable

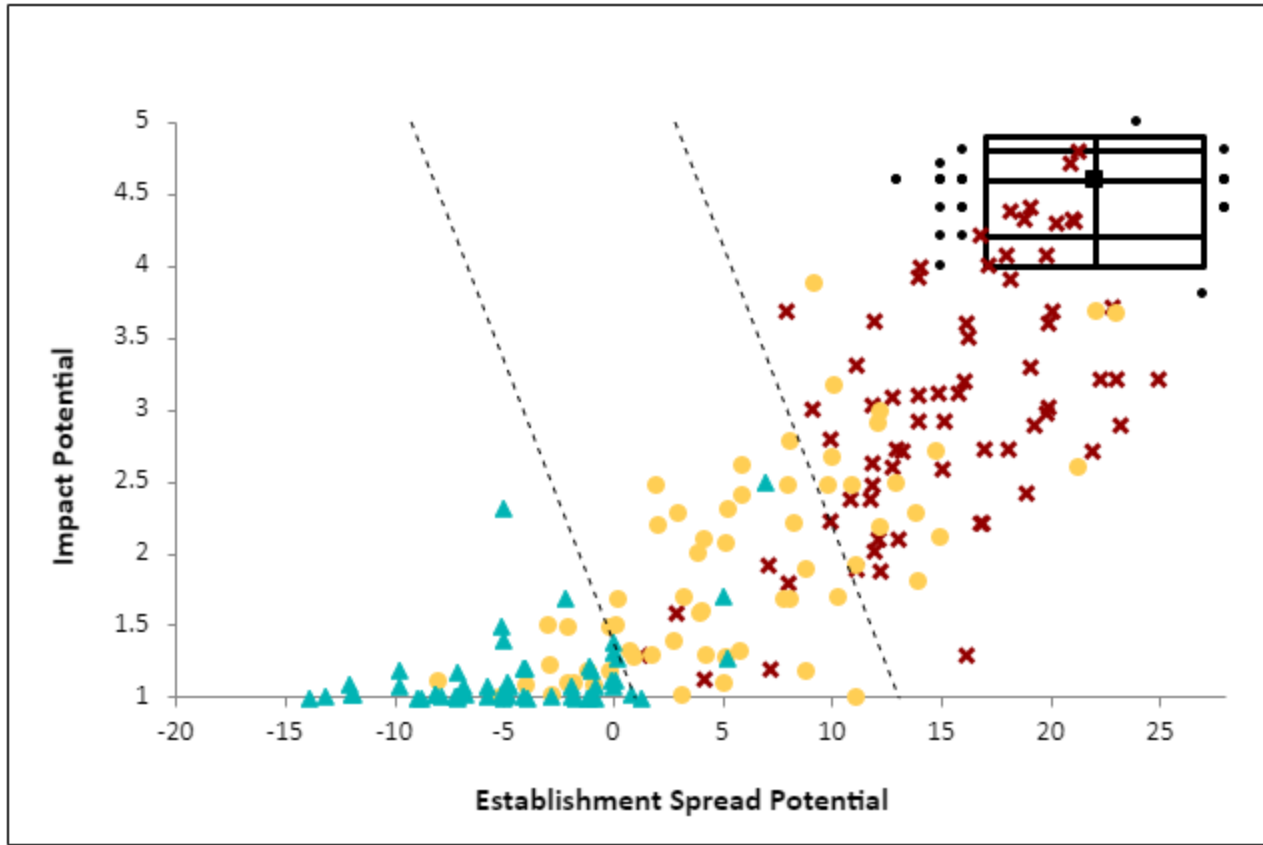


Figure 2. Risk and uncertainty results for *Eichhornia crassipes*. The risk score for this species (solid black symbol) is plotted relative to the risk scores of the species used to develop and validate the PPQ WRA model (Koop et al., 2012). The results from the uncertainty analysis are plotted around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

