United States Department of Agriculture

Weed Risk Assessment for *Hygrophila corymbosa* (Blume) Lindau (Acanthaceae) – Temple plant

United States Department of Agriculture

Animal and Plant Health Inspection Service

January 27, 2015

Version 1

Photographs illustrating different forms of *Hygrophila corymbosa* (source: Ševčík, 2012).

Agency Contact:

Plant Epidemiology and Risk Analysis Laboratory
Center for Plant Health Science and Technology

Plant Protection and Quarantine
Animal and Plant Health Inspection Service
United States Department of Agriculture
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

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 corymbosa (Blume) Lindau – Temple plant

Species Information

Family: Acanthaceae

Synonyms: *Nomaphila corymbosa* Blume.

Common names: Temple plant (Mukherjee, 2011), staghorn (Gann et al., 2014), giant hygro (GBIF, 2014), starhorn (NRCS, 2014).

Botanical description: *Hygrophila corymbosa* is a herbaceous aquatic plant that can grow either emerged or fully submerged. It has opposite leaves that are 8-10 cm long and 3-5 cm wide. The entire plant is covered with glandular hairs. *Hygrophila corymbosa* plants are highly variable and many different varieties exist (Kasselmann, 2003; Paffrath, 1979).

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 the United States. For example, *H. polysperma* is regulated as a U.S. Federal Noxious Weed (NRCS, 2014). Thus, the PERAL weed team initiated a weed risk assessment for *H. corymbosa*.

Foreign distribution: This species is native to India (Paffrath, 1979) and southeast Asia (Windeløv, 2004) and introduced to and naturalized in Taiwan (Wu et al., 2010). It is cultivated in Europe (Windeløv, 2004).

U.S. distribution and status: *Hygrophila corymbosa* has been cultivated in

aquariums in the United States since the 1970s (Rataj and Horeman, 1977). This species has recently naturalized in Florida in Hillsborough (USF Herbarium, 2014) and Broward counties (Gann et al., 2014; Kartesz, 2014) but is currently not regulated at the state or Federal level.

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

1. *Hygrophila corymbosa* analysis

Establishment/Spread Potential *Hygrophila corymbosa* is an aquatic plant that can grow either submerged or emerged (Paffrath, 1979). This species has naturalized in Taiwan (Wu et al., 2010), and in Hillsborough (USF Herbarium, 2014) and Broward counties in Florida (Gann et al., 2014; Kartesz, 2014). Like other *Hygrophila* species, ***H. corymbosa*** easily re-roots from broken off plants or side-shoots and cut vegetative pieces (Aqualand, 2011; Paffrath, 1979). One aquarist on an aquatic plant message board noted that he or she had dumped waste aquarium water containing ***H. corymbosa*** cuttings into his or her yard and the plants then rooted and began growing emerged (Aquatic Plant Central, 2006). We had very high uncertainty here due to the lack of information on the biology of this species; we answered several questions with general information about the genus *Hygrophila*.

Risk score = 13 Uncertainty index = 0.33

Impact Potential We found no information that ***H. corymbosa*** has caused negative impacts where it has naturalized. However, that may be because ***H. corymbosa*** has only very recently naturalized in new areas (Taiwan, Florida; see above). We answered most questions in this risk element as 'unknown,' resulting in an extremely high amount of uncertainty for this risk element.

Risk score = 1.2 Uncertainty index = 0.62

Geographic Potential Based on three climatic variables, we estimate that about 10 percent of the United States is suitable for the establishment of ***H. corymbosa*** (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. corymbosa*** represents the joint distribution of Plant Hardiness Zones 9-13, areas with 0-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, humid subtropical, and marine west coast. If grown submerged, ***H. corymbosa*** might be suitable for areas with <20 inches of precipitation, but we had high uncertainty about this. We had greater than average uncertainty for this section because we had very little geo-referenced point source data to use for this species.

[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).

The estimated area is likely a conservative estimate as 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. In Florida, *H. corymbosa* occurs in disturbed wetlands such as banks and canals (Gann et al., 2014).

Entry Potential We did not assess the entry potential of *H. corymbosa* because it is already present in the United States (Kartesz, 2014; NRCS, 2014; USF Herbarium, 2014).

