Maryland
Department
of Agriculture

May 22, 2019

Version 2

Weed Risk Assessment for *Berberis thunbergii* DC (Berberidaceae) – Japanese barberry

Berberis thunbergii, clockwise from upper left: shrub habit, flowering branch, typical woodland infestation in fall color, fruit, bloom and leaf close-up, all photographs by Leslie J. Mehrhoff, University of Connecticut, Bugwood.org

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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 harm; ecological harm; 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. The IPAC evaluates the risk potential of plants already present in Maryland, newly detected in Maryland or the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

The 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.

The 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 a 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. The IPAC then recommends regulations to reduce the risk of the Tiered invasive plants in Maryland.

1. Plant Information and Background

SPECIES: *Berberis thunbergii DC.* -- Japanese barberry

FAMILY: Berberidaceae

SYNONYMS: Three conspecific taxa (varieties) are listed in the USDA National Plant Germplasm System. They are *Berberis thunbergii* var. *atropurpurea*, *Berberis thunbergii* var. *minor*, and *Berberis thunbergii* var. *maximowiczii* (ARS 2019).

COMMON NAMES: Japanese barberry, Thunberg's barberry (ARS 2019).

BOTANICAL DESCRIPTION: Japanese barberry is a cultivated ornamental shrub growing 2 to 4' tall. Simple, spatulate leaves are bright green in spring and turn gold or crimson late in fall. Pale yellow bell-like flowers hang under the thorny branches in early spring; bright red oblong fruits appear in fall. Stems and roots are bright yellow inside. The shrub grows in mesic to dry forests and in old fields in the temperate zone, often under closed canopies (Brown and Brown 1972, Weakley et al. 2012).

INITIATION: This plant is listed on the MD Department of Natural Resources 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.

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

FOREIGN DISTRIBUTION: Japanese barberry is native to Japan (ARS 2019). Naturalized in eastern and central Canada (BONAP 2019). Naturalized or invasive in France (Weber 2003) and the U.K. (Clement 1994). Continuing to spread in SW Germany and Scandinavia (CABI 2015)

U.S. DISTRIBUTION AND STATUS: U.S. distribution and status: Occurs throughout much of the northeastern and upper midwestern United States as well as in parts of the southeast to South Carolina and west to Nebraska. Naturalized populations are also present in Arizona and Washington (BONAP 2019). The plant occurs widely throughout the mid-Atlantic states.

[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).

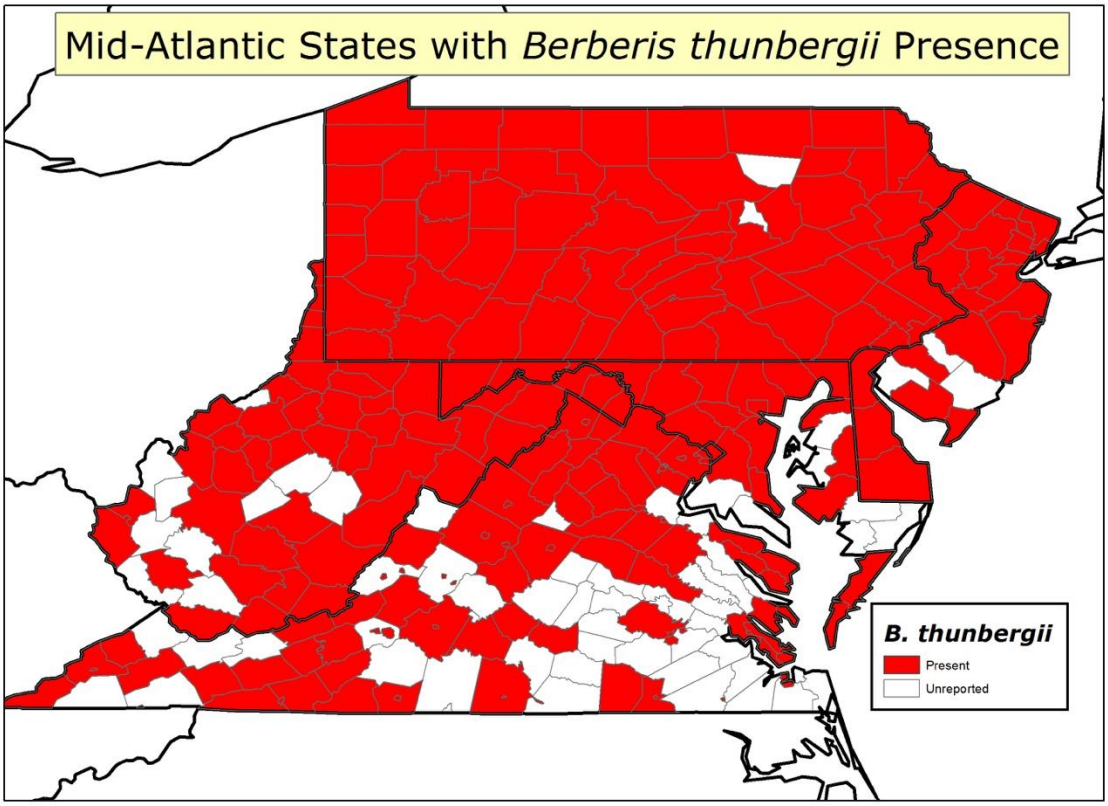

Figure 1. Known naturalized distribution of *Berberis thunbergii* in counties in mid-Atlantic states. The records shown here were obtained primarily from other species distribution databases (EDDMapS 2019, BONAP and USDA Plants Database) and were not independently verified by IPAC.