Discussion

The result of the weed risk assessment for *Eichhornia crassipes* is High Risk of becoming weedy or invasive and is well supported by the uncertainty analysis (Figure 2). The plant is distributed across the globe and is highly invasive (Kriticos and Brunel, 2016). Its growth habit and reproductive biology allow it to rapidly spread via stolons and prolific seed production, especially in nutrient-rich freshwaters (GISD, 2022; Gutiérrez et al., 2001). Not only do natural areas suffer, but water hyacinth is also a costly threat to public infrastructure because of clogged waterways and effects on hydroelectric power (Stohlgren et al., 2013). Infestations inhibit productivity of fisheries, reduce recreational use, and can increase evapotranspiration of waterbodies (Kriticos & Brunel, 2016). However, *E. crassipes* is common in aquatic plant trade and is available through many retailers. Though usually water hyacinth does not

survive freezing temperatures, populations are consistently present in four counties in Michigan (Livingston, Macomb, Oakland, Wayne), perhaps through continual reintroduction or accidental dispersal (Michigan Flora Online, 2011). This plant is not currently regulated in Michigan, but is prohibited in Wisconsin, Ontario and the city of Chicago (BONAP's North American Plant Atlas, 2014; Merritt, 2011; Wisconsin Department of Natural Resources). *Eichhornia crassipes* is also present in the surrounding states of Indiana, Minnesota, and both Pennsylvania and New York which border Lake Erie (BONAP's North American Plant Atlas, 2014).

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Appendix A.

Weed risk assessment for *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae). The following table includes the evidence and associated references used to evaluate the risk potential of this taxon. We also include the answer, uncertainty rating, and score for each question. 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	Very broad global distribution and is established in southeastern United States and California (Adebayo et al., 2011). Introduced range (Asia, Africa, Europe, North America, Central America and the Caribbean) (Zhang et al., 2010). Native to the Amazon Basin, invasive in waterways of Africa, and widespread in the southern United States by the early 1900's (Julien, 2001). Water hyacinth is present in Israel, Italy, Portugal, and Spain (Coetzee & Telléz, 2008). Flourishing on all continents except for Antarctica (Kriticos and Brunel, 2016).
ES-2 (Is the species highly domesticated)	n - high	0	Introduced by humans as ornamental plant for ponds and aquaria (Coetzee & Telléz, 2008). Introduced as animal food in China during the 1950's and 1960's. Introduced to ornamental ponds due to attractive purple flowers, most spread attributed to deliberate plantings (GISD, 2022). There is some evidence that there is a cultivar called "purple root water hyacinth" developed in China, however the extent to which it is grown is unclear (Shu et al., 2015).
ES-3 (Significant weedy congeners)	y - low	1	<i>Eichhornia azurea</i> (anchored water hyacinth), <i>Eichhornia diversifolia</i> (variable leafed water hyacinth), <i>Eichhornia paniculata</i> (Brazilian water hyacinth) (USDA NRCS Plant Database).
ES-4 (Shade tolerant at some stage of its life cycle)	n - low	0	Requires full sun or partial shade (<i>Eichhornia Crassipes</i> , n.d.)
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	y - negl	1	Clonal individuals can form through vegetative reproduction of fragmented rosettes, which can disperse by wind and water movement (NSW DPI, 2013).
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	In Spain, in the Guadiana River populations have been reported to double in 10-60 days (Coetzee & Telléz, 2008). Forms dense floating mats (GISD, 2022). This species rapidly grows and can double its biomass every 2-34 days and shade out native vegetation (Gutiérrez et al., 2001).
ES-7 (Aquatic)	y - negl	1	Is a free floating mobile macrophyte (Coetzee & Telléz, 2008).

Weed Risk Assessment for *Eichhornia crassipes* (Mart.) Solms (Common water hyacinth)