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

2. Results

Model Probabilities: P(Major Invader) = 41.3%
P(Minor Invader) = 54.5%
P(Non-Invader) = 4.1%

Risk Result = High Risk

Secondary Screening = Not Applicable

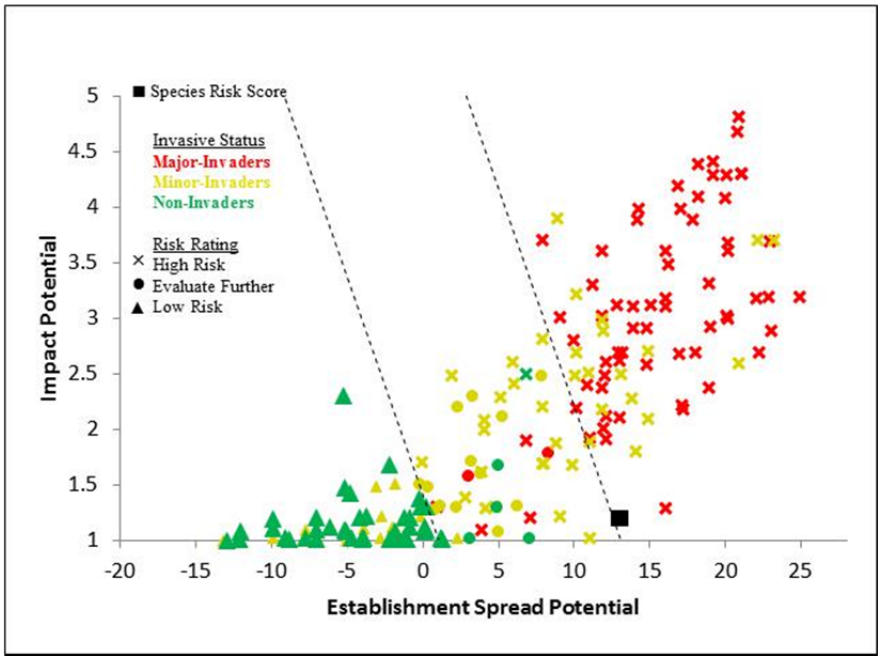

Figure 2. *Hygrophila corymbosa* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

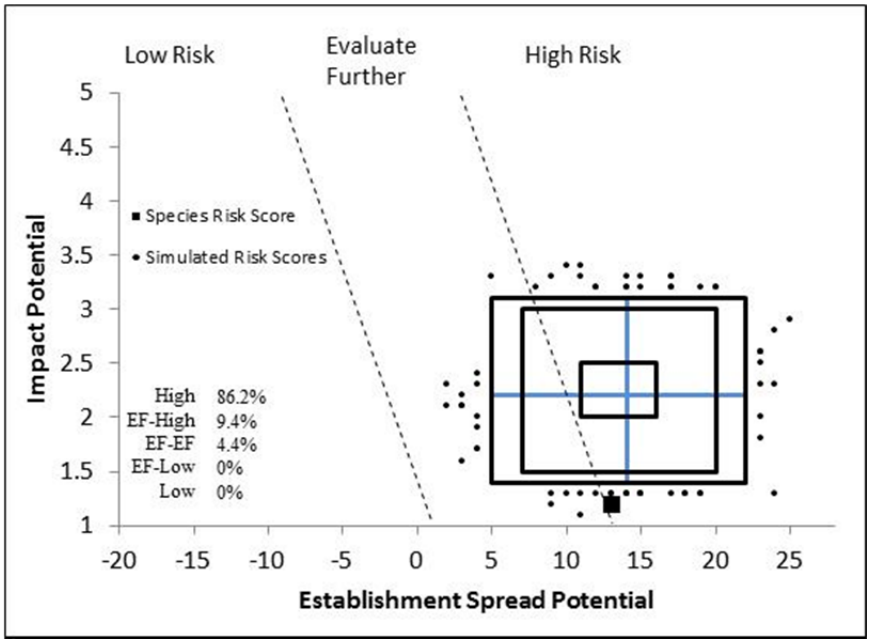

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *H. corymbosa*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *H. corymbosa* is High Risk. *Hygrophila corymbosa* received this result because it shares many establishment and spread traits with other known U.S. major invaders (Fig. 2). Even though our overall uncertainty for this risk assessment was very high, 86 percent of our simulated risk scores received a score of High Risk (Fig. 3). The Texas Parks and Wildlife Department conducted weed risk assessments for several *Hygrophila* species using a version of the Australian Weed Risk Assessment (Pheloung et al., 1999) modified for aquatic plants (Chilton, 2014). *Hygrophila corymbosa* received a score of 12 (Cook-Hildreth, 2014), well above the "reject" rating given to species with a score of 6 or higher.

We found no evidence that *H. corymbosa* has had any negative impacts, but that may be because it has only very recently become naturalized in Taiwan (Wu et al., 2010) and Florida (Kartesz, 2014; USF Herbarium, 2014). Consequently, we have no information about the behavior of this species in those new areas. *Hygrophila corymbosa* is available for sale as a cultivated aquatic plant in aquariums and in outdoor ponds (Paffrath, 1979; Stokes et al., 2004; Windeløv, 2004).

