



Michigan Department  
of Agriculture and Rural  
Development

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Version 1

## Weed Risk Assessment for *Pistia stratiotes* L. (Araceae) – Water lettuce



Top left: flowering water lettuce plant (source: wetplants.com). Top right: Dense mats forming on the water surface (source: University of Minnesota Extension). Bottom: Water lettuce removal efforts in the city of L.A. in 2020 (source: sepulvedabasinwildlife.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.

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:** *Pistia stratiotes* L. (Araceae) (Bánki et al., 2021).

**SYNONYMS:** *Apiospermum obcordatum* (Schleid.) Klotzsch, *Limnonesis commutata* (Schleid.) Klotzsch, *Limnonesis friedrichsthaliana* Klotzsch, *Pistia aegyptiaca* Schleid., *Pistia aethiopica* Fenzl ex Klotzsch, *Pistia africana* C.Presl, *Pistia amazonica* C.Presl, *Pistia brasiliensis* Klotzsch, *Pistia commutata* Schleid., *Pistia crispata* Blume, *Pistia cumingii* Klotzsch, *Pistia gardneri* Klotzsch, *Pistia horkeliana* Miq., *Pistia leprieuri* Blume, *Pistia linguiformis* Blume, *Pistia minor* Blume, *Pistia natalensis* Klotzsch, *Pistia obcordata* Schleid., *Pistia occidentalis* Blume, *Pistia schleideniana* Klotzsch, *Pistia spathulata* Michx., *Pistia stratiotes* var. *cuneata* Engl., *Pistia stratiotes* var. *linguiformis* Engl., *Pistia stratiotes* var. *obcordata* (Schleid.) Engl., *Pistia stratiotes* var. *spathulata* (Michx.) Engl., *Pistia texensis* Klotzsch, *Pistia turpinii* K.Koch, *Pistia weigeltiana* C.Presl, *Zala asiatica* Lour (Bánki et al., 2021).

**COMMON NAMES:** Water lettuce, pistia, Nile cabbage, shell-flower, tropical duckweed, water bonnet, water cabbage, floating aroid, water fern, water lily (CABI, 2021), River-lettuce (Thayer et al., 2022).

**BOTANICAL DESCRIPTION:** *Pistia stratiotes* L. is an aquatic, perennial monocotyledon, with a feathery root system that survives in tropical, sub-tropical, and warm temperate regions (EPPO, 2017). The free-floating plants form rosettes of soft leaves up to 20 cm long, and can reproduce via seed or stolons, forming dense mats of clonally propagated daughter plants which are the main mode of spread (CABI, 2021; Driesche et al., 2002). *Pistia stratiotes* is mainly found in slow-moving or stagnant freshwater, as it has a low salinity tolerance (Haller et al., 1974).

**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 AREA<sup>1</sup>:** United States and Territories.

**FOREIGN DISTRIBUTION:** The native distribution of *P. stratiotes* is a matter of debate (Evans, 2013; Renner and Zhang, 2004). Distribution is very broad, and descriptions of its native range have included South America (Cordo and Sosa, 1999; Dray and Center, 1989), Africa (Holm et al., 1977), northern Australia (Gillett et al., 1988), Asia (Habeck and Thompson, 1997), and even North America (southern Florida; Evans, 2008). Paleo-botanical, historical, and ecological evidence

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<sup>1</sup> 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).

demonstrates that it is native to neo-tropical America, northern Africa, and southern Asia (Evans, 2013). Historically, *Pistia stratiotes* was used as animal fodder and in medicines, which may explain its widespread distribution (Sculthorpe, 2017). It has since been introduced across most of Europe, where it has been listed on the European and Mediterranean Plant Protection Organization (EPPO) Alien Invasive Species List since 2012. Water lettuce is now established in Slovenia and parts of France (EPPO, 2022). *Pistia stratiotes* is also present across most of Africa where it is also considered invasive. Many Asian countries also consider *P. stratiotes* an invasive, with the exception of two Chinese provinces in which it is cultivated (CABI, 2021).

