United States Department of Agriculture

Weed Risk Assessment for *Hygrophila pinnatifida* (Dalzell) Sreem (Acanthaceae) – Fern hygrophila

United States Department of Agriculture

Animal and Plant Health Inspection Service

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Version 1

Left: Submerged *Hygrophila pinnatifida* plant (source: Ševčík, 2012). Right: Emerged *H. pinnatifida* specimen (© Kew Royal Botanic Gardens, 1878).

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 pinnatifida (Dalzell) Sreem – Fern hygrophila

Species Information

Family: Acanthaceae

Synonyms: *Adenosma pinnatifida*, *Nomaphila pinnatifida* Dalzell, *Synnema pinnatifidum* (The Plant List, 2010).

Common names: Fern *hygrophila* (EPPO, 2014), miramar weed, Indian swampweed (IUCN, 2014).

Botanical description: *Hygrophila pinnatifida* is an aquatic plant that can grow submerged or emerged. When grown emerged, *H. pinnatifida* is a 15-30 cm tall erect, branched, herbaceous plant with dense, glandular hairs. Its leaves grow 5-10 cm long and both sides have 6-8 lobes. When *H. pinnatifida* is grown submerged, its leaves become nearly twice as long, narrower, and have more lobes (Muth, 2009).

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 a Federal Noxious Weed (NRCS, 2014). Thus, the PERAL weed team initiated weed risk assessments for *H. pinnatifida*.

Foreign distribution: Native to India and introduced to Europe in 2008 as a

cultivated aquatic plant (Pedersen, 2010).

U.S. distribution and status: Introduced to the United States as an aquarium plant around 2010 (Hudson, 2011) and available for sale online (The Green Machine, 2013). Because *H. pinnatifida* is still relatively new to the aquarium trade (Hudson, 2011; Pedersen, 2010), it does not appear to be as widely cultivated as other *Hygrophila* species.

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

1. *Hygrophila pinnatifida* analysis

Establishment/Spread Potential

Hygrophila pinnatifida has only recently become commercially available as an aquarium plant (Hudson, 2011; Pedersen, 2010). Like other *Hygrophila* species, *H. pinnatifida* easily re-roots from side-shoots and vegetative pieces (Hudson, 2011; Wilson, 2006). Due to the lack of information on the biology of this species we answered several questions using general information about the genus *Hygrophila*. We had very high uncertainty in this risk element.

Risk score = 9 Uncertainty index = 0.34

Impact Potential

Hygrophila pinnatifida has only been in the nursery trade for a few years; it has not become naturalized and thus not had any impacts where it has been introduced for cultivation. Therefore, we answered the majority of 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 = 0.66

Geographic Potential

Based on three climatic variables, we estimate that 9.6 percent of the United States is suitable for the establishment of *H. pinnatifida* (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. pinnatifida* 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. pinnatifida* may be suitable for areas with less than 20 inches of rainfall, but we had high uncertainty about this. We had greater than average uncertainty for this section because we found no geo-referenced point source data for this species.

The area estimated likely represents 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

[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).

establish. In its native range in Asia, *H. pinnatifida* is found either floating or submerged in rivers and creeks (Muth, 2009; IUCN, 2014).

Entry Potential We did not assess the entry potential of *H. pinnatifida* because it is already present in the United States, where it is cultivated and commercially grown for aquaria (Hudson, 2011).

