Weed Risk Assessment for *Lythrum salicaria* L. (Lythraceae) – Purple loosestrife

Michigan Department of Agriculture and Rural Development

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Version 1

Top left: Flowering *L. salicaria* (source: Becca MacDonald, Sault College, Bugwood.org). Top right: *Lythrum salicaria* fruits (source: Leslie J. Mehrhoff, University of Connecticut, Bugwood.org). Bottom left: *Lythrum salicaria* seeds with dime for size comparison (source: Bruce Ackley, The Ohio State University, Bugwood.org). Bottom right: *Lythrum salicaria* field (source: Leslie J. Mehrhoff, University of Connecticut, Bugwood.org)

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Introduction The Michigan Department of Agriculture and Rural Development (MDARD) regulates aquatic species through a Prohibited and Restricted species list, under the authority of Michigan's Natural Resources and Environmental Protection Act (NREPA), Act 451 of 1994, Part 413 (MCL 324.41301-41305). Prohibited species are defined as species which "(i) are not native or are genetically engineered, (ii) are not naturalized in this state or, if naturalized, are not widely distributed, and further, fulfill at least one of two requirements: (A) The organism has the potential to harm human health or to severely harm natural, agricultural, or silvicultural resources and (B) Effective management or control techniques for the organism are not available." Restricted species are defined as species which "(i) are not native, and (ii) are naturalized in this state, and one or more of the following apply: (A) The organism has the potential to harm human health or to harm natural, agricultural, or silvicultural resources. (B) Effective management or control techniques for the organism are available." Per a recently signed amendment to NREPA (MCL 324.41302), MDARD will be conducting reviews of all species on the lists to ensure that the lists are as accurate as possible.

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

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

***Lythrum salicaria* L. – Purple loosestrife**

Species Information

Family: Lythraceae (NGRP, 2015).

Synonyms: No synonyms were found in the literature search. The Plant List (2015) lists no synonyms for this species.

Common names: purple loosestrife, rainbow weed, spiked loosestrife (Lavoie, 2010).

Botanical description: *Lythrum salicaria* is a perennial herb growing to 0.3-2.7 m tall (Brundu, 1999). It grows in wet meadows, marshes, and ditches in lowland and prairie habitats, with spikes of purplish flowers (Klinkenberg, 2015). For a full description of this species, see the Electronic Atlas of the Flora of British Columbia (Klinkenberg, 2015).

Initiation: In accordance with the Natural Resources and Environmental Protection Act Part 413, the Michigan Department of Agriculture and Rural Development was tasked with evaluating the aquatic species currently on Michigan's Prohibited and Restricted Species List (MCL 324.41302). USDA Plant Epidemiology and Risk Analysis Laboratory's (PERAL) Weed Team worked with MDARD to evaluate and review this species.

Foreign distribution: *Lythrum salicaria* has an extremely wide native range, from Eurasia (White et al., 1993) to Australia (ANBG, 1972). It has been introduced to New Zealand but has not yet naturalized (Ministry for Primary Industries, 2016). It is designated as an unwanted organism in New Zealand (Ministry for Primary Industries, 2016). This classification does not require legal action against *L. salicaria*; however, "It is an offence to breed, knowingly communicate, exhibit, multiply, propagate, release, or sell, an unwanted organism, unless permission is obtained from a chief technical officer" (New Zealand Plant Conservation Network, 2012). In North America, the range of *L. salicaria* has greatly expanded and it has invaded all of the southern provinces of Canada (Thompson 1989).

U.S. distribution and status: First reported on the eastern seaboard of northern USA in 1814 (Montague et al., 2008), *L. salicaria* now occurs across virtually all of the United States, with naturalized populations across the northeastern, Midwestern, and Pacific states, with localized occurrences throughout the southern states (Kartesz, 2015; GBIF, 2015). Varieties of *L. salicaria* are available from various retailers (OutsidePride.com, 2016; Goodness Grows, 2016). *Lythrum salicaria* is currently regulated as a noxious weed in 30 states.

