United States Department of Agriculture

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Animal and Plant Health Inspection Service

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Version 1

Weed Risk Assessment for *Hygrophila polysperma* (Roxb.) T. Anderson (Acanthaceae) – Miramar weed

Top: Submerged *Hygrophila polysperma* plant. Bottom: Emergent *H. polysperma* plants (source: Winterton, 2014).

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Introduction

Plant Protection and Quarantine (PPQ) regulates noxious weeds under the authority of the Plant Protection Act (7 U.S.C. § 7701-7786, 2000) and the Federal Seed Act (7 U.S.C. § 1581-1610, 1939). A noxious weed is defined as "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment" (7 U.S.C. § 7701-7786, 2000). We use weed risk assessment (WRA)—specifically, the PPQ WRA model (Koop et al., 2012)—to evaluate the risk potential of plants, including those newly detected in the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

Because the PPQ WRA model is geographically and climatically neutral, it can be used to evaluate the baseline invasive/weed potential of any plant species for the entire United States or for any area within it. As part of this analysis, we use a stochastic simulation to evaluate how much the uncertainty associated with the analysis affects the model outcomes. We also use GIS overlays to evaluate those areas of the United States that may be suitable for the establishment of the plant. For more information on the PPQ WRA process, please refer to the document, *Background information on the PPQ Weed Risk Assessment*, which is available upon request.

***Hygrophila polysperma* (Roxb.) T. Anderson – Miramar weed**

Species Information

Family: Acanthaceae

Synonyms: *Justicia polysperma* Roxb. (Weber, 2003).

Common names: miramar weed, East Indian swampweed, Indian swampweed, hygro, *Hygrophila*, miramar weed (Langeland and Burks, 1998; NGRP, 2014).

Botanical description: *Hygrophila polysperma* is an aquatic annual or perennial herb that can grow either emerged or fully submerged. It grows 10-20 cm tall and has scrambling or erect stems. The leaves of *H. polysperma* are opposite, 2-8 cm long, and lanceolate to ovate in shape (Les and Wunderlin, 1981; Zhengyi et al., 2014).

Initiation: PPQ received a market access request for *Hygrophila corymbosa*, *H. difformis*, *H. pinnatifida*, and *H. polysperma* aquatic plants for propagation from the Ministry of Food, Agriculture and Fisheries of the Danish Plant Directorate (MFAF, 2009). These *Hygrophila* species are not native to the United States (NGRP, 2014) and may pose a threat to U.S. natural and agricultural resources. Although *H. polysperma* is already regulated as a U.S. Federal Noxious Weed and did not need to be evaluated, the PERAL weed team evaluated it for comparison with the other *Hygrophila* species.

Foreign distribution: *Hygrophila polysperma* is native to India, Bangladesh, Bhutan, Nepal, Pakistan, Myanmar, Vietnam, and China (Bailey and Bailey, 1976; Langeland and Burks, 1998; NGRP, 2014). It is naturalized in Mexico

(Kasselmann, 2003; Mora-Olivo et al., 2008) and reported from Germany (Nault and Mikulyuk, 2009).

U.S. distribution and status: In the United States, *H. polysperma* is naturalized in Florida, Texas (NGRP, 2014), Alabama (Kartesz, 2014), Kentucky, and South Carolina (EDDMapS, 2014). It has also been reported from lakes in Virginia (NRCS, 2014) but this species is probably not naturalized there (Les and Wunderlin, 1981). *Hygrophila polysperma* is listed as a U.S. Federal Noxious Weed and as a state noxious weed in Alabama, California, Florida, Indiana, Massachusetts, Minnesota, North Carolina, New Hampshire, Oklahoma, South Carolina, and Vermont (NGRP, 2014).

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

1. *Hygrophila polysperma* analysis

Establishment/Spread Potential

Hygrophila polysperma was detected in Lee County, Florida in 1979 (Les and Wunderlin, 1981) and rapidly spread to dozens of other public water bodies in Florida (Langeland and Burks, 1998). It has also spread to South Carolina, Alabama (Kartesz, 2014), and Texas (Angerstein and Lemke, 1994). *Hygrophila polysperma* can grow at low light levels that occur at up to two meters underwater (Spencer and Bowes, 1985) as well as at the water surface, where it forms dense mats of vegetation (Doyle et al., 2003). This species can quickly spread by vegetative stem fragments that readily root to produce new plants (Angerstein and Lemke, 1994; Les and Wunderlin, 1981; van Dijk et al., 1986). *Hygrophila polysperma* is a popular aquarium plant (Les and Wunderlin, 1981) and may have been initially introduced into waterways through dumping of aquaria (Angerstein and Lemke, 1994). We had a moderate amount of uncertainty for this risk element.

