Weed Risk Assessment for *Nandina domestica* (Berberidaceae) – Nandina

Maryland Department of Agriculture

June 1, 2015

Version 1

Left: Nandina leaves. Right: Nandina fruits. Photos by Sylvan Kaufman.

Agency Contact:
Office of Plant Industries and Pest Management
Maryland Department of Agriculture
50 Harry S. Truman Pkwy.
Annapolis, Maryland, 21401
Telephone: 410-841-5870

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.

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 U.S. 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.

***Nandina domestica* Thunb. – Nandina**

Species Information

Family: Berberidaceae

Synonyms: *Nandina domestica* is the only known name for this species.

Common names: Nandina, heavenly bamboo, sacred bamboo (CABI 2015).

Botanical description: Nandina grows as an evergreen many-stemmed shrub. It is sometimes deciduous in Zone 6 (Dirr 2009). The dark, shiny green stems resemble thin stalks of bamboo. The large, alternate leaves are twice to thrice-divided, giving the leaves a somewhat lacy appearance. A large cluster of flowers forms at the uppermost leaf axil. Clusters of small fruits form. Each fruit is a round berry containing two seeds. Fruits mature to bright red and are often held on the plants through winter (Langeland et al. 2008; Ohwi 1984).

Initiation: This plant is listed on the MD Department of Natural Resources (MD DNR) Do Not Plant List, a policy document available from MD DNR that lists approximately 90 plant species that may not be planted on DNR land or for DNR projects.

Foreign distribution: Nandina is native to temperate China, Japan and South Korea. It has been widely cultivated as an ornamental in Europe, Africa, Australasia, North America, South America, Atlantic Islands, Indian Ocean Islands and Pacific Islands (Weber 2003).

U.S. distribution and status: Naturalized in the southeast and gulf coast states from Maryland to Texas and in California (BONAP 2015). Widely cultivated in zones 6-9 (Dirr 2009).

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

Summary Statement

Nandina domestica received a rating of High Risk under the PPQ WRA model because the species reproduces by seed and root fragments. It forms dense groves that reduce light levels to the ground below and displace native vegetation in natural areas, produces seeds toxic to some animals, and can be aggressive in gardens. The species received a Tier 2 ranking in the Maryland Filter analysis because it has been established in Maryland for more than 70 years and there is currently no documented evidence of its threatening endangered species or communities in the state.

1. *Nandina domestica* analysis

Establishment/

Nandina fruits are dispersed by birds and other animals (Stone 2009). Plants can

[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).

Spread Potential also spread from root fragments (Kaufman et al. 2013). Once established nandina forms dense groves in shady areas spreading from the roots (Miller et al. 2010). Little evidence is available on pollination, seed viability or seed banks for nandina (Cherry 2002; Stone 2009).
Risk score = 10 Uncertainty index = 0.22

Impact Potential In several states nandina is targeted for control (Miller et al. 2010; Cherry 2002) because it forms dense stands that reduce light levels at the ground level and displace native vegetation (Langeland et al. 2008; Stone 2009; Cherry 2002). Fruits are toxic to some animals (Kahn 2008; Burrows 2006). Nandina aggressively displaces desirable plants in gardens and is controlled by some gardeners (Dave's Garden 2014). We found no direct evidence of changes to community structure or threats to Federally endangered species.
Risk score = 3.2 Uncertainty index = 0.15

Geographic Potential Based on three climatic variables, we estimate that about 58 percent of the United States is suitable for the establishment of *Nandina domestica* (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 *Nandina domestica* represents the joint distribution of Plant Hardiness Zones 6-12, areas with 0-100 inches of annual precipitation, and the following Köppen-Geiger climate classes: Tropical rainforest, Tropical savanna, Steppe, Mediterranean, Humid subtropical, Marine west coast, Humid continental warm summers, and Humid continental cool summers. Note that in this risk assessment there are several reports of *Nandina domestica* occurring in areas with 0-10 inches of annual precipitation, one of which is geo-referenced. For this prediction, we assumed this environment is suitable for it.

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. Nandina most often grows under forest canopies and along forest edges (Miller et al. 2010).

Entry Potential We did not assess the entry potential of *Nandina* because it is already present in the United States (ARS, 2014).