### U.S. DISTRIBUTION AND STATUS:

*Pistia stratiotes* is thought to be native to southern Florida, where fossil records, historic observations between 1765 – 1774, and the presence of specialized insects and an endemic snail species (*Aphaostracon pycnus*) that uses *P. stratiotes* in its life cycle supports this notion (Evans, 2013). Because of this, it is considered native to the Lower 48, Puerto Rico and the Virgin Islands, but invasive to Hawaii according to the USDA-NRCS (2022). Today, *P. stratiotes* has been observed in over 30 states. It is established throughout the southern U.S. where it can overwinter (Thayer et al., 2022) and is listed as a noxious weed in Alabama, California, Connecticut, Florida, South Carolina, and Texas (USDA-NRCS, 2022). In other states, it is thought that *P. stratiotes* is not overwintering as much, rather producing seed or being continually reintroduced (Thayer et al., 2022). This species is not on the Federal Noxious Weed List (USDA-APHIS, 2022). *P. stratiotes* is commercially available for aquatic and water garden purposes but cannot be shipped to the following states due to restrictions: AL, CA, FL, LA, MS, PR, SC, TX, WI (pondplantsonline.com); it is also regulated in British Columbia and Manitoba, Canada (CCIPR, 2025). Adebayo et al. identified *Pistia stratiotes* in Michigan on Lake St. Clair and the Detroit River, where it can be found in the fall (2011). Control efforts are in place in some states, however controlling an established *P. stratiotes* infestation can be a costly endeavor. It is estimated that combined, *Pistia stratiotes* (water lettuce) and *Eichhornia crassipes* (water hyacinth) control in 2005-2006 in Florida alone cost \$107 per acre annually (Adams and Lee, 2007).

## Analysis

**ESTABLISHMENT/SPREAD POTENTIAL:** *Pistia stratiotes*' propensity for weedy overgrowth has long placed it among the world's list of most potentially invasive species (Holm et al., 1977). It is widely distributed across the globe and continuing to expand its range. It's spread is attributed to the accidental or deliberate release of plants from aquariums and water gardens, hitchhiking on materials, waterfowl or other animals, or simply the daughter plants breaking away from parent plants and drifting to new areas on current or wind-driven flow (EPPO, 2017; MacIsaac et al., 2016; Millane et al., 2014). It has the potential to rapidly reproduce via vegetative propagation to form thick, dense mats on the water's surface. This growth type allows it to outcompete for both space and light. In addition, mechanical cultivation or disruption may increase the number of daughter plants able to reproduce, worsening the problem. *Pistia stratiotes* is monoecious and seed production may also contribute to population growth,

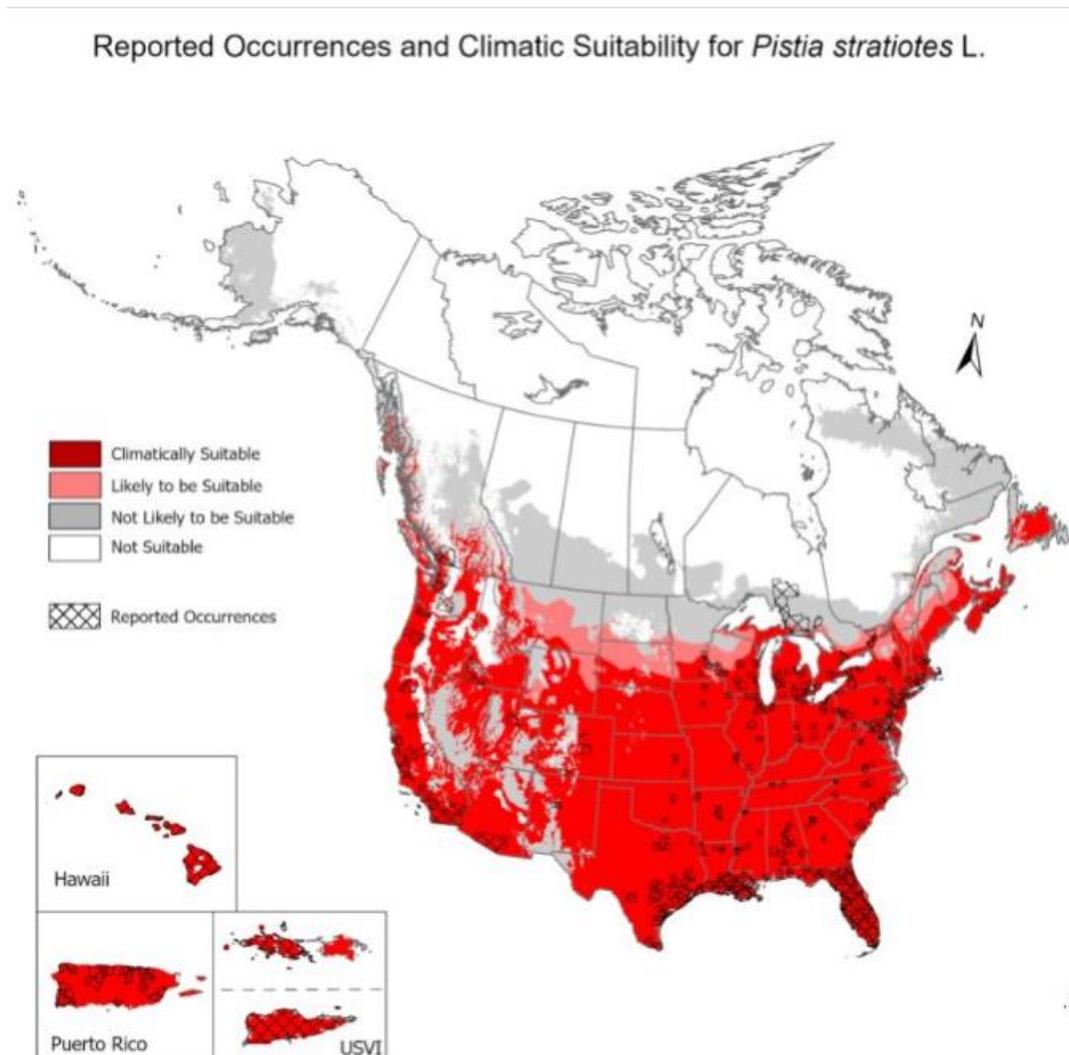
especially in places where vegetation may not be able to overwinter in cold temperatures. Seeds can survive in water that is 4 degrees Celsius for two months. We had Low uncertainty for this risk element.