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

1. *Lythrum salicaria* analysis

Establishment/Spread Potential *Lythrum salicaria* forms dense stands (Hight and Drea, 1991; White et al., 1993), producing 10,000 to 20,000 seedlings per square meter (Malecki et al. 1993; Mal et al. 1992). This species is a prolific seed producer with each plant producing up to 2.7 million seeds per year (Hight and Drea 1991; Thompson et al., 1987; White et al., 1993) and each spike is capable of producing up to 120,000 seeds (Sheley and Petroff, 1999). Seed viability is greater than 90 percent and seeds can remain viable in the soil for many years (Wilson et al., 2005). Seeds are dispersed in mud adhering to aquatic wildlife, livestock and humans (Thompson et al., 1987; Malecki et al., 1993), as well as vehicle tires or boots (Wilson et al., 2005). Seeds are also dispersed by wind (Wilson et al., 2005; Neff and Baldwin, 2005), water (Wilson et al., 2005; Malecki et al., 1993), and birds (New Hampshire Department of Environmental Services, 2010; Bender, 2001). We had a very low amount of uncertainty for this risk element.

Risk score = 22 Uncertainty index = 0.03

Impact Potential *Lythrum salicaria* spreads rapidly and replaces all native vegetation, forming mostly monocultures, reducing species diversity (Schooler et al., 2009; Thompson et al., 1987), and altering the structure of natural plant communities (Snyder and Kaufman, 2007). Because its stiff stems collect silt and debris, *L. salicaria* can change shallow water habitats into more terrestrial ones (Stackpoole, 2016). *Lythrum salicaria* results in the reduction in area of recreational wetlands and waterways (Hight and Drea, 1991; Utah Division of Wildlife Resources, 2010) as well as a reduction in their recreational and aesthetic value (Utah Division of Wildlife Resources, 2010) Prolific growth of this species clogs irrigation systems (Hight and Drea, 1991; National Wildlife Refuge Association, 2016). We had an average amount of uncertainty for this element.

Risk score = 3.4 Uncertainty index = 0.14

Geographic Potential Based on three climatic variables, we estimate that about 92 percent of the United States is suitable for the establishment of *Lythrum salicaria* (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 *L. salicaria* represents the joint distribution of Plant Hardiness Zones 3-12, areas with 0-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, desert, Mediterranean,

[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).

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. *Lythrum salicaria* is capable of invading many wetland habitats, including freshwater wet meadows, tidal and non-tidal marshes, river and stream banks, pond edges, reservoirs, and ditches.

Entry Potential We did not assess the entry potential of *L. salicaria* because it is already present in the United States (Utah Division of Wildlife Resources, 2010; (Indiana DNR, 2016b). *Lythrum salicaria* was first recorded on the eastern seaboard of northern USA in 1814 (Montague et al., 2008).

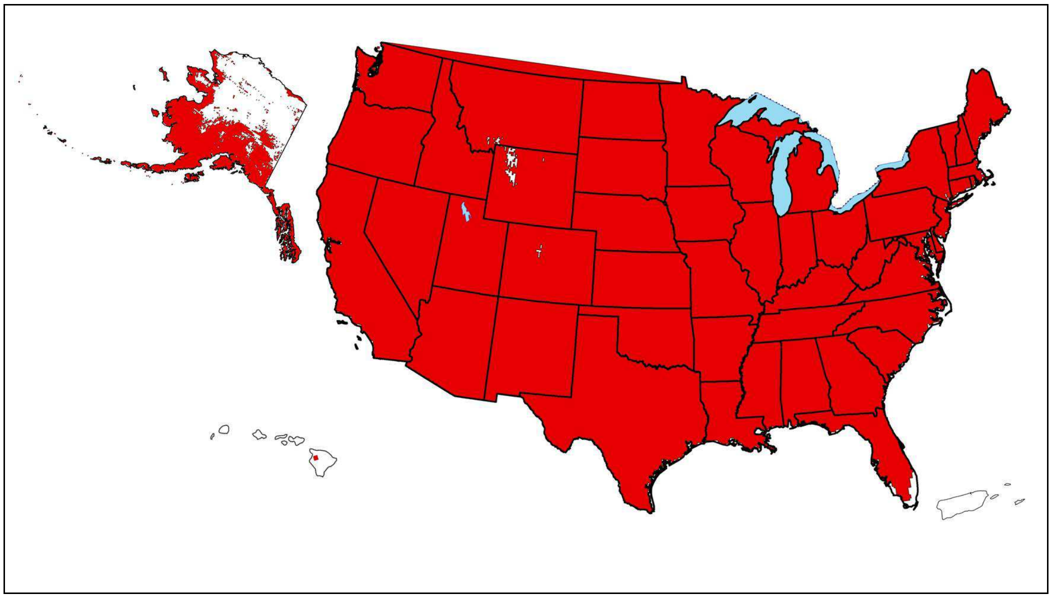

Figure 1. Predicted distribution of *L. salicaria* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 95.7%
P(Minor Invader) = 4.2%
P(Non-Invader) = 0.1%