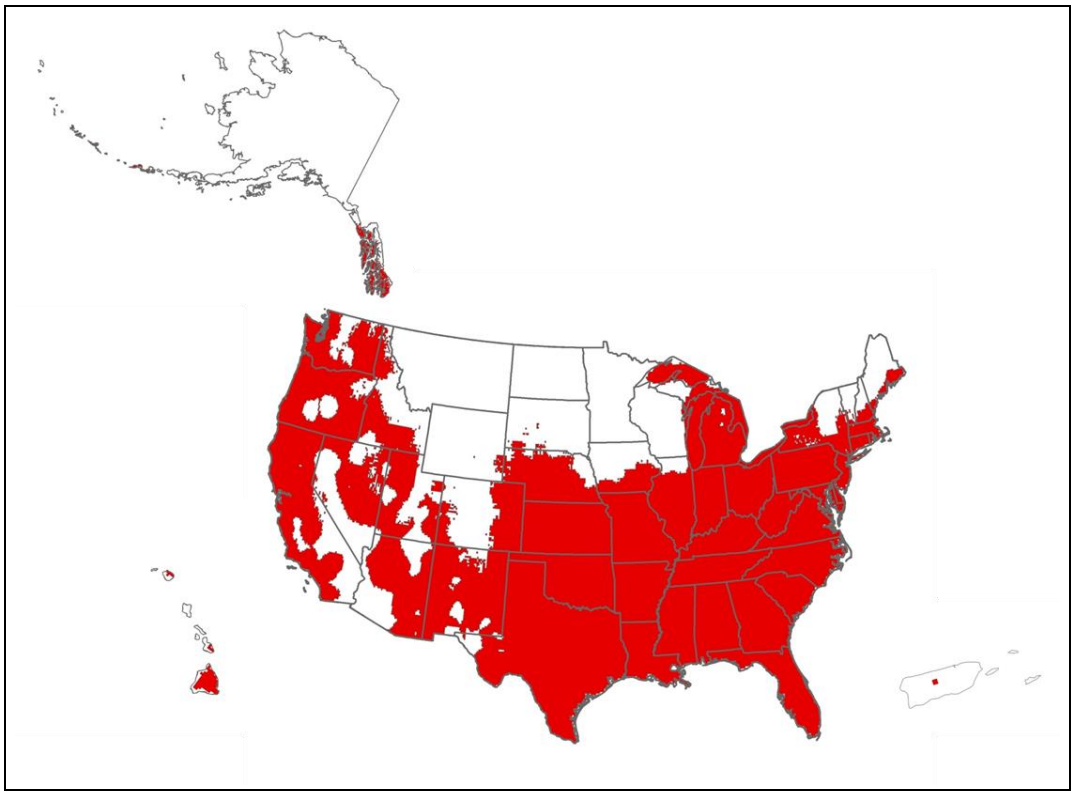

Figure 1. Predicted distribution of *Nandina domestica* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 53.7%
P(Minor Invader) = 43.8%
P(Non-Invader) = 2.5%

Risk Result = High Risk

Secondary Screening = Not Applicable

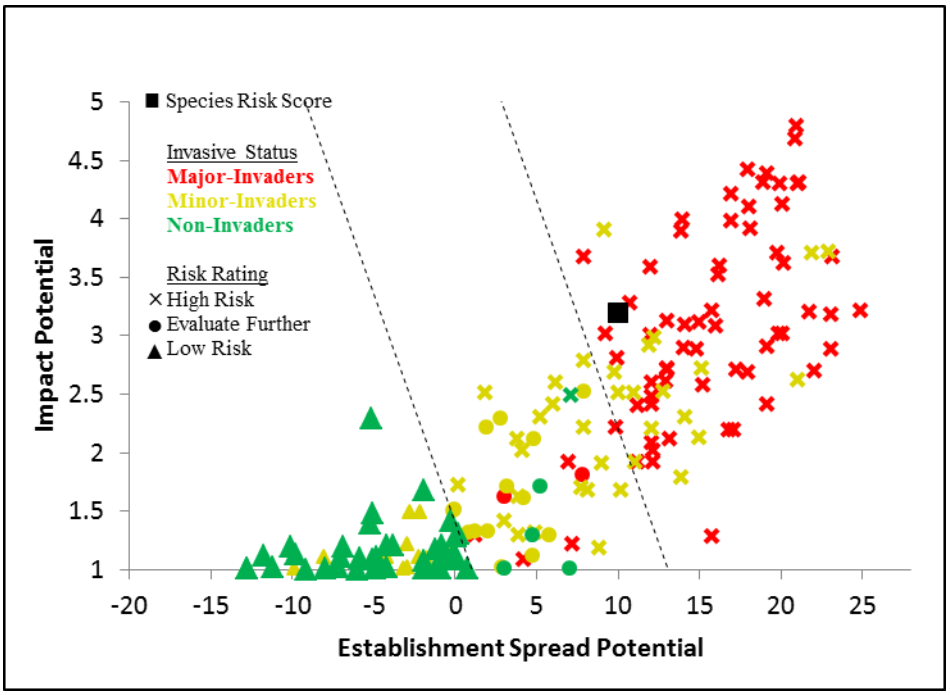

Figure 2. *Nandina domestica* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