3. Analysis

ESTABLISHMENT/SPREAD POTENTIAL

Japanese barberry is a shade-tolerant shrub (DeGasperis 2007) that forms dense thickets (Ehrenfeld 1999, Swearingen et al. 2010). It produces prolific red fruits dispersed by birds and small mammals (Brand et al. 2012). Stems resprout readily after cutting (Weber 2003). We had high uncertainty about the minimum generative time for barberry, because the literature is not definitive, but it likely takes at least two years and probably more to reach reproductive maturity (Ehrenfeld 1999). Overall, we had Very Low uncertainty for this risk element.

Risk score = 10 Uncertainty index = 0.05

IMPACT POTENTIAL

Japanese barberry is arguably allelopathic but it does alter soil microbial communities and soil chemistry including nitrification rates and pH (Coats et al. 2014, Ehrenfeld et al. 2001, Kourtev et al. 2002). It changes community composition by forming dense thickets in forest understories (Ehrenfeld 1999, Swearingen et al. 2010) and invasions result in a decline in plant species diversity (Silander and Klepeis 1999). It poses a threat to endangered species and ecosystems (Wixted and McGraw 2008; Zouhar 2008). Thickets of Japanese barberry are virtually impenetrable and limit recreational activities in invaded forests (EDDMaps Ontario 2015; NJDEP 2008). It is widely considered a weed, and is actively controlled in natural areas (Ward et al. 2013, Swearingen et al. 2010). Stands also harbor ticks carrying Lyme disease, posing a threat to human health (Ward et al. 2009). Canada limits the importation and sale of *B. thunbergii* cultivars to those that have been proven to be resistant to *Puccinia graminis*, a fungus that attacks wheat, but in general Japanese barberry is not considered to impact production systems. We had Low uncertainty about the species impacts other than allelopathy, about which our uncertainty was High. Overall, we had Average uncertainty about this risk element.

Risk score = 2.8 Uncertainty index = 0.14

GEOGRAPHIC POTENTIAL

Based on three climatic variables, we estimate that almost 91 percent of the United States is suitable for the establishment of *Berberis thunbergii* (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 *Berberis thunbergii* represents the joint distribution of Plant Hardiness Zones 3-11, areas with 0 to more than 100 inches of annual precipitation, and the following Köppen-Geiger climate classes: Steppe, Desert, Mediterranean, Humid subtropical, Marine west coast, Humid continental warm summers, Humid continental cool summers, Subarctic and Tundra. We had High uncertainty for the occurrence of *Berberis thunbergiil* in deserts, as supported by a single point in Utah, which appears to be adventive. However, because there is clear evidence for its occurrence in Steppe and Mediterranean climate classes, which bracket Desert, we assumed this environment was suitable for it.

The area estimated likely represents a conservative estimate as it uses 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. In Maryland, Japanese barberry grows outside cultivation in various habitats, including open sunny fields, road edges, woods edges and very shaded closed canopy forest.