Risk score = 21 Uncertainty index = 0.18

Impact Potential

In bodies of water in natural areas, *H. polysperma* can occupy the entire water column (ISSG, 2014), outcompeting and displacing native vegetation (Cuda and Sutton, 2000; Doyle et al., 2003; Weber, 2003). In urban and suburban areas, it forms large floating mats that clog and interfere with the functions of culverts, pump stations, and other water control structures (Cuda and Sutton, 2000; Duke et al., 2000; Sutton, 1995; van Dijk et al., 1986) and may increase desirable habitat for mosquito development (Cuda and Sutton, 2000; Nault and Mikulyuk, 2009). *Hygrophila polysperma* is listed as a U.S. Federal Noxious Weed (NRCS, 2014) and is controlled in natural areas, and urban and suburban settings (Duke et al., 2000; IFAS, 2012). We had a moderate amount of uncertainty for this risk element.

Risk score = 3.6 Uncertainty index = 0.13

[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).

Geographic Potential Based on three climatic variables, we estimate that about 40 percent of the United States is suitable for the establishment of *H. polysperma* (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 *H. polysperma* represents the joint distribution of Plant Hardiness Zones 7-13, areas with 0-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, desert, Mediterranean, humid subtropical, and marine west coast. Note that in this weed risk assessment it was not clear if *H. polysperma* occurs in Plant Hardiness Zone 7. Because *H. polysperma* has been reported surviving in a pond in Richmond, Virginia for 15 to 20 years (Cuda and Sutton, 2000), we assumed it could occur in Plant Hardiness Zone 7 for this prediction.

The area estimated is likely conservative since it only uses three climatic variables. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish. *Hygrophila polysperma* is an aquatic plant that can grow either emerged or fully submerged (Les and Wunderlin, 1981; Spencer and Bowes, 1985). It occurs in freshwater lakes, ponds, and in riparian habitats (Weber, 2003).

Entry Potential We did not assess the entry potential of *H. polysperma* because it is already present in the United States (Kartesz, 2014; Les and Wunderlin, 1981).

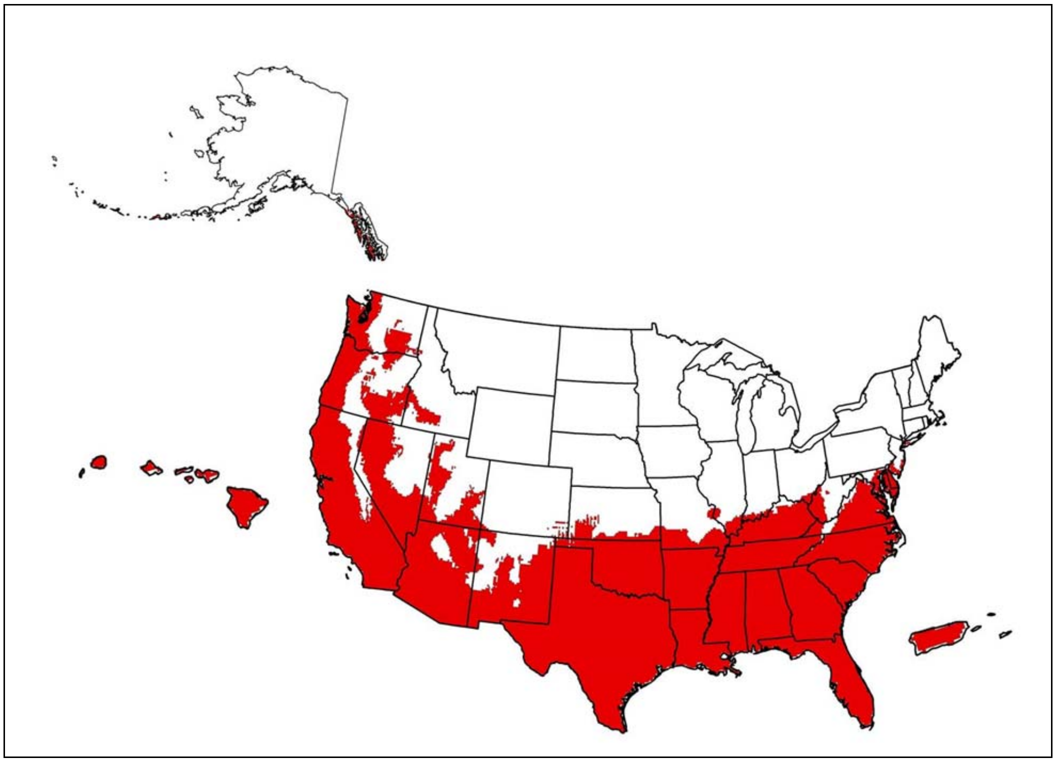

Figure 1. Predicted distribution of *H. polysperma* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 95.2%
P(Minor Invader) = 4.7%
P(Non-Invader) = 0.1%
Risk Result = High Risk
Secondary Screening = Not Applicable