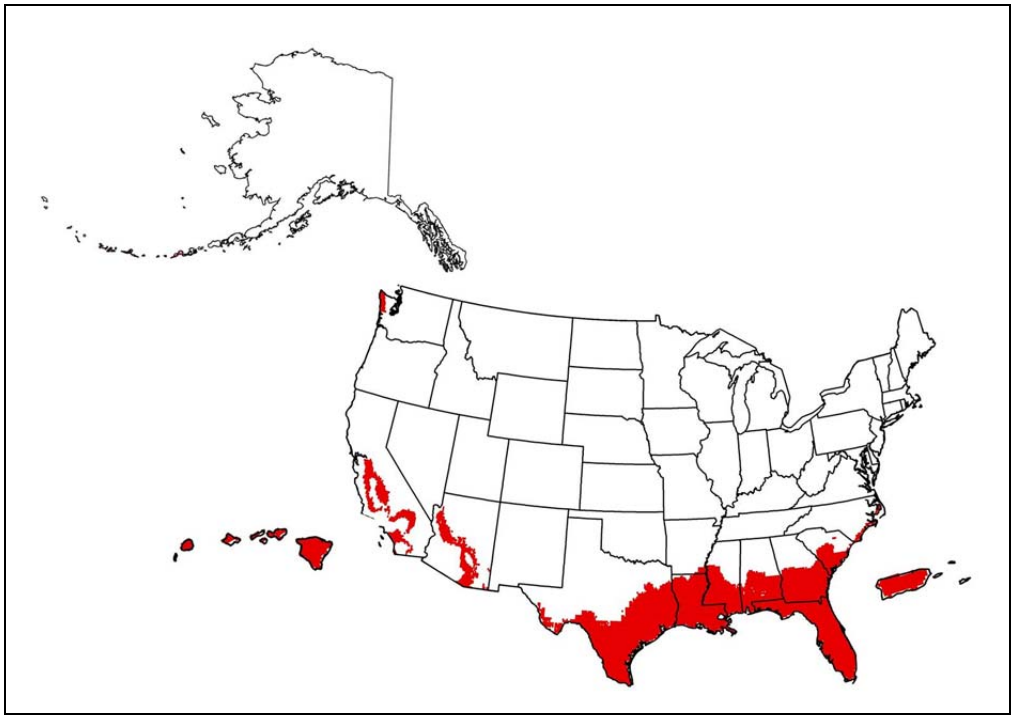

Figure 1. Predicted distribution of *H. pinnatifida* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 21.5%
P(Minor Invader) = 68.5%
P(Non-Invader) = 9.9%
Risk Result = Evaluate Further
Secondary Screening = Evaluate Further