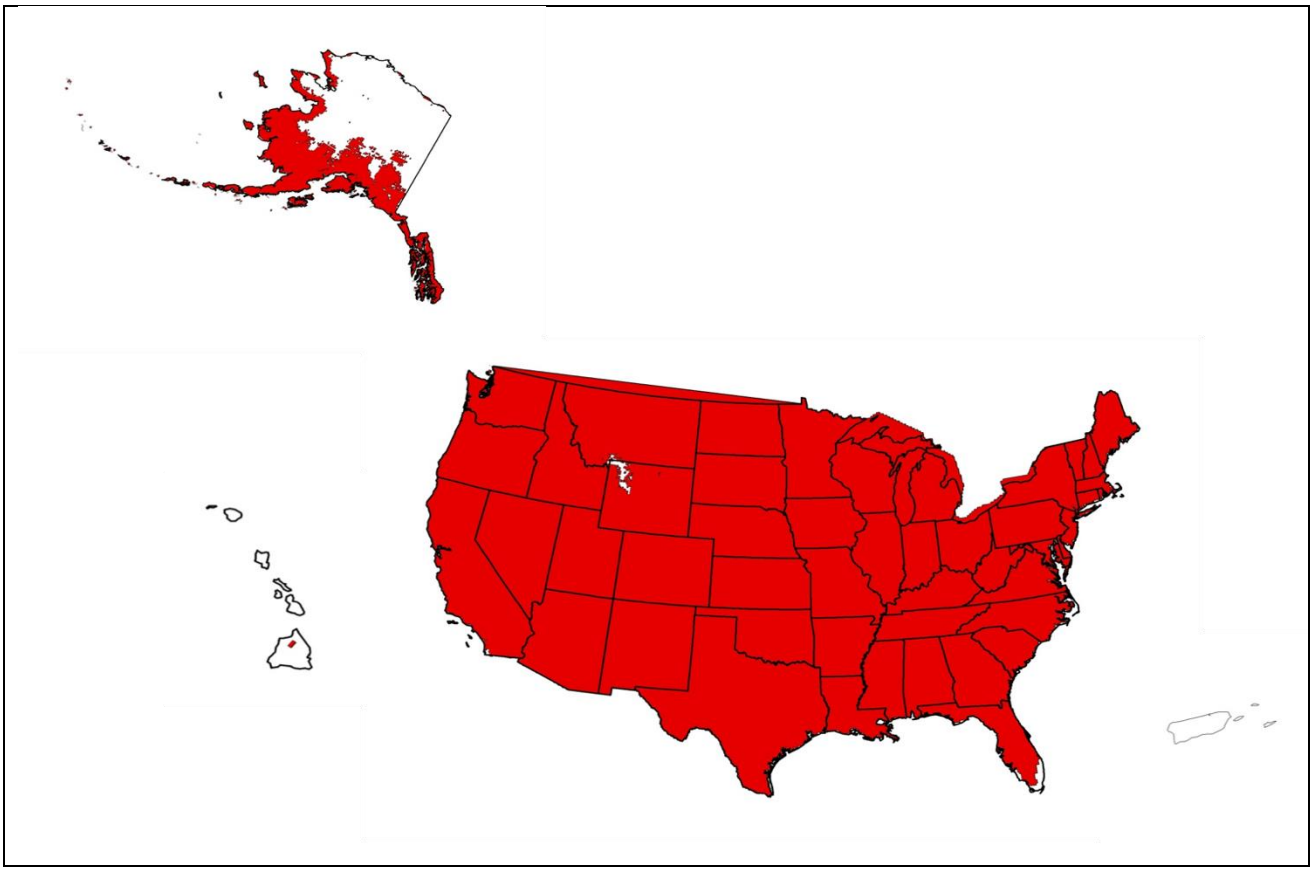

Figure 2. Potential geographic distribution of *Berberis thunbergii* in the United States. Map insets for Hawaii and Puerto Rico are not to scale.

ENTRY POTENTIAL

We did not assess the entry potential of Species because it is already present in the United States (BONAP 2019).

4. Predictive Risk Model Results

Model Probabilities: P(Major Invader) = 47.7%
P(Minor Invader) = 49.1%
P(Non-Invader) = 3.2%
Risk Result = High Risk
Secondary Screening = Not applicable

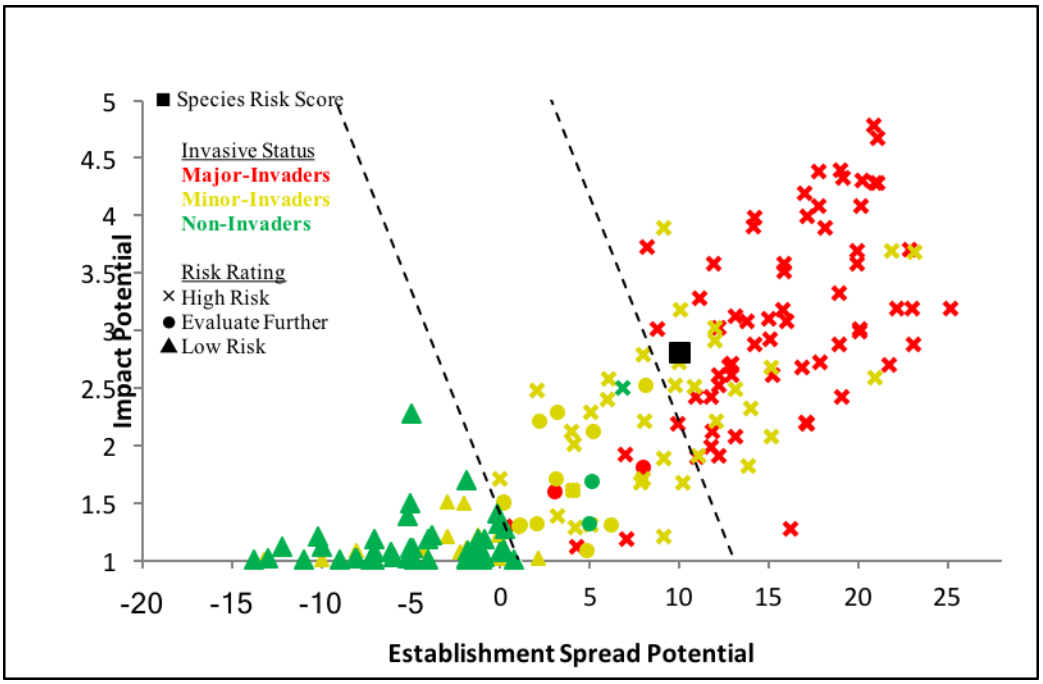

Figure 3. *Berberis thunbergii* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