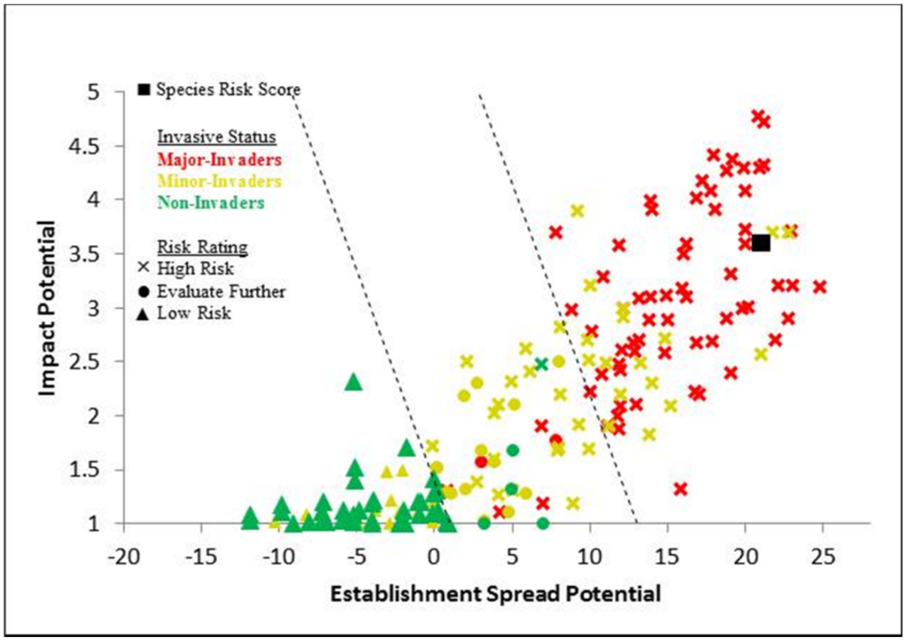

Figure 2. *Hygrophila polysperma* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

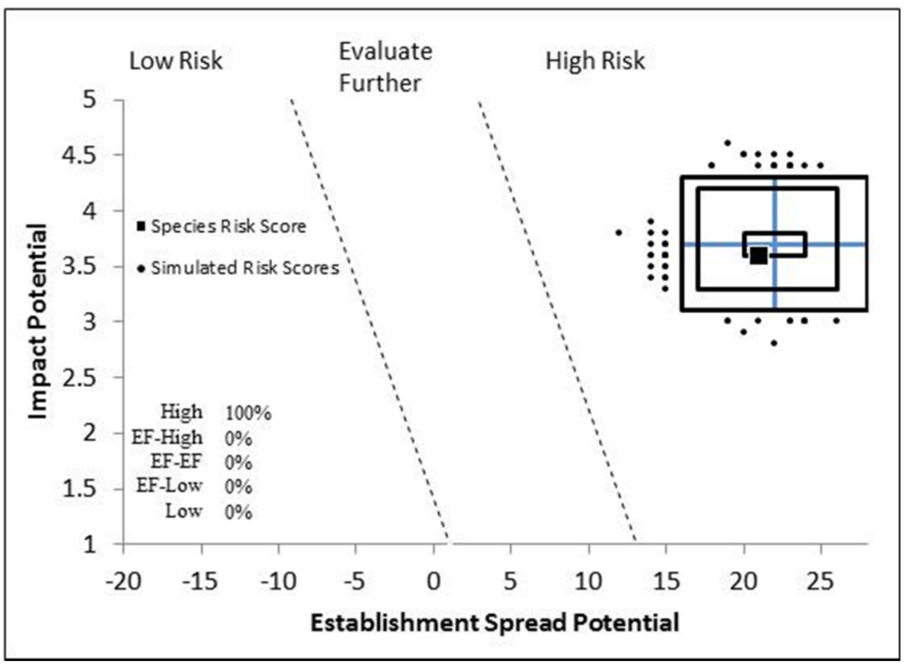

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Hygrophila polysperma*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *H. polysperma* is High Risk. *Hygrophila polysperma* shares traits in common with other major invaders (Fig. 2) used to develop and validate the PPQ WRA model. One hundred percent of the simulated risk scores received a rating of High Risk, indicating that our result is very robust. The results of this weed risk assessment support *H. polysperma*'s status as a U.S. Federal Noxious Weed and a State Noxious Weed in at least 11 states (NGRP, 2014). Control of existing infestations is challenging; mechanical control can disperse vegetative pieces that re-root to form new plants (Angerstein and Lemke, 1994; Les and Wunderlin, 1981; van Dijk et al., 1986). In experiments, *H. polysperma* stem fragment regrowth surpassed regrowth of even *Hydrilla* fragments (Spencer and Bowes, 1985). *Hygrophila polysperma* can also be difficult to control with herbicides (Cuda and Sutton, 2000), but grass carp can help control infestations in conjunction with herbicide applications (Sutton, 1995).

