Weed Risk Assessment for *Butomus umbellatus* L. (Butomaceae) – Flowering rush

Michigan
Department of
Agriculture and
Rural Development

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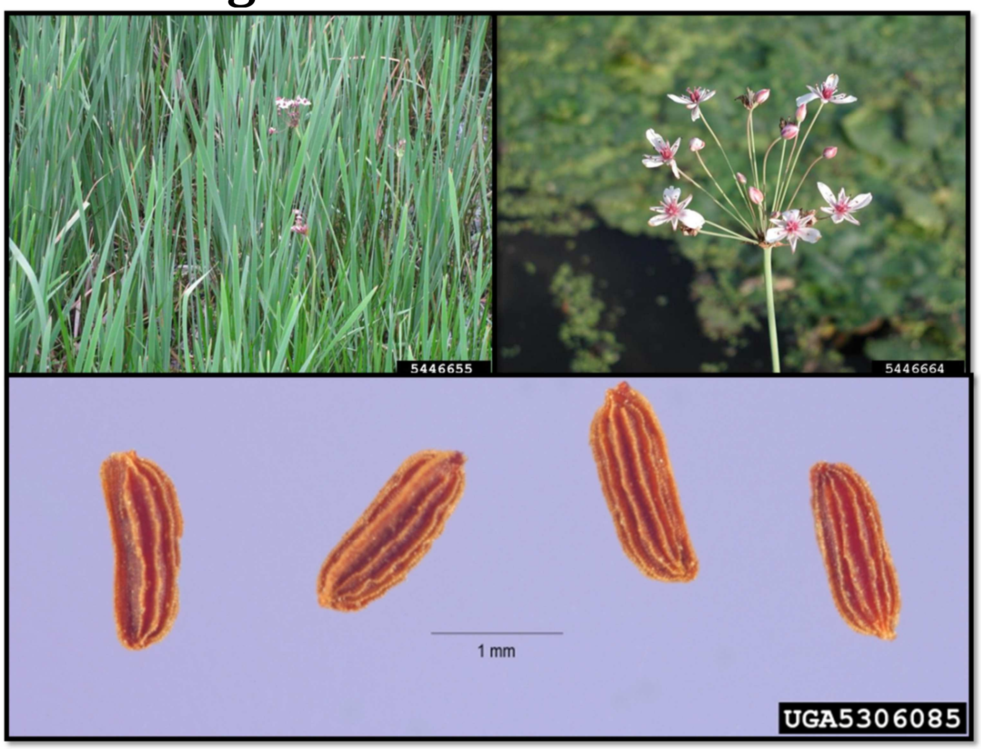
Version 1



Top left: Erect emergent growth form (Leslie J. Mehrhoff, University of Connecticut, Bugwood.org.) Top right: Umbrella-shaped flowering structure (Leslie J. Mehrhoff, University of Connecticut, Bugwood.org). Bottom: Seed shape and size (Steve Hurst, USDA NRCS PLANTS Database, 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.

	***Butomus umbellatus* L. – Flowering rush**
Species Information	Family: Butomaceae (AOSA, 2014; Bhardwaj and Eckert, 2001; Brown and Eckert, 2005). Synonyms: We found no synonyms for this species. The Plant List (2016) includes only varieties as synonyms. Common names: Flowering rush, grassy rush, water gladiolus (AOSA, 2014). Botanical description: *Butomus umbellatus* is an herbaceous, emergent aquatic perennial plant with linear, sword-like leaves (Hackett and Monfils, 2014). It may grow to 150 cm tall, with 20-25 pink flowers on inflorescences. It grows in saturated soils and shallow waters of streams, lakes, and ditches (Haynes, 2016). For a full botanical description, see Haynes (2016). 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 supported and contributed to this assessment. Foreign distribution: *Butomus umbellatus* is native to most of mainland Europe, the United Kingdom, Republic of Ireland, and temperate western Asia (Brown and Eckert, 2005; White et al., 1993; Johnson et al., 2008). outside of its native range, it is only known to occur in North America (GBIF, 2016). It was first recorded in North America in Canada on the St. Lawrence River in 1897 and spread into eastern Lake Ontario and Lake Champlain over the next 30 years (Brown and Eckert, 2005; Muenscher, 1930). U.S. distribution and status: This species was first observed in the United States within Lake Champlain, New York, in 1929 (Muenscher, 1930). Since this introduction, *B. umbellatus* has spread to twenty states, primarily in the northeast and midwest (Kartesz, 2014; MISIN, 2016). *Butomus umbellatus* is widely available in cultivation as a water garden plant (Wicklein's Water Gardens and Native Plants, 2016; AAA Pond Supply, 2016; AquariumPlants.com, 2016). This species is

