Maryland Department of Agriculture

June 2, 2015

Version 1

Weed Risk Assessment for *Ficaria verna* Huds. (Ranunculaceae) – Fig buttercup

Top: *Ficaria verna* infestation and plant habit (source: Sylvan Kaufman). Middle: Aerial bulbils at the bases of plant leaves, and underground tubers (source: Leslie J. Mehrhoff, University of Connecticut, Bugwood.org). Bottom: Infestation at a local park near Washington, D.C. (source: Spencer Johnson, Invasive Plant Control, Inc.).

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Introduction The Maryland Department of Agriculture regulates terrestrial ornamental invasive plants under the authority of Md. AGRICULTURE Code Ann. § 9.5-101 et seq. Invasive Plant Prevention and Control. An invasive plant is defined as a terrestrial plant species that a) did not evolve in the State, and b) if introduced within the State, will cause or is likely to cause, as determined by the Secretary: economic, ecological, environmental harm or harm to human health.

Maryland's Invasive Plant Advisory Committee (IPAC) was established by legislative mandate in October 2011. The IPAC's primary responsibility is to advise the Secretary of Agriculture on regulating the sale of invasive plants, and on preventing them from entering Maryland or from spreading further in the state. IPAC evaluates the risk potential of plants already present in Maryland, newly detected in the Maryland or the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

IPAC evaluates the potential invasiveness of plants using the weed risk assessment (WRA) process developed by the Plant Protection and Quarantine (PPQ) Program of the US Department of Agriculture's Animal and Plant Health Inspection Service (Koop et al. 2012). PPQ's risk model uses information about a species' biological traits and behavior to evaluate its risk potential (Koop et al. 2012).

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 specific region in the United States. In the PPQ process, the geographic potential of the species is evaluated separately so that risk managers can make decisions appropriate for their regions. With respect to Maryland's evaluation process, we use PPQ's Geographic Information System overlays of climate to evaluate the potential for a plant to establish and grow in Maryland. The PPQ weed risk assessment also uses a stochastic simulation to evaluate how the uncertainty associated with the assessments affects the model's predictions. Detailed information on the PPQ WRA process is available in the document, *Guidelines for the USDA-APHIS-PPQ Weed Risk Assessment Process* (APHIS PPQ 2015), which is available upon request.

IPAC uses a second tool, the Maryland Filter, to assign plant species that score as highly invasive either Tier 1 or Tier 2 status. Maryland regulations define Tier 1 plants as "invasive plant species that cause or are likely to cause severe harm within the State" and Tier 2 plants as "invasive plant species that cause or are likely to cause substantial negative impact within the State." The Maryland Filter considers the actual and potential distribution of the species in Maryland, its threat to threatened and endangered ecosystems and species in the state, the difficulty of control of the species, and whether added propagule pressure would be likely to increase its persistence and spread significantly. IPAC then recommends regulations to reduce the risk of the Tiered invasive plants in Maryland.

Species Information

***Ficaria verna* Huds. – Fig buttercup**

Family: Ranunculaceae

Synonyms: *Ranunculus ficaria* L. (NGRP 2015). Because the name *R. ficaria* is still widely used, we used that name and *F. verna* when conducting our literature review.

Common names: Fig buttercup, lesser celandine, pilewort, and ficaire (NGRP 2015; Stace 2010). Additional names are listed in Axtell et al. (2010).

Initiation: This plant is listed on the MD Department of Natural Resources (DNR) Do Not Plant List, a policy document available from MD DNR, which lists approximately 90 plant species that may not be planted on DNR land or for DNR projects. This assessment was originally completed when the Weed Specialist of the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) Division of Plant Industry was asked to evaluate *Ficaria verna* for listing as a State Noxious Weed (Iverson 2014). The PERAL Weed Team worked with the NCDA&CS's Weed Specialist to evaluate this species.

Foreign distribution: This species is native to a broad region, encompassing northern Africa (e.g., Algeria, Libya, Tunisia, and Morocco), northern Europe (e.g., Ireland, Denmark, Finland), eastern Europe (e.g., Belarus, Hungary, Croatia), and western Asia (Israel, Turkey, Georgia) (NGRP 2015). It has been introduced to and is now naturalized in Australia, Japan, and New Zealand (Esler and Astridge 1987; Howell and Sawyer 2006; Mito and Uesugi 2004; Richardson et al. 2006).

U.S. distribution and status: *Ficaria verna* has been present in the United States since at least 1867, when a specimen was collected in Pennsylvania (Axtell et al. 2010). It was probably introduced as an ornamental plant (Swearingen et al. 2002). It was cultivated at least 100 years ago, and possibly earlier (Snyder and Kaufman 2004). *Ficaria verna* is currently cultivated in the United States and Canada (Axtell et al. 2010; Page and Olds 2001). Plant Information Online notes that seven cultivars are available commercially in the United States (Univ. of Minn. 2015), but it is likely there are others. Currently, *Ficaria verna* is naturalized in 26 eastern states, as well as Oregon, Washington, and several provinces in Canada (Kartesz 2015; NRCS 2015; CISEH 2015). The populations in the Pacific Northwest (Reichard 2007) and a population in South Carolina (Marlow et al. 2014) were only recently detected, indicating that the species is still spreading in the United States. The South Carolina Native Plant Society has organized a citizen watch program so that infestations can be detected early and controlled (Stringer and Marlow 2015). *Ficaria verna* is banned, prohibited, or listed as a State Noxious Weed in Connecticut, Massachusetts, Oregon, and Washington (Anonymous 2015; Kartesz 2015; NGRP 2015; NRCS 2015).