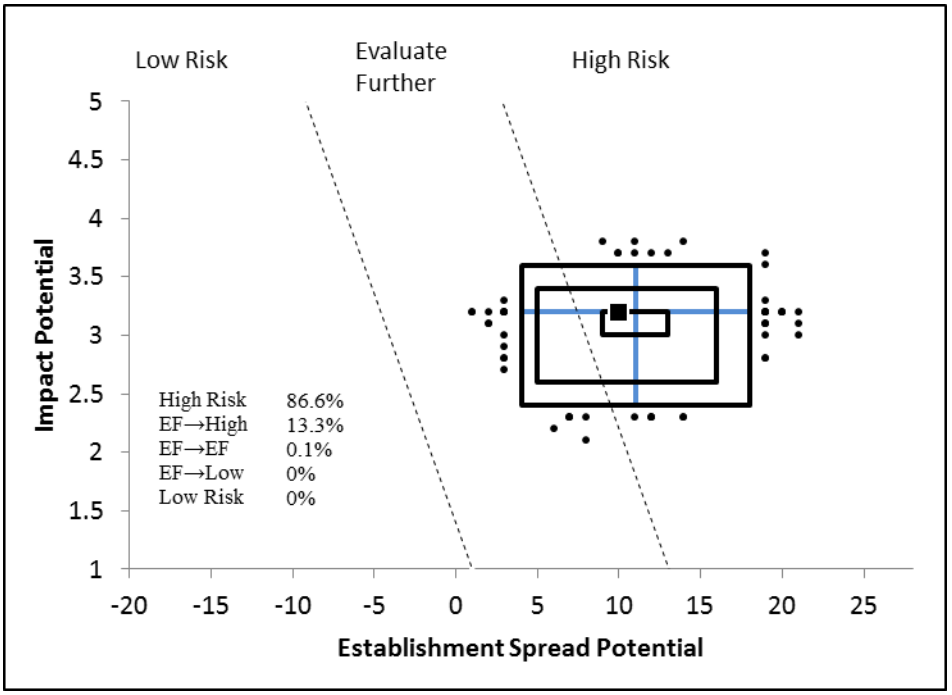

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Nandina domestica*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Nandina domestica* is High Risk. Nandina shares traits in common with other major invaders (Fig.2) used to develop and validate the PPQ WRA model. Eighty-seven percent of the simulated risk scores received a rating of High Risk (Fig.3), indicating that our assessment is very robust. The capacity of this plant to grow and reproduce in sun to full shade (Dirr 2009), its ability to form dense thickets that can alter light regimes and community composition (Cherry 2002; Stone 2009; Langeland et al. 2008), dispersal by birds and other animals (Stone 2009), and its ability to spread vegetatively (Miller et al. 2010) all support its rating as High Risk. The plant is reported by gardeners to spread invasively (Dave's Garden 2014).

Nandina domestica ranks as a Tier 2 plant (Appendix B). Nandina has a potentially wide distribution in Maryland and has been sold in the state for at least 78 years (Harrison's Nursery 1937). We found no documentation of its effect on threatened and endangered species or ecosystems in the state, but it is likely that it could affect species and ecosystems based on its wide distribution and ecosystem and community level impacts. Because the species is widely cultivated and has been in Maryland for a long time period, additional sales are unlikely to increase nandina's potential to persist and spread.

4. Literature Cited

ARS. 2014. Germplasm Resources Information Network Database.

BONAP. 2015. The Biota of North America Program. Accessed online February 17, 2015. http://bonap.net/NAPA/Genus/Traditional/County.

Burrows, G. E. and R. J. Tyrl. 2006. Handbook of toxic plants of North America. Ames, Iowa, Blackwell Pub.

CABI. 2014. *Nandina domestica* fact sheet. Invasive Species Compendium. Accessed online November 17, 2014. http://www.cabi.org/isc/datasheet/35692.

Cherry, H. M. 2002. Ecophysiology and control of *Nandina domestica*. MS Thesis. Gainesville, FL, USA: University of Florida. 74 p.

Cherry, H. M. 2005. Questionnaire for IFAS assessment of non-native plants in Florida's natural areas. University of Florida Institute of Food and Agricultural Sciences.

DavesGarden. 2014. Plant files database, Dave's Garden. Accessed online November 17, 2014. http://davesgarden.com/guides/pf/go/1547/

Del Tredici, P. 1995. Shoots from roots: a horticultural review. Arnoldia, Fall:3-19.

Dirr, M. 2009. Manual of woody landscape plants: their identification, ornamental characteristics, culture, propagation, and use, 6th ed. Stipes Press, Champaign, IL. 1325 pp.

EDDMapS. 2014. Early detection and distribution mapping system. Accessed online November 17, 2014: http://www.eddmaps.org/

FLEPPC. 2014. Florida EPPC's 2011 invasive plant species list. Florida Exotic Pest Plant Council. Accessed online November 17, 2014. http://www.fleppc.org/list/11list.html

Foxcroft, L.C., D.M. Richardson, and J.R.U. Wilson. 2008. Ornamental plants as invasive aliens: problems and solutions in Kruger National Park, South Africa. Environmental Management, 41(1):32-51.

GA-EPPC. 2014. List of non-native invasive plants in Georgia. Georgia Exotic Pest Plant Council. Accessed online November 17, 2014. http://www.gaeppc.org/list.cfm

GBIF. 2015. Global Biodiversity Information Facility. Accessed online May 28, 2015. http://www.gbif.org/

Harrison's Nursery. 1937. 1937 planter's guide. Berlin, MD. Accessed online June 1, 2015: http://www.biodiversitylibrary.org/page/42548167#page/12/mode/thumb.