regulated as a noxious weed in Connecticut, Indiana, Illinois, Michigan, Montana, Nebraska, Oregon, South Dakota, Vermont, Washington, and Wisconsin (National Plant Board, 2015). The Minnehaha Creek Watershed District, in conjunction with Waterfront Restoration, LLC, are conducting a pilot program to determine the effectiveness of hand removal for *B. umbellatus* populations in Lake Minnetonka, Minnesota, "to promote the growth of native plants" (Waterfront Restoration, LLC, 2012). Mechanical harvesting of *B. umbellatus* in Minnesota in the Detroit Lakes system was undertaken by the Minnesota Department of Natural Resources to improve boating and swimming. However, mechanical harvesting proved ineffective, and the program was cancelled (Pelican River Watershed District, 2016).

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

1. *Butomus umbellatus* analysis

Establishment/Spread Potential *Butomus umbellatus* forms dense stands (Parkinson et al., 2010) that dominate wetlands, the littoral zone of freshwater lakes, and river edges (Johnson et al., 2008). This species is composed of diploid and triploid individuals (Hackett and Monfils, 2014). Diploid populations reproduce sexually via seed, and vegetatively via bulbils that develop on rhizomes and inflorescence. Triploid populations reproduce vegetatively via large, branched rhizomes (Eckert et al., 2003). Diploid populations produce abundant viable seed (Brown and Eckert, 2005), and are fertile and self-compatible (Johnson et al., 2008; Krahulcová & Jarolímová, 1993). Seeds are spread via water currents (White et al., 1993; Johnson et al., 2008; Stuckey, 1968) and birds (Johnson et al., 2008; Hroudová and Zákravský, 1993), and fragments are spread by muskrats, who use them to build lodges, (Gaiser et al., 1949; University of Wisconsin-Stevens Point, 2014) and anglers and boaters (Indiana Department of Natural Resources, 2013; Pennsylvania Natural Heritage Program, 2016; USDA Forest Service, 2007). We had an average amount of uncertainty for this element.

Risk score = 19 Uncertainty index = 0.18

Impact Potential *Butomus umbellatus* can adversely impact native fish species by forming dense stands in waters previously unvegetated or sparsely vegetated by aquatic plants (Hackett and Monfils, 2014; Parkinson et al., 2010). Dense populations along lake shores interferes with boating, fishing, and swimming (Jacobs et al., 2011; Parkinson et al., 2010). Also, *B. umbellatus* stands provide habitat for the intermediate hosts (e.g. great

[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).

pond snail – *Lymnaea stagnalis* L.) of the swimmer's itch parasite (*Austrobilharzia variglandis*) (Hackett and Monfils, 2014; Parkinson et al., 2010). Dense populations growing within irrigation ditches reduce water availability and flow (Jacobs et al., 2011; Parkinson et al., 2010; Bannister, 2014). We had a high amount of uncertainty for this risk element because the ecological impacts of this species have not been well-studied, and require further research (White et al., 1993; Johnson et al., 2008).
Risk score = 3.2 Uncertainty index = 0.21

Geographic Potential Based on three climatic variables, we estimate that about 82 percent of the United States is suitable for the establishment of *Butomus umbellatus* (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 *Butomus umbellatus* represents the joint distribution of Plant Hardiness Zones 3-10, areas with 10-90 inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, Mediterranean, humid subtropical, marine west coast, humid continental warm summers, humid continental cool summers, and subarctic.

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 water turbidity, soil, and habitat type, may further limit the areas in which this species is likely to establish. *Butomus umbellatus* occurs from 0 to 1 m of water depth, with maximum frequency in shallow water (to 0.6 m), and prefers acidic soil (Hroudová and Zákravský, 1993b).

Entry Potential We did not assess the entry potential of *Butomus umbellatus* because it is already present in the United States (Muenscher, 1930).