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

<u>Summary Statement</u>

Ficaria verna received a score of High Risk under the PPQ WRA model. *Ficaria verna* has already proven to be a significant invader in the United States that readily spreads in moist sites (Mehrhoff and Westbrooks 2009; Post et al. 2009) and outcompetes plants in natural systems and home gardens (Axtell et al. 2010; Dave's Garden 2015; Hammerschlag et al. No Date; Snyder and Kaufman 2004). The species received a Tier 1 ranking in the Maryland Filter analysis because it occurs in floodplains along with Maryland threatened and endangered species.

<u>1. *Ficaria verna* analysis</u>

Establishment/Spread Potential *Ficaria verna* has already demonstrated a strong ability to establish and spread beyond its native range, particularly in the United States (Mehrhoff and Westbrooks 2009; Post et al. 2009). Several factors have contributed to this ability, including shade tolerance (Taylor and Markham 1978), an ability to form dense patches (Hammerschlag et al. No Date), sexual and vegetative reproduction (Axtell et al. 2010), self-compatibility (Marsden-Jones 1935), and a variety of dispersal mechanisms (Axtell et al. 2010; Post et al. 2009; Reisch and Scheitler 2009; Taylor and Markham 1978; van der Pijl 1982). *Ficaria verna* is competitively superior to most other U.S. native spring ephemerals because it is able to emerge earlier in the season than natives and to usurp light resources, although these factors are not explicitly considered by our WRA model (Axtell et al. 2010; ISSG 2015). We had average uncertainty for this risk element. Additional information about generation time for vegetatively reproducing plants and two persistence attributes would reduce uncertainty.
Risk score = 17 Uncertainty index = 0.13

Impact Potential *Ficaria verna* is primarily a weed of natural (Mito and Uesugi 2004; Randall 2007) and anthropogenic systems (Axtell et al. 2010; Richardson et al. 2006; Sell 1994; Taylor and Markham 1978). In natural areas it forms dense mats that exclude native species (Hammerschlag et al. No Date) and alters the structure of the understory (Snyder and Kaufman 2004). Because it is

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[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).

abundant in moist sites, it is likely a threat to Threatened and Endangered riparian taxa. In anthropogenic systems, *F. verna* is a turf and garden weed that competes with desirable species (Axtell et al. 2010; Dave's Garden 2015). This species is controlled in both systems (Dave's Garden 2015; Howell 2008; Marlow et al. 2014). Herbicide treatment studies have evaluated the most effective timing and concentration of herbicide applications (Hammerschlag et al. No Date). Several management options have been developed (Swearingen 2010). We had low uncertainty for this risk element.
Risk score = 2.8 Uncertainty index = 0.09

Geographic Potential Based on three climatic variables, we estimate that about 79 percent of the United States is suitable for the establishment of *Ficaria verna* (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 *F. verna* represents the joint distribution of Plant Hardiness Zones 4-11, areas with 10-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: Steppe, Mediterranean, Humid subtropical, Marine west coast, Humid continental warm summers, Humid continental cool summers, Subarctic, and Tundra.

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 soil and habitat type, may further limit the areas in which this species is likely to establish. Our literature review showed that *F. verna* prefers moist sites (Axtell et al. 2010). It occurs in damp meadows, shady lawns, forests, ditches, drainage ways, hedgerows, floodplains, alluvial woods, shaded turf, stream and riverbanks, pond margins, bogs, and marshes (Axtell et al. 2010; Sarver et al. 2008; Taylor and Markham 1978).

Entry Potential We did not assess the entry potential of *F. verna* because it is already present in the United States, where it is widely naturalized (NRCS, 2015; Weakley, 2012).

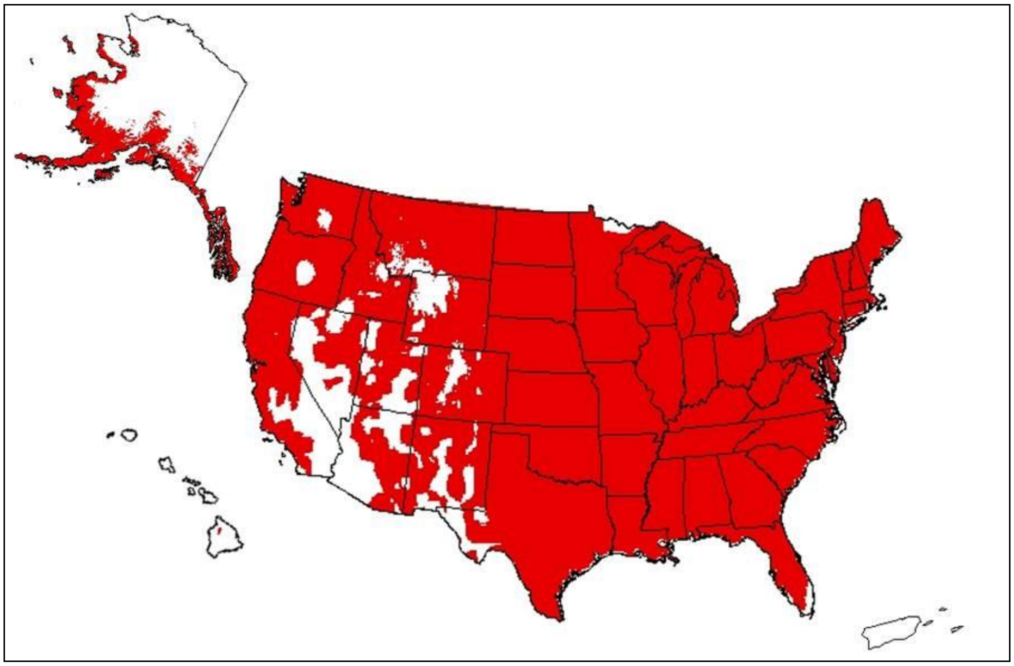

Figure 1. Predicted distribution of *Ficaria verna* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