Risk score = 16.0                  Uncertainty index = 0.07

**IMPACT POTENTIAL:** *Pistia stratiotes* is detrimental to the environments it invades. It can double in biomass in as little as a few days, which displaces native vegetation (Foxcroft, 2013). Its anti-algal properties reduce primary production, it reduces oxygen levels, increases concentrations of nitrate, ammonium, and phosphates, and decreases water turbidity (Cai, 2006; Neuenschwander et al., 2009). This results in higher mortality of fish (Dray & Center, 2002), shifts in the benthic macroinvertebrae communities (Coetzee et al., 2020), and reduces the habitat for threatened and endangered species such as the Everglade snail kite (Mikuyluk et al., 2021). These are negative consequences especially for fragile, freshwater systems and wetlands that are rich in biodiversity. The dense, impenetrable mats formed by *Pistia stratiotes* inhibit recreational activities like boating, wildlife use, and transportation of drainage or irrigation water as well as hydroelectric power (Dewald & Lounibos, 1990; Hill, 2003; Holm et al., 1977; Howard & Harley, 1998; Mbatia & Neuenschwander, 2005; EPPO, 2017; Reddy & Debusk, 1984). These mats create a micro-environment that provides reproductive habitat for disease-vectoring insects such as mosquitos. Additionally, control methods are expensive and labor-intensive, and Florida reportedly spent over \$1.4 million in 2005-2006 on *P. stratiotes* control (Thayer et al., 2021). We had Average uncertainty for this risk element.

Risk score = 3.6                  Uncertainty index = 0.13

**GEOGRAPHIC POTENTIAL:** Using the PPQ climate-matching model for weeds (Magarey et al., 2017), we estimate that about 67.8% percent of the United States is suitable for the establishment of *P. stratiotes* (Fig. 1). This area represents the joint distribution of Plant Hardiness Zones 4b-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-summers, temperate dry winter hot and warm-summers, temperate no dry season hot and warm-summers, and cold no dry season hot and warm-summers (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. *Pistia stratiotes* requires slow-moving to stagnant freshwater and wetlands for optimum growth. The ideal growing conditions are between 22-30°C, but can tolerate up to 35°C and small periods of time as low as -6.6°C. This makes summer in Michigan a potential for rapid water lettuce growth, continuing into fall, especially in warmer bodies of water. However, water lettuce plants will not survive the winter; seed production and/or reintroduction would be the primary means of spread.



**Figure 1.** Current and potential distribution of *Pistia stratiotes* 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 *P. stratiotes* was based on county distribution records from online databases and other sources (see text). Map components are shown at different scales.

