United States Department of Agriculture

Weed Risk Assessment for *Philydrum lanuginosum* Banks ex Gaertn. (Philydraceae) – Woolly frogs mouth

United States Department of Agriculture

Animal and Plant Health Inspection Service

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Version 1

A population of *Philydrum lanuginosum* in eastern North Carolina. Top left: Habitat and infestation that surrounds pond. Top right: Habit: Bottom right: Flower. Bottom left: dehisced capsules. Photographs by Anthony Koop.

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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 the PPQ weed risk assessment (WRA) process (PPQ, 2015) 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.

The PPQ WRA process includes three analytical components that together describe the risk profile of a plant species (risk potential, uncertainty, and geographic potential; PPQ, 2015). At the core of the process is the predictive risk model that evaluates the baseline invasive/weed potential of a plant species using information related to its ability to establish, spread, and cause harm in natural, anthropogenic, and production systems (Koop et al., 2012). Because the predictive model is geographically and climatically neutral, it can be used to evaluate the risk of any plant species for the entire United States or for any area within it. We then use a stochastic simulation to evaluate how much the uncertainty associated with the risk analysis affects the outcomes from the predictive model. The simulation essentially evaluates what other risk scores might result if any answers in the predictive model might change. Finally, we use Geographic Information System (GIS) overlays to evaluate those areas of the United States that may be suitable for the establishment of the species. For a detailed description of the PPQ WRA process, please refer to the *PPQ Weed Risk Assessment Guidelines* (PPQ, 2015), which is available upon request.

We emphasize that our WRA process is designed to estimate the baseline—or unmitigated—risk associated with a plant species. We use evidence from anywhere in the world and in any type of system (production, anthropogenic, or natural) for the assessment, which makes our process a very broad evaluation. This is appropriate for the types of actions considered by our agency (e.g., Federal regulation). Furthermore, risk assessment and risk management are distinctly different phases of pest risk analysis (e.g., IPPC, 2015). Although we may use evidence about existing or proposed control programs in the assessment, the ease or difficulty of control has no bearing on the risk potential for a species. That information could be considered during the risk management (decision-making) process, which is not addressed in this document.

	***Philydrum lanuginosum* Banks ex Gaertn. – Wooly frogs mouth**
Species Information	Family: Philydraceae
	Synonyms: *Garciana cochinchinensis* Lour. (Ohwi, 1984); *Philydrum cavaleriei* H. Léveillé (Wu and Larsen, 2016).
	Common names: Woolly frogs mouth (Zakaria and Rajpar, 2014), frogmouth and woolly waterlily (ALA, 2016), frogsmouth (CSIRO, 2010).
	Botanical description: *Philydrum lanuginosum* is an herbaceous, perennial, aquatic plant that grows 50 to 180 cm tall (Ohwi, 1984; Goldman, pers. obs.). Leaves are two-ranked and linear, rather spongy-thickened, relatively flat, and grow 30 to 70 cm long. Multiple yellow, bilaterally symmetrical flowers are produced on a simple (or sometimes few-branched) spike inflorescence, and flowers have only one stamen (Jesson et al., 2003; Ohwi, 1984). Fruit are three-valved dehiscent capsules that contain hundreds to a few thousand tiny (0.7 mm long) seeds (Goldman, 2016a; Hamann, 1998; Ohwi, 1984). For a more detailed botanical description of this species and the Philydraceae see (Hamann, 1998; Wu and Larsen, 2016).
	Initiation: On August 3, 2016, *Philydrum lanuginosum* was reported for the first time in the United States (SERNEC Data Portal, 2016). A population had been established and increasing in size in an artificial pond in Pender County, NC, for several years. Because the pond (formerly a borrow pit[1]) was created between 1998 and 2003, the population of *P. lanuginosum* is not more than 13-18 years old (Hall, 2016). This taxon's identity was independently confirmed by USDA (Goldman, 2016b) and North Carolina State University botanists (Wilson, 2016). The PERAL Weed Team evaluated this species to support policy and management decisions by both APHIS-PPQ and the North Carolina Department of Agriculture and Consumer Services (NCDA&CS).
	Foreign distribution and status: This species is native to tropical Asia (India, Malaysia, Myanmar, Papua New Guinea, Thailand, and Vietnam), three provinces in China (Fujian, Guangdong, and Guangxi), two provinces in Japan (Kyushu and Ryukyu), northern Australia, Palau, and Taiwan (MBG, 2016a; NGRP, 2016; Ohwi, 1984). It is also reported for and presumably native to Cambodia and Laos (Moody, 1989). *Philydrum lanuginosum* is commonly cultivated as an aquatic plant in Australia (Stephens and Dowling, 2002), and seeds and plants are readily available online in Australia (e.g., Bluedale Wholesale Nursery, 2016; Fair Dinkum Seeds, 2016; Wallis Creek Watergarden, 2016). It is sold by an international seed company (B&T World Seeds, 2016) and two vendors on eBay who ship worldwide (eBay, 2016). One of the eBay vendors is from France (eBay, 2016), however, *P. lanuginosum* may not be

[1] A borrow pit is a site where soil, sand, gravel, or rock is "borrowed" for construction at another site.

commonly cultivated in that country because it is not listed in *The European Garden Flora*, a 5-volume compendium of plants cultivated in Europe (Cullen et al., 2011). In Taiwan, *P. lanuginosum* is threatened by development and pollution (Peng et al., 1986).

U.S. distribution and status: *Philydrum lanuginosum* is native to Guam (MBG, 2016b; Stone, 1970) and was recently reported as naturalized in Pender County, NC (SERNEC Data Portal, 2016). It has not yet been reported as present in the continental United States by any major U.S. plant database (e.g., EDDMapS, 2016; Kartesz, 2016; NRCS, 2016). We found no evidence that this species is commercially cultivated in the United States (e.g., Bailey and Bailey, 1976; Dave's Garden, 2016; Univ. of Minn., 2016). However, specimens are grown at the Santa Barbara Botanic Garden (Schneider and Carlquist, 2005) and the University of Connecticut research greenhouses (Anonymous, 2016). The Missouri Botanical Garden also grew a specimen, but it died in 2001 (MBG, 2016a). Another specimen was kept in the research greenhouse of California State University at Chico; this plant was later discarded, but not before seeds were sent to the University of Connecticut (Devine, 2016). The University of Connecticut research greenhouses have maintained one or more specimens of this species since at least 2010 (Anonymous, 2016). Because this species was only recently detected, there have not been any attempts to control it. However, the NCDA&CS will likely attempt to eradicate the population in the state.