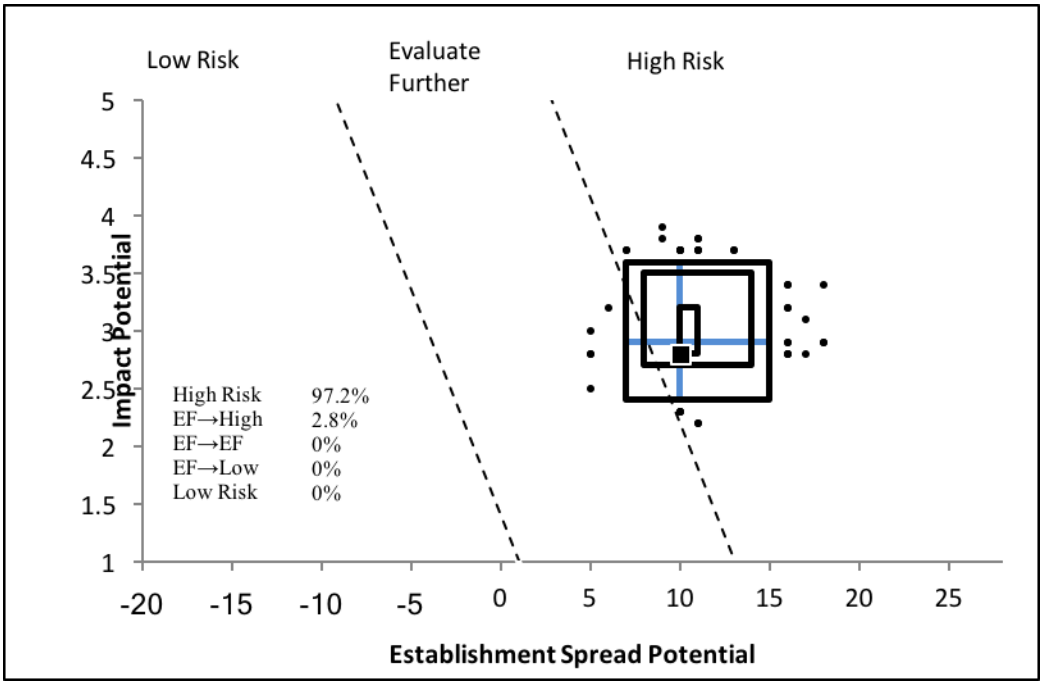

Figure 4. Model simulation results (N=5,000) for uncertainty around the risk score for *Berberis thunbergii*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

5. Discussion

The result of the weed risk assessment for *Berberis thunbergii* is High Risk. *Berberis thunbergii* shares traits in common with other invasive plants used to develop and validate the PPQ WRA model. Over 97% of the Monte Carlo simulation risk scores received a rating of High Risk, and all the Evaluate Further scores were upgraded to High Risk by the simulation (Figs 2, 3). These results indicate that our assessment is robust. Although sources differ in the number of states in which Japanese barberry has naturalized (34 in BONAP 2019, 30 in EDDMapS 2019, 27 in FNA 2019), all sources show that it is present outside cultivation and spreading in the mid-Atlantic states.

Japanese barberry persists in both open and shaded conditions, and can form dense thickets in closed canopy forest (Ehrenfeld 1999,DeGassperis 2007, Swearingen 2010). It is not domesticated in such a way as to reduce spread potential, and although work continues on the production of sterile cultivars, none yet have proven truly sterile (Brand et al. 2012). *Berberis thunbergii* does not require specialist pollinators and is a prolific seed producer (Silander and Klepeis 1999). Seeds are dispersed by both birds and small mammals (Silander and Klepeis 1999, Zouhar 2008).

The impacts of *Berberis thunbergii* occur primarily in natural systems, as it is deliberately planted as an ornamental in anthropogenic systems, and we found no evidence of any impacts to production systems. In natural areas, although Japanese barberry's allelopathic impacts are not certain, the plant demonstrably changes ecosystems processes by altering soil microbial communities (Coats et al. 2014) and soil nutrient processing (Ehrenfeld 2001, Kourtev et al. 2002, 2003). It changes habitat structure by forming a dense shrub layer in invaded forests (Ehrenfeld 1999, Silander and Klepeis 1999, Swearingen 2010), and species diversity declines under that layer (Silander and Klepeis 1999).

Of particular interest is the linkage between *Berberis thunbergii* and the incidence of Lyme disease. We responded "No with High uncertainty" to WRA question Imp A-1, as to whether the taxon negatively impacts human property, human health or public infrastructure. This plant and its cultivated varieties are highly prized and widely planted landscape shrubs. Yet substantial documentation exists indicating that woodlands invaded by Japanese barberry harbor more ticks, and therefore, more ticks carrying the *Borrelia burgdorferi* spirochete (Ward et al. 2009, Williams et al. 2009, Williams and Ward 2010), and that their presence discourages people from using infested recreational areas (Zimmer 2013). We found no evidence that the plant directly impacts human health, although the danger of scratches from its thorns exists (CABI 2015).

Berberis thunbergii is a hugely adaptable plant, tolerating a large range of cold and heat, drought and wet conditions, in numerous climates, as we found in the Geopotential analysis. Over 90% of the United States provides suitable habitat for its establishment. *Berberis thunbergii* ranks as a Tier 2 species for Maryland (Appendix B). It is documented as naturalized and has a wide distribution in the state, being present in all the physiographic provinces (MBP 2019). Control of the plant is difficult, because it does spread vegetatively and

regrows after cutting (Zouhar 2008). Although it does occur in a number of locations where it could threaten species listed as Threatened or Endangered in Maryland (Kyde 2019), it has been present in the state since 1944 (Norton-Brown 2019), and has naturalized in well over 20 locations (EDDMapS 2019, MBP 2019). See Appendix B for the full Maryland Filter analysis for this plant.

6. Acknowledgments

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SUGGESTED CITATION

Maryland Department of Agriculture. 2019. Weed risk assessment for *Berberi thungberii* DC.(Berberidaceae) – Japanese barberry. Maryland Department of Agriculture, Annapolis, MD 24 pp.