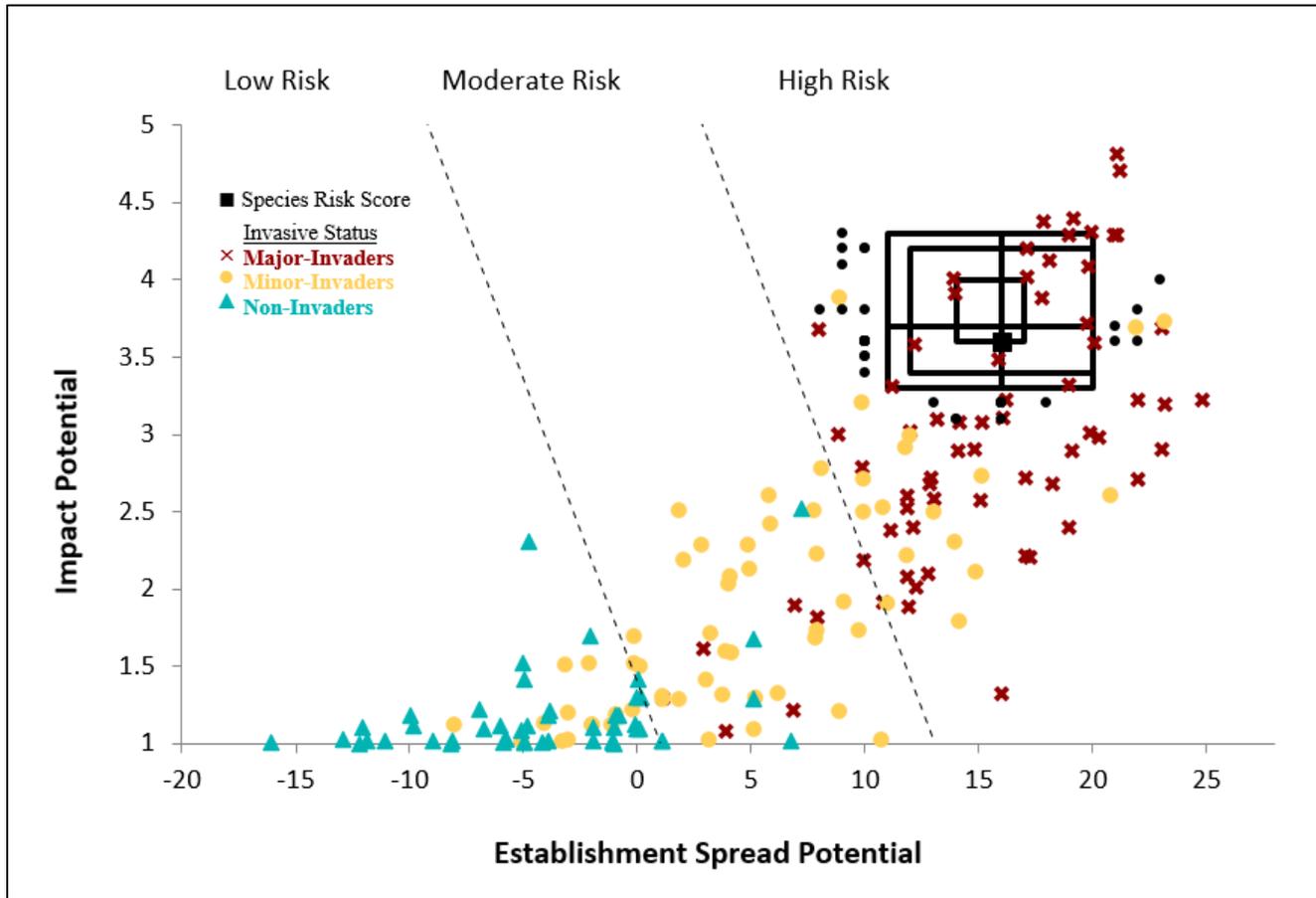
**ENTRY POTENTIAL:** We did not assess the entry potential of *Pistia stratiotes* because it is already present in the United States (Mikulyuk et al., 2021) (Fig. 1).

## Risk Model Results

Model Probabilities: P(Major Invader) = 85.8%  
 P(Minor Invader) = 13.7%  
 P(Non-Invader) = 0.5%

Risk Result = High Risk

Risk Result after Secondary Screening = Not Applicable



**Figure 2.** Risk and uncertainty results for *Pistia stratiotes*. 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 *Pistia stratiotes*. 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 *Pistia stratiotes* is High Risk of becoming weedy or invasive and is well supported by the uncertainty analysis (Figure 2). Water lettuce is an aquatic, perennial macrophyte invasive to slow-moving freshwater bodies and wetlands. It is debatably native to southern Florida and has been reported in 28 states as well as Puerto Rico and the U.S. Virgin Islands. Federally, this species is not regulated and is frequently sold in nurseries for aquatic gardens and aquariums. It is a noxious weed in Alabama, California, Connecticut, Florida, South Carolina, and Texas (USDA-NRCS, 2022). *P. stratiotes* grows rapidly, competing with native vegetation for light, space, and nutrients. Because of its ability to vegetatively reproduce via stolons, it forms dense patches of daughter plants that become a thick layer over the water’s surface. This environment drastically changes the ecosystem by impeding the growth of algae, reducing the amount of dissolved oxygen,