WRA area[2]: Entire United States, including territories.

1. *Philydrum lanuginosum* analysis

Establishment/Spread Potential

Philydrum lanuginosum is a self-pollinating, aquatic plant that produces thousands of dust-like seeds, which are dispersed by water. The seeds may also be dispersed by birds, wind, and other animals, as well as by people who engage in recreational activities in and around bodies of water. Seeds readily germinate in water, and seedlings can float for a while until they find a suitable site for establishment. Based on this species' behavior at the North Carolina site and other aspects of its biology, we believe it has a high capacity to establish and spread. We had a very high level of uncertainty for this risk element, because were unable to answer 6 of the 27 questions.
Risk score = 13 Uncertainty index = 0.36

Impact Potential

Because the North Carolina population represents the first report of this species' naturalization beyond its native range, there is no information about its impact potential. Consequently, our analysis of its ability to cause harm in natural, anthropogenic, and agricultural systems was hampered. Based on

[2] "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 abundance and density of plants at the North Carolina pond (App. B), we believe *P. lanuginosum* is affecting local species diversity and may present a threat to Threatened and Endangered plant species that are restricted to marshes, bogs, and other similar habitats. It is unknown what impacts it may have on the long-term survival of gopher frogs (*Rana capito*) at this pond, which is a federal species of concern (Anonymous, 2005). *Philydrum lanuginosum* is reported as a weed of rice by several authors (Holm et al., 1979; Moody, 1989; Wu and Larsen, 2016) and a weed of plantation crops in southern Thailand by another (Maxwell et al., 1987 cited in Randall, 2012). It is also reported to be toxic to cattle (McKenzie, 1997) and freshwater turtles (Anonymous, 2015), but we found no information on the specific cause of this toxicity. Due to limited information, we had very high uncertainty for this risk element, and were unable to answer 6 of the 18 questions.
Risk score = 1.8 Uncertainty index = 0.52

Geographic Potential Based on three climatic variables, we estimate that about 27 percent of the United States is suitable for the establishment of *P. lanuginosum* (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 *P. lanuginosum* represents the joint distribution of Plant Hardiness Zones 8-13, areas with 10-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, humid subtropical, steppe, desert, marine west coast, and Mediterranean. We did not find any specific information that it occurs in Mediterranean environments; however, there is no reason to believe that as an aquatic plant it could not survive in them if aquatic habitats were present. Ultimately, the factor that is most limiting for the distribution of aquatic plants is the availability of suitable habitats (e.g., ponds, lakes, etc.) and their cold tolerance.

The area of the United States shown to be climatically suitable (Fig. 1) is likely overestimated since our analysis considered only three climatic variables. Other environmental variables, such as habitat type, moisture level, and hydrology, may further limit the areas in which this species is likely to establish. *Philydrum lanuginosum* is restricted to permanently waterlogged soils that are subject to stochastic water level fluctuations, such as freshwater wetlands, marshes, streams, swamps, rice fields, and margins of streams and lakes (Anonymous, 2016; Knight et al., 2007; Prentis et al., 2006; Wu and Larsen, 2016; Zakaria and Rajpar, 2014). *Philydrum lanuginosum* can grow for extended periods in water as deep as 20 cm (Greenway and Polson, No Date).

Entry Potential Although *P. lanuginosum* is naturalized at one site in the United States (SERNEC Data Portal, 2016) and grown at two research facilities (Anonymous, 2016; Schneider and Carlquist, 2005), we analyzed its entry potential because its U.S. distribution is still highly restricted. *Philydrum lanuginosum* is valued by Indigenous Australians who use it as a medicinal plant (Smith, 1991), and by urban planners, who use it in constructed wetlands for cleaning storm water and wastewater (e.g., Browning and Greenway, No Date; Greenway and Polson, No Date). It is also marketed as an ornamental aquatic plant in Australia (Stephens and Dowling, 2002), and seeds are readily available online (B&T World Seeds, 2016; eBay, 2016). Consequently, we believe that the most likely pathway for entry is as an ornamental or a research plant. It is possible that it may enter as a contaminant of aquatic plants for propagation, but we did not find any direct evidence for this pathway. On a scale of 0 to 1, where one represents a maximum likelihood for entry, we ranked this species with a score of 0.5.
Risk score = 0.5 Uncertainty index = 0.15