Heap, I. 2014. The international survey of herbicide resistant weeds, Weed Science Society of America. Accessed online November 17, 2014. http://www.weedscience.org/summary/home.aspx

IPAMS. 2014. Invasive Plant Atlas of the MidSouth. Accessed online November 17, 2014. https://www.gri.msstate.edu/ipams/

IPPC. 2012. International standards for phytosanitary measures No. 5: glossary of phytosanitary terms. Food and Agriculture Organization of the United Nations, Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy.

Judd, W. S. 2003. New and noteworthy collections from Florida. Castanea, 68(1):81-83.

Kahn, C. M. (ed.). 2008. The Merck veterinary manual. Ninth Edition. Whitehouse Station, New Jersey, Merck & Co., Inc.

Kaufman, S. R. and W. Kaufman. 2013. Invasive plants: guide to identification and the impacts and control of common North American species, 2nd edition. Mechanicsburg, PA, U.S.A., Stackpole Books.

Knox, G. W. and S. B. Wilson. 2006. Evaluating north and south Florida landscape performance and fruiting of ten cultivars and a wild-type selection of *Nandina domestica*, a potentially invasive shrub. Journal of Environmental Horticulture, 24(3):137-142.

Knox, G. W. and S. B. Wilson. 2012. 'Firepower' nandina (*Nandina domestica*): a non-invasive nandina for Florida. University of Florida IFAS Extension. ENH1116. https://edis.ifas.ufl.edu/pdffiles/EP/EP38100.pdf.

Koop, A., L. Fowler, L. Newton, and B. Caton. 2012. Development and validation of a weed screening tool for the United States. Biological Invasions 14(2):273-294.

Kyde, K. 2015. Analysis of Bionet data. Maryland Dept.of Natural Resources.

Langeland, K. A. and K. C. Burks. 1998. Identification and biology of non-native plants in Florida's natural areas. Gainesville, Florida, University of Florida.

Langeland, K. A. and R. K. Stocker. 2001. Control of non-native plants in natural areas of Florida. Gainesville, FL, U.S.A., University of Florida,

Institute of Food and Agricultural Sciences: 34.
Langeland, K. A., H. M. Cherry, C. M. McCormick, and K. A. Craddock Burks. (eds). 2008. Identification and biology of non-native plants in Florida's natural areas, 2nd edition. Gainesville, FL, USA: University of Florida. 210 pp.
Lawrence, G. H. M. 1978. America's garden legacy: a taste for pleasure. Pennsylvania Horticultural Society. http://archive.org/stream/americas gardenle00lawr/americasgardenle00lawr_djvu.txt
Li, H.L. 2002. Chinese flower arrangement. Mineola, NY, USA: Dover Publications. 144 pp.
Li, T. 2009. ISSR analysis of genetic diversity of main germplasm resources of *Nandina domestica* in Hunan Province. Northern Horticulture, 2009(1): 166-170.
Magarey, R. D., D. M. Borchert, et al. 2008. "Global plant hardiness zones for phytosanitary risk analysis." Scientia Agricola 65 (Special Issue): 54-59.
Martin, P.G., and J.M. Dowd. 1990. A protein sequence study of the dicotyledons and its relevance to the evolution of the legumes and nitrogen fixation. Australian Systematic Botany 3:91-100.
Miller, J. H. 2003. Nonnative invasive plants of southern forests. Asheville, NC, U.S.A., United States Department of Agriculture, Forest Service, Southern Research Station: 93.
Miller, J. H. E. B. Chambliss, and N.J. Loewenstein. 2010. A field guide for the identification of invasive plants of southern forests. General Technical Report SRS-119. United States Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC, U.S.A. 126 pp.
Murray, B. R. and M. L., Phillips. 2010. Investment in seed dispersal structures is linked to invasiveness in exotic plant species of south-eastern Australia. Biological Invasions 12:2265-2275.
NAPPFAST. 2008. "Databases used in the NAPPFAST system." Retrieved September 5, 2008, from http://www.nappfast.org/databases/NAPPFAST %20Databases.htm.
New Zealand Plant Conservation Network. 2013. *Nandina domestica*, Accessed online November 17, 2014. http://www.nzpcn.org.nz/plant_distribution_ results.aspx?Species_Name=Nandina+domestica
Nickrent, D. L. and L. J. Musselman. 2004. Introduction to parasitic flowering plants. The Plant Health Instructor. DOI: 10.1094/PHI-I-2004-0330-01. http://www.apsnet.org/edcenter/intropp/pathogengroups/pages/parasiticpla nts.aspx
NRCS. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. Washington D.C., National Resource Conservation Service (NRCS), United States Department of Agriculture: 871.
Ohwi, J. 1984. Flora of Japan (edited English version, reprint. Original 1954). Tokyo, Japan, National Science Museum.
Prince, W. R. 1837. Annual catalogue of fruit and ornamental trees and plants cultivated at the Linnean Botanic Garden and Nurseries / William Prince

& Sons, proprietors, Flushing, Long Island, near New-York. http://www.biodiversitylibrary.org/page/22765334#page/40/mode/1up

Randall, J. M. 2007. The introduced flora of Australia and its weed status. Australia, CRC for Australian Weed Management, Department of Agriculture and Food, Western Australia.