4. Literature Cited

7 U.S.C. § 1581-1610. 1939. The Federal Seed Act, Title 7 United States Code § 1581-1610.

7 U.S.C. § 7701-7786. 2000. Plant Protection Act, Title 7 United States Code § 7701-7786.

Amritphale, D., A. Gutch, and A. I. Hsiao. 1993. Acidification, growth promoter and red light effects on germination of skotodormant seeds of *Hygrophila auriculata*. Environmental and Experimental Botany 33(4):471-477.

Aqualand. 2011. Temple Plant. Aqualand's inside scoop on *Hygrophila corymbosa.* Aqualand Fact Sheet. AqualandPetsPlus.com. Last accessed September 17, 2014, http://aqualandpetsplus.com/Plant,%20Temple%20Plant.htm.

Aquatic Plant Central. 2006. Question about *Hygrophila corymbosa* "angustifolia" Aquatic Plant Central, General Interest Forums, General Aquarium Plants Discussions. Last accessed November 6, 2013, http://www.aquaticplantcentral.com/forumapc/general-aquarium-plants-discussions/14143-question-about-hygrophila-corymbosa-angustifolia.html.

Champion, P. D., and J. S. Clayton. 2000. Border control for potential aquatic weeds. Stage 1. Weed risk model. Science for Conservation 141:1-48.

Chandran, R. P., S. Manju, M. V. Vysakhi, P. K. Shaji, and G. A. Nair.

2013. In vitro antimicrobial activities of *Hygrophila schulli* (Buch.-Ham) leaf and root extracts against clinically important human pathogens. Biomedical & Pharmacology Journal 6(2):421-428.

Chilton, E. W. 2014. Information about three *Hygrophila* species. Personal communication to L. Kohl on April 1, 2014, from Dr. Earl W. Chilton II, Aquatic Habitat Enhancement Program Director, Texas Parks and Wildlife Department, regarding weed risk assessments on *Hygrophila corymbosa*, *H. pinnatifida*, and *H. difformis* conducted by the Texas Parks and Wildlife Department.

Cook-Hildreth, L. 2014. Information about three *Hygrophila* species. Personal communication to L. Kohl on April 17, 2014, from Luci Cook-Hildreth, Aquatic Nuisance Species Biologist, Texas Parks and Wildlife Department, regarding weed risk assessments on Hygrophila corymbosa, H. pinnatifida, and H. difformis conducted by the Texas Parks and Wildlife Department.

Cuda, J. P., and D. L. Sutton. 2000. Is the aquatic weed hygrophila, *Hygrophila polysperma* (Polemoniales: Acanthaceae), a suitable target for classical biological control? Pages 337-348 *in* N. R. Spencer, (ed.). Proceedings of the X International Symposium on Biological Control of Weeds, Montana State University, Bozeman, Montana. July 4-14, 1999.

Dave's Garden. 2014. PlantFiles. Dave's Garden. Last accessed July 23, 2013, from http://davesgarden.com/guides/pf/.

Figuerola, J., and A. J. Green. 2002. Dispersal of aquatic organisms by waterbirds: a review of past research and priorities for future studies. Freshwater Biology 47(3):483-494.

FishandTips.com. 2014. *Hygrophila corymbosa* (giant hygro, temple plant). FishandTips.com. Last accessed April 18, 2014, http://www.fishandtips.com/displaydb.php?ID=72.

Gann, G. D., K. A. Bradley, and S. W. Woodmansee. 2014. The Floristic Inventory of South Florida Database Online. The Institute for Regional Conservation, Delray Beach, Florida. http://regionalconservation.org/. (Archived at PERAL).

GBIF. 2014. Data Portal. Global Biodiversity Information Facility (GBIF). Last accessed January 3, 2014, http://data.gbif.org/welcome.htm.

Gorham, P., and J. Hosking. 2013. Weed Alert: *Hygrophila*. New South Wales Department of Primary Industries, New South Wales, Australia. Last accessed March 31, 2014, http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/profiles/hygrophila.

Heap, I. 2014. The International Survey of Herbicide Resistant Weeds Last accessed January 3, 2014, http://www.weedscience.org.

Heide-Jørgensen, H. S. 2008. Parasitic Flowering Plants. Brill Publishers, Leiden, The Netherlands. 442 pp.