ES-8 (Grass)	n - negl	0	Water hyacinth is in the Pontederiaceae family (USDA Plants Database).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	It is a free floating mobile macrophyte (Coetzee & Telléz, 2008).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Seed production is low in temperate areas (Barrett, 1980). Seeds produced in large number and persist for up to 20 years (Coetzee & Telléz, 2008). Produces abundant long-lived seeds, reproduces sexually and vegetatively (GISD, 2022). This species seeds can remain viable for up to 5-20 years (USDA Plants Database).
ES-11 (Self-compatible or apomictic)	y - negl	1	Can reproduce clonally (Adebayo et al., 2011). <i>E. crassipes</i> likely result from severe genetic bottlenecks during colonization and prolific clonal propagation (Zhang et al., 2010). Reproduces vegetatively via daughter plants and by seed (Coetzee & Telléz, 2008). High level of self-compatibility (GISD, 2022).
ES-12 (Requires specialist pollinators)	n - low	0	Species is pollinated by several species of bees (GISD, 2022).
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]	a - negl	2	In Spain, in the Guadiana River populations have been reported to double in 10-60 days (Coetzee & Telléz, 2008). The plant can produce flowers and seeds within 12 weeks of germination (Coetzee & Telléz, 2008). This species rapidly grows and can double its biomass every 2-34 days (Gutiérrez et al., 2001).
ES-14 (Prolific seed producer)	y - low	1	Seed production is low in temperate areas (Barrett, 1980). Seeds produced in large number and persist for up to 20 years (Coetzee & Telléz, 2008). Produces abundant long-lived seeds, reproduces sexually and vegetatively (GISD, 2022). Seeds are the main source of new infestations and are carried in the water and in mud, on machinery or boots, as well as by birds (NSW DPI, 2013). This species seeds can remain viable for up to 5-20 years (Jacono et al., 2022). Each seed capsule may produce up to 450 seeds (Batcher, 2000).
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	Introduced by humans as ornamental plant for ponds and aquaria (Coetzee & Telléz, 2008). Seeds can be translocated by machinery (GISD, 2022). May frequently be introduced into waterways after disposal from water gardens (Adebayo et al., 2011). Clonal individuals can disperse to new areas when fragments are transported by water. Seeds are the main source of new infestations and are carried in the water and in mud, on machinery or boots, as well as by birds (NSW DPI, 2013).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	n - high	-1	There is no evidence that propagules are potential hitchhikers on any of these products. Research from Minnesota supports that a staggering amount of orders from aquatic plant vendors include unordered plant materials and seeds, however, which could be a potential pathway (Maki &

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			Galatowitsch, 2004). They report <i>Eichhornia crassipes</i> has not been a contaminant in other aquatic shipments.
ES-17 (Number of natural dispersal vectors)	3	2	0
ES-17a (Wind dispersal)	y - negl		Daughter plants are dispersed by wind and wave action (Coetzee & Telléz, 2008). Clonal individuals can form through vegetative reproduction of fragmented rosettes, which can disperse by wind and water movement (NSW DPI, 2013).
ES-17b (Water dispersal)	y - negl		Daughter plants are dispersed by wind and wave action (Coetzee & Telléz, 2008). Forms thick mats that can become entangled in boat propellers and trailers to be spread to other bodies of water (Sullivan et al., 2017). Clonal individuals can form through vegetative reproduction of fragmented rosettes, which can disperse by wind and water movement (NSW DPI, 2013).
ES-17c (Bird dispersal)	? - mod		Seeds are the main source of new infestations and are carried in the water and in mud, on machinery or boots, as well as by birds (NSW DPI, 2013).
ES-17d (Animal external dispersal)	y - high		Other mammals may disperse propagules stuck in the mud (Rojas-Sandoval & Acevedo-Rodríguez, 2013).
ES-17e (Animal internal dispersal)	n - low		Studies have shown that germinations rates of ingested seeds after passing through the gut of sheep are 0% (Pérez et al., 2015).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	Seed bank persists up to 20 years (Coetzee & Telléz, 2008). This species seeds can remain viable for up to 5-20 years (Jacono et al., 2022).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - low	1	Clonal individuals can be moved to new areas when fragments are transported to new areas. Forms thick mats that can become entangled in boat propellers and trailers to be spread to other bodies of water (Sullivan et al., 2017). Clonal individuals can form through vegetative reproduction of fragmented rosettes, which can disperse by wind and water movement (NSW DPI, 2013).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	The herbicide 2,4-D kills <i>E. crassipes</i> and reduces the populations of native species to some extent (Ivanov et al. 2007). No evidence of herbicide resistance.
ES-21 (Number of cold hardiness zones suitable for its survival)	5	0	
ES-22 (Number of climate types suitable for its survival)	7	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	y - low	0.1	Water hyacinth has been shown to be allelopathic against algae, crop seedlings, and have antimicrobial activity. When the plants break down,