Randall, R. P. 2008. A global compendium of weeds, Department of Agriculture of Western Australia.

Russel, A. B., J. W. Hardin, et al. 2009. Poisonous plants of North Carolina, North Carolina Cooperative Extension Service, North Carolina State University.

Santi, C., D. Bogusz, and C. Franche. 2013. Biological nitrogen fixation in non-legume plants. Annals of Botany 111(5):743-767.

Stanley, C. J. and I. J. Warrington. 1988. Seasonal frost tolerance of some ornamental evergreen broad-leaved and coniferous tree and shrub species. New Zealand Journal of Experimental Agriculture 16(3):239-248. http://dx.doi.org/10.1080/03015521.1988.10425646.

Stewart, M., J. W. Prince. 2013. Hyland Road park wetlands and riparian corridor: plan of management for Holroyd City Council. New South Wales, Australia: Molino Stewart Pty Ltd. http://www.holroyd.nsw.gov.au/wp-content/uploads/downloads/2013/05/0487-Hyland-Rd-Park-Final-PoMAugust2012V10a.pdf.

Stone, K. R. 2009. *Nandina domestica*. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Accessed online November 17, 2014. http://www.fs.fed.us/database/feis/.

TexasInvasives.org. 2014. Invasives database, *Nandina domestica*. Accessed online November 17, 2014. http://texasinvasives.org/plant_database/detail.php?symbol=NADO

TN-EPPC. 2014. Tennessee Exotic Pest Plant Council. Accessed online November 17, 2014. http://www.tneppc.org.

Tropicos.org. 2014. Missouri Botanical Garden. Accessed online November 17, 2014. http://www.tropicos.org/Name/3500026

USDA-NRCS. 2014. The PLANTS Database. National Plant Data Center, Baton Rouge, USA. Accessed online Nov. 17, 2014. http://plants.usda.gov/.

Walker, R. 2014. Parasitic Plants Database. Accessed online November 17, 2014. http://www.omnisterra.com/bot/pp_home.cgi

Watterson, G. 1834. An address delivered before the Columbian Horticultural Society. Washington, DC. http://www.biodiversitylibrary.org/page/29690089#page/41/mode/1up

Weakley, A. S. 2008. Flora of the Carolinas, Virginia, Georgia, northern Florida, and surrounding areas (working draft). Chapel Hill, NC, U.S.A., University of North Carolina Herbarium.

Weber, E. 2003. Invasive plant species of the world: a reference guide to environmental weeds. Wallingford, UK, CABI Publishing.

Wilson, S. B., G.W. Knox, Z. Deng, K. L. Noland, and J. Aldrich. 2014.

Landscape performance and fruiting of 9 heavenly bamboo selections grown in northern and southern Florida. HortScience 49(6):706-713.

Woldemeskel, M. and E.L. Styer. 2010. Feeding behavior-related toxicity due to *Nandina domestica* in cedar waxwings (*Bombycilla cedrorum*). Veterinary Medicine International 2010:81859. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3005831/.

Wu, C.Y., P. H. Raven, D.Y. Hong, (eds). 2011. Flora of China. *Nandina domestica*. Vol. 19:715. Beijing, China and St. Louis, Missouri, USA: Science Press & Missouri Botanical Garden Press. http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=200008408

Appendix A. Weed risk assessment for *Nandina domestica* Thunb. (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 - mod	5	Nandina is native to temperate China, Japan and South Korea (Wu et al. 2011; Ohwi 1984). It has been widely cultivated as an ornamental in Europe, Africa, Australasia, North America, South America, Atlantic Islands, Indian Ocean Islands and Pacific Islands (Weber 2003). Considered invasive in the southeastern U.S. where it is "observed throughout Florida ... in conservation areas, woodlands and floodplains" (Langeland et al. 2008). Mature plants are found far from cultivation (Langeland and Craddock Burks 2008). Naturalized in Australia (Randall 2007; Randall, 2008), including in Royal National Park in southeastern Australia (Murray and Phillips 2010). Naturalized in Kruger National Park in South Africa near cultivated plants (Foxcroft et al. 2008). We answered "f" with moderate uncertainty since most reports outside the U.S. are of plants naturalizing but plants clearly spread into natural areas within the U.S. and Australia at a considerable distance from cultivated plants. Alternative answers for the Monte Carlo simulation are both "e."
ES-2 (Is the species highly domesticated)	n - mod	0	Nandina is widely cultivated and many cultivars exist. Dwarf forms produce fewer fruits and seeds than standard size plants (Knox and Wilson 2006). In Florida trials, several cultivated varieties were found to produce no flowers or fruits (Wilson et al. 2014; Knox and Wilson 2012). Although a few cultivars are highly domesticated to produce few or no fruits, most do produce fruits. We answered "no" with moderate uncertainty.
ES-3 (Weedy congeners)	n - negl	0	*Nandina domestica* is the only species in the genus *Nandina* (ARS 2014).
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	Plants show photosensitivity at light levels above 50% (Stone 2009). Plants tend to grow in forests with low light (Stone 2009).
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	Nandina is a shrub (Langeland et al. 2008). It is neither a vine nor an herb with a basal rosette.