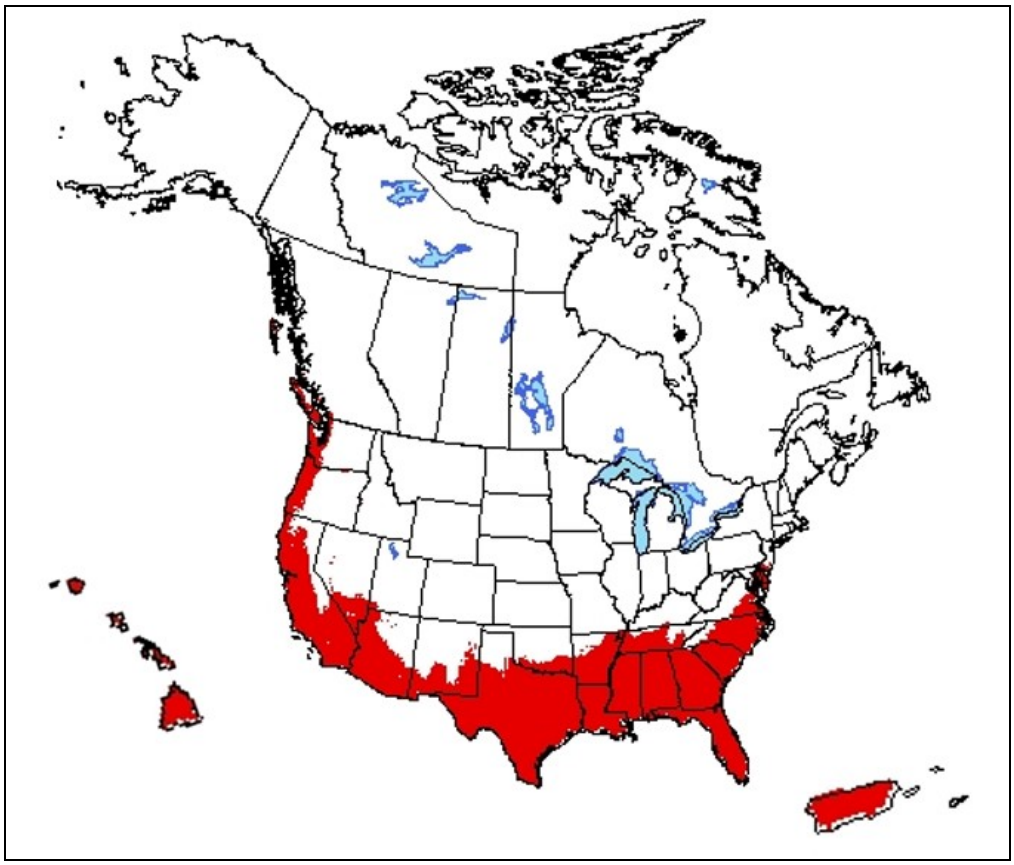

Figure 1. Potential geographic distribution of *Philydrum lanuginosum* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 50.3%
P(Minor Invader) = 46.8%
P(Non-Invader) = 2.9%
Risk Result = High Risk
Secondary Screening = Not Applicable

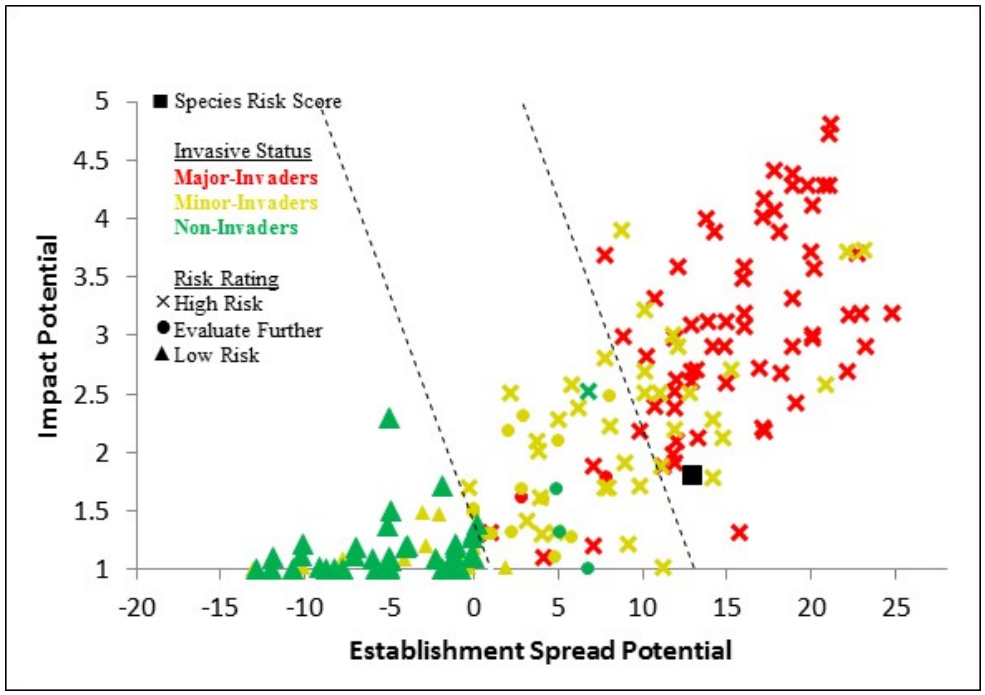

Figure 2. *Philydrum lanuginosum* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

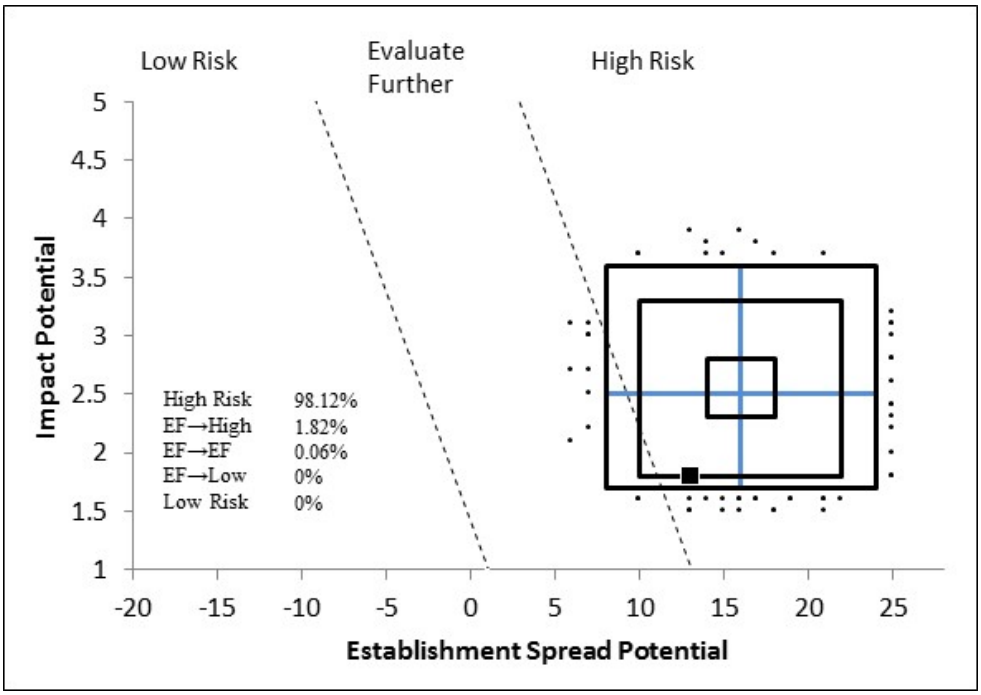

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *P. lanuginosum*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *P. lanuginosum* is High Risk (Fig. 2) and was almost exclusively driven by this species' ability to escape and spread. Although the risk score was close to our decision threshold for Moderate Risk (i.e., Evaluate Further), and was low on the Impact axis relative to other major U.S. invaders (Fig. 2), there was a very high level of uncertainty associated with this analysis. While some aspects of this species' biology have been well studied (e.g., floral morphology and anatomy; Simpson and Burton, 2006), there is relatively little information on other aspects, such as seed dispersal, prolonged seed dormancy, and tolerance to mutilation. Furthermore, because the report from Pender County, NC, is the first record of this species' naturalization outside of its native range, there is no precedent for how it may behave in introduced areas. However, despite this uncertainty, our analysis indicates that our conclusion of High Risk is relatively robust, because 99 percent of the simulated risk scores from the uncertainty analysis also resulted in the same conclusion (Fig. 3). In fact, these results suggest that the risk score is likely to be higher on both axes as additional information on the species becomes available.