<u>2. Results</u>

Model Probabilities: P(Major Invader) = 82.6%
P(Minor Invader) = 16.8%
P(Non-Invader) = 0.6%

Risk Result = High Risk

Secondary Screening = Not Applicable

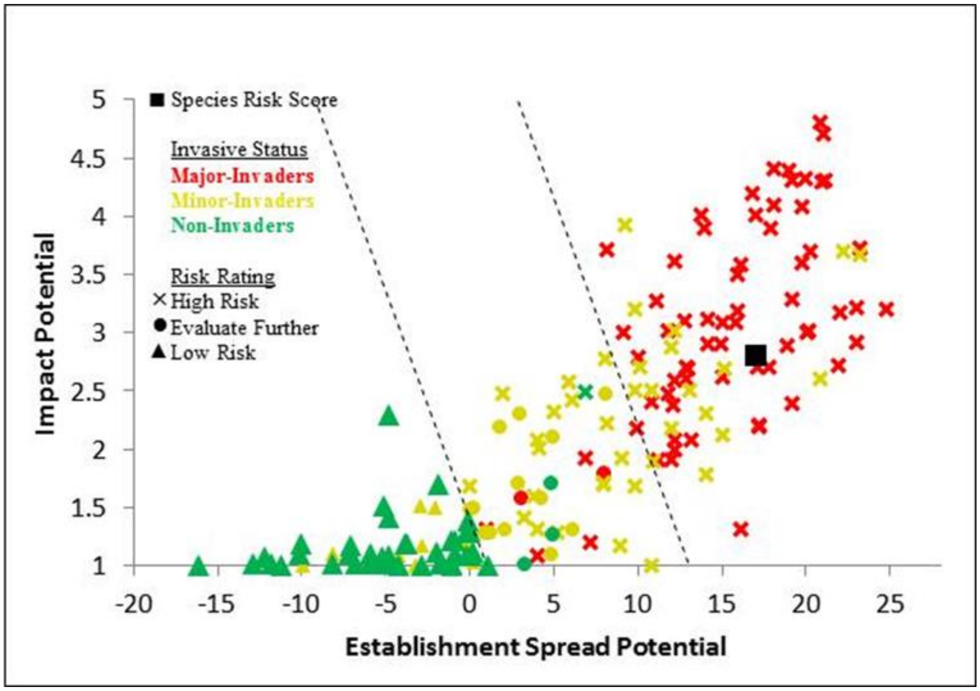

Figure 2. *Ficaria verna* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

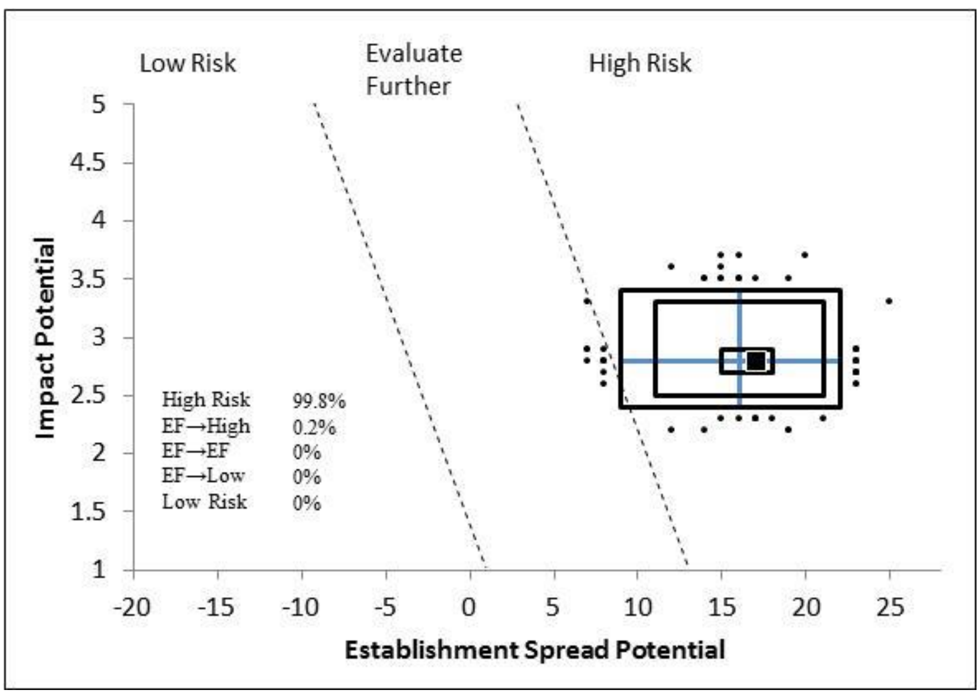

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Ficaria verna*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Ficaria verna* is High Risk (Fig. 2). The result of our uncertainty simulation indicates that our conclusion is statistically robust (Fig. 3), though additional information would reduce uncertainty further, and perhaps move the risk score further into the high risk region. *Ficaria verna* has already proven to be a significant invader in the United States that readily spreads in moist sites (Mehrhoff and Westbrooks 2009; Post et al. 2009) and outcompetes plants in natural systems and home gardens (Axtell et al. 2010; Dave's Garden 2015; Hammerschlag et al. No Date; Snyder and Kaufman 2004). This species is still spreading into new areas and regions of the United States (Marlow et al. 2014; Reichard 2007), and additional impacts may emerge as it is studied further. This species should be of particular concern to natural resource managers of bottomland or otherwise moist sites because *F. verna* can form extensive monocultures that cover several acres (Marlow et al. 2014).