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Appendix A. Weed risk assessment for *Hygrophila polysperma* (Roxb.) T. Anderson (Acanthaceae). The following information came from the original risk assessment, which is available upon request (full responses and all guidance). We modified the information to fit on the page.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 (Status/invasiveness outside its native range)	f - negl	5	Native to Southeast Asia (Bailey and Bailey, 1976; Langeland and Burks, 1998; NGRP, 2014). Naturalized in Lee County, Florida (Les and Wunderlin, 1981); Texas (Angerstein and Lemke, 1994); and Mexico (Mora-Olivo et al., 2008). In Florida, "extensive growth *Hygrophila* has been found at various locations" (van Dijk et al., 1986). "Subsequent collections [from Florida] have shown [*H. polysperma*] to be well distributed and established in Lee County" (Les and Wunderlin, 1981). "[E]xpanding problem in south Florida canals....Found in a dozen public lakes and rivers by 1990...and in 18 public water bodies by 1994" (Langeland and Burks, 1998). "*Hygrophila* is continuing to expand its range and become increasingly more abundant" (Cuda and Sutton, 2000). Also occurs in South Carolina and Alabama (Kartesz, 2014). Alternate answers for the Monte Carlo simulation were both "e."
ES-2 (Is the species highly domesticated)	n - low	0	A few cultivars of *H. polysperma* exist (Dave's Garden, 2014) but we found no evidence of breeding efforts to reduce weed potential.
ES-3 (Weedy congeners)	y - negl	1	*Hygrophila costata*, which is native to North and South America, is a Class 2 Regionally Prohibited Weed in New South Wales, Australia (all outbreaks must be reported within 24 hours, eradicated from any sites where it is present, and the plant is prohibited from sale) because *H. costata* displaces native species and interferes with boating and recreational water activities (Gorham and Hosking, 2013). Holm et al. (1979) lists *Hygrophila pobeguini* as a significant weed in Nigeria, *H. angustifolia* as a principal weed in Cambodia, and *H. phlomoides* as a principal weed in India and Cambodia.
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	Submerged *H. polysperma* plants have "low light compensation and saturation points for photosynthesis" and can grow at over 2 meters of water depth; "[t]hey are thus shaded-adapted plants and are able to show net CO_2 uptake under very low light conditions" (Spencer and Bowes, 1985). *Hygrophila polysperma* can also grow at higher light levels, growing fully and partially submerged in water, as well as an emergent plant on the shore (Botts et al., 1990; Spencer and Bowes, 1985). Prefers riverine habitats (Les and Wunderlin, 1981). Low to very high light is recommended for aquarium growth (Windeløv, 2004).
ES-5 (Climbing or smothering growth form)	n - low	0	We found no evidence. *Hygrophila polysperma* is not a vine; it is an aquatic plant in the family Acanthaceae (NGRP, 2014).
ES-6 (Forms dense thickets)	y - negl	2	Can form dense mats of submerged vegetation (Langeland and Burks, 1998; Spencer and Bowes, 1985; Weber, 2003), and forms a dense canopy at the water-air surface (Doyle et al., 2003).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-7 (Aquatic)	y - negl	1	Grows as a submerged or emerged aquatic plant (Les and Wunderlin, 1981; Spencer and Bowes, 1985).
ES-8 (Grass)	n - negl	0	Not a grass; aquatic plant in the family Acanthaceae (NGRP, 2014).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	Herbaceous plant in the family Acanthaceae (Bailey and Bailey, 1976) which is not known to contain nitrogen-fixing species (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	y - low	1	Produces seeds (Gunn and Ritchie, 1988; Les and Wunderlin, 1981; Spencer and Bowes, 1985), but it is not known if seeds are a major factor in reproduction in Florida (Spencer and Bowes, 1985; Sutton, 1995). Only emergent plants produce flowers (Kovach et al., 1992). Because seeds may not contribute to dispersal in Florida, we used low uncertainty.
ES-11 (Self-compatible or apomictic)	y - mod	1	"There is a high percentage of seed set in the Florida populations indicating that the species is probably autogamous" (Les and Wunderlin, 1981). We used moderate uncertainty because the author was speculating.
ES-12 (Requires special pollinators)	n - low	0	"The flowers are probably self-pollinating because most set seed" (Sutton, 1995). Based on this evidence, we answered no, because self-pollinating flowers will not require specialist pollinators. However, we used moderate uncertainty because the author was speculating.
ES-13 (Minimum generation time)	a - high	2	"Elongation of shoots begins with the increase in water temperature around March. Shoots reach the surface in late spring. During the summer, fragments with numerous adventitious roots break away from the mats. Upon contact with soil they will readily root. During the hot weather of late August the whole shoot will break off near the root crown....The whole mat can sink and produce a new colony, or individual pieces can do so. The old root crowns quickly produce new shoots, which grow slowly during the winter" (ISSG, 2014). The brittle stems fragment easily and readily root to form new stands of plants (Sutton, 1995; Langeland and Burks, 1998). "[A]ble to expand a population rapidly, in one case from 0.04 ha (0.1 acre) to over 0.41 ha (10 acres) in 1 year" (Langeland and Burks, 1998). "*Hygrophila* has a high growth rate and is capable of rapidly expanding a population ten-fold in one year" (Cuda and Sutton, 2000). Annual (Bailey and Bailey, 1976). Perennial herb (Les and Wunderlin, 1981). Based on this information, *H. polysperma* is likely to reproduce at least once a year. However, based on the rapid vegetative spread of this plant, we answered "a" because we think *H. polysperma* can reproduce several times a year vegetatively. Because the generative time for *H. polysperma* is not explicitly stated in the literature, we used high uncertainty. The alternate answers for the Monte Carlo simulation were both "b."
ES-14 (Prolific reproduction)	? - max	0	Unknown. "Each flower may produce 20 to 30 seeds, but it is unknown whether the seeds are a major factor in the reproduction and spread of [the] species" (Sutton, 1995).
ES-15 (Propagules likely	y - negl	1	This species was initially misidentified as a species of