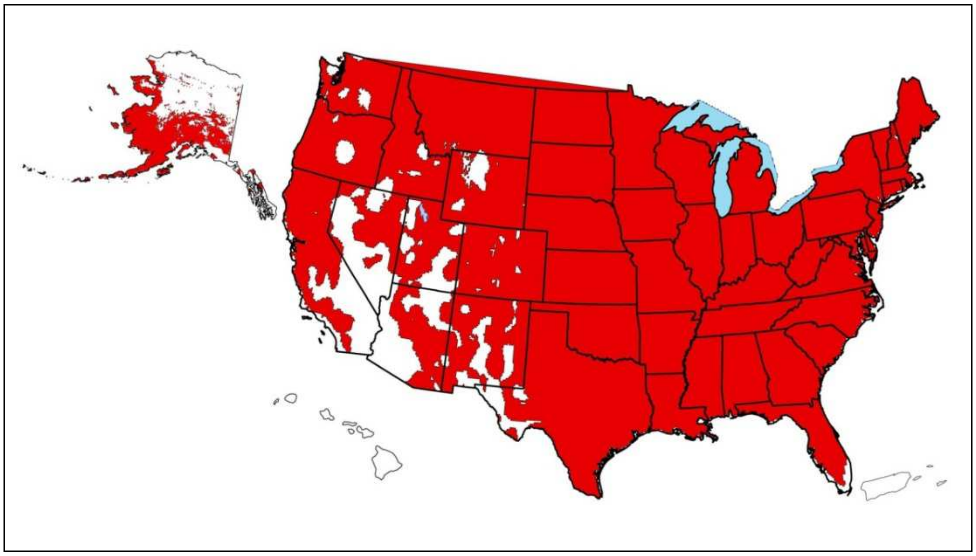

Figure 1. Predicted distribution of *B. umbellatus* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 90.6%
P(Minor Invader) = 9.1%
P(Non-Invader) = 0.3%

Risk Result = High Risk

Secondary Screening = Not applicable

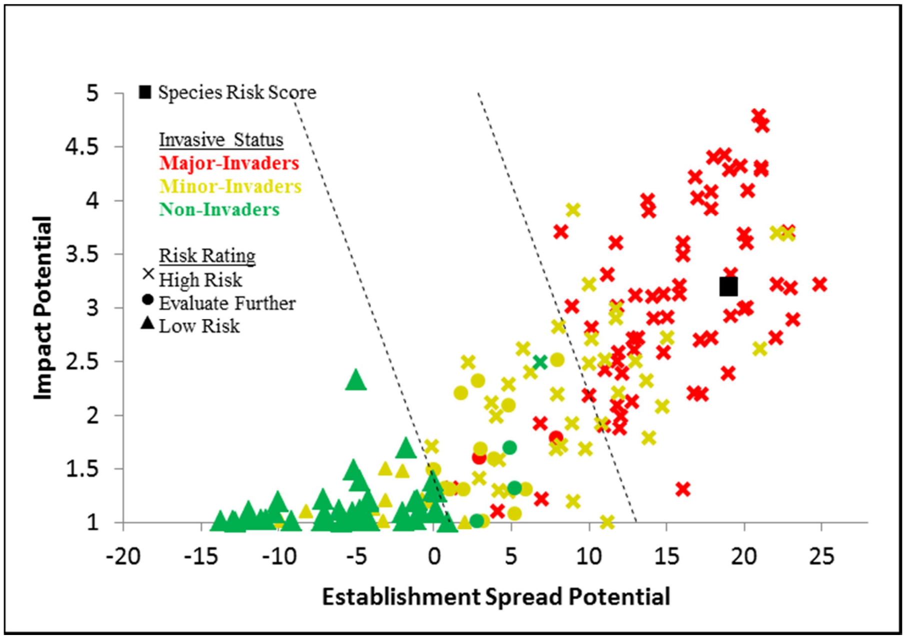

Figure 2. *Butomus umbellatus* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