and increasing the nutrient concentrations to a level that is deathly for fish and other macroinvertebrates. Further, it impairs recreational use of the water, hydroelectric capabilities and ability to transport irrigation and drainage water. Over 67.8% of the United States is climatically suitable for the species to establish. Though it cannot overwinter in colder climates, if it can produce seed during the warmer months, those seeds will allow it to come back the following year. Reintroduction through human release is another mode of spread. Water lettuce has the potential to spread further throughout the U.S. through aquatic and nursery trade through fragmentation of existing populations, water dispersal, and hitchhiking on equipment and animals. Places experiencing higher precipitation and/or warmer temperatures in the future will be at a greater risk as well.

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## Appendix A.

Weed risk assessment for *Pistia stratiotes* L. (Araceae). 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)
<b>ESTABLISHMENT/SPREAD POTENTIAL</b>			
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	Its native distribution is a matter of debate (Evans, 2013; Renner & Zhang, 2004). Distribution is very broad and descriptions of its native range, including South America (Cordo & Sosa, 1999; Dray & Center, 1989), Africa (Holm et al., 1977), northern Australia (Gillett et al., 1988), Asia (Habeck & Thompson, 1997), and North America (southern Florida; Evans, 2008). Evans (2013) argued that paleo-botanical, historical, and ecological evidence demonstrates that it is native to neo-tropical America, northern Africa, and southern Asia. Fossil records from Florida, historic WL observations from 1765 – 1774, and the presence of specialized insect species and an endemic snail species ( <i>Aphaostracon pycnus</i> ) that use WL as part of their life cycle supports the notion that WL is native to southern Florida (Evans, 2013).
ES-2 (Is the species highly domesticated)	y - negl	-3	<i>Pistia stratiotes</i> is widely sold as an ornamental species and sold/exchanged between aquarists. Further, <i>P. stratiotes</i> is widely used for phytoremediation of metals, chemical products, oil, removal of pharmaceuticals and personal care products or for urban sewage treatment. Its biomass can be used for bioethanol production, with ethanol yields per unit biomass comparable to that of other agricultural biomasses (Mishima et al., 2008), and biogas production (Abbasi et al., 1991), but unlikely to be economically viable based on experiences in Uganda and elsewhere (EPPO, 2017). The fibre content, carbohydrate and crude protein content of <i>P. stratiotes</i> is comparable to that of quality forages (Parsons & Cuthbertson, 2001). Can be fed to pigs or used in Ayurvedic medicine and for its diuretic, antidiabetic, antidermatophytic, antifungal and antimicrobial properties (Thayer et al., 2021).
ES-3 (Significant weedy congeners)	n - negl	0	<i>Pistia stratiotes</i> is the only widely accepted species name in this genus (The World Flora Online, 2022).
ES-4 (Shade tolerant at some stage of its life cycle)	n - low	0	Water lettuce requires full to partial sun (Puisis, 2021), although plants grown for sale are grown in shade (Brand, 2016).
ES-5 (Plant a vine or scrambling plant, or forms)	n - negl	0	See question E-6