Risk Result = High Risk

Secondary Screening = Not applicable

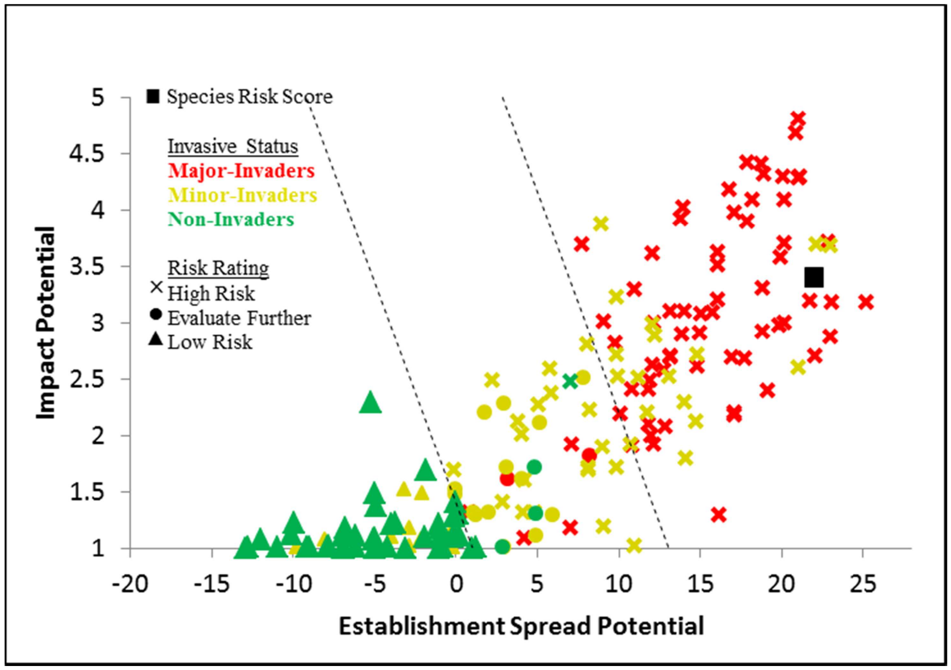

Figure 2. *Lythrum salicaria* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