Question ID	Answer - Uncertainty	Score	Notes (and references)
to be dispersed unintentionally by people)			Ludwigia and given the common name "oriental ludwigia" when it was first introduced to the aquarium trade (Angerstein and Lemke, 1994). Les and Wunderlin (1981) thought that *H. polysperma* became established in Florida as "the result of the careless disposal of cultivated aquarium specimens…[or] it was planted in Florida to supply local aquarium plant dealers and...has escaped." Angerstein and Lemke (1994) surmised that *H. polysperma* was introduced into Texas "directly through cultivation by local aquatic plant nurseries...or indirectly through careless dumping by aquarists."
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - low	2	"It is also possible for *H. polysperma* to be a 'hitchhiker' plant with other species ordered through water garden catalogs" (Nault and Mikulyuk, 2009). Listed as a potential seed contaminant by in the GRIN database (NGRP, 2014). Aquatic plants in general are easily moved with aquatic organisms in the horticultural trade (Maki and Galatowitsch, 2004).
ES-17 (Number of natural dispersal vectors)	2	0	Fruit and seed description used to answer questions ES-17a through ES-17e: "Fruit a capsule, 4-6 mm long, explosively dehiscent by 2 valves. Seeds minute" (Les and Wunderlin, 1981). 20-30 seeds per capsule (Zhengyi et al., 2014).
ES-17a (Wind dispersal)	n - mod		We found no evidence. The related species *H. costata* is described as spreading by wind and water (Gorham and Hosking, 2013) but this may be referring to wind moving the plant stems along the water surface.
ES-17b (Water dispersal)	y - negl		Species of *Hygrophila* "...have adpressed seed hairs, which are erected in water to form a slimy mass" that enlarges the surface area of the seeds and allows the seeds to float on water (van der Pijl, 1982). Stem fragments float to new areas to produce new populations (Sutton, 1995).
ES-17c (Bird dispersal)	? - max		Aquatic plants in general are frequently dispersed by waterfowl (Brochet et al., 2009; Figuerola and Green, 2002) but we found no direct evidence that this occurs for *Hygrophila*. Thus, we answered unknown.
ES-17d (Animal external dispersal)	y - mod		*Hygrophila polysperma* is transported "by wildlife moving between water bodies" (Nault and Mikulyuk, 2009). The related species *H. costata* spreads to new areas "when seeds and plant fragments attach to animals" (Gorham and Hosking, 2013). Because there was little information about this dispersal method, we used moderate uncertainty.
ES-17e (Animal internal dispersal)	n - mod		We found no evidence that *H. polysperma* is dispersed this way.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	Unknown. We found no evidence about seed dormancy in *H. polysperma*. However, secondary dormancy (when seeds become dormant under certain unfavorable environmental conditions) can be triggered in the related species *H. auriculata* by storing seeds in the dark for 5-20 days (Amritphale et al., 1993).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	Mutilation of plants is likely to disperse *H. polysperma*, because vegetative stem fragments readily and profusely root to produce new plants (Angerstein and Lemke, 1994; Les and Wunderlin, 1981; van Dijk et al., 1986). In