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Appendix A. Weed risk assessment for *Ficaria verna* Huds. (Ranunculaceae). 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]	f - negl	5	*Ficaria verna* is native to a broad region that includes Europe, northern Africa, and western Asia (NGRP 2015; Taylor and Markham 1978). This species is naturalized in Australia (Richardson et al. 2006), Japan (Mito and Uesugi 2004), and New Zealand (Esler and Astridge 1987; Howell and Sawyer 2006). A widespread distribution in some areas of Victoria, Australia (Richardson et al. 2006) suggests it is or has readily spread there. This species has been present in the United States for at least 150 years, but increasing reports of naturalization over the last 20 years indicate it has moved out of the invasion lag phase and is now rapidly spreading across the country (Mehrhoff and Westbrooks 2009; Post et al. 2009). It was recently detected as naturalized in the Pacific Northwest (Reichard 2007). This species spreads rapidly once established (Snyder 1987; Swearingen et al. 2002). Alternate answers for the Monte Carlo were both "e."
ES-2 (Is the species highly domesticated)	n - low	0	Plants are cultivated, including in the United States and Canada, with several ornamental hybrids available (Axtell et al. 2010; Page and Olds 2001). Plant Information Online notes that seven cultivars are available commercially in the United States (Univ. of Minn. 2015), but it is likely there are others. Cultivars were developed as early as the 1500s (Kaufman and Kaufman 2007). Plants are also used medicinally for treating hemorrhoids and scurvy (Axtell et al. 2010). The young tubers are non-toxic and can be consumed raw or prepared (Axtell et al. 2010). However, we found no evidence the species has been highly domesticated or bred for traits associated with reduced weed potential.
ES-3 (Weedy congeners)	y - negl	1	The genus *Ficaria* includes five European and Asian species (Mabberley 2008). Randall (2012) lists three other species of *Ficaria* as potentially weedy, but it is not clear if these are significant weeds. Because some taxonomists place *Ficaria* in the genus *Ranunculus*, we also considered congeners in that genus, which includes about 600 species (Mabberley 2008). Dozens of *Ranunculus* taxa have been reported as weedy, escaping, or naturalized (Randall 2012). Of these, eight species (*R. acris*, *R. arvensis*, *R. bulbosus*, *R.*

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
			muricatus, *R. parviflorus*, *R. repens*, *R. sardous*, and *R. sceleratus*) may be significant weeds based on the dozens of references Randall cites for each. Holm et. al. (1979) list five species of *Ranunculus* as serious or principal weeds of agriculture (*R. acer*, *R. acris*, *R. arvensis*, *R. calthaefolius*, and *R. repens*). *Ranunculus acer*, *R. cantoniensis*, *R. caucasicus*, *R. japonicus*, *R. lomatocarpus*, and others are considered economically significant weeds (Reed 1977). *Ranunculus repens* is problematic in lawns and fields (DiTomaso and Healy 2007). *Ranunculus arvensis* is a troublesome invasive weed in the southeastern United States in agricultural fields and disturbed sites (Riefner and Boyd 2007).
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	*Ficaria verna* occurs in disturbed shady environments (Axtell et al. 2010). "The diploid occurs in both shady and open situations, but the bulbiferous form is more local and found chiefly in shade" (Taylor and Markham 1978). It is characteristic of woodland habitats in one part of its native range (Taylor and Markham 1978). Although it prefers open sites, it does well in shaded ones (Taylor and Markham 1978). Produces seed in sun or shade, but it is important to note that shade is a relative term because this species grows and blooms before tree canopies have emerged (Marsden-Jones 1935).
ES-5 (Climbing or smothering growth form)	n - negl	0	Species is an herbaceous perennial that forms a mounded rosette of leaves (Axtell et al. 2010; Taylor and Markham 1978). It is neither a vine nor a plant with a tightly appressed basal rosette of leaves.
ES-6 (Forms dense thickets)	y - negl	2	Forms dense carpet-like colonies on the forest floor, particularly along streams, and other water bodies (Axtell et al. 2010). Forms dense patches (Hammerschlag et al. No Date). Dense and widespread in poorly drained lawns in Victoria, Australia (Richardson et al. 2006). Forms near solid ground cover along creeks (Snyder 1987). Sometimes forms "pure stands" in its native range (Taylor and Markham 1978).
ES-7 (Aquatic)	n - negl	0	Species is not an aquatic plant. It is a terrestrial perennial that occurs in woodlands, forests, and floodplains (Axtell et al. 2010; Taylor and Markham 1978).
ES-8 (Grass)	n - negl	0	Species is not a grass; it is in the Ranunculaceae family (NGRP 2015).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen. It is an herbaceous perennial and not a woody plant (Swearingen et al. 2002). Furthermore, this species is not in a family known to contain nitrogen-fixing