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Appendix B. *Berberis thunbergii* DC (Berberidaceae) Japanese barberry

Weed risk assessment for *Berberis thunbergii* (Berberidaceae). The following information came from the original risk assessment, which is available upon request (full responses and all guidance). We modified the information to fit on the page.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 [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	Berberis thunbergii, Japanese barberry is native to Japan (ARS 2015). It was introduced to the US in 1875 (Kaufman and Kaufman 2013). Since then it is described as forming a continuous canopy in forest understories in several states (Zouhar 2009). The species is an "aggressively invasive [shrub] that has become established well beyond managed landscapes and is naturalized in at least 31 states and 5 Canadian provinces" (Ward et al. 2009). It" forms dense stands in closed canopy forests, open woodlands, wetlands, fields and other areas" (Swearingen et al. 2010). The species occurs throughout much of the northeastern and upper midwestern US and Canada as well as in parts of the southeast to South Carolina and west to Nebraska. Naturalized populations are also present in Arizona and Washington (BONAP 2015). Naturalized or invasive populations are reported in France (Weber 2003) and the U.K. (Clement 1994). Barberry is continuing to spread in southwestern Germany and in Scandinavia (CABI 2015). Alternative answers for the Monte Carlo simulation both "e."
ES-2 (Is the species highly domesticated)	n - low	0	The species is not highly domesticated, but there is strong interest in developing cultivars with reduced weediness trait (Brand 2016, Brand et al. 2012). So far, cultivars bred to produce fewer fruits still produce some fruits as they mature (Brand et al. 2012). Work to produce sterile triploids involves crossing induced tetraploids with diploid plants. Tetraploid induction efficiencies of about 20% have been reported, with low but present reversion to diploid seedlings with one year (Lehrer et al. 2008).
ES-3 (Significant weedy congeners)	y - negl	1	Berberis darwinii and B. glaucocarpa are listed as significant environmental weeds in Australia and New Zealand by Weber (2003). B. glaucocarpa is listed by New Zealand on its National Pest Plant Accord (Popay et al. 2010). B. vulgaris used to be a significant weed in the United States because it harbored wheat rust (Kaufman and Kaufman 2013). Japanese barberry may also form a hybrid with B. vulgaris (Berberis x ottawensis) (Connolly et al. 2013).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-4 (Shade tolerant at some stage of its life cycle)	y - low	1	Plants growing in dense shade may not produce as much fruit, but they do reproduce (CABI 2015). Japanese barberry is a shade adapted-species, persisting under very low light levels (1 to 2%) (DeGasperis 2007). Xu et al. found that the species' photosynthetic capacity was "highest in the spring open canopy, and declined with canopy closure" but adjusted to lower light through active nitrogen reallocation and leaf morphological modifications (Xu et al. 2007).
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	The plant is a shrub and does not have a climbing or smothering growth habit (ARS 2015).
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	B. thunbergii forms dense thickets (CABI 2015; Swearingen et al. 2010) "The shrub…forms dense, nearly inpenetrable thickets, even under closed canopies (Ehrenfeld 1999).
ES-7 (Aquatic)	n - negl	0	Japanese barberry is a terrestrial shrub, and not aquatic (ARS 2015).
ES-8 (Grass)	n - negl	0	Japanese barberry is in the Berberidaceae family and not a grass (ARS 2015).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	Plants in the Berberidaceae are not known to fix nitrogen (Santi et al. 2013; Martin and Dowd 1990).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Seed germination in a woodland ranged from 12 - 31% (Brand et al 2012). Both B. thunbergii and B. thunbergii var. purpurea had germination rates of about 25% in different natural environments (Lubell and Brand 2011). Thirteen to fifteen seeds germinated in samples from natural dispersal in riparian forests (Eschtruth and Battles 2011). Seeds planted outdoors and protected from freezing reached 60-70% germination, but freezing killed large numbers of imbibed seeds (Davis 1927).
ES-11 (Self-compatible or apomictic)	n - low	-1	This species has evolved an anther tripping mechanism that deposits pollen on visiting insects (Lebuhn and Anderson 1994), suggesting the species is trying to outcross. We found no evidence of plants being self-compatible. Studies on congeners demonstrate either self-incompatibility (Ebadi 2010) or necessary insect pollination for fruit production despite genetic self-compatibility (US FWS 1997).
ES-12 (Requires specialist pollinators)	n - negl	0	Pollinated by small and large Bombus bees (Silander and Klepeis 1999; LeBuhn and Anderson 1994) as well as honeybees and halictid bees (LeBuhn and Anderson 1994).
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]	d - high	-1	No direct evidence could be found for minimum generative time. As barberry is a shrub it probably requires at least two years before it sets fruit. A demographic study states that shrubs in forest understories grow slowly after their first year or two of establishment indicating that reproductive maturity would be more likely after 3 or more years (Ehrenfeld 1999). Barberry grows more rapidly in open fields and sunny conditions however (Lubell and Brand 2011). Answering

Question ID	Answer - Uncertainty	Score	Notes (and references)
			"d" with high uncertainty and alternative answers are both "c."
ES-14 (Prolific seed producer)	y - low	1	A plant can produce 200-1800 fruits/year (Silander and Klepeis 1999). In a study of cultivars, seeds/fruit ranged from 0.1 to 1.8. One plant produced 12903 seeds in one year and several cultivars produced more than 5000 seeds/plant/year (Brand et al. 2012).
ES-15 (Propagules likely to be dispersed unintentionally by people)	n - mod	-1	We found no evidence of unintentional dispersal. Seeds could be transported in movement of soil and cut branches could take root.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	n - low	-1	We found no evidence of dispersal in trade.
ES-17 (Number of natural dispersal vectors)	2	0	B. thunbergii has bright red slightly oblong dry fruits 0.25 - 0.4 " long mature in late summer (Kaufman and Kaufman 2013). Each fruit contains several seeds (Brand et al. 2012).
ES-17a (Wind dispersal)	n - low		We found no evidence for wind dipsersal.
ES-17b (Water dispersal)	n - low		We found no evidence for water dispersal although plants can grow in riparian areas (Eschtruth and Battles 2011).
ES-17c (Bird dispersal)	y - negl		B. thunbergii secondary seed rain, those seeds free of intact fruit and likely dispersed by birds, was collected from seed traps with and without perches for birds in habitats in central New York state (McCay et al. 2009). Fruits are bird dispersed, including by turkeys and grouse (Silander and Klepeis 1999).
ES-17d (Animal external dispersal)	n - low		We found no evidence for external dispersal by animals and fruits do not have characteristics likely to aid in external dispersal.
ES-17e (Animal internal dispersal)	y - negl		Fruits are eaten by small mammals (Zouhar 2008)
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	n - low	-1	At the end of a three-year study, B. thunbergii seed had a 24% germination rate, with 89% of the seed germinating in the first year and about 10% the second (Lubell and Brand 2011). Most seeds appear to germinate within one year (D'Appollonio 2006; Zouhar 2008).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - low	1	Stems reprout from root crown readily after cutting (Weber 2003) and after fire (Zouhar 2008).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	Berberis is not listed as an herbicide resistant weed (Heap 2015).
ES-21 (Number of cold hardiness zones suitable for its survival)	9	0	
ES-22 (Number of climate types suitable for its survival)	7	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - high	0	Coats et al. (2014) suggest that allelopathic secondary metabolites with antimicrobial properties produced by