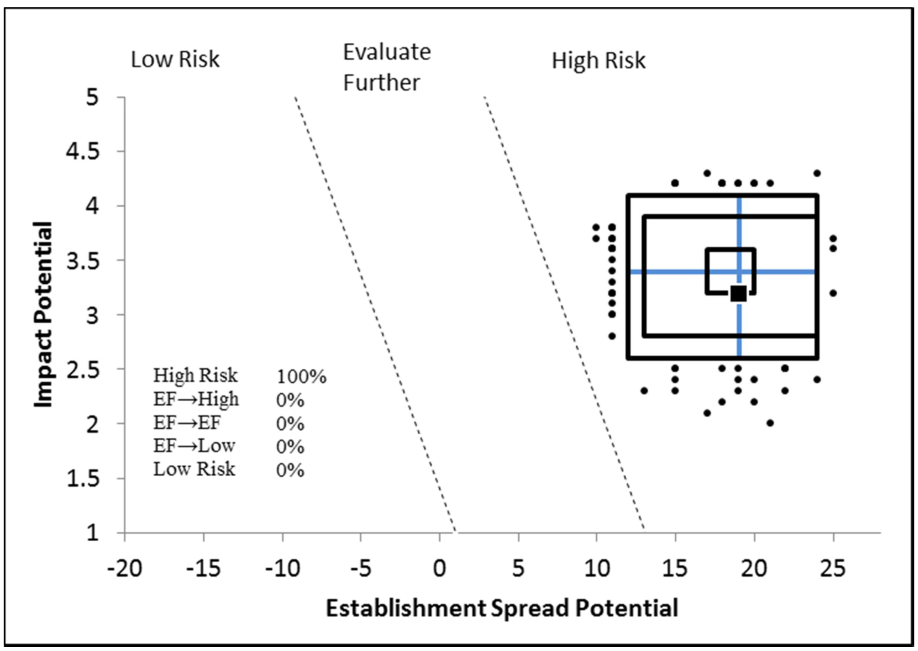

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Butomus umbellatus*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *B. umbellatus* is High Risk. When compared with the species of known weeds used to validate the WRA model, this species ranked among other High Risk weeds (Fig. 2). Our categorization of "High Risk" is well supported by the uncertainty analysis (Fig. 3). Managing *B. umbellatus* can be problematic for several reasons. First, it is difficult to detect *B. umbellatus* populations when they are not flowering, and so there has been a recent push to use remote sensing to identify populations of *B. umbellatus*, however at this time it is cost-prohibitive to use on a large scales (Hacket and Monfils, 2014). Thus, most states still utilize site visits to identify *B. umbellatus* populations (Hacket and Monfils, 2014). Further, the differences in reproduction between diploid and triploid populations require different methods to prevent spread: diploid populations reproduce sexually via seed and vegetatively via bulbils that develop on rhizomes and inflorescences, while triploid populations reproduce vegetatively via large, branched rhizomes (Eckert et al., 2003). Seeds and bulbils are relatively small reproductive organs, while the fragments are larger and easier to identify/prevent from spreading. Finally, it is extremely expensive to treat *B. umbellatus*; companies that manage *B. umbellatus* populations can spend over $60,000 per year battling *B. umbellatus* (Hackett and Monfils, 2014), not including the costs of chemical treatment.