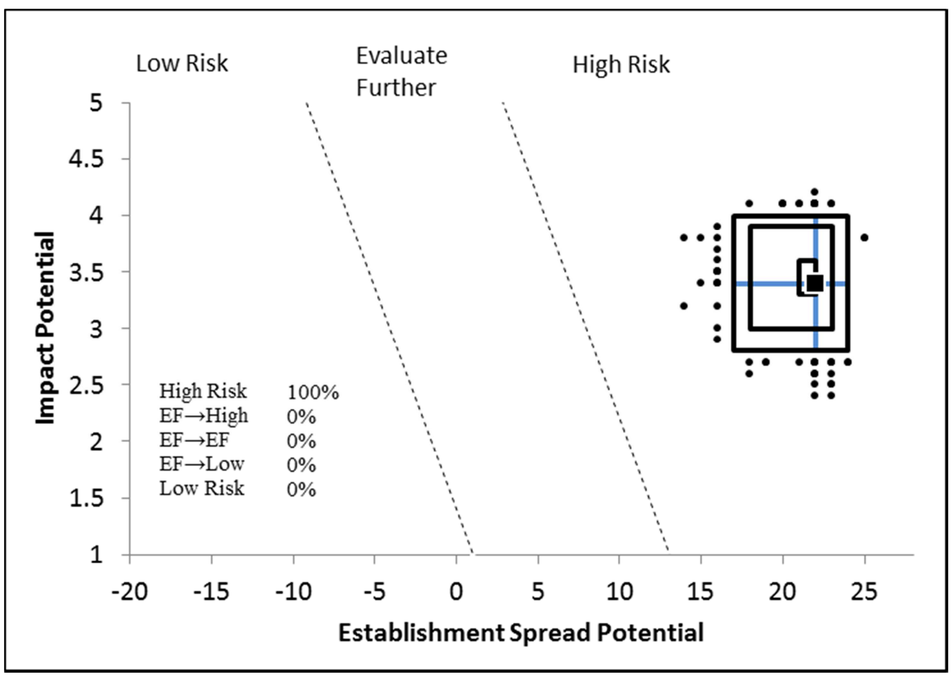

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *L. salicaria*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *L. salicaria* is High Risk. When compared with the species of known weeds used to validate the WRA model, this species ranked amongst other High Risk weeds (Fig. 2). Our categorization of "High Risk" is well supported by the uncertainty analysis (Fig. 3). This plant is considered one of the worst invasive plants in Mississippi (Winters et al., 2016) and Ohio (Ohio Invasive Plants Council, 2015). *Lythrum salicaria* establishes dense stands (Hight and Drea, 1991; White et al., 1993) and produces thousands seeds per plant (Hight and Drea 1991; Thompson et al., 1987; White et al., 1993), and would be able to establish in practically the entire United States (Fig. 1). *Lythrum salicaria* is very popular among gardeners (OutsidePride.com, 2016; Goodness Grows, 2016). Many varieties of this species have been developed for horticulture, and several were previously considered sterile (Manitoba Purple Loosestrife Project, 2010). The ornamental cultivars Morden Pink, Dropmore Purple, Morden Gleam, and Morden Rose, once believed seedless (Royer and Dickson, 1999) have been discovered to be capable of producing large numbers of viable seeds when fertilized with pollen from naturalized populations, although the resulting hybrids are highly infertile (Ottenbreit, 1991; White et al., 1993). One recommendation for further research is a systematic study of these "sterile" cultivars to determine if the cultivars are capable of producing seed under natural conditions. *Lythrum salicaria* is a restricted plant in Michigan; however its "sterile" cultivars are exempt from this regulation. Allowing cultivars to be sold in trade that are not truly sterile and can cross with the parent species will continue to contribute to the establishment and spread of this species. It is important to understand the extent of sterility for cultivars in order to prevent these garden varieties from contributing to the larger weed problem of *L. salicaria*.

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Appendix A. Weed risk assessment for *L. salicaria* L. (Lythraceae). 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	*Lythrum salicaria* is native to Eurasia (White et al., 1993) and Australia (ANBG, 1972), and has been introduced to North America and New Zealand (Ministry for Primary Industries, 2016). Since it was first reported in the 1800s the range of *L. salicaria* has greatly expanded and it has invaded all of the southern provinces of Canada (Thompson 1989). *Lythrum salicaria* occurs across virtually all of the United States (Kartesz, 2015) and southern Canada (White et al., 1993). In New Zealand, scattered infestations are found in the lower half of the North Island, and throughout the South Island (Marlborough District Council, 2016). Given this species' wide range throughout the United States, we are answering "f", with alternate answers of "e" for the Monte Carlo simulation.
ES-2 (Is the species highly domesticated)	n - low	0	Although there are several cultivars that have been reported to be sterile, we found no evidence that the species as a whole has been highly domesticated. The ornamental cultivars Morden Pink, Dropmore Purple, Morden Gleam, and Morden Rose, once believed seedless (Royer and Dickson, 1999) have been discovered to be capable of producing large numbers of viable seeds when fertilized with pollen from naturalized populations although the resulting hybrids are highly infertile (Ottenbreit, 1991; White et al., 1993).
ES-3 (Weedy congeners)	n - mod	0	The genus *Lythrum* contains 36 species (Mabberley, 2008). *Lythrum hyssopifolia* L. (hyssop loosestrife) is a widespread minor weed of damp and flooded areas throughout Australia (Auld and Medd, 1987); however, there is no evidence that this is a significant weed.
ES-4 (Shade tolerant at some stage of its life cycle)	n - low	0	Typically found in open areas, *L. salicaria* will tolerate some shade, but growth, reproduction and survival may be substantially reduced under shaded conditions (Munger, 2002). This species is generally found in full sun but can survive in 50% shade (Bender, 2001), however we found no evidence it will survive in full shade.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	*Lythrum salicaria* is neither a vine nor does it form tightly appressed basal rosettes, but rather it is an erect herbaceous plant (Stevens and Peterson, 1996).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	*Lythrum salicaria* establishes dense stands (Hight and Drea, 1991; White et al., 1993), producing 10,000 to 20,000 plants per square meter (Malecki et al. 1993; Mal et al. 1992).
ES-7 (Aquatic)	n - mod	0	*Lythrum salicaria* is a perennial emergent aquatic weed (Thompson et al., 1987). This species prefers very moist soil or standing water and can withstand prolonged periods of water logging (Brown et al., 2002) with stems submerged under water developing aerenchyma tissue characteristic of aquatic plants (WSDE, 2008). It can survive in dry gravel where water level is 10-15 cm below the surface (Bastlova-Hanzelyova, 2001). *Lythrum salicaria* can inhabit both wet and dry soils (Stevens and Peterson, 1996). Because this species is capable of thriving in dry soils, we are answering no.
ES-8 (Grass)	n - negl	0	This species is not a grass, but rather is an erect herbaceous plant in the family Lythraceae (USDA-GRIN, 2008).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen, nor is it in a plant family known to have N-fixing capabilities (Martin and Dowd, 1990). Further, this is not a woody plant, but, rather, an herbaceous perennial (White et al., 1993, USDA-GRIN, 2008).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Seed viability is greater than 90 percent and seeds can remain viable in the soil for many years (Wilson et al., 2005). Seed viability decreased from 99% to 80% after two years of storage in a natural body of water (Bender, 2001). Seeds can germinate in a wide variety of environmental conditions (White et al., 1993).
ES-11 (Self-compatible or apomictic)	n - negl	-1	*Lythrum salicaria* is self-incompatible (Nicholls, 1987; Brown et al., 2002).
ES-12 (Requires specialist pollinators)	n - negl	0	Studies by Brown et al. (2002) showed that the generalist pollinators, honeybees (*Apis mellifera*) and bumble bees (*Bombus* sp.) together accounted for more than half of all floral visits to this species. Pollinated by several types of bees including Megachilinae, Apinae, Xylopinae and Bombinae and by several species of butterflies including *Pieris rapae*, *Colias philodice*, and *Cercyonis pegala* (Bender, 2001)
ES-13 [What is the taxon's minimum generation time? (a) less than a year with multiple generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) unknown]	b - negl	1	*Lythrum salicaria* is an herbaceous perennial (Montague et al., 2008). Shoots arise from rhizomes in the spring after overwintering (Mal et al., 1992). Although plants are perennial and remerge each year from rhizomes, plants can germinate form seed, grow, and produce seed all in their first season. Seedlings established in the spring grow rapidly and flower 8-10 weeks after germination (Bender, 2001). Flowering of *L.*