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Japanese barberry are probably responsible for the shifts in the soil microbial community structure reported upon plant introduction. They cite two lab studies (Singh et al. 2010, Villinski et al. 2003) demonstrating the anti-bacterial properties of barberry constituents. Significant changes in soil activity and chemistry have been reported by multiple authors (Ehrenfeld et al. 2001, Kourtev et al. 2002, 2003); such changes could conceivably affect the growth or metabolism of other plants in a barberry infestation. Given the guidance for this question, we are answering "no" with high uncertainty.
Imp-G2 (Parasitic)	n - low	0	Plants in the Berberidaceae (ARS 2015) are not known to be parasitic.
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	y - low	0.4	Barberry alters soil chemistry including pH and nitrification rates (Ehrenfeld et al. 2001, Kourtev et al. 2002, 2003), and creates microclimate temperature and humidity changes (Williams and Ward 2010).
Imp-N2 (Changes habitat structure)	y - negl	0.2	Forms dense thickets in forest understories (Ehrenfeld 1999; Silander and Klepeis 1999, Swearingen et al. 2010). Link et al. (2018) found barberry infested forests harbored substantially lower densities of native tree seedlings.
Imp-N3 (Changes species diversity)	y - low	0.2	Native species diversity declines under Japanese barberry thickets (Silander and Klepeis 1999). Japanese barberry alters the microbial community in the soil (Coats et al. 2014; Kourtev et al. 2002). Kourtev et al. found significantly higher earthworm densities, and all exotic earthworms, in the soil under B. thunbergii (Kourtev et al. 1999). However, Flinn et al. (2014) found no significant effect on forest understory plant communities in a Pennsylvania forest with moderate *B. thunbergii* invasion.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - low	0.1	Because Japanese barberry grows in relatively undisturbed closed canopy forests and changes ecosystem properties, community structure composition, it is highly likely to affect Threatened and Endangered species. Japanese barberry is a threat to *Panax quinquefolia*, a state listed plant in several states (Wixted and McGraw 2009). It occurs in the same location and habitat types as several Maryland listed threatented and endangered species, including Erythronium albidum (S2T), Geranium robertianum (S1), *Hydrophyllum macrophyllum (*S2T*),*and *Phacelia coveillei* (S2E)(Kyde 2019, Steury and Davis 2003).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	y - low	0.1	Occurs in Appalachian Blue Ridge and Appalachian Mixed Mesophytic forests (Zouhar 2008).
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	c - negl	0.6	Japanese barberry occurs in many natural areas and there are numerous control efforts (Ward et al. 2013, 2010, 2009; Zouhar 2008; Swearingen et al. 2010). Alternative answers both "b."