ES-6 (Forms dense thickets, patches, or populations)	y - low	2	Stone (2009) summarizes reports of dense growth mainly from Florida, Georgia, and Texas. "Forms dense groves in habitats of Florida Caverns State Park" (Langeland et al. 2008).
ES-7 (Aquatic)	n - negl	0	Nandina is a terrestrial plant in the genus Berberidaceae (ARS 2014).
ES-8 (Grass)	n - negl	0	Nandina is not in the Poaceae family (ARS 2014) and therefore not a grass.
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	This plant is in the Berberidaceae family (ARS 2014) and not known to be a nitrogen fixing (Martin and Dowd 1990; Santi et al. 2013).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	There are numerous reports of seedlings growing near cultivated plants and one report of seeds germinating after a fire (Stone 2009).
ES-11 (Self-compatible or apomictic)	? - max	0	No information available
ES-12 (Requires specialist pollinators)	? - max		No information available
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 - low	0	One report says nandina can begin to produce fruits at 18 months (Cherry 2002), but others say it can take several years before plants produce fruits (Stone 2009). Alternate answers for the Monte Carlo simulation are both "d."
ES-14 (Prolific reproduction)	n - mod	-1	In one study, 9 plants produced up to ~1500 fruits (mature and immature), which could hold 2 seeds each; 85% of these seeds were viable (Knox 2006), so the level for "prolific" is not met.
ES-15 (Propagules likely to be dispersed unintentionally by people)	n - high	-1	Plants spread by root sprouts (Miller et al. 2010) and runners disposed of by gardeners could result in new plants. Seeds are used in flower arrangements and wreaths which when discarded could lead to unintentional dispersal. There is no direct evidence of either of these occurrences in the literature however. We answered "no" with high uncertainty.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	n - mod	-1	We found no evidence that propagules are likely to be dispersed as contaminants or hitchhikers.
ES-17 (Number of natural dispersal vectors)	2	0	Dense clusters of small red fruits grow along branches and at the ends of the branches. Each spherical berry (0.2-0.3 in diameter) contains two seeds (Miller et al. 2010).
ES-17a (Wind dispersal)	n - negl		Fruit possesses no obvious adaptations for wind dispersal nor are there reports of wind dispersal.
ES-17b (Water dispersal)	? - max		Seeds may be dispersed by water (Stone 2009), but there is no information on whether seeds actually have been dispersed by water.
ES-17c (Bird dispersal)	y - negl		In the United States seeds are dispersed by mockingbirds, northern cardinals, cedar

			waxwings, American robins (Stone 2009).
ES-17d (Animal external dispersal)	n - low		There are no structures on the seeds that would attach to animals and we found no evidence of external dispersal by animals.
ES-17e (Animal internal dispersal)	y - negl		Seeds are spread by Virginia opossum, and northern raccoon (Stone 2009).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	"It is not known if sacred bamboo seeds persist longer than a year in the soil seed bank" (Stone 2009).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - mod	1	Plants reproduce from root fragments (Kaufman and Kaufman 2013), so it should be able to tolerate mutilation. Nandina forms an extensive tap root (Weber 2003), and some gardener's attempts to eradicate the plant from their gardens have failed because of its extensive root system (DavesGarden 2014) which allows it to resprout, despite extensive cutting.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - mod	0	We found no evidence of herbicide resistance.
ES-21 (Number of cold hardiness zones suitable for its survival)	7	0	
ES-22 (Number of climate types suitable for its survival)	8	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - mod	0	Nandina is not known to be allelopathic (ARS 2014).
Imp-G2 (Parasitic)	n - negl	0	Not mentioned among parasitic plants (Walker 2014) and plants in the Berberidaceae family are not known to be parasitic (Nickrent and Musselman 2004).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	y - mod	0.4	Nandina reduces light levels by 44% in temperate hardwood and broadleaf forests in North Florida (Cherry 2002). "Provides a subshrub layer that is dense (sometimes monotypic) in a community which is normally more open" (Cherry 2005).
Imp-N2 (Changes habitat structure)	y - mod	0.2	Changes forest structure by adding a subshrub layer (Cherry 2005).
Imp-N3 (Changes species diversity)	y - mod	0.2	Plants displace native vegetation (Langeland et al. 2008).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - mod	0.1	Nandina poses a threat to several Florida endangered plant species at Florida Caverns State Park, Tom Brown Park, and Hogtown (Langeland et al. 2008; Cherry 2005). It forms a subshrub layer reducing light levels in