Question ID	Answer - Uncertainty	Score	Notes (and references)
			experiments, *H. polysperma* surpassed hydrilla regrowth potential from stem fragments; "*Hygrophila* showed a substantial capacity for regrowth....management practices should be selected to minimize *Hygrophila* dispersion by fragmentation" (Spencer and Bowes, 1985). Mechanical control methods may disperse stem fragments (Sutton, 1995). Laboratory studies determined that cutting leaves off *H. polysperma* plants had little effect on the physiological functioning of the remaining leaves (Kovach et al., 1992).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	? - max		*Hygrophila polysperma* is more tolerant to several aquatic herbicides than hydrilla, and *H. polysperma* plants in Florida treatment plots quickly regrew to pretreatment levels after being burned down with endothal (Sutton, 1995). "Chemical treatments using invert applications of endothal (7-oxabicyclo [2.2.1) heptane-2, 3, dicarboxylic acid) plus copper did not seem to be effective for *Hygrophila*" but the plant is sensitive to endothal (Spencer and Bowes, 1985). Difficult to control with registered herbicides (Cuda and Sutton, 2000). Not listed by Heap (2014). Because this is evidence for tolerance, but not true resistance, we answered unknown.
ES-21 (Number of cold hardiness zones suitable for its survival)	7	0	
ES-22 (Number of climate types suitable for its survival)	7	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - high	0	*Hygrophila* species have anti-microbial properties (Chandran et al., 2013; Meng and Liu, 2009; Pal and Samanta, 2011). Because we did not find any evidence of allelopathy against plants, we answered no, but used high uncertainty.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this plant is parasitic; it is an aquatic plant in the family Acanthaceae (NGRP, 2014), which is not reported to contain parasitic plants (Heide-Jørgensen, 2008; Nickrent, 2009).
Impacts to Natural Systems			
Imp-N1 (Change ecosystem processes and parameters that affect other species)	y - low	0.4	"The dense stands and mats of vegetation that are characteristically formed when *H. polysperma* is introduced outside of its native range can decrease the oxygen levels by limiting water circulation and increased decomposition of dead plants. Increased sediment levels are observed with increasing *H. polysperma* abundance....Dense mats of *H. polysperma* also have the ability to change water hydrology and quality, negatively affecting the ecosystem in which it occurs" (Nault and Mikulyuk, 2009).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-N2 (Change community structure)	? - max		Can occupy the entire water column (ISSG, 2014) and forms monocultural stands (Langeland and Burks, 1998). From this evidence it is not clear if *H. polysperma* changes the structure of an aquatic community, so we answered unknown.
Imp-N3 (Change community composition)	y - negl	0.2	Outcompetes and displaces native vegetation (Cuda and Sutton, 2000; Doyle et al., 2003; Weber, 2003). Forms monocultural stands (Langeland and Burks, 1998). Submerged *H. polysperma* plants may be able to outcompete native plants because *H. polysperma* is able to grow and fix CO_2 at low light levels where native plants experience a net CO_2 loss (Spencer and Bowes, 1985; van Dijk et al., 1986). Additionally, *H. polysperma* grows large amounts of biomass at the water surface and outcompetes submersed aquatic plants (Doyle et al., 2003; Spencer and Bowes, 1985; van Dijk et al., 1986). "In the locales in which it has been introduced, it has often become the dominant plant species, outcompeting both native and previously established exotic species" (Nault and Mikulyuk, 2009).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species)	y - negl	0.1	Threat to the endangered Texas wild rice (*Zizania texana*) in the San Marcos River (Owens et al., 2001). "The high growth potential of *H. polysperma* may pose a serious threat to the native flora and biotic integrity of the Comal and San Marcos river ecosystems" (Angerstein and Lemke, 1994). *Hygrophila polysperma* can completely displace native submersed plants in river ecosystems (Cuda and Sutton, 2000). "Decomposing mats of *H. polysperma* also have the ability to cause fish kills by creating low oxygen levels in the water" (Nault and Mikulyuk, 2009).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	y - low	0.1	"[*Hygrophila*] *polysperma* poses a serious threat to the biotic integrity of the Comal and San Marcos Rivers" (Doyle et al., 2003).
Imp-N6 (Weed status in natural systems)	c - negl	0.6	Osceola County, Florida was awarded a $2,881,000 grant by the Environmental Protection Agency (EPA) to manage *Hygrophila* and *Hydrilla* in the Upper Kissimmee Chain of Lakes (IFAS, 2012). Reported to be a problem of the Withacoochee River in Florida (Sutton and Dingler, 2000) and a threat to the Comal and San Marcos Rivers in Texas (Doyle et al., 2003). Based on this evidence, we answered "c." The alternate answers for the Monte Carlo simulation were both "b."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	y - negl	0.1	The fragments form large floating mats that clog culverts, pump stations, and other water control structures, and interfere with their function (Cuda and Sutton, 2000; Duke et al., 2000; Sutton, 1995; van Dijk et al., 1986). May increase desirable habitat for mosquito reproduction and development (Cuda and Sutton, 2000; Nault and Mikulyuk, 2009).
Imp-A2 (Changes or limits recreational use of an area)	y - low	0.1	"[Impedes] recreational activities, and diminish[es] aesthetic value" (Nault and Mikulyuk, 2009). Interferes with navigation in Florida canals (Langeland and Burks,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			1998; Ramey and Peichel, 2001).
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	y - mod	0.1	Grows very fast in aquariums and may crowd out other aquarium plants without regular pinching (Windeløv, 2004).
Imp-A4 (Weed status in anthropogenic systems)	c - negl	0.4	Targeted for control in Florida canals using herbicides and grass carp (Sutton, 1995) and mechanical control (Cuda and Sutton, 2000; Duke et al., 2000). Regulated as a Federal Noxious Weed by USDA-APHIS and as a state noxious weed by Alabama, California, Florida, Indiana, Massachusetts, Minnesota, North Carolina, New Hampshire, Oklahoma, South Carolina, and Vermont (NGRP, 2014). *Hygrophila polysperma* has caused "serious weed problems, most notably in canals in South Florida" (van Dijk et al., 1986). Present in water management canals in Florida (Spencer and Bowes, 1985). "[The] reduction in recreational and aesthetic value associated with *H. polysperma* can also cause a decline in waterfront property values, as well as possible declines in tourism related revenue for the community" (Nault and Mikulyuk, 2009). 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 of *H. polysperma* having this impact.
Imp-P2 (Lowers commodity value)	n - mod	0	We found no evidence of *H. polysperma* having this impact.
Imp-P3 (Is it likely to impact trade)	y - high	0.2	*Hygrophila polysperma* is listed as an invasive alien plant by the European and Mediterranean Plant Protection Organization (EPPO) (2012), which means that EPPO "strongly recommends countries endangered by [*H. polysperma*] to take measures to prevent...introduction and spread, or to manage unwanted populations (for example with publicity, restrictions on sale and planting, and control measures)." *Hygrophila polysperma* can move as a contaminant of other aquatic plants in trade (Nault and Mikulyuk, 2009). Based on this evidence, we answered yes, but with high uncertainty because EPPO only recommends regulating *H. polysperma*.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - negl	0.1	Clogs irrigation channels and pumps (Cuda and Sutton, 2000; Langeland and Burks, 1998; van Dijk et al., 1986). Problematic in agricultural irrigation canals in Mexico (Mora-Olivo et al., 2008).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - negl	0	Rated as non-toxic by Cuda and Sutton (2000). Grass carp feed on *Hygrophila* (Duke et al., 2000; Spencer and Bowes, 1985) but are ineffective at controlling this plant because it appears to be rather unpalatable to the fish (Cuda and Sutton, 2000). In parts of Asia, the seed masses of *Hygrophila* species are consumed by humans (van der Pijl, 1982).
Imp-P6 (Weed status in production systems)	b - low	0.2	Reported to be a weed of rice fields in India (Moody, 1989). Threat to rice fields (Cuda and Sutton, 2000;