Question ID	Answer - Uncertainty	Score	Notes (and references)
control; (c) taxon a weed and evidence of control efforts]			
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - mod	0	Coats et al. (2014) suggest that allelopathic secondary metabolites with antimicrobial properties produced by Japanese barberry are probably responsible for the shifts in the soil microbial community structure reported upon plant introduction. They cite two lab studies (Singh et al. 2010, Villinski et al. 2003) demonstrating the anti-bacterial properties of barberry constituents. Significant changes in soil activity and chemistry have been reported by multiple authors (Ehrenfeld et al. 2001, Kourtev et al. 2002, 2003); such changes could conceivably affect the growth or metabolism of other plants in a barberry infestation. Given the guidance for this question, we are answering "no" with high uncertainty.
Imp-A2 (Changes or limits recreational use of an area)	y - low	0.1	Plants in the Berberidaceae (ARS 2015) are not known to be parasitic.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - low	0	We found no evidence that barberry replaces plants in gardens or lawns.
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]	b - high	0.1	Barberry alters soil chemistry including pH and nitrification rates (Ehrenfeld et al. 2001, Kourtev et al. 2002, 2003), and creates microclimate temperature and humidity changes (Williams and Ward 2010).
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - high	0	Native species diversity declines under Japanese barberry thickets (Silander and Klepeis 1999). Japanese barberry alters the microbial community in the soil (Coats et al. 2014; Kourtev et al. 2002). Kourtev et al. found significantly higher earthworm densities, and all exotic earthworms, in the soil under B. thunbergii (Kourtev et al. 1999). However, Flinn et al. (2014) found no significant effect on forest understory plant communities in a Pennsylvania forest with moderate B. thunbergii invasion.
Imp-P2 (Lowers commodity value)	n - mod	0	Because Japanese barberry grows in relatively undisturbed closed canopy forests and changes ecosystem properties, community structure composition, it is highly likely to affect Threatened and Endangered species. Japanese barberry is a threat to Panax quinquefolia, a state listed plant in several states (Wixted and McGraw 2009). It occurs in the same location and habitat types as several Maryland listed threatented and endangered species, including Erythronium albidum (S2T), Geranium robertianum (S1), Hydrophyllum macrophyllum (S2T),and Phacelia coveillei (S2E)(Kyde 2019, Steury and Davis 2003).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-P3 (Is it likely to impact trade?)	n - mod	0	Occurs in Appalachian Blue Ridge and Appalachian Mixed Mesophytic forests (Zouhar 2008).
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)	n - low	0	Japanese barberry is not listed as toxic by the ASPCA (2015) or Cornell University Department of Animal Science (2015).
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	In production systems there is no evidence that Japanese barberry is a weed. Alternative answers are both "b."
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - low	N/A	We found no evidence that the species occurs in this zone.
Geo-Z2 (Zone 2)	n - low	N/A	We found no evidence that the species occurs in this zone.
Geo-Z3 (Zone 3)	y - mod	N/A	One point occurs in British Columbia and three in Quebec. Only one is clearly adventive; the others may be cultivated. We answered "yes" with moderate uncertainty.
Geo-Z4 (Zone 4)	y - negl	N/A	One point occurs on Hokkaido in Japan, several in Russia, two in Norway, two in Austria. Multiple points occur in Quebec, and in the US, several in each of WI and MN.
Geo-Z5 (Zone 5)	y - negl	N/A	Points occur in Austria, Canada (BC, ON, NB and NS), Estonia (one likely cultivated), Finland, Japan, Norway. US points occur in CO, IA, IL, IN, MA, ME, MI, NH, NY, VT, and WI.
Geo-Z6 (Zone 6)	y - negl	N/A	Many points occur in Japan. Austria, Canada (BC, NS, ON, PE), Finland, Germany, Norway, and Sweden all have points. A single point occurs in each of Poland and Slovenia. US has multiple points in the northeast and mid-Atlantic, spreading into the mid-West and southeast: CT, IL, IN, KS, KY, MA, MD, ME, MI, MO, NC, NH, NJ, NY, OH, PA, VA, and WV.
Geo-Z7 (Zone 7)	y - negl	N/A	Points occur in Canada (BC, NS, ON), Finland, France, Germany, Norway, and Sweden. Two, one likely cultivated, occure in Slovakia. Many points occur in Japan. In the US, points occur in CT, MA, MD, MI, MO, NC, NJ, PA, RI, TN, UT, VA, and WA.
Geo-Z8 (Zone 8)	y - negl	N/A	A handful of points occur in Australia. Many points occur in Belgium, Denmark, Finland, Japan, Netherlands, Norway, Sweden and the UK. A few points occur in France and Spain; several occur in Canada in BC. In the US, AL, MA, NC, NY, OR and WA have points.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z9 (Zone 9)	y - negl	N/A	Several countries -- Australia, France, Ireland, New Zealand, and Spain -- have one or a few points. Belgium, Denmark, Japan, Netherlands, Norway, Sweden and the UK all have many points.
Geo-Z10 (Zone 10)	y - negl	N/A	Many points occur in Japan; one in Spain.
Geo-Z11 (Zone 11)	y - low	N/A	Several points occur in New Zealand, and one point in Australia occurs in this zone.
Geo-Z12 (Zone 12)	n - negl	N/A	We found no evidence that the species occurs in this zone.
Geo-Z13 (Zone 13)	n - negl	N/A	We found no evidence that the species occurs in this zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - low	N/A	We found no evidence that the species occurs in this zone.
Geo-C2 (Tropical savanna)	n - low	N/A	We found no evidence that the species occurs in this zone.
Geo-C3 (Steppe)	y - mod	N/A	One point occurs in Colorado, three in Spain.
Geo-C4 (Desert)	y - high	N/A	Although work has been done in China on drought stress on Berberis, we have been able to obtain only one paper on a congener, *B. hemsleyana* (Guo et al. 2016). The single point in UT is clearly adventive, not cultivated; it was reported through iNaturalist. We answered "yes" but with high uncertainty.
Geo-C5 (Mediterranean)	y - low	N/A	One point occurs in Australia, one in California, several in OR and WA.
Geo-C6 (Humid subtropical)	y - negl	N/A	Multiple points in Japan and the UK; one in Poland. In the US, points occur in AL, KY, MD, MO,NC, NJ, NY, TN, VA and WV.
Geo-C7 (Marine west coast)	y - negl	N/A	Points occur in Australia, Denmark, France, Germany, the Netherlands, New Zealand and Spain.
Geo-C8 (Humid cont. warm sum.)	y - negl	N/A	Points in this climate class occur primarily in Japan, Canada and the US: CT, DE, IL, IN, KS, , MA, MD, MI, MO, NJ, NY, OH, PA, VA and WI. ,
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Hokkaido, Japan has a few points. Other points occur in Denmark, Estonia, Finland, Germany, the Netherlands, Norway, Poland and Sweden. In Canada, ON, NB, NS and PE have points. In the US, points occur in MA, ME, MI, MN, NH, NJ, NY, OH, PA, VT, WI and WV.
Geo-C10 (Subarctic)	y - negl	N/A	Austria, Finland, Germany, and Norway all have points.
Geo-C11 (Tundra)	y - negl	N/A	More than 70 points occur in Norway, and one in Germany.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that the species occurs in this zone.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - high	N/A	One point occurs in Utah, along a boundary road at Sand Island Campground. This is clearly an area of low preciptation. We are unable to locate information relating to drought tolerance of *B. thunbergii* ,although at least one congener is reported to have high drought tolerance (Guo et al. 2015), and gardening websites recommend it