## Weed Risk Assessment for *Pistia stratiotes* L. (Water lettuce)

Question ID	Answer - Uncertain y	Score	Notes (and references)
tightly appressed basal rosettes)			
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	Is a clonal plant that forms small colonies with daughter plants attached to the mother plant through stolons. Dispersal is enhanced through detachment of daughter plants which form new colonies (EPPO, 2017).
ES-7 (Aquatic)	y - negl	1	Water lettuce <i>Pistia stratiotes</i> L., Araceae, is a flowering invasive aquatic floating weed of South American origin (Cordo & Sosa, 1999; Dray & Center, 1992).
ES-8 (Grass)	n - negl	0	<i>Pistia</i> is in the Araceae family (Cordo & Sosa, 1999; Dray & Center, 1992).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	Perennial floating aquatic macrophyte. (EPPO, 2017).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	The peduncle bends after fertilization and pushes the fruits under water where up to 30 seeds per fruit can be released (Kurugundla, 2014; Neuenschwander et al., 2009).
ES-11 (Self-compatible or apomictic)	y - negl	1	Water lettuce is monoecious (male and female reproductive structures on same individual; Haynes 1988) and has imperfect flowers (possessing either male or female reproductive structures). Reproduces vegetatively via daughter plants and by seed (EPPO, 2017). The main mode of propagation of <i>P. stratiotes</i> is via stolons (Kurugundla, 2014), but seed formation seems the only way for it to survive periods of drought (Den Hollander et al., 1999; Kurugundla, 2014).
ES-12 (Requires specialist pollinators)	n - negl	0	Flowers may be wind or insect pollinated (Haynes 1988; Parsons and Cuthbertson 2001). The insect species that pollinate WL are unknown but its floral traits suggest it is fly pollinated (Gibernau et al., 2010)
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	Water lettuce is also capable of rapid vegetative reproduction, producing clonal daughter plants at the ends of stolons (Haynes 1988). A single parent plant can produce up to 15 clonal daughter plants and up to four generations of rosettes can be connected via stolons (Driesche et al., 2002). Seed production may also be a significant source of population growth (Dray & Center, 1989).
ES-14 (Prolific seed producer)	n - mod	-1	According to Dray 1989, seed production was calculated to be 765 seeds per square meter in Florida, not meeting this requirement to be a "prolific seed producer".
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - low	1	Parent and daughter plants can become easily detached through fragmentation (Haynes 1988). The accidental or deliberate release of plants from aquariums and water gardens is typically considered the primary means of WL introduction (MacIsaac et al., 2016; EPPO, 2017). Plants and seeds may attach to watercraft, trailers, and other boating equipment and be transported to uninfected waterbodies (Neuenschwander et al., 2009).

## Weed Risk Assessment for *Pistia stratiotes* L. (Water lettuce)

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	Parent and daughter plants can become easily detached through fragmentation (Haynes 1988). The accidental or deliberate release of plants from aquariums and water gardens is typically considered the primary means of WL introduction (Maclsaac et al., 2016; EPPO, 2017).
ES-17 (Number of natural dispersal vectors)	3	2	0
ES-17a (Wind dispersal)	n - low		Water dispersal is the main mechanism.
ES-17b (Water dispersal)	y - negl		The accidental or deliberate release of plants from aquariums and water gardens is typically considered the primary means of WL introduction (Maclsaac et al., 2016; EPPO, 2017). Secondary spread can occur by daughter plants breaking away from parent plants and drifting on current or wind-driven flow.
ES-17c (Bird dispersal)	y - mod		Likewise, plants and seeds may become attached to animals, particularly waterfowl, and subsequently transported to new locations (Millane et al., 2014).
ES-17d (Animal external dispersal)	y - mod		Likewise, plants and seeds may become attached to animals, particularly waterfowl, and subsequently transported to new locations (Millane et al., 2014).
ES-17e (Animal internal dispersal)	n - high		Seeds may also be ingested by wildlife and transported to new waterbodies but their viability after passing through the digestive tract is unknown.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	n - low	-1	The seeds float for 1 – 2 days and then fall to the substrate (Holm et al., 1977; Mikulyuk et al., 2021; Neuenschwander et al., 2009). Water lettuce dies back completely in drought or freezing conditions and regenerates from buried seeds in the seed bank (Buzgó, 2011; Neuenschwander et al., 2009). However, these seeds remain viable for months, not >1 year, and this is highly dependent on the water temperature. <i>Pistia</i> seeds can survive in the water for 2 months at temperatures 4°C, or weeks under ice to -5°C (Hussner et al., 2014).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - high	1	Since <i>Pistia</i> is vegetatively propagated, some mechanical cultivation will create more daughter plants.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - negl	0	No cases reported (Heap, 2022), and herbicide resistance in aquatic weeds was recently reviewed here (Ortiz et al., 2020).
ES-21 (Number of cold hardiness zones suitable for its survival)	5	0	
ES-22 (Number of climate types suitable for its survival)	6	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
<b>IMPACT POTENTIAL</b>			