Holm, L. G., J. V. Pancho, J. P. Herberger, and D. L. Plucknett. 1979. A Geographical Atlas of World Weeds. Krieger Publishing Company,

Malabar, Florida, U.S.A. 391 pp.
Huang, J.-C., W.-K. Wang, K.-H. Hong, and T.-Y. Chiang. 2001. Population differentiation and phylogeography of *Hygrophila pogonocalyx* based on RAPDs fingerprints. Aquatic Botany 70:269-280.
IPPC. 2012. International Standards for Phytosanitary Measures No. 5: Glossary of Phytosanitary Terms. Food and Agriculture Organization of the United Nations, Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy.
Kartesz, J. T. 2014. North American Plant Atlas [maps generated from Kartesz, J.T. 2010. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press)]. The Biota of North America Program, Chapel Hill, N.C. http://www.bonap.org/MapSwitchboard.html. (Archived at PERAL).
Kasselmann, C. 2003. Aquarium plants. Krieger Publishing Company, Malabar, Florida. 518 pp.
Koop, A., L. Fowler, L. Newton, and B. Caton. 2012. Development and validation of a weed screening tool for the United States. Biological Invasions 14(2):273-294.
Langeland, K. A., and K. C. Burks. 1998. Identification and biology of non-native plants in Florida's natural areas. University of Florida, Gainesville, Florida.
Les, D. H., and R. B. Wunderlin. 1981. *Hygrophila polysperma* (Acanthaceae) in Florida. Florida Science 44(3):189-192.
Maki, K., and S. Galatowitsch. 2004. Movement of invasive aquatic plants into Minnesota (USA) through horticultural trade. Biological Conservation 118(3):389-396.
Martin, P. G., and J. M. Dowd. 1990. A protein sequence study of the dicotyledons and its relevance to the evolution of the legumes and nitrogen fixation. Australian Systematic Botany 3:91-100.
Meng, L., and Y. Liu. 2009. Inhibitory effects of *Hygrophila difformis* on the growth of *Microcystis aeruginosa*. Environmental Pollution and Control.
MFAF. 2009. Aquarium plants in growing medium – Denmark - Pre-Requisite Requirements for Commodity Risk Assessments. Ministry of Food, Agriculture and Fisheries (MFAF), The Danish Plant Directorate, Denmark, Lyngby, Denmark. 4 pp.
Mora-Olivo, A., T. F. Daniel, and M. Martínez. 2008. First record in the Mexican flora of *Hygrophila polysperma* (Acanthaceae), an aquatic weed. Revista Mexicana de Biodiversidad 79(1):265-269.
Mukherjee, A. 2011. Prospects for classical biological control of the aquatic invasive weed *Hygrophila polysperma* (Acanthaceae), University of Florida, Gainesville, Florida.
Nault, M. E., and A. Mikulyuk. 2009. East Indian Hygrophila (*Hygrophila polysperma*). A technical review of distribution, ecology, impacts, and management. PUB-SS-1049. Wisconsin Department of Natural Resources Bureau of Science Services, Madison, Wisconsin.

NGRP. 2014. Germplasm Resources Information Network (GRIN). United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program (NGRP). http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl?language=en. (Archived at PERAL).

Nickrent, D. 2009. Parasitic plant classification. Southern Illinois University Carbondale, Carbondale, IL, U.S.A. Last accessed June 12, 2009, http://www.parasiticplants.siu.edu/ListParasites.html.

NRCS. 2014. The PLANTS Database. United States Department of Agriculture, Natural Resources Conservation Service (NRCS), The National Plant Data Center. Last accessed January 3, 2014, http://plants.usda.gov.

Paffrath, K. 1979. *Hygrophila corymbosa* (Blume). Aqua Planta 4(3):9-10.

Pal, D., and K. Samanta. 2011. CNS activities of ethanol extract of aerial parts of *Hygrophila difformis* in mice. Acta Poloniae Pharmaceutica - Drug Research 68(1):75-81.

Pet Product News International. 2011a. Texas proposal could stop trade in dozens of aquarium plants. Pet Product News International. Last accessed November 6, 2013, http://www.petproductnews.com/headlines/2011/01/07/texas-proposal-could-stop-trade-in-dozens-of-aquarium-plants.aspx.

Pet Product News International. 2011b. Texas updates 'white list' of aquatic plants as approval vote nears. Pet Product News International. Last accessed November 6, 2013, http://www.petproductnews.com/headlines/2011/01/12/texas-updates-white-list-of-aquatic-plants.aspx.

Pheloung, P. C., P. A. Williams, and S. R. Halloy. 1999. A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. Journal of Environmental Management 57:239-251.

Randall, R. P. 2012. A Global Compendium of Weeds. 2nd edition. Department of Agriculture and Food, Western Australia, South Perth, Australia. 1119 pp.