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			an abundance of compounds are released including chloro- and nitro-phenols (Shanab et al., 2010)
Imp-G2 (Parasitic)	n - negl	0	Water hyacinth is not known to be parasitic.
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	y - negl	0.4	The introduction of hyacinth to the Delta has caused significant ecological alterations in the surrounding community (Toft et al., 2003). These plants have a high growth rate in nutrient-rich environments. It as also been shown that the presence of water hyacinth greatly increases the rate of evapotranspiration (Rojas-Sandoval & Acevedo-Rodríguez, 2013).
Imp-N2 (Changes habitat structure)	y - negl	0.2	This species can form dense mats that shade out other species (Rojas-Sandoval & Acevedo-Rodríguez, 2013).
Imp-N3 (Changes species diversity)	y - negl	0.2	Biodiversity is negatively affected by water hyacinth. Native vegetation does not compete well can be greatly reduced or outcompeted completely. In addition to plants, fish, birds and other invertebrates can be negatively affected mostly due to loss of habitat (Rojas-Sandoval & Acevedo-Rodríguez, 2013). Algae can be shaded out, and therefore the food source for many species decreases as a direct result. The decomposition can cause anoxic conditions that is detrimental to various life forms (Robinson, 2003).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - low	0.1	The Everglade snail kite, <i>Rostrhamus sociabilis plumbeus</i> , is affected by water hyacinth through habitat alteration (Rojas-Sandoval & Acevedo-Rodríguez, 2013).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	y - low	0.1	It is a threat to the Mississippi river and tributaries (Ricketts, 1999).
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	This species is one of the worst weeds in the world and negatively effects aquatic ecosystems it invades by competing with native vegetation for sunlight, reducing dissolved oxygen needed for aquatic life, and altering species diversity. Attempts at control ave ranged from biological control using seven different natural enemies, mechanical control using cutting or other removal efforts, as well as herbicide use (Jacono et al., 2022).
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	y - negl	0.1	There is evidence that water hyacinth can cause damage to bridges as well as clog dams (Stohlgren et al., 2013). It also can prevent drainage and increase flood waters (Jacono et al., 2022). Additionally, the dense mats formed by water hyacinth create breeding grounds where mosquitoes may proliferate, increasing disease spread in ares where there are serious invasions (Stohlgren et al., 2013). Water hyacinth can also impact the water supply through interference with municipal and industrial piping systems

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			(Villamagna & Murphy, 2010) as well as interfere with hydroelectric power generation (Water Hyacinth, n.d.).
Imp-A2 (Changes or limits recreational use of an area)	y - negl	0.1	Forms thick mats that can become entangled in boat propellers and trailers to be spread to other bodies of water (Sullivan et al., 2017). Water hyacinth can choke waterways and prevent recreational boating which may also negatively effect tourism (Kriticos & Brunel, 2016).
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - negl	0	Water hyacinth is commonly used in aquatic gardens and as an ornamental in ponds favored for its showy flowers.
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 - mod	0.4	Water hyacinth is a weed in anthropogenic systems because of the reasons stated above and control efforts are in place to manage these consequences, ranging from biological, physical, and chemical control measures. In the state of Benin, biological control of water hyacinth costed over \$2 million dollars to manage an infestation (Jacono et al., 2022).
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - mod	0.4	As an aquatic weed, water hyacinth may reduce the productivity of fisheries (Villamagna & Murphy, 2010). An inverse relationship between water hyacinth and amount of tilapia in Lake Victoria, Kenya is one example of these effects (Ongore et al., 2018). It also reportedly reduces production of paddy rice in India (Parsons & Cuthbertson, 1992). Water hyacinth is an alternative host for the Asian corn borer as well as the rice root nematods (Groves et al., 1995).
Imp-P2 (Lowers commodity value)	n - mod	0	This species does not directly lower commodity value, however, lack of irrigation water, increased difficulties raising crops, etc. may increase costs. No direct quantitative evidence of this could be found in the literature.
Imp-P3 (Is it likely to impact trade?)	y - mod	0.2	Water hyacinth has the potential to be transported on trailers, boats, and in ballast water. Online trade of this species as well as sale for aquatic gardens is a primary means of spread. Water hyacinth is listed as a noxious weed in Florida where it is illegal to possess without a permit, is a noxious weed in Alabama, and is potentially invasive in Connecticut. The city of Chicago has prohibited its sale (CABI, 2019; Merritt, 2011; USDA Plants Database).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - negl	0.1	Mats of water hyacinth can increase evapotranspiration between 2.67 to 3.2 times as much as open water alone, reducing the availability of water (Kriticos & Brunel, 2016). Pipe systems for agricultural use can also be impacted (Villamagna & Murphy, 2010).