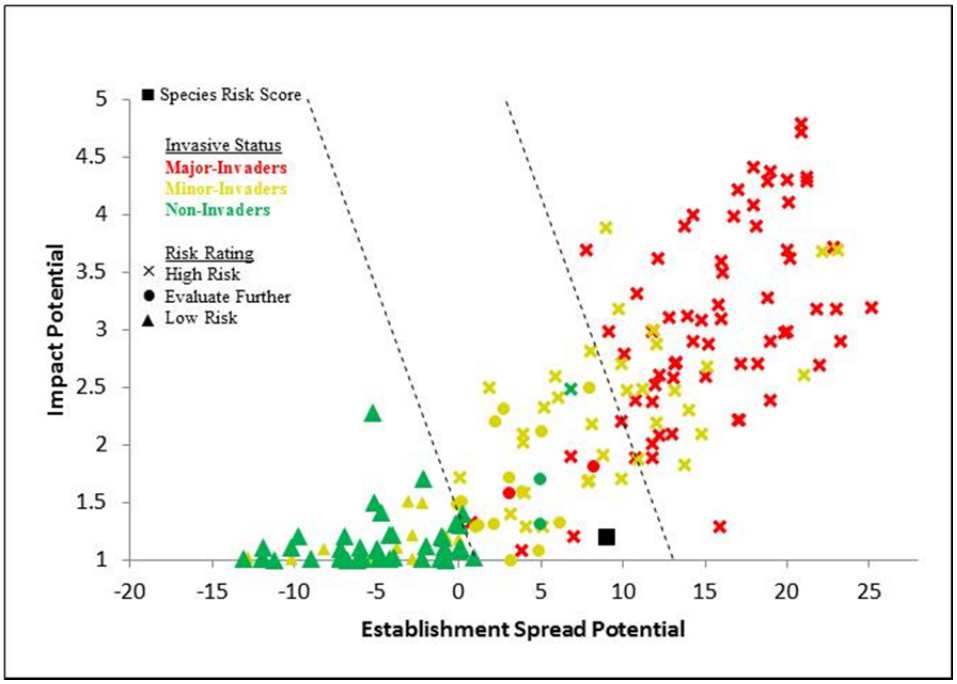

Figure 2. *H. pinnatifida* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

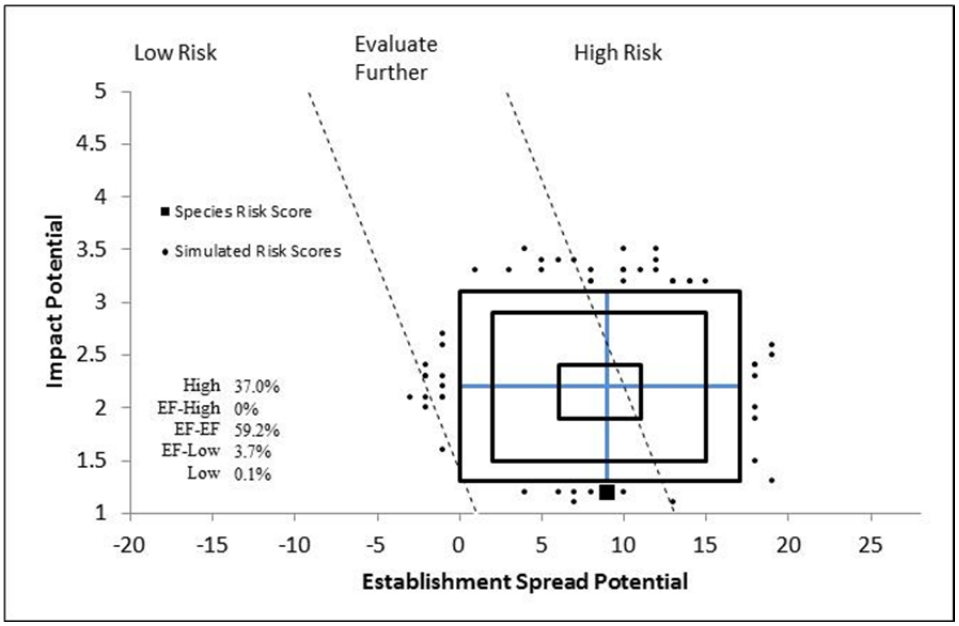

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *H. pinnatifida*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *H. pinnatifida* is Evaluate Further, and the result of the secondary screening is also Evaluate Further (Fig. 2). The Texas Parks and Wildlife Department used a version of the Australian Weed Risk Assessment (Pheloung et al., 1999) modified for aquatic plants and conducted weed risk assessments for several *Hygrophila* species (Chilton, 2014). *Hygrophila pinnatifida* received a score of 10 (Cook-Hildreth, 2014), greater than the "Reject" threshold score of 6.

Hygrophila pinnatifida has only recently been introduced outside of its native range (Pedersen, 2010) and has only been cultivated in the United States for a few years (Hudson, 2011). Thus, we found very little information about the biology of this species and answered many questions as unknown. This resulted in very large uncertainty (Fig. 3). *Hygrophila pinnatifida* is highly prized by aquarists for its unique, fern-like leaves (Muth, 2009; Pedersen, 2010), so this species may become more popular in the aquarium trade. Although it is available for sale online (The Green Machine, 2013) it is not yet widely available in big-box pet supply stores like other *Hygrophila* species (PetCo, 2013; PetSmart, 2013).

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.

Angerstein, M. B., and D. E. Lemke. 1994. First records of the aquatic weed *Hygrophila polysperma* (Acanthaceae) from Texas. Sida 16(2):365-371.

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.

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.

EPPO. 2014. PQR - EPPO's Plant Quarantine Data Retrieval System Version 5.0. European and Mediterranean Plant Protection Organization (EPPO), Paris, France.

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.

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.

Hudson, R. P. 2011. Updated: *Hygrophila pinnatifida*. Aqua Botanic's Aqua Bloggin. Last accessed November 6, 2013, http://www.aquabotanic.com/?p=1027.

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.

IUCN. 2014. *Hygrophila pinnatifida*. The IUCN red list of threatened species. International Union for Conservation of Nature and Natural Resources. Last accessed April 18, 2014, http://www.iucnredlist.org/details/168882/0.

Kew Royal Botanic Gardens. 1878. *Hygrophila pinnatifida* (Dalzell) Sreem. Specimen K000882363. Royal Botanic Garden, Kew. ©The Board of

Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew. http://specimens.kew.org/herbarium/K000882363.

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.

Muth, H. 2009. *Hygrophila pinnatifida* (Dalzell) Sreemadhavan (Acanthaceae), ein aquaristisch neuer Wasserfreund aus Indien. Aqua Planta 2:48-56.