Question ID	Answer - Uncertainty	Score	Notes (and references)
			species (Martin and Dowd 1990; Santi et al. 2013).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Seed production in *Ficaria verna* varies greatly among the different subspecies. The diploid subspecies reproduce through seed, whereas the tetraploid subspecies reproduce primarily through aerial bulbils (Axtell et al. 2010). About 63 percent of the diploid seeds are viable, whereas only 2 percent of the seeds are viable in tetraploid plants (Marsden-Jones 1935). One researcher suggests that tetraploid plants produce very few viable seeds because valuable resources are diverted from seed production into bulbil formation (Marsden-Jones 1935). Other accounts of seed production indicate that seed is either rarely found (cited in Sedgwick and Cameron 1907) or primarily nonviable (Metcalfe 1939). Based on the extensive studies of Marsden-Jones, it seems likely that these other researchers were examining tetraploid populations. We answered “yes” with negligible uncertainty, because the diploid taxa produce viable seed.
ES-11 (Self-compatible or apomictic)	y - mod	1	Species biology suggests that plants are adapted for some self-pollination because "[i]n the second stage [of flowering] the inner stamens arch over and stand above the carpels ..., and although the anthers dehisce extrorsely, failing insect visits, self-pollination takes place, and if the plant is not self-sterile a small proportion of seed is set" (p. 42 Marsden-Jones 1935). Yet in experiments where plants were caged to prohibit access by pollinators seed set was greatly reduced (Marsden-Jones 1935). The author concluded that plants are completely self-sterile or produce only a small percentage of seeds that would have been possible had insects effected pollination (Marsden-Jones 1935). Self-pollination occurs in the absence of insect visitors (Sell 1994). Another study reports that sometimes, when flowers are emasculated, embryos still develop, indicating that seeds are produced through apomixis, but it was not confirmed whether these seeds germinate (Metcalfe 1939). Some plants are either only female or male (Marsden-Jones 1935), and thus would need cross-pollination (Marsden-Jones 1935). We answered “yes” because some plants are self-compatible, but used moderate uncertainty because cross pollination is still very important for this species (Marsden-Jones 1935).
ES-12 (Requires special pollinators)	n - negl	0	We found no evidence that this species requires specialist pollinators. One study (Masters and Emery 2015) documented that 18 different insect pollinators

Question ID	Answer - Uncertainty	Score	Notes (and references)
			visited *F. verna*, including flies. Another study noted that *F. verna* subspecies *bulbifera* is pollinated by ants (Jung et al. 2008). Pollen and nectar, which is produced at the base of the petals, are available as rewards to insects; bees, small beetles, and flies are pollinators (Taylor and Markham 1978). Finally, in one field study of flower visitors, the author noted a wide diversity of visitors, including the European honeybee (Marsden-Jones 1935).
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]	c - high	0	*Ficaria verna* is a perennial species that reproduces through both sexual and vegetative means (Sell 1994). Diploid seedlings do not begin producing flowers until their second year (Marsden-Jones 1935). Some plants developing from bulbils flowered in their first year (Marsden-Jones 1935), but then their seedlings wouldn't flower until their second year. We found no information on whether plants that originate from bulbils produce bulbils in their first year, but this may be possible. We found no evidence that there are multiple generations per year, or that generation time is longer than 3 years. Consequently, we answered "c" with high uncertainty, and alternate answers for the Monte Carlo simulation were both "b."
ES-14 (Prolific reproduction)	y - high	1	Vegetative reproduction: A local myth in England about "potato rain" relates to the fact that each leaf develops a bulbil (Halket 1927). Plants produce on average 24.1 bulbils, of which only about 60- 80 percent "germinate" (Marsden-Jones 1935). One land manager estimates that plants occur at densities of about 428 plants per square meter (Manning 2015). If all of these produce 24.1 bulbils at a 60 percent germination rate, there would be approximately 6188 bulbils produced per square meter. In another study, the maximum number of bulbils per plant that was observed was 140 (Jung et al. 2008). Sexual reproduction: "[T]he diploid produces large numbers which ripen and are shed by early June" (Taylor and Markham 1978). In one study, the researcher collected an average of 73 viable achenes per plant out of 20 diploid plants, representing 63 percent of the total seeds produced (Marsden-Jones 1935). Only 2 percent of the achenes are viable in tetraploid plants (Marsden-Jones 1935). Assuming these fecundity rates, we would need to have at least 68 diploid plants per square meter to meet our threshold of 5000 for an herbaceous species, which is realistic based on Manning's estimate of plant density (2015). We answered "yes" for this question, but used high uncertainty because it is not clear that all plants at the population density reported

Question ID	Answer - Uncertainty	Score	Notes (and references)
			by Manning (2015) are reproducing.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	Mowing turf may spread aerial bulbils and promote the establishment of new plants (Reisch and Scheitler 2009). Mechanical removal is very likely to result in the spread of tubers (Axtell et al. 2010). The tubers and bulbils are spread by ploughing and digging (Taylor and Markham 1978). One of the earliest collections from New Jersey (1898) was from ship ballast from Europe (Snyder 1987). Plants spread from yard waste (Post et al. 2009).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	n - mod	-1	We found no evidence for this kind of dispersal. It seems unlikely that *F. verna* would contaminate most vegetable crops since it is not a weed of row crops. However, it could invade plant beds of perennial nursery stock.
ES-17 (Number of natural dispersal vectors)	2	0	Fruit and seed description for ES-17a through ES-17e: Fruit is an achene that is about 2.5-5 mm long, and with a very short beak (Sell 1994; Stace 2010). Achenes occur in globular clusters (Richardson et al. 2006; Taylor and Markham 1978). "As the plants of subsp. *chrysocephalus* die, the stalks bend over so that the falling seeds form a ring round the old plant and later produce a circle of seedlings" (Sell 1994). Some subspecies of *F. verna* also produce aerial bulbils from leaf axils (Post et al. 2009). These can also disperse (see evidence immediately below).
ES-17a (Wind dispersal)	n - low		We found no direct evidence. This species does not possess any morphological traits typically associated with wind-dispersed seeds (e.g., wings, plumes). Also, the achenes are relatively large for wind dispersal. Consequently, we answered “no” with low uncertainty.
ES-17b (Water dispersal)	y - negl		This species is very common and abundant along creeks and floodplain forests (Snyder 1987). Bulbils and tubers are easily dispersed during flood events (Swearingen et al. 2002). Dispersed by rain wash (van der Pijl 1982). "Plants thrive in mesic environments on the banks of rivers, streams, lakes, and ponds, as well as in wetland sites. This contributes to the spread of the species along major waterways because tubers, bulbils, seeds, and small plants may be dislodged by swift-moving or seasonal flood waters and transported downstream. This phenomenon was confirmed through firsthand observation in the spring of 2006 in Wake County, NC, where the banks of a local stream were found infested with lesser celandine, and inspection, 1 km upstream revealed a large source population in a shaded lawn" (Axtell et al. 2010). Fruits can travel extensive distances downstream in flood waters