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Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - mod	0	According to a research study on mice, feeding water hyacinth leaves did not result in any acute toxicity (Wu et al., 2014). It was also found to be a beneficial protein source for pigs, with no toxic effects (Akankali & Elenwo, 2019). Leaf protein extract was further analyzed showing nutritional value with heavy metal values within dietary range (Adeyemi & Osubor, 2016). Some evidence shows it may be toxic to dogs, cats, and horses, though this would not normally be ingested by these animals (Pond Informer, 2019).
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	Water hyacinth is a problem in production systems mostly indirectly through changing the landscape and land use capabilities. However, there are certain cases where it directly impacts yield of paddy rice, fishery production, and reduces the availability of irrigation water. It is also regulated as a noxious weed in some states due to the impact that its spread has.
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	Cannot survive freezing temperatures
Geo-Z2 (Zone 2)	n - negl	N/A	Cannot survive freezing temperatures
Geo-Z3 (Zone 3)	n - negl	N/A	Cannot survive freezing temperatures
Geo-Z4 (Zone 4)	n - negl	N/A	Cannot survive freezing temperatures
Geo-Z5 (Zone 5)	n - negl	N/A	Cannot survive freezing temperatures
Geo-Z6 (Zone 6)	n - negl	N/A	Cannot survive freezing temperatures
Geo-Z7 (Zone 7)	n - negl	N/A	Cannot survive freezing temperatures
Geo-Z8 (Zone 8)	n - negl	N/A	Cannot survive freezing temperatures
Geo-Z9 (Zone 9)	y - mod	N/A	Cannot survive freezing temperatures
Geo-Z10 (Zone 10)	y - negl	N/A	0
Geo-Z11 (Zone 11)	y - negl	N/A	0
Geo-Z12 (Zone 12)	y - negl	N/A	0
Geo-Z13 (Zone 13)	y - negl	N/A	0
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - mod	N/A	0
Geo-C2 (Tropical savanna)	y - mod	N/A	0
Geo-C3 (Steppe)	n - mod	N/A	0
Geo-C4 (Desert)	n - mod	N/A	0
Geo-C5 (Mediterranean)	y - mod	N/A	0
Geo-C6 (Humid subtropical)	y - mod	N/A	0
Geo-C7 (Marine west coast)	y - mod	N/A	0
Geo-C8 (Humid cont. warm sum.)	y - mod	N/A	Some parts of the southern lower peninsula are this climate class.
Geo-C9 (Humid cont. cool sum.)	y - mod	N/A	Michigan is mostly this climate class.
Geo-C10 (Subarctic)	n - negl	N/A	Cannot survive freezing temperatures
Geo-C11 (Tundra)	n - negl	N/A	Cannot survive freezing temperatures

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Geo-C12 (Icecap)	n - negl	N/A	Cannot survive freezing temperatures
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - negl	N/A	0
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	0
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	0
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	0
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Southern part of the state
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Upper penninsula and northern lower penninsula.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	0
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	0
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	0
Geo-R10 (90-100 inches; 229-254 cm)	y - negl	N/A	0
Geo-R11 (100+ inches; 254+ cm)	y - negl	N/A	0
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	0
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 [Human value & cultivation/trade status: (a) Neither cultivated or positively valued; (b) Not cultivated, but positively valued or potentially beneficial; (c) Cultivated, but no evidence of trade or resale; (d) Commercially cultivated or other evidence of trade or resale]	-	N/A	
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	
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	