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.

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.

Pandey, A. K., and N. N. Tripathi. 2010. Diversity and distribution of aromatic

plants in forests of Gorakhpur division, U.P., India. Biological Forum - An International Journal 2(2):25-33.

Pedersen, O. 2010. New Plants at InterZoo 2010. The Aquatic Gardener 23(3):7-15.

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.

PetCo. 2013. *Hygrophila difformis*. Petco Animal Supplies, Inc., San Diego, California. Last accessed December 5, 2013, http://www.petco.com/product/102913/Hygrophila-difformis.aspx.

PetSmart. 2013. Water wisteria plant. PetSmart Store Support Group, Inc., Phoenix, Arizona. Last accessed December 5, 2013, http://www.petsmart.com/product/index.jsp?productId=3958051&lmdn=Fish+Decor&f=PAD%2FpsNotAvailInUS%2FNo.

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.

Ševčík, J. 2012. *Hygrophila pinnatifida* (Dalzell) Sreem. photograph. Biological Library. BioLib.cz. Image used with permission from photographer. Last accessed December 18, 2014, http://www.biolib.cz/en/taxon/id1068238/.

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.

Sutton, D. L. 1995. *Hygrophila* is replacing *Hydrilla* in south Florida. Aquatics 14(3):4-10.

The Green Machine. 2013. *Hygrophila pinnatifida*. The Green Machine, Wrexham, United Kingdom. Last accessed November 6, 2013, http://www.thegreenmachineonline.com/shop/aquatics/plants/tropica-potted-plants/hygrophila-pinnatifida.

The Plant List. 2010. The Plant List. Version 1. United Nations Decade on Biodiversity, Kew Royal Botanic Gardens, and the Missouri Botanical Garden. http://www.theplantlist.org/. (Archived at PERAL).

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.
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 pinnatifida* (Dalzell) Sreem (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)	b - low	-2	Native to India, and introduced to Europe in 2008 (Pedersen, 2010) and to the United States around 2010 as an ornamental aquatic plant (Hudson, 2011). Because this plant is recently introduced with no evidence of escape, we answered "b" with low uncertainty. The alternate answers for the Monte Carlo simulation were both "d."
ES-2 (Is the species highly domesticated)	n - low	0	We found no evidence of breeding efforts to reduce weediness or to produce any new cultivars of this species in general. This plant is sold under the species name online (The Green Machine, 2013).
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	"Commonly found growing in large or small water bodies either floating or submerged" (IUCN, 2014). Low to medium light is recommended in aquaria (The Green Machine, 2013). Occurs along canal banks in India (Pandey and Tripathi, 2010). The related species *H. polysperma* has "low light compensation and saturation points for photosynthesis" and is a "shaded-adapted...able to show net CO_2 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 pinnatifida* is not a vine; it is a 15-30 cm tall erect, branched, herbaceous aquatic plant (Muth, 2009).
ES-6 (Forms dense thickets)	? - max	0	We did not find any information on *H. pinnatifida* forming dense thickets. However, *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 and the overall lack of information on this taxon, we answered unknown.
ES-7 (Aquatic)	y - negl	1	Aquatic plant that grows submerged (Pedersen, 2010) or emerged (Hudson, 2011).
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 (The Plant List, 2010) which is not known to contain nitrogen-fixing species (Martin and Dowd, 1990).
ES-10 (Does it produce viable	? - max	0	Produces seeds (IUCN, 2014). Other species of *Hygrophila*