Question ID	Answer - Uncertainty	Score	Notes (and references)
			for xeriscaping (Wilson Bros Gardens no date), so we are answering "yes" with high uncertainty.
Geo-R2 (10-20 inches; 25-51 cm)	y - low	N/A	Points occur in Spain, Canada (BC) and the US (CA).
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Points occur in Australia, Finland, France, Germany, Slovakia, Spain, Sweden and the UK. In the US, there is one point in CO.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Australia, Austria, Canada (ON), Denmark, Finland, France, the Netherlands, Norway, Poland, Spain, Sweden and the UK all have points. In the US, IA, IL, KS, MD, MI, MN, MO, VA, VT, WA, and WI have points.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Points occur in Canada (NS, ON, PE), Denmark, Germany, Ireland, the Netherlands, New Zealand, Norway, Sweden and the UK. In the US, points occur in CT, DE, IL, IN, MA, MD, ME, MI, MO, NC, NH, NJ, NY, OH, PA, RI, VA, VT, and WV.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Austria, Canada (BC, ON, NB, NS), France, Germany, Japan, Norway and the UK. Fourteen US states have points: AL, CT, KY, MA, ME, NC, NH, NJ, NY, OH, PA, TN, VT, WV.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	There are points in Germany, Japan Germany, New Zealand, Norway, the UK, and the US in OR.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Points occur in Austria, Germany, Japan, Norway, the UK, and the US in NC.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	Germany, Japan, Norway, Slovenia and the UK have points.
Geo-R10 (90-100 inches; 229-254 cm)	y - low	N/A	Canada (BC) and Japan have points. There are eight points in Norway, some of which may be cultivated.
Geo-R11 (100+ inches; 254+ cm)	y - low	N/A	There are several points in Norway.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	Barberry is widely planted as an ornamental and has naturalized throughout much of the northeastern, upper midwest, and southeastern US as well as eastern Canada (BONAP 2015). The species or certain cultivars have been banned from sale in Minnesota (MNDNR 2015), Massachusetts (MIPAG 2015), New York (NYDEC 2015), and New Hampshire (NHDA 2015).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 [Human value & cultivation/trade status: (a) Neither cultivated or positively valued; (b) Not cultivated, but positively valued or potentially beneficial; (c) Cultivated, but no evidence of trade or resale; (d) Commercially cultivated or other evidence of trade or resale]	-	N/A	
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central	-	N/A	

Question ID	Answer - Uncertainty	Score	Notes (and references)
America, the Caribbean or China)			
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	
Ent-4c (Contaminant of seeds for planting)	-	N/A	
Ent-4d (Contaminant of ballast water)	-	N/A	
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	
Ent-4f (Contaminant of landscape products)	-	N/A	
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	
Ent-4i (Contaminant of some other pathway)	-	N/A	
Ent-5 (Likely to enter through natural dispersal)	-	N/A	

Appendix B. Maryland Filter Ranking for *Berberis thunbergii DC* (Berberidaceae)

Maryland Filter
Berberis thunbergii DC

1a. There are reports of occurrences of this plant outside of cultivation within Maryland and it does, or can potentially…

2a. Occupy part of two or fewer MD physiographic provinces.....

3a. Species is documented as occurring in a state listed S1 or S2 community, OR it occurs within a population or habitat of a Threatened or Endangered species, or a CITES-listed species, OR it is documented as harming a Threatened or Endangered species in Maryland, then Species is ranked Tier 1.

3b. Species is not documented as above….Species is ranked Tier 2.

2b. Occupy part of three or more MD physiographic provinces OR 50% or more of any one province……

4a. Species displays resistance to any herbicide OR has a seedbank of two or more years OR reproduces vegetatively…….

5a. Species has been present in Maryland for less than 50 years AND is present in fewer than 20 natural area sites AND
6a. the answers to ANY of WRA questions ES14, ES15 or ES16 are Yes, OR
6b. the answer to WRA question ES17 is equal to or greater than 2
……..Species is ranked Tier 1

5b. Species is not as above…… Species is ranked **Tier 2**

4b. Species has none of these characters….go to **3**

1b. There are NOT reports of occurrences of this plant outside of cultivation within Maryland but it can potentially…

7a. occupy LESS THAN part of two MD physiographic provinces…… go to **3**

7b. occupy part of three or more MD physiographic provinces, OR 50% or more of any one province ….. Species is ranked Tier 1

Notes: 1a and 2b – Japanese barberry has been reported in the wild from all the physiographic provinces that occur within Maryland. 4a – The species does reproduce vegetatively, and is therefore difficult to control. 5b – The species was introduced to Arnold Arboretum in Boston in 1875, and the Norton-Brown herbarium included a specimen collected from Davidsonville in 1944, so it has been present here for well over 50 years. EDDMapS and

Maryland Biodiversity Project records document it as escaped from cultivation in well over 20 locations. Although the plant is a prolific seed producer (ES14 = Yes), is it not likely to be unintentionally dispersed by humans (ES15 = No), nor are its propagules likely to be dispersed as contaminants (ES16 = No). The answer to ES17 is 2 natural dispersal vectors. The combination of factors that would merit a Tier 1 ranking are not present, and thus the species is ranked **Tier 2.**