Rataj, K., and T. J. Horeman. 1977. Aquarium plants: Their identification, cultivation and ecology. T.F.H. Publications, Neptune, New Jersey 448 pp.

Sand-Jensen, K. 2003. Drag and reconfiguration of freshwater macrophytes. Freshwater Biology 48(2):271-283.

Ševčík, J. 2012. *Hygrophila corymbosa* (Blume) Lindau photographs. Biological Library. BioLib.cz. Images used with permission from photographer. Last accessed December 18, 2014, http://www.biolib.cz/en/taxon/id192873/.

Spencer, W., and G. Bowes. 1985. *Limnophila* and *Hygrophila*: A review and physiological assessment of their weed potential in Florida. Journal of Aquatic Plant Management 23:7-16.

Stokes, K., K. O'Neill, and R. A. McDonald. 2004. Invasive Species in Ireland. Environment & Heritage Service and National Parks &

Wildlife Service, Belfast, Ireland. 153 pp.
Sutton, D. L. 1995. *Hygrophila* is replacing *Hydrilla* in south Florida. Aquatics 14(3):4-10.
USF Herbarium. 2014. University of South Florida Herbarium. Department of Cell Biology, Microbiology and Molecular Biology, University of South Florida, Tampa, Florida. Available at http://biology.usf.edu/cmmb/research/herbarium/.
van der Pijl, L. 1982. Principles of Dispersal in Higher Plants (3 ed.). Springer-Verlag, Berlin. 214 pp.
van Dijk, G. M., D. D. Thayer, and W. T. Haller. 1986. Growth of *Hygrophila* and *Hydrilla* in flowing water. Journal of Aquatic Plant Management 24:85-87.
Weber, E. 2003. Invasive Plant Species of the World: A Reference Guide to Environmental Weeds. CABI Publishing, Wallingford, UK. 548 pp.
Wilson, R. 2006. The genus *Hygrophila*. Tropical Fish Hobbyist June 2006.
Wilstermann-Hildebrand, M. 2012. Die Gattung *Hygrophila* - Wasserfreunde. Heimbiotop. Last accessed September 17, 2014, http://www.heimbiotop.de/hygrophila.html.
Windeløv, H. 2004. Tropica Aquarium Plants Catalogue. Tropica Aquarium Plants, Egå, Denmark. 97 pp.
Wu, S.-H., T. Y. A. Yang, Y.-C. Teng, C.-Y. Chang, K.-C. Yang, and C.-F. Hsieh. 2010. Insights of the latest naturalized flora of Taiwan: Change in the past eight years. Taiwania 55(2):139-159.
Zhengyi, W., P. H. Raven, and H. Deyuan. 2014. Flora of China. Missouri Botanical Garden Press, St. Louis, Missouri. Last accessed January 3, 2014, http://flora.huh.harvard.edu/china/.