In its native range, *Philydrum lanuginosum* is often a frequent and dominant species in seasonal wetlands and other aquatic habitats (Kershaw, 1975; Knight et al., 2007; Prentis et al., 2006). Based on its behavior at the site in North Carolina where it has become naturalized, we believe that it may behave similarly throughout the southeastern United States, where there are numerous freshwater wetlands.

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Appendix A. Weed risk assessment for *Philydrum lanuginosum* Gaertn. (Philydraceae). Below is all of the evidence and associated references used to evaluate the risk potential of this taxon. We also include the answer, uncertainty rating, and score for each question. The Excel file, where this assessment was conducted, is available upon request.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 [What is the taxon's establishment and spread status outside its native range? (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown]	e - high	2	*Philydrum lanuginosum* is native to tropical Asia, southeastern China, southern Japan, Australia, Taiwan, and Guam (NGRP, 2016; Ohwi, 1984; Stone, 1970). It was introduced to England in 1774 (Sims, 1804) and was reported to be in cultivation by 1800 (Donn, 1811). It is also cultivated in France (eBay, 2016) though likely to a very limited extent as this species does not appear in *The European Garden Flora* (Cullen et al., 2011). *Philydrum lanuginosum* has also been introduced to the United States, where it is grown in research greenhouse and in a botanical garden (Anonymous, 2016; Schneider and Carlquist, 2005). We found no evidence that it has been introduced elsewhere. *Philydrum lanuginosum* is described on gardening websites as readily self-seeding (Bluedale Wholesale Nursery, 2016), indicating that it is able to establish a persistent population. The North Carolina record (SERNEC Data Portal, 2016) is the first report of this species naturalizing outside of its native range. Comparison of pictures taken in November 2013 with those from August 2016 show a noticeable increase in the abundance and density of this species around the perimeter of the pond (Anthony Koop, personal observation, but also see images in Appendix B4). We answered this question as "e" because this is the only known site where *P. lanuginosum* has become naturalized and there is no evidence of spread to other sites. We used high uncertainty and answered "f" for both of our alternate answers because we believe, based on its behavior at the NC pond and widespread native distribution, that this species could readily spread to other areas in the United States.
ES-2 (Is the species highly domesticated)	n - low	0	This species is cultivated as an aquatic plant (Winterton and Scher, October 2007) and is commercially available (Bluedale Wholesale Nursery, 2016; Fair Dinkum Seeds, 2016; Wallis Creek Watergarden, 2016). However, we found no evidence of the availability of specific cultivars or that it has been bred for traits associated with reduced weed potential.
ES-3 (Weedy congeners)	n - low	0	*Philydrum lanuginosum* is the only species in this genus (Mabberley, 2008). Furthermore, there are only five species in four genera in the family Philydraceae (Mabberley, 2008). We found no evidence that any of them are considered weedy (e.g., Randall, 2012).
ES-4 (Shade tolerant at some stage of its life cycle)	n - high	0	We found no direct evidence that this species is shade tolerant. *Philydrum lanuginosum* is an emergent aquatic plant that occurs in marshes (Zakaria and Rajpar, 2014), swamps (CSIRO, 2010) and rice fields (Wu and Larsen,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			2016), and along the margins of streams and lakes (Anonymous, 2016; Knight et al., 2007). These are all relatively high-light environments. Horticultural sources report that it prefers full sun to part-shade (Bluedale Wholesale Nursery, 2016; Oz Watergardens, 2016). However, at the North Carolina site, there were plants growing completely submerged in 2-3 feet of water (Goldman, pers. obs.). Based on this information, we answered no, but used high uncertainty because it is not known how well seedlings, which may germinate (Prentis et al., 2006) and establish under water, tolerate shade. In some freshwater aquatic environments, light availability attenuates very quickly as water depth increases.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	This species is not a vine, nor does it form tightly appressed basal rosettes (Hamann, 1998).
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	We found no direct evidence in the published literature or on the internet that this species forms dense populations. However, at the Pender County site, *P. lanuginosum* has formed a relatively dense population growing along the perimeter of the pond (Appendix B, Fig. B1). At one spot at the upper edge of the population, I estimated that there were about 14 clumps of *P. lanuginosum* in one square meter (see top right image on cover page). Some clumps consisted of 3-4 individual plants, possibly connected through underground rhizomes. An image of this species from Queensland also shows a similarly dense, if not more so, population (p. 63, Stephens and Dowling, 2002). Consequently, based on these observations, we answered yes with negligible uncertainty.
ES-7 (Aquatic)	y - negl	1	This species is an amphibious plant restricted to permanently water-logged soils (Prentis et al., 2006). Seeds germinate equally well on water-logged soil and underwater, and seedlings can float (Prentis et al., 2006). Furthermore, seedlings can establish even after prolonged buoyancy of about 40 days (Prentis et al., 2006). Leaves are thick and contain arenchyma (i.e., spongy) tissue (Hamann, 1998), which is an adaptation that aquatic plants possess.
ES-8 (Grass)	n - negl	0	This species is not a grass; it is a member of the monocot family Philydraceae (Hamann, 1998).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen. Furthermore, it is an herbaceous plant (CSIRO, 2010; Hamann, 1998) and contains no woody tissue.
ES-10 (Does it produce viable seeds or spores)	y - negl	1	It produces viable seed (Prentis et al., 2006; Winterton and Scher, October 2007) and is propagated through seeds (Fair Dinkum Seeds, 2016).
ES-11 (Self-compatible or apomictic)	y - negl	1	"No field observations on the pollination of the nectarless and scentless pollen flowers of the Philydraceae are known. Cultivated plants of *Philydrum lanuginosum*, which regularly set seeds, are autogamous. The pale yellow flowers last only 1 day, and the few flowers of the whole inflorescence bloom simultaneously. After anthesis the