Question ID	Answer - Uncertainty	Score	Notes (and references)
			(Hammerschlag et al. No Date).
ES-17c (Bird dispersal)	n - mod		We found no direct evidence. The species does not produce fleshy fruit that would be attractive to birds. However, because the achenes may nevertheless be eaten by seed-eating birds, we answered ”no” with moderate uncertainty.
ES-17d (Animal external dispersal)	y - mod		Bulbils and tubers may be accidentally and easily dispersed by animals (Axtell et al. 2010; ISSG 2015), but we could not find the original citations. Seeds are dispersed by ants which are attracted to elaiosomes (fat/oil bodies that attract ants) (Jung et al. 2008), but this is the only report of ant dispersal or the production of elaiosomes. We used moderate uncertainty because these were all anecdotal comments.
ES-17e (Animal internal dispersal)	n - mod		We found no evidence that animals consume plants or seeds, or any evidence of gut-passage survival.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - high	1	In a series of experiments, researchers showed that seeds require a resting period of a few months to fully mature, and even then only some of them germinate (Taylor and Markham 1978). However, when the pericarp of the seed is removed, germination is much faster and reaches 100 percent after 36 weeks from the start of the experiment (Taylor and Markham 1978). In this study, seeds with their pericarp still intact remained intact and firm after 18 months (Taylor and Markham 1978), suggesting that seeds may be able to persist for more than a year in the soil. Consequently, we answered “yes” but with high uncertainty, until long-term dormancy can be established.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - mod	1	The root system produces tuberous roots (Stace 2010) that are club-shaped and range in length from 5 mm to 100 mm long (Axtell et al. 2010). The taxon survives frequent mowing (Taylor and Markham 1978), although growth tends to decrease under these conditions (Axtell et al. 2010). We note that disturbance by mowing increases the genetic diversity of populations in mowed meadows, probably due to greater dispersal of propagules in meadows (Reisch and Scheitler 2009).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - mod	0	We found no evidence that it is resistant to herbicides. It is not listed on the Weed Science Society of America's database of herbicide resistant weeds (Heap 2015). However, we note that a congener, *Ranunculus acris*, is reported to be resistant to two different types of herbicides in New Zealand pastures (Heap 2015). It is unknown if *R. acris* and *F. verna* can hybridize.
ES-21 (Number of cold hardiness zones suitable for	8	0	

Question ID	Answer - Uncertainty	Score	Notes (and references)
its survival)			
ES-22 (Number of climate types suitable for its survival)	8	2	
ES-23 (Number of precipitation bands suitable for its survival)	10	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	y - mod	0.1	In one field study the authors investigated the allelopathic potential of this species by controlling for soil nutrients and potential allelopathic chemicals with carbon (Cipollini and Schradin 2011). They found that without carbon addition, *F. verna* decreased the number and reproductive capability of native species (Cipollini and Schradin 2011). In a laboratory study, the same authors found that, when ground up and sprayed on soil, the leaves inhibited the germination of *Arabidopsis* in potting soil (Cipollini et al. 2012).
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this species is parasitic. Furthermore, it is not a member of a plant family known to contain parasitic species (Heide-Jorgensen 2008; Nickrent 2009).
Impacts to Natural Systems			
Imp-N1 (Change ecosystem processes and parameters that affect other species)	n - high	0	We found no evidence of this impact. Given that *F. verna* can form extensive populations in alluvial habitats (see image on the cover page of this document), it is possible it may change mineral deposition and hydrology, but this has not been studied.
Imp-N2 (Change habitat structure)	y - mod	0.2	Forms extensive carpets in the forest understory (ISSG 2015; Marlow et al. 2014). Forms near monocultures and "has significantly altered the structure of natural plant communities" (Snyder and Kaufman 2004). "[L]ike other woodland perennials in shade it can form a continuous carpet which tends to inhibit the colonization of the ground beneath by other species" (Taylor and Markham 1978). We answered “yes” because it forms monocultures and because of the statement from Snyder and Kaufman (2004), however, we used moderate uncertainty because information on how it affects habitat structure is lacking.
Imp-N3 (Change species diversity)	y - negl	0.2	Dense colonies form in moist areas and exclude other species because it emerges earlier than other species (Axtell et al. 2010; ISSG 2015). It forms mats in forest understories that block sunlight to other spring ephemerals (Kaufman and Kaufman 2007). Pollinators visit *F. verna* instead of native showy plants reducing seed set in native plants (Masters and Emery, 2015).