			forests (Cherry 2005). Because of this species' threat to state listed species and ecosystem and community effects it could affect federally listed species.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	y - mod	0.1	Nandina could affect globally outstanding ecoregions in the southeast and the western coastline, based on hardiness zones (7-9), rainfall (15-25 inches/yr or 40-60 inches/yr), soils (inceptisols, entisols and alfisols) and ecoregions (Humid subtropical, Marine west coast and Mediterranean/dry summer subtropical) (GBIF 2014). It currently occurs in some areas considered globally outstanding ecoregions in the southeast.
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	Nandina is controlled in Florida and other states in natural areas (Langeland et al. 2008; Stone 2009). Alternative answers both "b" for the Monte Carlo simulation.
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - low	0	We found no evidence that nandina has this impact.
Imp-A2 (Changes or limits recreational use of an area)	n - low	0	We found no evidence that nandina has this impact.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	y - low	0.1	Escaped in some urban/suburban parks in southeastern U.S. (TexasInvasives.org 2014). Numerous reports of removal in gardens due to aggressiveness on Dave'sGarden (2014).
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]	c - mod	0.4	Escaped in some urban/suburban parks in southeastern U.S. (TexasInvasives.org 2014). Numerous reports of removal in gardens due to aggressiveness on Dave'sGarden (2014). Alternate answers for the Monte Carlo simulation are "a" and "b" since many gardeners also report that they do not consider nandina to be a weed and want it to spread vegetatively as a groundcover.
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - low	0	We found no evidence that nandina has this impact.
Imp-P2 (Lowers commodity value)	n - low	0	We found no evidence that nandina has this impact.
Imp-P3 (Is it likely to impact trade?)	n - low	0	We found no evidence that nandina has this impact.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - low	0	We found no evidence that nandina has this impact.

Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	y - negl	0.1	Cyanogenic glycosides in foliage and fruits may cause cyanide poisoning if large amounts are consumed by grazing animals, especially ruminants (Kahn 2008); many cultivars of nandina are cyanogenic and are toxic to ruminants and puppies (Burrows 2006). Nandina has a low toxicity (Russel et al. 2009), but can result in sickness or death if a large amount is eaten (Kahn 2008).
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 - high	0	Considered a weed of agriculture in China (Randall 2008) and Australia (Randall 2007), but no evidence of control in production systems. We could find no primary literature on what agricultural systems it impacts. Alternative answers are "b" and "c" for the Monte Carlo simulation.
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically-referenced points (pts.) obtained from the Global Biodiversity Information Facility (GBIF), accessed in May 2015. Non-georeferenced locations from GBIF and other sources are noted as occurrences (occ.). Records include PERAL's data from searches prior to 2015.
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that the species occurs in this zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence that the species occurs in this zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence that the species occurs in this zone.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no evidence that the species occurs in this zone.
Geo-Z5 (Zone 5)	n - high	N/A	Occ.data (GBIF 2015) place species in Kangwon-do province, South Korea, which includes an area in this zone. Frost-hardy and lethal temperatures reported for this species (Stanley and Warrington 1988) make it unlikely that nandina occurs here, so we answered "no" with high uncertainty.
Geo-Z6 (Zone 6)	y - negl	N/A	Multiple pts in Japan; South Korea: (GBIF 2015 occ.); U.S: Pts in KS, KY, occ. in PA. One pt. reported from MD (EDDMapS 2015). Hardy to zone 6-9 (DavesGarden 2008, IPAMS 2009)
Geo-Z7 (Zone 7)	y - negl	N/A	Japan; South Korea (occ.); Multiple pts throughout southeastern U.S. (GBIF 2015, EDDMapS 2015); Hardy to zones 6-9 (DavesGarden 2008; IPAMS 2009);
Geo-Z8 (Zone 8)	y - negl	N/A	Australia; China; Japan; New Zealand; South

			Korea (occ.); Taiwan (occ.); U.S.: AL, TX, SC. One pt. exists in NM that may have been planted, but locations within this zone in other U.S. states reduce uncertainty to "negl." Hardy to zones 6-9 (DavesGarden, 2008; IPAMS, 2009)
Geo-Z9 (Zone 9)	y - negl	N/A	Australia; Brazil (occ.); China; Japan; Mexico; New Zealand; South Africa; South Korea (occ.); Taiwan; U.S.: FL, HI - an occ. in the vicinity of Hilo, TX (GBIF 2015); multiple pts. in southeastern U.S. (EDDMapS 2015). Hardy to zones 6-9 (DavesGarden 2008; IPAMS, 2009)
Geo-Z10 (Zone 10)	y - negl	N/A	Australia; Brazil; China; Japan; Taiwan; (occ.); U.S.: several pts. in CA (GBIF 2015), one in FL (EDDMapS 2015)
Geo-Z11 (Zone 11)	y - negl	N/A	Australia (occ.); Brazil (occ.); Taiwan (occ.); U.S.: one pt. in CA
Geo-Z12 (Zone 12)	y - mod	N/A	Taiwan (occ.)
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)	y - high	N/A	One pt. in Hawaii in the U.S., in the Hilo vicinity
Geo-C2 (Tropical savanna)	y - mod	N/A	Brazil (occ.) and U.S.: Hawaii occ.
Geo-C3 (Steppe)	y - negl	N/A	Australia (occ.); Mexico; U.S.: Pts in HI and TX; additional pt. in NM which may be planted.
Geo-C4 (Desert)	n - mod	N/A	Australia (occ.); Saudi Arabia: one pt. reported, likely cultivated but it is impossible to tell this from the GBIF record. Stone's (2009) report of the species' photosensitivity makes it seem unlikely to persist in the desert.
Geo-C5 (Mediterranean)	y - negl	N/A	Australia (occ.); U.S.: CA and OR
Geo-C6 (Humid subtropical)	y - negl	N/A	Australia; Brazil; China; Japan; South Africa; Taiwan; U.S.: numerous pts. throughout southeastern and Mid-Atlantic states (GBIF 2015, EDDMapS 2015)
Geo-C7 (Marine west coast)	y - negl	N/A	Australia; China; New Zealand
Geo-C8 (Humid cont. warm sum.)	y - negl	N/A	China; Japan; South Korea (occ.); U.S.: Single pts in KS, MD
Geo-C9 (Humid cont. cool sum.)	y - low	N/A	China (occ.); Japan (occ.)
Geo-C10 (Subarctic)	n - negl	N/A	We found no evidence that the species occurs in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence that the species occurs in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that the species occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - high	N/A	Australia (occ.); China (occ.); Saudi Arabia;