Question ID	Answer - Uncertainty	Score	Notes (and references)
			tepals and bract dose around the pistil and stamen. The twisted anther comes into contact with the stigma, and the pollen tetrads germinate partly inside the dehiscent anther" (Hamann, 1998).
ES-12 (Requires specialist pollinators)	n - negl	0	Since its plants are autogamous (i.e., they self-pollinate; see evidence under ES-11), this species does not require specialist pollinators.
ES-13 [What is the taxon's minimum generation time? (a) less than a year with multiple generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) unknown]	b - high	1	*Philydrum lanuginosum* is a perennial herb (Saarela et al., 2008; Simpson, 1985) that reproduces through seed production (Prentis et al., 2006; Winterton and Scher, October 2007) and mostly likely through clonal expansion from short rhizomes. All members of this family produce either rhizomes or corms (Saarela et al., 2008; Simpson, 1985). We found no information on the generation time of this species. It seems unlikely that such a small seed (see description under ES-17) would be able to germinate, grow to reproductive size, and produce seed in a single year. However, we expect for a perennial herb with rhizomes, that once a plant has matured, it would be able to produce vegetative offshoots each year, and those offshoots would be able to produce their own offshoots within a year. Consequently, we answered "b," but with high uncertainty without more direct evidence. A short generation time would be consistent with the rate at which this plant filled in the perimeter of the North Carolina pond (SERNEC Data Portal, 2016). Alternate answers for the uncertainty simulation were both "c."
ES-14 (Prolific seed producer)	y - negl	1	*Philydrum lanuginosum* produces small and numerous seeds (Simpson and Burton, 2006) as do other members of the Philydraceae (Hamann, 1998). At a dense patch of the North Carolina population, I estimated there are about 40 inflorescences per square meter and about 30 capsules per inflorescence (Anthony Koop, personal observation). Another USDA botanist estimated there were 1590 seeds in one seed capsule alone (Goldman, 2016a). Assuming that 78 percent of the seeds germinate (Prentis et al., 2006), plants in one square meter alone may be producing as many as 1.5 million viable seeds. Although additional population counts should be taken to estimate sample means and variances, there is no doubt that this species meets our threshold of prolific reproduction.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - high	1	We found no published information about the unintentional dispersal of this species. However, we believe that unintentional dispersal via human activity in infested ponds is likely to disperse seeds. *Philydrum lanuginosum* produces seeds that float (Carthey et al., 2016; Prentis et al., 2006). During a site visit to the Pender County population, there were thousands of seeds floating on the surface of the water, often forming rafts (Goldman, 2016b). While examining some of the plants at the edge of the pond, I noticed dozens of seeds readily sticking to my damp skin (Anthony Koop, personal observation). Consequently, we believe any kind of activity by people in infested populations (fishing, boating, wading, swimming),

Question ID	Answer - Uncertainty	Score	Notes (and references)
			as well as by pets and other animals, will result in the unintentional dispersal of seeds if they are deposited in similar habitats.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	? - max	0	We found no evidence that this species has dispersed as a contaminant or hitchhiker in trade. Furthermore, we found no evidence that U.S. inspectors have intercepted it (AQAS, 2016). Because this is an aquatic/wetland plant, it seems unlikely that it would have many opportunities to contaminate most trade goods. However, trade of other aquatic plant species that are either wild-collected or cultivated with flowering *P. lanuginosum* may inadvertently introduce this species to other regions. It has been well established that the aquatic plant trade often leads to the unintentional introduction and movement of other aquatic plant species, including duckweed, which is a very small aquatic plant that floats on the water surface (e.g., Maki and Galatowitsch, 2004), similar to the seeds of *P. lanuginosum*.
ES-17 (Number of natural dispersal vectors)	2	0	Propagule properties relevant for questions ES-17a through ES-17e: Fruit are dehiscent capsules that contain hundreds of tiny (0.7-0.9 mm by 0.3-0.4 mm) seeds (CSIRO, 2010; Ohwi, 1984). At a very fine scale, the seed surfaces are bumpy, which may help them float by trapping tiny air bubbles (Carthey et al., 2016).
ES-17a (Wind dispersal)	? - high		We found no evidence that this species is dispersed by wind. However, we answered unknown because seeds are rather small and dust-like, and could possibly be dispersed long distances under strong wind currents.
ES-17b (Water dispersal)	y - negl		Seeds that are retained in the capsule for more than a week after the capsules have opened exhibit prolonged buoyancy (Prentis et al., 2006). Seeds can float for at least 14 days (Carthey et al., 2016). Seedlings are also buoyant and can successfully establish even if they first germinated in water-logged soil and were later dislodged due to flooding (Prentis et al., 2006). Local wind currents on still ponds and lakes may contribute to the dispersal of seeds or seedlings floating on the surface of the water.
ES-17c (Bird dispersal)	y - high		We found no direct evidence that seeds of this species are dispersed by birds, either internally or externally. However, based on how easily these small seeds stick to surfaces (see discussion under ES-15), we believe that waterfowl pose a high likelihood of dispersing seeds to other ponds and water bodies (see reviews in Figuerola and Green, 2002; Santamaría, 2002).
ES-17d (Animal external dispersal)	? - max		We found no information on whether animals can disperse seeds in this fashion. While it is likely that seeds would cling to animal fur (see evidence and discussion under ES-15), we do not know how important this pathway would be for the spread of this species. Consequently, we answered unknown.
ES-17e (Animal internal dispersal)	? - max		Unknown. We found no information on the ability of this species to survive gut passage.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	Unknown. We found no information on whether this species can form a persistent seed bank. Some seeds freshly-colleted from Pender County on August 26, 2016 began to germinate within 6 days of planting in petri dishes (Cross and Oderkirk, 2016). These seeds were not subjected to any kind of scarification or other treatment to stimulate germination.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	? - max	0	*Philydrum lanuginosum* produces a short and erect rhizome (CSIRO, 2010; Hamann, 1998) that may be able to help the plants respond to massive aboveground loss of biomass. However, without additional evidence, we answered this question as unknown.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	We found no evidence that this species is resistant to herbicides (e.g., Heap, 2016). Because we found no evidence that this species is routinely sprayed with herbicides, it seems unlikely that herbicide resistance has had an opportunity to evolve. Consequently, we answered no with low uncertainty.
ES-21 (Number of cold hardiness zones suitable for its survival)	6	0	
ES-22 (Number of climate types suitable for its survival)	7	2	
ES-23 (Number of precipitation bands suitable for its survival)	10	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - mod	0	We found no evidence that this species is allelopathic.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this species is parasitic (e.g., Hamann, 1998). Furthermore, it is not a member of a plant family that contains known parasitic plants (Heide-Jorgensen, 2008; Nickrent, 2009; Walker, 2014).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	? - max		Because the Pender County population of *P. lanuginosum* represents the first report of this species' naturalization outside of its native range, our ability to evaluate this species' impacts in natural systems is severely hampered and is based solely on observations of its behavior at this one site. Furthermore, we found no published information on the ecology of this species in its native range. With respect to this question, we do not know if this species is likely to have any significant impacts on ecosystem processes such as nutrient cycling or hydrology. As an aquatic plant, it is possible that it may impact sedimentation rates.
Imp-N2 (Changes habitat structure)	? - max		Unknown. Comparison of pictures taken of the pond in November 2013 with those from August 2016 shows a noticeable increase in vegetation density around the perimeter of the pond due to population growth of *P. lanuginosum* (Anthony Koop, personal observation; but also see Appendix B4). This suggests that *P. lanuginosum* is able to change habitat structure. However, because this pond is artificial and only 13-18 years old (Hall, 2016), it is not clear whether this species would have changed habitat