Question ID	Answer - Uncertainty	Score	Notes (and references)
			salicaria begins in June and can last until early October. Fruits mature approximately a month after floral anthesis (Montague et al., 2008). Seeds germinate the following season (Minnesota Sea Grant, 2009). Alternate answers for the Monte Carlo are "c", as this plant is a perennial.
ES-14 (Prolific seed producer)	y - negl	1	This species is a prolific seed producer with each plant producing up to 2.7 million seeds per year (Hight and Drea, 1991; Thompson et al., 1987; White et al., 1993) and each spike is capable of producing up to 120,000 seeds (Sheley and Petroff, 1999).
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - low	1	Seeds are dispersed in mud adhering to livestock (Thompson et al., 1987; Malecki et al., 1993) and the mud of vehicle tires or boots (Wilson et al., 2005).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - low	2	This species was probably introduced to North America on imported sheep, or in livestock feed (White et al., 1993), however, it may also have been first introduced into the U.S. from seed contained in ships' ballast (Missouri Botanical Garden, 2016). Seeds may contaminate wildflower seed mixtures (White et al., 1993).
ES-17 (Number of natural dispersal vectors)	4	4	Fruit and seed description for questions ES-17a through ES-17e: The fruit is an oblong-ovoid capsule with up to 130 seeds (Bastlova-Hanzelyova, 2001). Seeds are brown to black, minute (<1mm across) (Royer and Dickson, 1999), and weigh 0.06 mg (Bender, 2001).
ES-17a (Wind dispersal)	y - negl		Seeds are wind dispersed (Wilson et al., 2005). Seeds were collected from wind traps designed to capture airborne seeds at a tidal freshwater marsh in Washington, DC (Neff and Baldwin, 2005).
ES-17b (Water dispersal)	y - negl		The lightweight seeds that are shed throughout the winter are water dispersed (Wilson et al., 2005; Malecki et al., 1993) seeds are buoyant and are dispersed in water currents (Bender, 2001).
ES-17c (Bird dispersal)	y - low		Seeds are easily dispersed on the feathers of birds (New Hampshire Department of Environmental Services, 2010) and may be dispersed on the feet of water fowl (Bender, 2001). In a study where researchers purposefully fed mallards *L. salicaria* seeds, Soons et al. (2008) found that seeds do germinate from mallard feces, however Neff and Baldwin (2005) in their study of wetland plant seed dispersal methods found no evidence of *L. salicaria* seeds in goose feces, and birds will not eat the small, hard seed (PSU Extension, 2016; Indiana DNR, 2016a).
ES-17d (Animal external dispersal)	y - low		Seeds dispersed in mud adhering to aquatic wildlife and livestock (Thompson et al., 1987; Malecki et al., 1993).
ES-17e (Animal internal	n - low		We found no evidence that this species is spread