## Weed Risk Assessment for *Pistia stratiotes* L. (Water lettuce)

Question ID	Answer - Uncertainty	Score	Notes (and references)
<b>General Impacts</b>			
Imp-G1 (Allelopathic)	y - mod	0.1	According to these studies, there is a mild allelopathic effect on terrestrial plants when used as an incorporated soil amendment, and on media (Bhadha et al., 2014; Bich & Kato-Noguchi, 2012).
Imp-G2 (Parasitic)	n - negl	0	There is no evidence that water lettuce is parasitic, nor is it in a known parasitic plant family.
<b>Impacts to Natural Systems</b>			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	y - negl	0.4	Dense mats of <i>P. stratiotes</i> block sunlight, reducing primary production, and decrease water turbidity (Cai, 2006; Neuenschwander et al., 2009). Furthermore, the water shaded by <i>Pistia</i> shows decreased levels of oxygen and increased levels of nitrate, ammonium and phosphorus (Neuenschwander et al., 2009).
Imp-N2 (Changes habitat structure)	y - negl	0.2	<i>Pistia stratiotes</i> (water lettuce) have spread throughout the world's waterways as a result of anthropogenic activities. With the potential to double in biomass in a few days or weeks and the ability to spread easily due to their free-floating vegetative form, these species can successfully colonise new habitats, form dense mats along shoreline and displace native vegetation (Foxcroft, 2013).
Imp-N3 (Changes species diversity)	y - negl	0.2	<i>Pistia</i> alters the composition of benthic macroinvertebrates, while biological control of water lettuce resulted in the recovery of species diversity (Coetzee et al., 2020). Higher mortality rates of fish were also reported (Dray & Center, 2002).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - low	0.1	<i>Pistia stratiotes</i> is present in freshwater bodies and wetlands, which often harbor rare species. In Europe, a number of Threatened and endangered species are at risk including <i>Isoetes malinverniana</i> (Critically Endangered, Italy), <i>Elatine brochonii</i> (Vulnerable, France and Spain), <i>Anagallis crassifolia</i> and <i>Marsilea strigosa</i> (Vulnerable, France, Italy and the Iberian Peninsula), <i>Pilularia minuta</i> (Endangered), <i>Damasonium polyspermum</i> and <i>Ipomoea sagittata</i> (Vulnerable) (Daniel et al., 2017). The United States also lists <i>Pistia</i> as potentially harmful to <i>Rostrhamus sociabilis plumbeus</i> (Everglade snail kite) due to loss of habitat (Mikulyuk et al., 2021).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	y - low	0.1	Located in Papua New Guinea, Australia; several regions in Africa; and warm parts of North America (Foxcroft, 2013). Water lettuce <i>Pistia stratiotes</i> , that were found at a number of locations in Lake St. Clair and Detroit River during autumn 2010 (Adebayo, 2011).
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon a weed but	c - low	0.6	<i>Pistia stratiotes</i> could be regarded as noxious weeds (Caffrey & Wade, 1996). Complete control obtained in Queensland and some areas of South Africa (Foxcroft et al., 2013).

## Weed Risk Assessment for *Pistia stratiotes* L. (Water lettuce)

Question ID	Answer - Uncertain y	Score	Notes (and references)
no evidence of control; (c) taxon a weed and evidence of control efforts]			
<b>Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)</b>			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	y - low	0.1	It's harmful effects include impediment of the transport of irrigation and drainage water, interference with hydroelectric schemes from artificial lakes, hindrance of navigation and fishing and the creation of habitats favourable for the transmission of water-borne diseases (Dewald & Lounibos, 1990; Hill, 2003; Holm et al., 1977; Howard & Harley, 1998; Mbatia & Neuenschwander, 2005; EPPO, 2017; Reddy & Debusk, 1984).
Imp-A2 (Changes or limits recreational use of an area)	y - low	0.1	<i>P. stratiotes</i> often form large expanses of dense, impenetrable floating mats limiting boat traffic, recreation flood control and wildlife use (Driesche et al., 2002; Hill, 2003; Howard & Harley, 1998; EPPO, 2017).
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	" <i>Pistia stratiotes</i> is deliberately imported for trade and subsequently sold in Ireland in aquarium outlets or by such retailers or individual vendors on the internet as an oxygenator / ornamental plant for garden ponds and aquaria" (Millane et al., 2014).
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	Controlling an established WL infestation can be a costly endeavor. It is estimated that WL and <i>E. crassipes</i> control cost \$107 per acre in Florida annually (Adams & Lee, 2007).
<b>Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)</b>			
Imp-P1 (Reduces crop/product yield)	n - high	0	No evidence of harm to crop yields. One source shows increased crop production with <i>Pistia stratiotes</i> being part of the cow manure.
Imp-P2 (Lowers commodity value)	n - high	0	No evidence lowering commodity value. Seen as a commodity for animal feed and biomass fuel. Water lettuce as an invader lignocellulosic biomass with high crop yield can be used in anaerobic food digestion to generate liquid or gaseous fuel (Whangchai 2021).
Imp-P3 (Is it likely to impact trade?)	y - mod	0.2	Plants and seeds may attach to watercraft, trailers, and other boating equipment and be transported to uninfected waterbodies (Neuenschwander et al., 2009), therefore trade via the Great Lakes could be impacted.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - low	0.1	" Water lettuce grows in a variety of aquatic habitats, e.g., slow-moving rivers, streams, lakes, reservoirs, wetlands, seasonal waterbodies, floodplains, ponds, irrigation channels, canals, and rice fields (Bhadha et al.,