Question ID	Answer - Uncertainty	Score	Notes (and references)
			structure had it invaded an already existing native plant community, or if established and succession of native species would have resulted in a similar change in vegetation structure. Consequently, we answered this question as unknown.
Imp-N3 (Changes species diversity)	y - high	0.2	In its native range in Australia, *P. lanuginosum* is described as a frequent and dominant species in the littoral zone of aquatic habitats (Kershaw, 1975; Knight et al., 2007). Consistent with the species' status in Australia, the Pender County population was the most abundant herbaceous species surrounding the pond and occurred at a high density (see images on the cover page and in App. B). For the majority of the pond's circumference, *P. lanuginosum* probably accounted for 90 percent of the plant biomass (Anthony Koop, personal observation). At this density and abundance, either it has affected native species diversity or, given that the pond was constructed 13-18 years ago, it may have prevented some native species from establishing. For these reasons, we answered this question as yes, but with high uncertainty since these observations are based on one site.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - high	0.1	Given the density at which *P. lanuginosum* occurs, it seems likely that it would affect rare native plants (e.g., carnivorous plants) that live in marshy habitats and forested wetlands. A population of gopher frog (*Rana capito*) is present at the Pender County pond where *P. lanuginosum* has become established (SERNEC Data Portal, 2016). Gopher frogs are categorized as a Federal species of concern (Anonymous, 2005) and are known from only seven sites in North Carolina (NC-WRC, 2012). "Gopher frogs … breed in isolated upland ponds – usually upland depression ponds, Carolina bays, sinkhole ponds, or borrow pits. Breeding ponds need to remain ephemeral with an open canopy and a grassy aquatic structure" (NC-WRC, 2012). Egg masses are typically laid on submerged, graminaceous vegetation (Anonymous, 2005). It is unclear whether invasion and dominance of these habitats by *P. lanuginosum* would affect habitat suitability for this frog.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	? - max		Based on our geographic potential analysis, the climate in the southeastern United States is suitable for the establishment of *P. lanuginosum* (Fig. 1). This region contains globally outstanding ecoregions (Ricketts et al., 1999). However, without evidence that this species has or could have major ecosystem-level impacts, we could not answer this question as yes.
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon a weed but no evidence of control; (c) taxon a weed and evidence of control efforts]	b - high	0.2	The biologists who initially discovered and identified *P. lanuginosum* in North Carolina were concerned about its potential to invade other wetland sites in the state (SERNEC Data Portal, 2016). Similarly, biologists with the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) and the USDA are concerned about the weedy behavior of this species, and are planning to attempt to eradicate it (Wilson, 2016). Consequently we answered "b" with high uncertainty, and we selected "c" for

Question ID	Answer - Uncertainty	Score	Notes (and references)
			both alternate answers because of the intent to control this population.
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - mod	0	We found no evidence of this impact.
Imp-A2 (Changes or limits recreational use of an area)	? - max		We found no evidence that this species reduces or would reduce recreational use of areas. However, because it is a large aquatic herb that grows 50 to 180 cm tall (Ohwi, 1984), it may limit fishing and swimming activities.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	? - max		We found no evidence of this impact. However, based on the abundance and density of the North Carolina population, it seems that this species would likely outcompete ornamental, aquatic plants that would be planted along pond edges. Consequently, we answered unknown.
Imp-A4 [What is the taxon's weed status in anthropogenic systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	a - high	0	We found no evidence that this species is considered a weed of anthropogenic systems. However, due to limited information, we used high uncertainty. For both alternate answers for the uncertainty simulation, we chose "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - high	0	We found no evidence that this species reduces yield. Because it is reported as a weed of rice (see evidence under Imp-P6), and there are no accounts of its behavior in rice fields, we answered no with high uncertainty.
Imp-P2 (Lowers commodity value)	n - high	0	We found no evidence that this species lowers commodity value. Because it is reported as a weed of rice (see evidence under Imp-P6), but we found no information about its specific behavior in rice fields, we answered no with high uncertainty.
Imp-P3 (Is it likely to impact trade?)	n - mod	0	We found no evidence that this species is specifically regulated (e.g., APHIS, 2016) or that it has been intercepted as a contaminant of trade.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	? - high		Although we found no evidence of this impact, as an aquatic plant, *P. lanuginosum* may be able to impact irrigation and drainage channels. Consequently, we answered unknown with maximum uncertainty.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	y - high	0.1	In a special invited lecture, a veterinarian with the Queensland Department of Primary Industries commented that *P. lanuginosum* is toxic to cattle, irritating the animals' bowels and leading to diarrhea (McKenzie, 1997). On an Australian online forum for hobbyists of aquatic freshwater turtles, *P. lanuginosum* was categorized as toxic (Anonymous, 2015). We answered yes, but with high uncertainty without additional information about the nature of this toxicity.
Imp-P6 [What is the taxon's weed status in production systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control;	b - mod	0.2	*Philydrum lanuginosum* is present in rice fields (Wu and Larsen, 2016) and is described as a weed of rice in Cambodia, Myanmar, Laos, Malaysia, Thailand, and Vietnam (Moody, 1989). It has been described as an