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Mukherjee, 2011). Reported to be a problem in citrus groves in Florida by Sutton and Dingler (2000) but these authors did not include any information about how *H. polysperma* was impacting citrus plants. Because we found no evidence of *H. polysperma* being targeted for management in production systems, we answered "b" with low uncertainty. The alternate answers for the Monte Carlo simulation were both "c."
GEOGRAPHIC POTENTIAL			Note: Below "p.s." refers to geo-referenced point source (latitude/longitude) data; "occur." refers to occurrence (presence only) data for a region.
Plant cold hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence of *H. polysperma* occurring in this zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence of *H. polysperma* occurring in this zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence of *H. polysperma* occurring in this zone.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no evidence of *H. polysperma* occurring in this zone.
Geo-Z5 (Zone 5)	n - low	N/A	We found no evidence of *H. polysperma* occurring in this zone.
Geo-Z6 (Zone 6)	n - high	N/A	We found no evidence of *H. polysperma* occurring in this zone.
Geo-Z7 (Zone 7)	y - low	N/A	The United States (Virginia) (Cuda and Sutton, 2000, occur.) and Germany (Nault and Mikulyuk, 2009, occur.). A gardening website lists this species as being hardy at 5-40 °F (Dave's Garden, 2014). Because *H. polysperma* has been reported surviving in a pond in Richmond, Virginia for 15 to 20 years (Cuda and Sutton, 2000), we assumed it could occur in Plant Hardiness Zone 7.
Geo-Z8 (Zone 8)	y - low	N/A	Germany (Nault and Mikulyuk, 2009, occur.). A gardening website lists this species as being hardy at 5-40 °F (Dave's Garden, 2014).
Geo-Z9 (Zone 9)	y - negl	N/A	Mexico (GBIF, 2014, p.s.) and China (NGRP, 2014, occur.). A gardening website lists this species as being hardy at 5-40 °F (Dave's Garden, 2014).
Geo-Z10 (Zone 10)	y - negl	N/A	Mexico (GBIF, 2014, p.s.), Pakistan, and Nepal (NGRP, 2014, occur.). A minimum temperature of 4 °C (39 °F) is required for growth (Nault and Mikulyuk, 2009; Ramey and Peichel, 2001). A gardening website lists this species as being hardy at 5-40 °F (Dave's Garden, 2014).
Geo-Z11 (Zone 11)	y - negl	N/A	The United States (Florida) and Mexico (GBIF, 2014, p.s.). A gardening website lists this species as being hardy at 5-40 °F (Dave's Garden, 2014).
Geo-Z12 (Zone 12)	y - low	N/A	Malaysia (Nault and Mikulyuk, 2009, occur.).
Geo-Z13 (Zone 13)	y - low	N/A	Malaysia (Nault and Mikulyuk, 2009, occur.). 22-28 °C (71-82 °F) is the optimum temperature range for growth (Ramey and Peichel, 2001). Grows at 18-30 °C in the environment and in aquariums (ISSG, 2014; Windeløv, 2004).
Köppen-Geiger climate			