Question ID	Answer - Uncertainty	Score	Notes (and references)
seeds or spores)			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. pinnatifida* 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 pinnatifida*. Other species of *Hygrophila* do not require specialist pollinators: *H. pogonocalyx* is pollinated by 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	Flowers and fruits from January to March in its native habitat in India (Pandey and Tripathi, 2010). In aquaria, "[t]he plant is easy to culture and spreads almost too well once introduced to the tank…fast-growing and spreads all over the tank" (Pedersen, 2010). Grows slower than other *Hygrophila* species (Muth, 2009). Slow to moderate growth in aquaria (Hudson, 2011; The Green Machine, 2013). Because we found very little information on how quickly this plant reproduces, we answered "b" with high uncertainty. The alternate answers for the Monte Carlo simulation were "c" and "a."
ES-14 (Prolific reproduction)	? - max	0	Unknown.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - mod	1	The related species *H. costata* is spread by machinery and watercraft (Gorham and Hosking, 2013) and *H. polysperma* was likely introduced into Texas "directly through cultivation by local aquatic plant nurseries...or indirectly through careless dumping by aquarists" (Angerstein and Lemke, 1994). One aquarist on an aquatic plant message board noted that he or she had dumped waste water containing cuttings of the related species *H. corymbosa* into his or her yard and the plants then rooted and began growing in an emerged state (Aquatic Plant Central, 2006) Based on this evidence, we answered yes, but with moderate uncertainty because this information is based on congeners.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - high	2	We did not find any information specific to *H. pinnatifida* but *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 though (Maki and Galatowitsch, 2004). Based on this evidence, we answered yes, but with high uncertainty.
ES-17 (Number of natural dispersal vectors)	2	0	Fruit description and genus-level seed description used to answer ES-17a through ES-17e: "Seeds discoid, covered with long mucilaginous trichomes" (Zhengyi et al., 2014); "Fruits capsule, narrow, sessile" (Pandey and Tripathi, 2010)
ES-17a (Wind dispersal)	n - mod		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 - low		Species of *Hygrophila* "...have adpressed seed hairs, which are erected in water to form a slimy mass," which enlarges the

Question ID	Answer - Uncertainty	Score	Notes (and references)
			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 are 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. pinnatifida*. However, secondary dormancy (when seeds become dormant under certain unfavorable environmental conditions) can be triggered in *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 pinnatifida* is easily propagated from side shoots produced by stems (Hudson, 2011). 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 *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. pinnatifida*. Not listed by Heap (2014). We used moderate uncertainty because very little information exists on control methods for this species. However, because *H. pinnatifida* 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	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	? - max		*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; 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	? - max		We found very little information about this species. *Hygrophila*

Question ID	Answer - Uncertainty	Score	Notes (and references)
processes and parameters that affect other species)			*pinnatifida* has only recently been introduced outside of its native range to Europe (Pedersen, 2010) and the United States (Hudson, 2011). Thus, we answered unknown for the majority of 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 - high	0.2	In 2011, Texas proposed listing *H. pinnatifida* as a species ineligible to be sold in the state of Texas (Pet Product News International, 2011a), but this regulation was never enacted due to concerns expressed by business interests (Pet Product News International, 2011b). The Texas Parks and Wildlife Department used a version of the Australian Weed Risk Assessment (Pheloung et al., 1999) modified for aquatic plants and conducted weed risk assessments for several *Hygrophila* species (Chilton, 2014). *Hygrophila pinnatifida* received a score of 10 (Cook-Hildreth, 2014), greater than the "Reject" threshold score of 6. Based on this evidence, we answered "b" with high 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. Relatively slow-growing in aquariums (Muth, 2009).
Imp-A4 (Weed status in anthropogenic systems)	a - high	0	We found no evidence of *H. pinnatifida* 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. pinnatifida* 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.
Imp-P4 (Reduces the quality or availability of irrigation, or	? - max		Unknown. We found no evidence that *H. pinnatifida* limits water in production systems, but *H. polysperma* clogs irrigation