## Weed Risk Assessment for *Pistia stratiotes* L. (Water lettuce)

Question ID	Answer - Uncertainty	Score	Notes (and references)
			2015; Gul et al., 2017; Howard & Harley, 1998; Khan et al., 2014; Tamire & Mengistou, 2012; Thomaz et al., 2006).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	Cows find <i>P. stratiotes</i> unpalatable, the plants can be fed to pigs (Holm et al., 1977; Thayer et al.; EPPO, 2017).
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	Water lettuce is not in direct competition as a weed in production systems, rather it can impact other things like irrigation.
<b>GEOGRAPHIC POTENTIAL</b>			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF).
<b>Plant hardiness zones</b>			
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	Some evidence it can survive short periods of cold to -6.6°C ( <i>Pistia</i> Species, Nile Cabbage, Shellflower, Water Cabbage, Water Lettuce, 2022).
Geo-Z10 (Zone 10)	y - mod	N/A	Can survive this temperature ( <i>Pistia</i> Species, Nile Cabbage, Shellflower, Water Cabbage, Water Lettuce, 2022).
Geo-Z11 (Zone 11)	y - mod	N/A	Can survive this temperature ( <i>Pistia</i> Species, Nile Cabbage, Shellflower, Water Cabbage, Water Lettuce, 2022).
Geo-Z12 (Zone 12)	y - negl	N/A	Water lettuce can survive temperatures at and above 15°C (GISD, 2022).
Geo-Z13 (Zone 13)	y - negl	N/A	Optimal growth conditions are between 22-30°C with the maximum temperature being 35°C (GISD, 2022).
<b>Köppen -Geiger climate classes</b>			
Geo-C1 (Tropical rainforest)	y - mod	N/A	Preferred (Mikulyuk et al., 2021).
Geo-C2 (Tropical savanna)	y - mod	N/A	Preferred (Mikulyuk et al., 2021).
Geo-C3 (Steppe)	n - mod	N/A	Map comparisons between <i>pistia</i> distribution and climate classes around the globe indicate this is not a suitable climate for growth ( <a href="https://www.discoverlife.org/mp/20m?kind=Pistia+stratiotes">https://www.discoverlife.org/mp/20m?kind=Pistia+stratiotes</a> )
Geo-C4 (Desert)	n - mod	N/A	Map comparisons between <i>pistia</i> distribution and climate classes around the globe indicate this is not a suitable

## Weed Risk Assessment for *Pistia stratiotes* L. (Water lettuce)

Question ID	Answer - Uncertainty	Score	Notes (and references)
			climate for growth ( <a href="https://www.discoverlife.org/mp/20m?kind=Pistia+stratiotes">https://www.discoverlife.org/mp/20m?kind=Pistia+stratiotes</a> )
Geo-C5 (Mediterranean)	n - high	N/A	0
Geo-C6 (Humid subtropical)	y - mod	N/A	Tolerated (Mikulyuk et al., 2021).
Geo-C7 (Marine west coast)	y - mod	N/A	0
Geo-C8 (Humid cont. warm sum.)	y - mod	N/A	Southern part of lower peninsula (Mikulyuk et al., 2021).
Geo-C9 (Humid cont. cool sum.)	y - mod	N/A	Most of Michigan, tolerated by <i>Pistia</i> (Mikulyuk et al., 2021).
Geo-C10 (Subarctic)	n - negl	N/A	Cannot survive freezing temperatures
Geo-C11 (Tundra)	n - negl	N/A	Cannot survive freezing temperatures
Geo-C12 (Icecap)	n - negl	N/A	Cannot survive freezing temperatures
<b>10-inch precipitation bands</b>			
Geo-R1 (0-10 inches; 0-25 cm)	y - negl	N/A	Answering yes to all since this is an aquatic species, not necessarily dependent on precipitation but on the availability of open bodies of water.
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 peninsula and northern lower peninsula.
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
<b>ENTRY POTENTIAL</b>			
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	-	N/A	

## Weed Risk Assessment for *Pistia stratiotes* L. (Water lettuce)

Question ID	Answer - Uncertainty	Score	Notes (and references)
no evidence of trade or resale; (d) Commercially cultivated or other evidence of trade or resale]			
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	