Question ID	Answer - Uncertainty	Score	Notes (and references)
classes			
Geo-C1 (Tropical rainforest)	y - low	N/A	Bangladesh (NGRP, 2014, occur.) and Malaysia (Nault and Mikulyuk, 2009, occur.).
Geo-C2 (Tropical savanna)	y - negl	N/A	Mexico and Burma (GBIF, 2014, p.s.).
Geo-C3 (Steppe)	y - low	N/A	Pakistan (NGRP, 2014, occur.).
Geo-C4 (Desert)	y - mod	N/A	Pakistan (NGRP, 2014, occur.). We used moderate uncertainty because this is an aquatic plant.
Geo-C5 (Mediterranean)	y - low	N/A	Pakistan (NGRP, 2014, occur.).
Geo-C6 (Humid subtropical)	y - negl	N/A	The United States (Florida) and Taiwan (GBIF, 2014, p.s.).
Geo-C7 (Marine west coast)	y - low	N/A	Germany (Nault and Mikulyuk, 2009, occur.).
Geo-C8 (Humid cont. warm sum.)	n - high	N/A	We found no evidence that it occurs in this climate class.
Geo-C9 (Humid cont. cool sum.)	n - low	N/A	We found no evidence that it occurs in this climate class.
Geo-C10 (Subarctic)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C12 (Icecap)	n - negl	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 - mod	N/A	Pakistan (NGRP, 2014, occur.). We used moderate uncertainty because *H. polysperma* is an aquatic plant, but answered yes because submerged plants would be buffered from the effects of low precipitation.
Geo-R2 (10-20 inches; 25-51 cm)	y - mod	N/A	Pakistan (NGRP, 2014, occur.). We used moderate uncertainty because *H. polysperma* is an aquatic plant, but answered yes because submerged plants would be buffered from the effects of low precipitation.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Mexico (GBIF, 2014, p.s.).
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Mexico (GBIF, 2014, p.s.).
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	The United States (Florida) (GBIF, 2014, p.s.).
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Mexico (GBIF, 2014, p.s.).
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Mexico (GBIF, 2014, p.s.).
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Mexico (GBIF, 2014, p.s.).
Geo-R9 (80-90 inches; 203-229 cm)	y - low	N/A	Bangladesh (NGRP, 2014, occur.).
Geo-R10 (90-100 inches; 229-254 cm)	y - low	N/A	Bangladesh (NGRP, 2014, occur.).
Geo-R11 (100+ inches; 254+ cm)	y - low	N/A	Bhutan (NGRP, 2014, occur.).
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	Naturalized in Florida, Texas (NGRP, 2014), Alabama (Kartesz, 2014), Kentucky, and South Carolina (EDDMapS, 2014). Reported from lakes in Virginia (NRCS, 2014) but this species is probably not naturalized

Question ID	Answer - Uncertainty	Score	Notes (and references)
			there (Les and Wunderlin, 1981). First reported from Florida in 1965 (Les and Wunderlin, 1981).
Ent-2 (Plant proposed for entry, or entry is imminent)		N/A	
Ent-3 (Human value & cultivation/trade status)		N/A	"It is likely that *H. polysperma* has been introduced into Florida via the aquarium plant industry because the species has been extremely popular with aquarium enthusiasts since its introduction into the market in 1948" (Les and Wunderlin, 1981). Available for sale on the internet (Darbyshire and Prasad, 2009). *Hygrophila polysperma* seeds are used as a medication in parts of Asia (Spencer and Bowes, 1985).
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	