Appendix A. Weed risk assessment for *Hygrophila corymbosa* (Blume) Lindau (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)	e - low	2	Native to India (Paffrath, 1979) and southeast Asia (Windeløv, 2004). Introduced to and naturalized in Taiwan (Wu et al., 2010). Naturalized in Florida in Hillsborough (USF Herbarium, 2014) and Broward counties (Gann et al., 2014; Kartesz, 2014), where it was described as "abundant" (USF Herbarium, 2014). Based on this evidence, we answered "e." The alternate answers for the Monte Carlo simulation were both "f."
ES-2 (Is the species highly domesticated)	n - low	0	Several different varieties of *H. corymbosa* are available for sale (Windeløv, 2004) but we found no evidence of breeding efforts to reduce weediness.
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 - high	1	Depending on the variety, *H. corymbosa* requires low to very high light in aquariums (Paffrath, 1979; Windeløv, 2004). Grows more commonly on land than under water (Sand-Jensen, 2003). "Grows easily above the water surface" (Windeløv, 2004). The related species *H. polysperma* has "low light compensation and saturation points for photosynthesis" and is a "shaded-adapted...able to show net CO2 uptake under very low light conditions" (Spencer and Bowes, 1985). Based on this evidence, we answered yes, but with high uncertainty.
ES-5 (Climbing or smothering growth form)	n - low	0	*Hygrophila corymbosa* is not a vine; it is an erect, branched, aquatic plant (Kasselmann, 2003).
ES-6 (Forms dense thickets)	? - max	0	We did not find any information on *H. corymbosa* forming dense thickets. However, the related species *H. polysperma* forms dense mats of vegetation in the environment (Langeland and Burks, 1998; Spencer and Bowes, 1985; Weber, 2003), as does *H. costata* (Gorham and Hosking, 2013). Based on this evidence, we answered unknown.
ES-7 (Aquatic)	y - negl	1	Can be grown as either a submerged or emergent aquatic plant (Paffrath, 1979).
ES-8 (Grass)	n - negl	0	Not a grass; aquatic plant in the family Acanthaceae (NGRP, 2014).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-9 (Nitrogen-fixing woody plant)	n - low	0	*Hygrophila corymbosa* shoots can become woody (Wilstermann-Hildebrand, 2012) but this plant is in the family Acanthaceae (NRCS, 2014; Paffrath, 1979), which is not known to contain nitrogen-fixing species listed by Martin and Dowd (1990).
ES-10 (Does it produce viable seeds or spores)	? - max	0	Will produce seed when grown emersed (Aqualand, 2011). The *H. corymbosa* specimen from Hillsborough County in Florida was producing an inflorescence (USF Herbarium, 2014). Other species of *Hygrophila* produce viable seeds (Amritphale et al., 1993; Gorham and Hosking, 2013; Les and Wunderlin, 1981). We answered unknown because we do not know if the seeds produced by *H. corymbosa* are viable.
ES-11 (Self-compatible or apomictic)	? - max	0	Unknown.
ES-12 (Requires special pollinators)	n - high	0	We found no information for *Hygrophila corymbosa*. Other species of *Hygrophila* do not require specialist pollinators: *H. pogonocalyx* is pollinated bees (Huang et al., 2001) and H. polysperma is thought to be self-pollinated (Les and Wunderlin, 1981). Based on this information, we answered no, but with high uncertainty.
ES-13 (Minimum generation time)	b - high	1	Perennial (NRCS, 2014). "It grows fast [in aquaria] and the shoots must be pinched out regularly if you want to keep the plant under water" (Windeløv, 2004). Can be propagated from a leaf cutting (Aquatic Plant Central, 2006). The variety *H. corymbosa* "Siamensis" will grow out of aquariums to bloom (Wilson, 2006). We answered "b" based on the aquatic growth form of this plant. However, because we did not find any information about how quickly this plant reproduces under natural conditions, we used high uncertainty. The alternate answers for the Monte Carlo simulation were "a" and "c."
ES-14 (Prolific reproduction)	? - max	0	Unknown.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - low	1	One aquarist on an aquatic plant message board noted that he or she had dumped waste aquarium water containing *H. corymbosa* cuttings into his or her yard and the plants then rooted and began growing in an emerged state (Aquatic Plant Central, 2006). Many different varieties of this species exist in the aquatic plant trade (Wilson, 2006; Windeløv, 2004). These varieties are highly variable in appearance and are sometimes mislabeled as different species (i.e., *H. corymbosa* "Siamensis" may be labeled for sale as *H. siamensis*) (Wilson, 2006).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - high	2	We did not find any information specific to *H. corymbosa*, but the related species *H. polysperma* can move as a "hitchhiker" plant with other species ordered through water garden catalogs (Nault and Mikulyuk, 2009), and aquatic plants in general are easily moved with aquatic organisms in the horticultural trade (Maki and Galatowitsch, 2004). Based on this evidence, we answered yes, but with high uncertainty.
ES-17 (Number of natural dispersal vectors)	2	0	Genus-level seed description used to answer ES-17a through ES-17e: "Seeds discoid, covered with long mucilaginous trichomes" (Zhengyi et al., 2014).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17a (Wind dispersal)	n - mod		We found no evidence for *H. corymbosa*. 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 - low		Species of *Hygrophila* "...have adpressed seed hairs, which are erected in water to form a slimy mass" which enlarges the surface area of the seeds and allows the seeds to float on water (van der Pijl, 1982). Other species of *Hygrophila* are dispersed by water (Gorham and Hosking, 2013; Sutton, 1995).
ES-17c (Bird dispersal)	? - max		Aquatic plants in general are frequently dispersed by waterfowl (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 - high		The related species *H. costata* spreads to new areas "when seeds and plant fragments attach to animals" (Gorham and Hosking, 2013) and *H. polysperma* is transported "by wildlife moving between water bodies" (Nault and Mikulyuk, 2009). Based on this evidence and the genus-level seed description, we answered yes, but with high uncertainty because our answer was based on congeneric information.
ES-17e (Animal internal dispersal)	n - mod		We found no evidence that *Hygrophila* species can be 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. corymbosa*. 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 - low	1	*Hygrophila corymbosa* is propagated by cuttings and side-shoots (Aqualand, 2011; Paffrath, 1979). Plants in the genus *Hygrophila* easily re-root from cut stem pieces to produce new plants (Wilson, 2006). Mechanical control methods can disperse stem fragments of the related species *H. polysperma* (Sutton, 1995) and *H. costata* (Gorham and Hosking, 2013). Based on this evidence, we answered yes with low uncertainty.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - mod	0	We found no evidence of herbicide resistance or tolerance in *H. corymbosa*. Not listed by Heap (2014). We used moderate uncertainty because very little information exists on control methods for this species. However, because *H. corymbosa* is not a weed of agricultural areas, it is unlikely to have been exposed to herbicides and developed resistance.
ES-21 (Number of cold hardiness zones suitable for its survival)	5	0	
ES-22 (Number of climate types suitable for its survival)	5	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	