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Naturalists report that prior to extensive colonies of *F. verna* at one park, there existed a variety of native ephemerals (Hammerschlag et al. No Date). A management study at that same park showed that relative to control plots, which were untreated with herbicides, native species cover increased following treatment of *F. verna* (Hammerschlag et al. No Date), demonstrating that this species suppresses native plant communities.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species)	y - mod	0.1	Because this species invades natural areas, forming dense mats and excluding spring ephemerals (see evidence in Imp-N2 and Imp-N3), it seems likely to affect threatened and endangered species. We note that this species invades floodplains and riparian areas that are known to generally contain sensitive native species.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	? - max	0	Although this species can occur in U.S. globally outstanding ecoregions (Ricketts et al. 1999 and see Fig. 1), we found no evidence that it affects ecosystem properties (e.g., nutrient cycling) or otherwise has a fundamental impact on ecosystems at large scales. However, because it does reduce native species diversity and alter habitat structure, and because it can dominate large areas (see image on cover page), we answered unknown.
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]	c - negl	0.6	It is a natural areas weed in Australia (Randall 2007). Managed in natural areas (ISSG 2015). Species is controlled in natural areas with herbicide treatments, but managers have not been able to eradicate extensive populations, only suppress them (Axtell et al. 2010). Controlled on conservation land in New Zealand (Howell 2008). Herbicide treatment studies have been performed to evaluate the most effective timing and concentration of herbicide applications (Hammerschlag et al. No Date). Several management options have been developed (Swearingen 2010). Alternate answers for the Monte Carlo simulation were both "b."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	n - low	0	We found no evidence, and this impact seems unlikely for a small herbaceous perennial.
Imp-A2 (Changes or limits recreational use of an area)	n - low	0	We found no evidence, and this impact seems unlikely for a small herbaceous perennial.
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	y - low	0.1	Prevents establishment of favorable grasses in turf (cited in Axtell et al. 2010). Smothers daffodils and overruns spring ephemerals in gardens (Dave's Garden 2015).
Imp-A4 [What is the taxon's	c - negl	0.4	Establishes in yards (Snyder 1987) and lawns (Krings

Question ID	Answer - Uncertainty	Score	Notes (and references)
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]			et al. 2005). A weed of lawns, gardens, and horticultural plantings (Axtell et al. 2010; Richardson et al. 2006; Sell 1994; Taylor and Markham 1978). "*Ranunculus ficaria* is a weed of lawns, grassy paths, shrubberies, roadside verges and hedgerows" in its native range (Taylor and Markham 1978). Forms of *F. verna* that produce bulbils in the leaves are troublesome in United Kingdom gardens (Metcalfe 1939; Salisbury 1961). Of the nine comments under this species in the online forum Dave's Garden, eight are negative while the other one is neutral (Dave's Garden 2015). Overall, gardeners who have either planted this species in their gardens or have had the plant invade their yards from elsewhere, note that plants are difficult if not impossible to remove and urge others to not use this plant (Dave's Garden 2015). One commenter said "I can't believe it is still legal to buy this plant!" (Dave's Garden 2015). "Two other promising herbicides currently being evaluated for their efficacy on lesser celandine include a fall application of the preemergent herbicide oxadiazon in turf and the preemergent granular herbicide flumioxazin in landscape ornamentals" (Axtell et al. 2010). 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 - low	0	Overall, we found no evidence that this species is a weed or causes any specific or significant impacts in production systems. However, we note that it occurs in rough pasture (Taylor and Markham 1978), and that other species of *Ranunculus* are toxic under some circumstances (see Imp-P5).
Imp-P2 (Lowers commodity value)	n - low	0	We found no evidence.
Imp-P3 (Is it likely to impact trade)	n - low	0	We found no evidence.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - low	0	We found no evidence.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	y - high	0.1	Fresh plants contain compounds that are known to be toxic to most mammals (cited in Axtell et al. 2010). Leaves can be used in salads, but they turn poisonous as the fruit mature on plants (ISSG 2015). In one case, a person who was taking extracts of *F. verna* for 10 days developed acute hepatitis and required hospitalization; once she stopped taking the