Question ID	Answer - Uncertainty	Score	Notes (and references)
strongly competes with plants for water)			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. pinnatifida* or other *Hygrophila* species are toxic to animals. In India, the entire plant is boiled and used to treat diarrhea (Pandey and Tripathi, 2010). 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. pinnatifida* 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 that *H. pinnatifida* occurs in this hardiness zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence that *H. pinnatifida* occurs in this hardiness zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence that *H. pinnatifida* occurs in this hardiness zone.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no evidence that *H. pinnatifida* occurs in this hardiness zone.
Geo-Z5 (Zone 5)	n - low	N/A	We found no evidence that *H. pinnatifida* occurs in this hardiness zone.
Geo-Z6 (Zone 6)	n - mod	N/A	We found no evidence that *H. pinnatifida* occurs in this hardiness zone.
Geo-Z7 (Zone 7)	n - high	N/A	We found no evidence that *H. pinnatifida* occurs in this hardiness zone.
Geo-Z8 (Zone 8)	n - high	N/A	We found no evidence that *H. pinnatifida* occurs in this hardiness zone.
Geo-Z9 (Zone 9)	y - high	N/A	India and Vietnam (IUCN, 2014, occur.).
Geo-Z10 (Zone 10)	y - low	N/A	India, Vietnam, and Laos (IUCN, 2014, occur.).
Geo-Z11 (Zone 11)	y - low	N/A	Malaysia and Cambodia (IUCN, 2014, occur.).
Geo-Z12 (Zone 12)	y - low	N/A	Malaysia and Cambodia (IUCN, 2014, occur.).
Geo-Z13 (Zone 13)	y - low	N/A	Malaysia and Cambodia (IUCN, 2014, occur.). 20-28 °C is recommended for growth in aquaria (The Green Machine, 2013).
Köppen-Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - low	N/A	Malaysia and Cambodia (IUCN, 2014, occur.).
Geo-C2 (Tropical savanna)	y - low	N/A	Cambodia and Vietnam (IUCN, 2014, occur.).
Geo-C3 (Steppe)	y - mod	N/A	India (IUCN, 2014, occur.).
Geo-C4 (Desert)	n - high	N/A	We found no evidence *H. pinnatifida* occurs in this climate class.
Geo-C5 (Mediterranean)	n - high	N/A	We found no evidence *H. pinnatifida* occurs in this climate class.
Geo-C6 (Humid subtropical)	y - low	N/A	Vietnam and India (IUCN, 2014, occur.).
Geo-C7 (Marine west coast)	y - mod	N/A	India (IUCN, 2014, occur.).
Geo-C8 (Humid cont. warm sum.)	n - high	N/A	We found no evidence that *H. pinnatifida* occurs in this climate class.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C9 (Humid cont. cool sum.)	n - low	N/A	We found no evidence that *H. pinnatifida* occurs in this climate class.
Geo-C10 (Subarctic)	n - negl	N/A	We found no evidence that *H. pinnatifida* occurs in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence that *H. pinnatifida* occurs in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that *H. pinnatifida* occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - high	N/A	India (IUCN, 2014, occur.). We used high uncertainty because *H. pinnatifida* is an aquatic, but answered yes because submerged plants would be buffered from the effects of low precipitation.
Geo-R2 (10-20 inches; 25-51 cm)	y - high	N/A	India (IUCN, 2014, occur.). We used high uncertainty because *H. pinnatifida* 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 - mod	N/A	India (IUCN, 2014, occur.).
Geo-R4 (30-40 inches; 76-102 cm)	y - mod	N/A	India (IUCN, 2014, occur.).
Geo-R5 (40-50 inches; 102-127 cm)	y - low	N/A	Cambodia and India (IUCN, 2014, occur.).
Geo-R6 (50-60 inches; 127-152 cm)	y - low	N/A	Laos and Vietnam (IUCN, 2014, occur.).
Geo-R7 (60-70 inches; 152-178 cm)	y - low	N/A	Laos and Cambodia (IUCN, 2014, occur.).
Geo-R8 (70-80 inches; 178-203 cm)	y - low	N/A	Laos and Vietnam (IUCN, 2014, occur.).
Geo-R9 (80-90 inches; 203-229 cm)	y - low	N/A	Laos and Vietnam (IUCN, 2014, occur.).
Geo-R10 (90-100 inches; 229-254 cm)	y - low	N/A	Laos and Vietnam (IUCN, 2014, occur.).
Geo-R11 (100+ inches; 254+ cm)	y - low	N/A	Malaysia and Laos (IUCN, 2014, occur.).
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	Cultivated and commercially grown for aquaria in the United States (Hudson, 2011). Available for sale online (The Green Machine, 2013).
Ent-2 (Plant proposed for entry, or entry is imminent)		N/A	
Ent-3 (Human value & cultivation/trade status)		N/A	Commercially grown as an ornamental aquatic plant in the United States (Hudson, 2011). One of the most popular plants at a 2010 aquatic plant show in Europe (Pedersen, 2010). Available for sale online (The Green Machine, 2013).
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		N/A	

Question ID	Answer - Uncertainty	Score	Notes (and references)
propagative material (except seeds)			
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	