			U.S.: TX (EDDMapS 2015). This band is included within four huge Australian states, but all the Australian pt. locations are in higher precipitation bands. The same is true for the China occurrence, as this band occurs within Sichuan, but the pt. data for the species are in higher precipitation bands. The pt. in Saudi Arabia is noted in GBIF as a fuzzy taxon match and the country is derived from the coordinates. The Texas pt. was reported by a Texas Invaders volunteer; it is clearly not a planted location, but a roadside, and was reviewed by EDDMapS staff. We answered "yes" because of the four locations, but with high uncertainty.
Geo-R2 (10-20 inches; 25-51 cm)	y - high	N/A	Australia (occ.); China (occ.); South Africa; U.S.: CA, NM, TX. This band is included within four huge Australian states, but all the Australian pt. locations are in higher precipitation bands. One pt. in China is right on the border of bands R2 and R3. For the U.S. pts, the CA pt. is in a natural area but in the vicinity of houses abandoned years earlier, the NM pt. is possibly cultivated. The TX pts, although reported by invasive plant volunteers and reviewed by EDDMapS staff, may be cultivated. We answered "yes" because of the number of reports, but with high uncertainty.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Australia; China; U.S.: TX
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Australia (occ.); China; Japan; South Korea (occ.); U.S.: KS, TX
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Australia; Brazil (occ.); China; Japan; South Korea (occ.); U.S.: DC, IL, MD, NC, SC, VA (GBIF 2015), FL (EDDMapS 2015)
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Australia; Brazil; China; Japan; Mexico; South Korea (occ.); U.S.: multiple pts. in south-eastern and south central states, plus OR (GBIF 2015), MS (EDDMapS 2015)
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Australia (occ.); Brazil (occ.); China; Japan; South Korea (occ.); U.S.: AL, GA (GBIF 2015), MS (EDDMapS 2015)
Geo-R8 (70-80 inches; 178-203 cm)	y - low	N/A	Australia (occ.); Brazil; China; Japan; U.S.: HI
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	Brazil; China; Japan; U.S.: FL (EDDMapS 2015)
Geo-R10 (90-100 inches; 229-254 cm)	y - negl	N/A	China; Japan
Geo-R11 (100+ inches; 254+ cm)	y - negl	N/A	China; Japan; Taiwan
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	Nandina is widely cultivated in the southern United States including Maryland and has naturalized in the southeastern and gulf states

			as well as in California (BONAP 2015). It has been present in the United States since at least 1834 (Watterson 1834).
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	
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 *Nandina domestica* Thunb. (Berberidaceae).

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	Nandina is widely cultivated and many cultivars exist. Dwarf forms produce fewer fruits and seeds than standard size plants (Knox and Wilson 2006). Nandina 'Firepower', 'Firehouse', 'Firestorm' and 'AKA' were found to produce no flowers or fruits (Wilson et al. 2014; Knox and Wilson 2012).
2. Is the plant currently naturalized in Maryland? Yes OR no	yes	Go to Question 3	Naturalized in at least two counties in Maryland (EDDMapS 2015; BONAP 2015).
3. What is the species' potential distribution in Maryland? wide OR narrow	wide	Go to question 4	Nandina could occur throughout Maryland according to the geographic analysis in this weed risk assessment.
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	no	Go to question 5	Nandina is not currently documented in any habitats containing Maryland threatened or endangered species or community types (Kyde 2015).
5. How feasible is control of the species? easy OR difficult	difficult	Go to question 6	Colonizes by root sprouts (Miller et al. 2010).
6. Is added propagule pressure from sales significantly increasing potential of the species to persist and spread? yes OR no	no	Tier 2	Nandina has been present in the United States since at least 1834 (Watterson 1834) and has probably been cultivated in Maryland for more than 20 years.