Question ID	Answer - Uncertainty	Score	Notes (and references)
dispersal)			from animal consumption of seeds. .
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	Seeds are long-lived (Malecki et al., 1993) and seeds can remain viable in the soil for many years (Wilson et al., 2005). Seed viability decreased from 99% to 80% after two years of storage in a natural body of water (Bender, 2001).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	*Lythrum salicaria* exhibits rapid regeneration following cutting (Mahaney et al., 2006). Forced grazing has been shown to promote the growth of this species by encouraging more suckering from the rhizome (Kadrmas and Johnson, 2002). Root fragments cut from the plant can produce new plants and stem pieces may generate new infestations when they float downstream and lodge against a streambank. (Wilson et al., 2005).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	We found no evidence this species is resistant to herbicides. Furthermore, it is not listed by Heap (2013) as resistant. For small infestations, eradication is possible with spot applications of glyphosate herbicides (Bender, 2001). Knezevic et al. (2004) found that excellent season-long control (>90%) of *L. salicaria* was achieved with higher rates of glyphosate, 2,4-D dimethylamine, triclopyr, and metsulfuro. Excellent control (>90%) that lasted more than 1 year was achieved with imazapyr and metsulfuro. Two higher rates of imazapyr and both rates of metsulfuron provided 90 to 100% control for over two years (Knezevic et al., 2004).
ES-21 (Number of cold hardiness zones suitable for its survival)	10	1	
ES-22 (Number of climate types suitable for its survival)	9	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - low	0	We found no evidence that this species is allelopathic.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this species is parasitic. Furthermore, *L. salicaria* does not belong to a family known to contain parasitic plants (Heide-Jorgensen, 2008; USDA-GRIN, 2008).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	y - negl	0	It is a concern along rivers, where it slows the flow of water (Royer and Dickson 1999). This species directly impacts and alters the hydrology of wetland systems because its dense stems trap soil and can change shallow wetland habitats into more terrestrial ones (Stackpoole, 2016).
Imp-N2 (Changes habitat	y - mod	0.2	Established plants are tall with 30-50 stems

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
structure)			forming wide topped crowns that dominate the herbaceous canopy (Malecki et al., 1993). This forms a near monoculture that alters the structure of natural plant communities (Snyder and Kaufman, 2007). *Lythrum salicaria* spreads rapidly and replaces all native vegetation, destroying wetland areas (Royer and Dickson, 1999). Because its stiff stems collect silt and debris, *L. salicaria* can change shallow water habitats into more terrestrial ones (Stackpoole, 2016). We are answering yes to this question due to the evidence of monotypic stands and alteration of habitat, but with moderate uncertainty since we found little evidence regarding habitat structure prior to *L. salicaria* invasion.
Imp-N3 (Changes species diversity)	y - negl	0.2	*L. salicaria* has drastically altered wetlands across North America forming monotypic stands that exclude native species (Thompson et al., 1987) and are not well utilized by native fauna (McKeon, 1959), therefore reducing wetland herbivore diversity (Schooler et al., 2009). *Lythrum salicaria* displaces native vegetation when established in natural areas and in severe infestations all of the original vegetation may be lost (White et al., 1993). Schooler et al. (2009) found a negative correlation between native moth species richness and the abundance of the invasive plant species in wetland field sites in the Pacific Northwest. *Lythrum salicaria* abundance is negatively associated with density, height, and biomass of native vegetation
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - negl	0.1	*Lythrum salicaria* forms dense homogeneous stands that restrict native wetland plant species, including some endangered orchids (Swearingen, 2005). In 1995, the National Park Service determined that *L. salicaria* was a potential threat to listed endangered plant species, special concern plant species, and two globally rare calcareous riverside plant communities documented from the Delaware Water Gap National Recreation Area (Snyder & Kaufman, 2004)
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	y - low	0.1	*Lythrum salicaria* is already present in many counties in the states of Alabama, Arizona, California, North Carolina, Oregon, Virginia, and Washington that are designated as globally outstanding ecoregions (Ricketts et al., 1999). Given the impacts described under Imp-N2 and the fact that this species can transform habitats from aquatic to terrestrial, this species is likely to or is affecting globally outstanding ecoregions in the United States.
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon	c - negl	0.6	Considered one of the five invasive alien plants that have had a major impact on natural ecosystems in Canada (White et al., 1993). State