Question ID	Answer - Uncertainty	Score	Notes (and references)
			supplement, her condition improved (Yilmaz et al. 2015). Toxicity in the genus is due to a glycoside that is hydrolyzed to protoanemonin when plant tissues are macerated, but later, this compound is polymerized to form the inactive anemonin (Burrows and Tyrl 2013). The genus *Ranunculus* has a long history of various medicinal uses, and some species are known to have antibacterial, antifungal, and antimutagenic effects (Burrows and Tyrl 2013). Some species are known to cause irritations of the digestive tract, but generally, large quantities of material need to be consumed for any disease to manifest and in most cases only a few animals are seriously affected (Burrows and Tyrl 2013). Occasionally, large numbers of deaths are seen, as happened with the loss of 150 sheep in a flock of 800 after they ate *R. testiculatus* (Burrows and Tyrl 2013). We answered “yes” because the species and the genus in general can be toxic under certain circumstances. However, we used high uncertainty because it does not appear to be common.
Imp-P6 [What is the taxon’s weed status in production systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	a - low	0	Occurs in rough pasture (Taylor and Markham 1978). However, we found no evidence it is considered a weed in production systems. Alternate answers for the Monte Carlo simulation were both "b."
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2015).
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 - mod	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z4 (Zone 4)	y - low	N/A	Two points in Finland. A few points in Austria in the Alps region. Two points in Russia. A range map for the species in Europe places it in this zone (regional occurrence data; Taylor and Markham 1978).
Geo-Z5 (Zone 5)	y - negl	N/A	Some points in Austria, Germany, and Norway. Hardy to Zones 5-10 (Page and Olds 2001).
Geo-Z6 (Zone 6)	y - negl	N/A	Austria, Germany, Norway, Sweden, and the United States. Hardy to Zones 5-10 (Page and Olds 2001).
Geo-Z7 (Zone 7)	y - negl	N/A	Germany, Norway, Sweden, and the United States. Hardy to Zones 5-10 (Page and Olds 2001).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z8 (Zone 8)	y - negl	N/A	France, Spain, the United Kingdom, and the United States. The main bud withstands temperatures of -9 °C (Taylor and Markham 1978). Hardy to Zones 5-10 (Page and Olds 2001).
Geo-Z9 (Zone 9)	y - negl	N/A	Ireland, Spain, and the United Kingdom. Requires a chilling temperature between 4 and 6 °C for several weeks and then warmer temperatures for reproduction (Markham in Axtell et al. 2010). Hardy to Zones 5-10 (Page and Olds 2001).
Geo-Z10 (Zone 10)	y - mod	N/A	Some points in Portugal and Spain. Three points in Australia. Hardy to Zones 5-10 (Page and Olds 2001).
Geo-Z11 (Zone 11)	y - high	N/A	We found some points along the coasts of Portugal and Spain. We answered "yes" based on the number of points, but its presence in coastal Portugal and Spain seems odd given that this species requires chilling temperature for growth. Perhaps these populations are specifically adapted to this climate. Consequently, we used high uncertainty.
Geo-Z12 (Zone 12)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z13 (Zone 13)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C2 (Tropical savanna)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C3 (Steppe)	y - high	N/A	Many points in Spain. Two points in Iran. Because this species likes ample moisture, it is likely restricted to wetter sites in this climate class. Because a range map for the species in Europe does not include most of this steppe region in Spain (regional occurrence data; Taylor and Markham 1978), we used high uncertainty.
Geo-C4 (Desert)	n - mod	N/A	One point in each of Australia, Tunisia, and Spain. These may be erroneous records or plants may be growing in protected microsites. Because the species in general prefers moist sites, we answered "no."
Geo-C5 (Mediterranean)	y - negl	N/A	Greece, Italy, Portugal, Spain, and the United States.
Geo-C6 (Humid subtropical)	y - low	N/A	Some points in the United States (MD, NC, and VI).
Geo-C7 (Marine west coast)	y - negl	N/A	France, New Zealand, Spain, and the United Kingdom.
Geo-C8 (Humid cont. warm sum.)	y - negl	N/A	Many points in the United States.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Austria, Germany, and Sweden.
Geo-C10 (Subarctic)	y - low	N/A	Many points in Norway and Sweden. Some points in Finland.
Geo-C11 (Tundra)	y - high	N/A	Some points in Austria, Germany, and Norway, but all

Question ID	Answer - Uncertainty	Score	Notes (and references)
			coastal. A few points in France.
Geo-C12 (Icecap)	n - mod	N/A	We found no evidence that it occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - mod	N/A	A few points in Spain. We suspect these plants occur in areas where water is impounded. Because this species prefers wetter sites, we answered no with moderate uncertainty.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Many points in Spain. A few points in Greece and Italy. Also a range map for the species in Europe includes this precipitation band (regional occurrence data; Taylor and Markham 1978).
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Spain, Sweden, and the United Kingdom.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	France, Germany, and Spain. In the United States it occurs in areas where rainfall is more than 800 mm annually, but can occur in drier areas if supplemented with irrigation (Axtell et al. 2010).
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	France, Germany, Portugal, and Spain.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Austria, Germany, Portugal, and Spain.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Germany, Ireland, Spain, and the United Kingdom.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Germany, Norway, and the United Kingdom.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	Germany, Norway, and the United Kingdom.
Geo-R10 (90-100 inches; 229-254 cm)	y - low	N/A	Norway and the United Kingdom.
Geo-R11 (100+ inches; 254+ cm)	y - low	N/A	Norway.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	This species is widely naturalized in the United States (NRCS 2015; Weakley 2012).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	
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	

Question ID	Answer - Uncertainty	Score	Notes (and references)
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	

Appendix B. Maryland Filter assessment for *Ficaria verna* Huds. (Ranunculaceae).

Maryland Filter questions	Answer	Instructions/Result	Notes
1. Is the plant a sterile cultivar or used for root stock only? yes OR no	no	Go to question 2	Seed production in *Ficaria verna* varies greatly among the different subspecies. The diploid subspecies reproduce through seed, whereas the tetraploid subspecies reproduce primarily through aerial bulbils (Axtell et al. 2010).
2. Is the plant currently naturalized in Maryland? Yes OR no	yes	Go to Question 3	Plants mainly occur in central Maryland from Harford County to Montgomery and Prince George's County with occasional naturalized populations elsewhere (EDDMapS 2015).
3. What is the species' potential distribution in Maryland? wide OR narrow	wide	Go to question 4	Currently occurs in the Coastal Plain, Piedmont, and Appalachian Plateau regions (EDDMapS 2015).

4. Does or could the species harm threatened or endangered Maryland species or community types or CITES listed species occurring in MD? yes OR no	yes	Tier 1	Occurs in the Piscataway Creek floodplain along with threatened and endangered Maryland species including *Diplazium pyconcarpon*, *Matelea carolinense, M. gonocarpa, Juncus torreyi*, *Gentiana andrewsii*, *Mecardonia acuminata*, and *Pedicularis lanceolata* (Steury and Davis 2003).
5. How feasible is control of the species? easy OR difficult		Questions 5 and 6 are not answered because question 4 resulted in a ranking of Tier 1.	
6. Is added propagule pressure from sales significantly increasing potential of the species to persist and spread? yes OR no			