Question ID	Answer - Uncertainty	Score	Notes (and references)
(c) Taxon a weed and evidence of control efforts]			unranked agricultural weed in Vietnam (Holm et al., 1979) and a weed of plantation crops in southern Thailand (Maxwell et al., 1987 cited in Randall, 2012). Because we found no evidence of control we answered "b," but with moderate uncertainty. Alternate answers for the uncertainty simulation were both "c."
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2016).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z5 (Zone 5)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z6 (Zone 6)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z7 (Zone 7)	n - high	N/A	This species occurs in Australia, and in Japan's Kyushu Province (NGRP, 2016; Ohwi, 1984). Although both of these regions include areas with this hardiness zone, because this zone represents a small portion of these regions, we answered no.
Geo-Z8 (Zone 8)	y - low	N/A	Some points in Australia (GBIF, 2016). Reported to occur in the Kyushu region of Japan (Ohwi, 1984), which includes this hardiness zone. Recently discovered naturalized in an area Pender County, North Carolina (SERNEC Data Portal, 2016) that is located in this zone.
Geo-Z9 (Zone 9)	y - negl	N/A	Many points in Australia, and one point in China. Regional occurrence for Fujian, Guangdong, and Guangxi, China (Wu and Larsen, 2016). Reported to be hardy to zone 9 (B&T World Seeds, 2016).
Geo-Z10 (Zone 10)	y - negl	N/A	Many points in Australia, and some in China.
Geo-Z11 (Zone 11)	y - negl	N/A	Many points in Australia, and some in China and Taiwan.
Geo-Z12 (Zone 12)	y - negl	N/A	Many points in Australia, a few in China, and one in Thailand.
Geo-Z13 (Zone 13)	y - negl	N/A	Some points in Papua New Guinea. Overall, this species is reported to occur from Australia, north through Malesia, and into southeast Asia (NGRP, 2016). This hardiness zone occurs throughout this region.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - negl	N/A	Some points in Australia, Papua New Guinea, and Thailand. Most Philydraceae live in tropical and subtropical climates (Hamann, 1998). Overall, this species is reported to occur from Australia, north through Malesia, and into southeast Asia (NGRP, 2016), and this climate class occurs throughout this region.
Geo-C2 (Tropical savanna)	y - negl	N/A	Many points in Australia. Most Philydraceae live in tropical and subtropical climates (Hamann, 1998).
Geo-C3 (Steppe)	y - negl	N/A	Many points in Australia.
Geo-C4 (Desert)	y - high	N/A	Three points west of Tanami, Australia. While deserts in general would not be ideal environments for aquatic plants, this species would be able to grow in any protected areas where water pools.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C5 (Mediterranean)	y - high	N/A	We found no evidence that this species occurs in this climate class. However, there is no reason to believe that an aquatic species would not be able to grow in this type of climate provided there are suitable habitats. Consequently we answered yes, but with high uncertainty.
Geo-C6 (Humid subtropical)	y - negl	N/A	Australia and China. Reported to occur in the Kyushu region of Japan (Ohwi, 1984), where this climate class is well represented. Recently discovered naturalized in Pender County, NC (SERNEC Data Portal, 2016), that is located in this climate class. Most Philydraceae live in tropical and subtropical climates (Hamann, 1998).
Geo-C7 (Marine west coast)	y - negl	N/A	Many points in Australia.
Geo-C8 (Humid cont. warm sum.)	n - negl	N/A	We found no evidence that this species occurs in this climate class.
Geo-C9 (Humid cont. cool sum.)	n - negl	N/A	We found no evidence that this species occurs in this climate class.
Geo-C10 (Subarctic)	n - negl	N/A	We found no evidence that this species occurs in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence that this species occurs in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that this species occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - high	N/A	We found no evidence that this species occurs in this precipitation band.
Geo-R2 (10-20 inches; 25-51 cm)	y - low	N/A	A few points in Australia. While regions with such limited precipitation are not ideal for aquatic plants, aquatic plants could occur in protected sites where water pools.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Australia.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Australia.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Australia.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Australia and Taiwan. This species is reported to occur from Australia, north through Malesia, and into southeast Asia (NGRP, 2016), a broad region where this precipitation band frequently occurs.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Australia and Taiwan. This species is reported to occur from Australia, north through Malesia, and into southeast Asia (NGRP, 2016), a broad region where this precipitation band frequently occurs.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Australia and Taiwan. This species is reported to occur from Australia, north through Malesia, and into southeast Asia (NGRP, 2016), a broad region where this precipitation band frequently occurs.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	Australia, China, and Taiwan. This species is reported to occur from Australia, north through Malesia, and into southeast Asia (NGRP, 2016), a broad region where this precipitation band frequently occurs.
Geo-R10 (90-100 inches; 229-254 cm)	y - negl	N/A	China and Taiwan. This species is reported to occur from Australia, north through Malesia, and into southeast Asia (NGRP, 2016), a broad region where this precipitation band frequently occurs.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R11 (100+ inches; 254+ cm)	y - negl	N/A	China and Taiwan. This species is reported to occur from Australia, north through Malesia, and into southeast Asia (NGRP, 2016), a broad region where this precipitation band frequently occurs.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - negl	0	*Philydrum lanuginosum* is naturalized at one site in North Carolina in the United States (SERNEC Data Portal, 2016) and grown at the Santa Barbara Botanic Garden (Schneider and Carlquist, 2005) and University of Connecticut research greenhouses (Anonymous, 2016). However, because the North Carolina population of this species will likely be eradicated, we chose no in order to evaluate this risk element.
Ent-2 (Plant proposed for entry, or entry is imminent)	n - low	0	We found no evidence that this species has been proposed for entry into the United States.
Ent-3 (Human value & cultivation/trade status)	d - negl	0.5	*Philydrum lanuginosum* is used by Indigenous Australians as an antiseptic wash for skin sores and other conditions (Smith, 1991). It is also used in Australian constructed wetlands for cleaning storm water and wastewater (e.g., Browning and Greenway, No Date; Greenway and Polson, No Date). In China, it was selected for a study examining its potential use in lead phytoremediation because it is fast-growing, widely distributed, and requires few nutrients (Yang and Ye, 2015). However, it did not perform well, dying under the high lead concentration treatment (Yang and Ye, 2015). *Philydrum lanuginosum* is commonly cultivated as an aquatic plant in Australia (Stephens and Dowling, 2002). Seeds and plants are readily available online in Australia (e.g., Bluedale Wholesale Nursery, 2016; Fair Dinkum Seeds, 2016; Wallis Creek Watergarden, 2016). It is also sold by two vendors on eBay who state that they ship worldwide (eBay, 2016). It is also available from another global vendor that specializes in plant seeds (B&T World Seeds, 2016).
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	y - negl		This species is not reported to be present in Canada, Mexico, or the Caribbean (Acevedo-Rodríguez and Strong, 2012; Brouillet et al., 2016; NGRP, 2016). However, it is native to southeastern China in the provinces of Fujian, Guangdong, and Guangxi (Wu and Larsen, 2016). The major city of Hong Kong is located in Guangdong Province.
Ent-4b (Contaminant of plant propagative material (except seeds))	n - high	0	We found no evidence, but see Ent-4e.
Ent-4c (Contaminant of seeds for planting)	n - mod	0	We found no evidence of spread via this pathway.
Ent-4d (Contaminant of ballast water)	? - max		Unknown. We found no evidence of spread via this pathway; however, because seeds readily float on water, and because this species occurs along coastal regions where it is native (GBIF, 2016), it may contaminate ballast water and other shipping equipment in contact with the