Question ID	Answer - Uncertainty	Score	Notes (and references)
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	? - max	0	*Hygrophila* species have anti-microbial properties (Chandran et al., 2013; Meng and Liu, 2009; Pal and Samanta, 2011). Because this information is from laboratory studies and not field observations, we answered unknown.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this plant is parasitic; the family Acanthaceae 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)	? - max		We found very little information about this species. *Hygrophila corymbosa* has only started naturalizing in its introduced range in the past few years (USF Herbarium, 2014; Wu et al., 2010), which may not be enough time for it to cause noticeable impacts. Thus, we answered unknown for most questions in the natural areas and anthropogenic sections of this weed risk assessment.
Imp-N2 (Change community structure)	? - max		Unknown.
Imp-N3 (Change community composition)	? - max		Unknown.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species)	? - max		Unknown.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	? - max		Unknown.
Imp-N6 (Weed status in natural systems)	b - mod	0.2	In 2011, Texas proposed making *H. corymbosa* ineligible for sale (Pet Product News International, 2011a) but that regulation was never enacted due to concerns expressed by business interests (Pet Product News International, 2011b). The Texas Parks and Wildlife Department conducted weed risk assessments for several *Hygrophila* species using a version of the Australian Weed Risk Assessment (Pheloung et al., 1999) modified for aquatic plants (Chilton, 2014). *Hygrophila corymbosa* received a score of 12 (Cook-Hildreth, 2014), well above the "reject" rating given to species with a score of 6 or higher. Randall (2012) lists this plant as a weed because it has naturalized in Florida. Because the state of Texas considered listing this species, we concluded that *H. corymbosa* has been considered a weed, and answered "b" with moderate uncertainty. The alternate answers for the Monte Carlo simulation were "a" and "c."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	? - max		Unknown. See comment in Imp-N1.
Imp-A2 (Changes or limits recreational use of an area)	? - max		Unknown.
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	? - max		Unknown.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-A4 (Weed status in anthropogenic systems)	a - high	0	We found no evidence of *H. corymbosa* impacting urban and suburban areas. Thus, we answered "a" but used high uncertainty due to the lack of information on this species. The alternate answers for the Monte Carlo simulation were both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - high	0	We found no evidence about *H. corymbosa* having impacts in production systems. Thus, we answered no for questions Imp-P1, Imp-P2, and Imp-P3, but used high uncertainty because very little information is available about this species.
Imp-P2 (Lowers commodity value)	n - high	0	See comment in Imp-P1.
Imp-P3 (Is it likely to impact trade)	n - high	0	See comment in Imp-P1. According to National Agriculture Security Service (NASS) standards, *Hygrophila corymbosa* is a plant species accepted for import as seed or nursery stock into New Zealand (Champion and Clayton, 2000).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	? - max		Unknown. We found no evidence that *H. corymbosa* limits water in production systems, but the related species *H. polysperma* clogs irrigation channels and pumps (Cuda and Sutton, 2000; Langeland and Burks, 1998; Mora-Olivo et al., 2008; van Dijk et al., 1986).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	We found no evidence that *H. corymbosa* or other *Hygrophila* species are toxic to animals. 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)	a - high	0	We found no evidence of *H. corymbosa* impacting agricultural systems. Thus, we answered "a" but used high uncertainty due to the lack of information on this species. The alternate answers for the Monte Carlo simulation were both "b."
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. corymbosa* occurring in this zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence of *H. corymbosa* occurring in this zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence of *H. corymbosa* occurring in this zone.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no evidence of *H. corymbosa* occurring in this zone.
Geo-Z5 (Zone 5)	n - low	N/A	We found no evidence of *H. corymbosa* occurring in this zone.
Geo-Z6 (Zone 6)	n - low	N/A	We found no evidence of *H. corymbosa* occurring in this zone.