Question ID	Answer - Uncertainty	Score	Notes (and references)
a weed but no evidence of control; (c) taxon a weed and evidence of control efforts]			statutes directs the Minnesota Department of Natural Resources to coordinate a control program to curb the growth of *L. salicaria* (Minnesota DNR, 2016a) and Minnesota DNR provides guidelines for herbicide application, mechanical control, and biological control for property owners (Minnesota DNR, 2016b). Biological control of *L. salicaria* is the most effective control of *L. salicaria* in natural areas (Blossey, 1996). Alternate answers for the Monte Carlo simulation are both "b".
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 this species impacts personal property, human safety, or public infrastructure.
Imp-A2 (Changes or limits recreational use of an area)	y - negl	0.1	*Lythrum salicaria* has resulted in the reduction of natural habitats for recreational enjoyment (Hight and Drea, 1991). The recreational and aesthetic value of wetlands and waterways is diminished as dense stands of *L. salicaria* choke waterways and decrease biodiversity (Utah Division of Wildlife Resources, 2010). According to White et al. (1993) this species may eliminate or reduce populations of waterfowl and small fur-bearing animals. This may negatively impact hunting and related recreational activities.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - low	0	We found no evidence that this species affects ornamental plants. One commenter on Dave's Garden (2016) stated that "mixed with tiger lilies it is spectacular and hasn't crowded mine out at all".
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 - negl	0.4	Weed of disturbed areas (Darbyshire, 2003). The Indiana Department of Natural Resources released two small leaf eating beetles, *Galerucella calmariensis* and *G. pusila*, between July 1998, and July 1999, and the amount of *L. salicaria* around the control area, a boat ramp at Pleasant Lake in St. Joseph county, decreased dramatically (Indiana DNR, 2016b). Chemical control was undertaken by King County Noxious Weed Control Program within the Carnation Golf Course in Carnation, Washington (Messick, 2010). Alternate answers for the Monte Carlo simulation are both "b".
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - low	0.4	*Lythrum salicaria* decreases crop yield by blocking the flow of water in drainage and irrigation ditches (New Hampshire Department of Environmental Services, 2010). It is a weed of pastures (Darbyshire, 2003) and causes the degradation and loss of forage in lowland pastures (National Wildlife Refuge

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Association, 2016). The invasion of *L. salicaria* into North America has resulted in agricultural losses due to the degradation of wetland pasture and hay meadows attributed to lower palatability of *L. salicaria* compared to native grasses and sedges (Thompson et al., 1987).
Imp-P2 (Lowers commodity value)	y - mod	0.2	*Lythrum salicaria* affects crop quality because it blocks water flow in drainage and irrigation ditches (New Hampshire Department of Environmental Services, 2010).
Imp-P3 (Is it likely to impact trade?)	n - mod	0	This species was probably introduced to North America on imported sheep, or in livestock feed (White et al., 1993) and may contaminate wildflower seed mixtures (White et al., 1993). This species may therefore impact trade in these commodities but we found no evidence of trade regulation (APHIS, 2015).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - low	0.1	Prolific growth of this species clogs irrigation systems (Hight and Drea, 1991). *Lythrum salicaria* also affects farmlands by clogging irrigation and drainage ditches (National Wildlife Refuge Association, 2016).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - mod	0	We found no evidence that this species is toxic to animals.
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]	b - mod	0	Economic losses to agriculture due to *L. salicaria* can exceed $2.6 million annually (Washington Department of Ecology, 2016). Studies in Canada suggests that repeated mowing and grazing with deep discing and harrowing are effective control measures where it is a problem on land utilized for agriculture (White et al., 1993). Alternate answers for the Monte Carlo are both "c".
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2016).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that this species exists in or could survive in this plant hardiness zone.
Geo-Z2 (Zone 2)	n - mod	N/A	Two points in Canada, but we found no additional evidence in the literature that this species can survive in this plant hardiness zone, so we suspect these points may be erroneous.
Geo-Z3 (Zone 3)	y - low	N/A	Several points in Canada, China, Finland, and the United States: Minnesota.
Geo-Z4 (Zone 4)	y - negl	N/A	Canada, China, Finland, Norway, Sweden, and the United States: Idaho, Minnesota, North Dakota, Washington, and Wisconsin.
Geo-Z5 (Zone 5)	y - negl	N/A	Austria and the United States: Illinois, Indiana, Iowa, Nebraska, Nevada, Oregon, Washington, and Wisconsin.
Geo-Z6 (Zone 6)	y - negl	N/A	Afghanistan, Canada, China, and the United