Question ID	Answer - Uncertainty	Score	Notes (and references)
			water. Because this is a freshwater species, contamination would need to happen in coastal freshwater systems.
Ent-4e (Contaminant of aquarium plants or other aquarium products)	? - max		Unknown. We found no evidence that this species is a contaminant of vegetative plant material. However, we believe that this pathway is likely for an aquatic plant (see comments under ES-16).
Ent-4f (Contaminant of landscape products)	? - max		Unknown. We found no evidence of this kind of spread, but this species could readily spread in muck and other soils taken from wetlands where the species occurs.
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	n - mod	0	We found no evidence for this pathway, and we believe that it is unlikely.
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	n - mod	0	We found no evidence.
Ent-4i (Contaminant of some other pathway)	? - max		We found no evidence of spread via another pathway, but we believe that it could be readily spread on contaminated boats and fishing equipment. Thus, we answered unknown.
Ent-5 (Likely to enter through natural dispersal)	n - negl	0	Because this species is not known to be present in a nearby geographic region, it is unlikely it will enter the United States via this pathway.

Appendix B. Additional photographs of the Pender County, North Carolina population of *Philydrum lanuginosum*. With one noted exception, all images were taken by Anthony Koop on August 26, 2016.

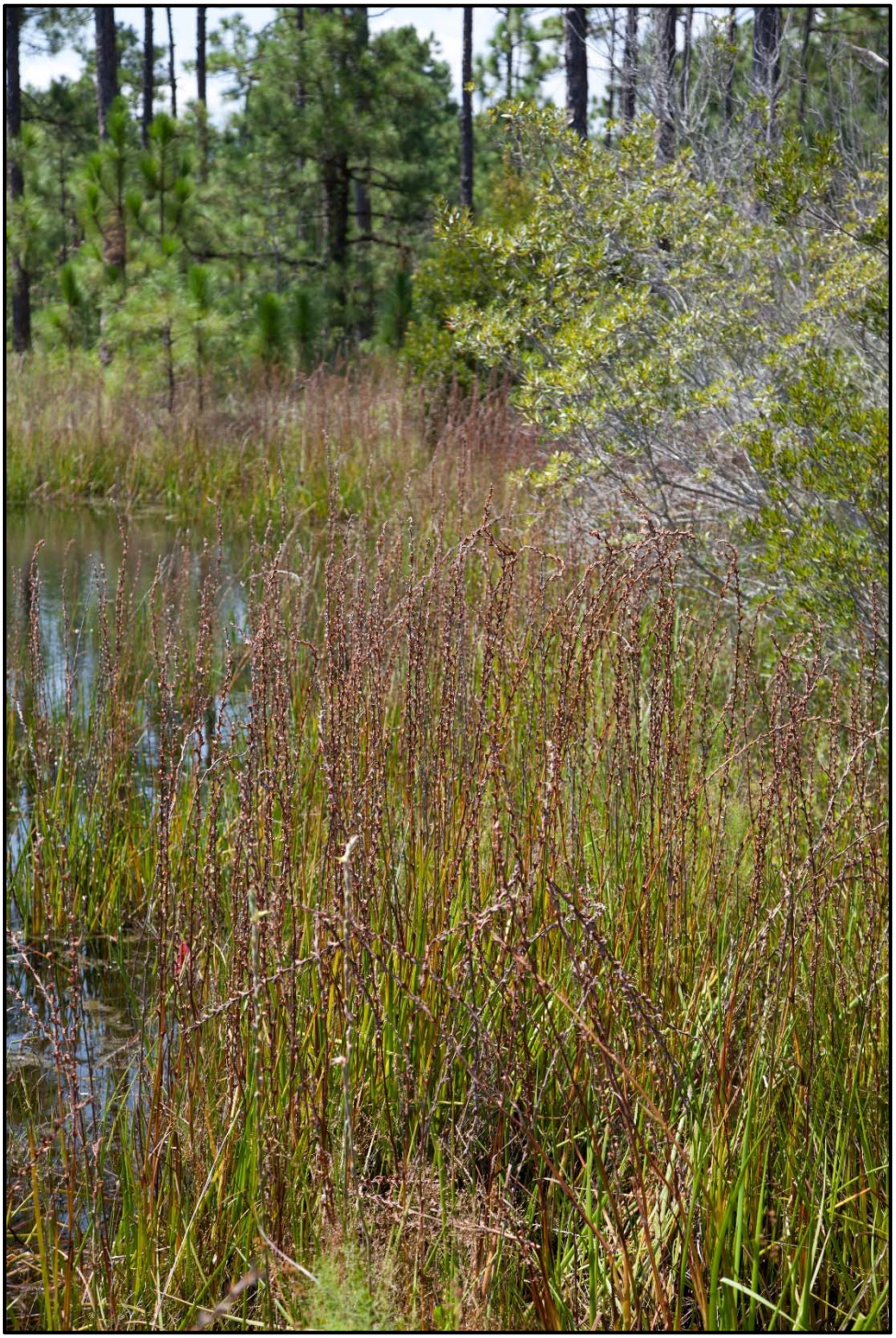

Figure B1. Population density of *Philydrum lanuginosum* along the shore of the pond (source: Anthony Koop).

Figure B2. *Philydrum lanuginosum* plants growing in deeper areas of the pond. Source: Anthony Koop.

Figure B3. Left: Density of flowering stems of *Philydrum lanuginosum* in a Pender County population. Right: Fruiting stems with capsules that have opened and dispersed their seeds. Source Anthony Koop.

Figure B4. Photographs of the Pender County pond taken from the same vantage point but about three years apart, demonstrating the spread and in-filling of the population (compare circled ares). Top: Photograph taken by the homeowner in November 2013. Bottom: Photograph taken by Anthony Koop on August 26, 2016.