Geo-Z7 (Zone 7)	n - mod	N/A	We found no evidence of *H. corymbosa* occurring in this zone.
Geo-Z8 (Zone 8)	n - high	N/A	We found no evidence of *H. corymbosa* occurring in this zone.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z9 (Zone 9)	y - mod	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.). A gardening website lists this species as being hardy at 25-40 °F (Dave's Garden, 2014).
Geo-Z10 (Zone 10)	y - low	N/A	Taiwan (GBIF, 2014, p.s.) and the United States (Florida) (Gann et al., 2014; Kartesz, 2014, occur.). A gardening website lists this species as being hardy at 25-40 °F (Dave's Garden, 2014).
Geo-Z11 (Zone 11)	y - low	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.), Thailand (FishandTips.com, 2014; Windeløv, 2004, occur.). A gardening website lists this species as being hardy at 25-40 °F (Dave's Garden, 2014).
Geo-Z12 (Zone 12)	y - low	N/A	Thailand, Malaysia, and India (FishandTips.com, 2014; Windeløv, 2004, occur.).
Geo-Z13 (Zone 13)	y - low	N/A	Thailand, Malaysia (FishandTips.com, 2014; Windeløv, 2004, occur.). 20-30 °C is recommended for aquarium growth (Windeløv, 2004).
Köppen-Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - low	N/A	The United States (Florida) (Gann et al., 2014; Kartesz, 2014, occur.), India (FishandTips.com, 2014; Paffrath, 1979, occur.), and Malaysia (FishandTips.com, 2014; Windeløv, 2004, occur.).
Geo-C2 (Tropical savanna)	y - low	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.), Thailand (FishandTips.com, 2014; Windeløv, 2004, occur.).
Geo-C3 (Steppe)	y - mod	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.).
Geo-C4 (Desert)	n - high	N/A	We found no evidence of *H. corymbosa* occurring in this climate class.
Geo-C5 (Mediterranean)	n - high	N/A	We found no evidence of *H. corymbosa* occurring in this climate class.
Geo-C6 (Humid subtropical)	y - negl	N/A	Taiwan (GBIF, 2014, p.s.), the United States (Florida) (Gann et al., 2014; Kartesz, 2014, occur.), and India (FishandTips.com, 2014; Paffrath, 1979, occur.).
Geo-C7 (Marine west coast)	y - mod	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.).
Geo-C8 (Humid cont. warm sum.)	n - mod	N/A	We found no evidence of *H. corymbosa* occurring in this climate class.
Geo-C9 (Humid cont. cool sum.)	n - low	N/A	We found no evidence of *H. corymbosa* occurring in this climate class.
Geo-C10 (Subarctic)	n - negl	N/A	We found no evidence of *H. corymbosa* occurring in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence of *H. corymbosa* occurring in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence of *H. corymbosa* occurring in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - high	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.). We used high uncertainty because *H. corymbosa* is an aquatic plant, but answered yes because submerged plants would be buffered from the affects of low precipitation.
Geo-R2 (10-20 inches; 25-51 cm)	y - high	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.). We used high uncertainty because *H. corymbosa* is an aquatic plant, but answered yes because submerged plants would be buffered from the affects of low precipitation.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R3 (20-30 inches; 51-76 cm)	y - mod	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.).
Geo-R4 (30-40 inches; 76-102 cm)	y - low	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.).
Geo-R5 (40-50 inches; 102-127 cm)	y - low	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.).
Geo-R6 (50-60 inches; 127-152 cm)	y - low	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.), Thailand (FishandTips.com, 2014; Windeløv, 2004, occur.).
Geo-R7 (60-70 inches; 152-178 cm)	y - low	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.).
Geo-R8 (70-80 inches; 178-203 cm)	y - low	N/A	India (FishandTips.com, 2014; Paffrath, 1979, occur.), Thailand (FishandTips.com, 2014; Windeløv, 2004, occur.).
Geo-R9 (80-90 inches; 203-229 cm)	y - low	N/A	Thailand (FishandTips.com, 2014; Windeløv, 2004, occur.) and the United States (Florida) (Gann et al., 2014; Kartesz, 2014, occur.).
Geo-R10 (90-100 inches; 229-254 cm)	y - low	N/A	Thailand (FishandTips.com, 2014; Windeløv, 2004, occur.).
Geo-R11 (100+ inches; 254+ cm))	y - negl	N/A	Taiwan (GBIF, 2014, p.s.), Malaysia (FishandTips.com, 2014; Windeløv, 2004, occur.).
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	Present the United States in Florida (Kartesz, 2014; NRCS, 2014).
Ent-2 (Plant proposed for entry, or entry is imminent)		N/A	
Ent-3 (Human value & cultivation/trade status)		N/A	Cultivated in aquariums and in outdoor ponds (Paffrath, 1979). Imported into Ireland for cultivation (Stokes et al., 2004).
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	