Question ID	Answer - Uncertainty	Score	Notes (and references)
			States: California, Indiana, Michigan, Missouri, Nebraska, Oregon, and Washington.
Geo-Z7 (Zone 7)	y - negl	N/A	Canada, China, Indian, New Zealand, and the United States: California, Idaho, Kentucky, Michigan, New Mexico, Oregon, Tennessee, Texas, and Washington.
Geo-Z8 (Zone 8)	y - negl	N/A	Australia, Canada, China, Japan, New Zealand, and the United States: California, New Mexico, Oregon, and Washington.
Geo-Z9 (Zone 9)	y - negl	N/A	Australia, China, Greece, New Zealand, Syria, and the United States: California, Oregon, and Washington.
Geo-Z10 (Zone 10)	y - negl	N/A	Australia, China, Israel, New Zealand, Syria, the United States: California and Oregon, and West Bank.
Geo-Z11 (Zone 11)	y - low	N/A	Australia, Greece, Israel, Morocco, Portugal, Spain, and the United States: California.
Geo-Z12 (Zone 12)	n - mod	N/A	Several points in Israel. Although this plant has records in Israel in this plant hardiness zone, we answered “no”. This plant prefers more temperate zones, and we found no evidence in the literature that this species naturally occurs in areas as warm as Zone 12. As *L. salicaria* is a very popular plant for cultivation, we believe these points represent cultivated populations.
Geo-Z13 (Zone 13)	n - low	N/A	We found no evidence that this species exists in or could survive in this plant hardiness zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	We found no evidence that this species exists or could survive in this climate class.
Geo-C2 (Tropical savanna)	n - low	N/A	We found no evidence that this species exists or could survive in this climate class.
Geo-C3 (Steppe)	y - negl	N/A	Australia, Canada, China, Spain, and the United States: Colorado and Oregon.
Geo-C4 (Desert)	y - mod	N/A	Several points in Australia, Afghanistan, and Pakistan.
Geo-C5 (Mediterranean)	y - negl	N/A	Australia, Canada, Indiana, Israel, Spain, Syria, and the United States: California, Oregon, and Washington.
Geo-C6 (Humid subtropical)	y - negl	N/A	Australia, China, India, Japan, and the United States: Colorado, Maryland, New Jersey, New York, and Nevada.
Geo-C7 (Marine west coast)	y - negl	N/A	Australia, Canada, China, Georgia, and New Zealand.
Geo-C8 (Humid cont. warm sum.)	y - negl	N/A	Canada, China, Japan, and the United States: Connecticut, Illinois, Indiana, Iowa, Kansas, Massachusetts, Michigan, Missouri, Nebraska, Ohio, Pennsylvania, and Utah.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Canada, China, Japan, and the United States: Connecticut, Idaho, Massachusetts, Michigan, New Hampshire, New York, North Dakota, Ohio, Utah, and Vermont.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C10 (Subarctic)	y - negl	N/A	Austria, France, Germany, Norway, Slovenia, Spain, Sweden, and Switzerland.
Geo-C11 (Tundra)	y - low	N/A	Austria, Canada, France, Norway, and Switzerland.
Geo-C12 (Icecap)	n - low	N/A	We found no evidence that this species exists or could survive in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - low	N/A	Australia, Morocco, and the United States: Arizona, California, and New Mexico.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Australia, France, Italy, Spain, and the United States: California, Colorado, Idaho, Texas, and Utah.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Australia, France, Italy, Morocco, New Zealand, Portugal, and Spain.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Australia, France, Germany, Morocco, New Zealand, Portugal, and Spain.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Australia, France, Germany, New Zealand, Portugal, and Spain.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Australia, France, Germany, New Zealand, Portugal, Spain, and Switzerland.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Austria, France, Germany, Ireland, Portugal, Spain, and Switzerland.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Austria, France, Germany, Slovenia, Switzerland, and the United Kingdom.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	Austria, France, Germany, Japan, New Zealand, Switzerland, and the United Kingdom.
Geo-R10 (90-100 inches; 229-254 cm)	y - negl	N/A	Canada, China, France, Italy, Japan, Slovenia, and the United Kingdom.
Geo-R11 (100+ inches; 254+ cm)	y - low	N/A	Canada, China, Japan, and New Zealand.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	*Lythrum salicaria* was first recorded on the eastern seaboard of northern USA in 1814 (Montague et al., 2008), and now occurs across virtually all of the United States, with naturalized populations across the northeastern, Midwestern, and Pacific states, with localized occurrences throughout the southern states (Kartesz, 2015; GBIF, 2015).
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	-	N/A	

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
for planting)			
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	