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Appendix A. Weed risk assessment for *Butomus umbellatus* L. (Butomaceae). 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	*Butomus umbellatus* is native to most of mainland Europe, the United Kingdom, Republic of Ireland, and temperate western Asia (Brown and Eckert, 2005; White et al., 1993; Johnson et al., 2008). *Butomus umbellatus* appears to have only been introduced to North America (GBIF, 2016). It was first recorded in North America on the St. Lawrence River in Canada in 1897 and spread into eastern Lake Ontario and Lake Champlain over the next 30 years (Brown and Eckert, 2005; Muenscher, 1930). By 1955, the plant had spread along the St. Lawrence River and into eastern Ontario and expanded its range in southwestern Ontario and adjacent Michigan (White et al., 1993). By 1991, flowering-rush had been found in mainland Nova Scotia, Manitoba, Alberta, and British Columbia, in Canada; and South Dakota, North Dakota, Montana, Minnesota, Idaho, and Ohio in the United States (White et al., 1993). Many reports of its discovery in a new area also mention the plant's occurrence as large or extensive populations (White et al., 1993). Within the Great Lakes, *B. umbellatus* spread from a localized point on the River Rouge (Detroit, MI) northward into Lake St. Clair and to the southeast throughout Lake Erie past the Lake Erie islands in less than twenty years (Stuckey, 1968). A second center of expansion occurred in southwestern Lake Erie, where it was first recorded in 1918, and subsequently spread into Michigan, Ohio, and southwestern Ontario around Lake Erie and into Lake St. Clair by the mid-1900s (Brown and Eckert, 2005). The introduced range has since expanded westward and eastward to encompass most states and provinces along the Canada/USA border (Brown and Eckert, 2005). We answered "f" due to the extensive spread of this species throughout North America. Alternate answers for the Monte Carlo simulation are both "e".
ES-2 (Is the species highly domesticated)	n - low	0	*Butomus umbellatus* is sold as a water garden plant (Wicklein's Water Gardens and Native Plants, 2016; AAA Pond Supply, 2016; AquariumPlants.com, 2016), however we found no evidence that this species has been domesticated or that it has been selectively bred for traits associated with reduced weediness potential. Consequently, we answered no, with low uncertainty.
ES-3 (Weedy congeners)	n - negl	0	The family Butomaceae consists of a single genus, *Butomus* (Bailey and Bailey, 1976), and the genus *Butomus* consists of a single species, *B. umbellatus* (White et al., 1993; Bailey and Bailey, 1976).
ES-4 (Shade tolerant at some stage of its life cycle)	n - negl	0	This species will not grow in shade (USDA Forest Service, 2007; Pennsylvania Natural Heritage Program, 2016; Montana Weed Control Association, 2016). *Butomus umbellatus* seedlings need an open soil surface without shading by other

Question ID	Answer - Uncertainty	Score	Notes (and references)
			plants for at least for two months (Hroudová and Zákravský, 1993).
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	*Butomus umbellatus* is not a vine nor does it form tightly appressed basal rosettes, but rather it is a rooted erect aquatic herbaceous plant (Bailey and Baily, 1976; Johnson et al., 2008; Eckert et al., 2000).
ES-6 (Forms dense thickets, patches, or populations)	y - low	2	*Butomus umbellatus* forms dense stands (Parkinson et al., 2010) that dominate wetlands, the littoral zone of freshwater lakes, and river edges (Johnson et al., 2008). The western shore of Lake Erie was reported as having patchy to dense populations, and most populations were reported as sparse in Lake St. Clair, except for dense populations at Metro Beach MetroParks (Hackett and Monfils, 2014). We answered yes with low uncertainty, as populations appear to span a range of densities but are capable of forming dense populations.
ES-7 (Aquatic)	n - high	1	*Butomus umbellatus* is an emergent aquatic macrophyte (Johnson et al., 2008; Eckert et al., 2000). Soil must be permanently saturated with water in order to support growth (Hroudová and Zákravský, 1993). It requires wet soil and can grow in water (USDA Forest Service, 2007). It is typically found in shallow waters, but can survive and grow across a range of water depths. It has been observed growing submerged in very clear water at depths up to 20 feet (Jacobs et al., 2011).
ES-8 (Grass)	n - negl	0	This species is not a grass, but rather is a flowering aquatic perennial in the family Butomaceae (AOSA, 2014; Bhardwaj and Eckert, 2001; Brown and Eckert, 2005).
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 a rooted aquatic monocot (Johnson et al., 2008; Eckert et al., 2000).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Diploid populations produce abundant viable seed (Brown and Eckert, 2005). One Minnesota population produces viable seeds (Minnesota Department of Natural Resources, 2016). Triploids in natural populations do not produce seed (Hroudová and Zákravský, 1993). Eckert et al. (2000) found that *B. umbellatus* populations in Ontario naturally set seed. While germination rates in the field were not analyzed, greenhouse tests showed a germination rate of about 32% (Eckert et al., 2000). Germination of diploid seeds collected from natural populations reached 90% under optimum greenhouse conditions, but viability of seedlings was low (Hroudová and Zákravský, 1993a). Germination of seeds in a pond used for experimental purposes ranged from 20-82%, depending on whether seeds germinated in water or moist sand, respectively. After three months, germination rates ranged from 51-68% for seeds germinated in water or moist sand, respectively (Lukina and Papchenkov, 1999).
ES-11 (Self-compatible or apomictic)	y - high	1	Butomus umbellatus is a monoecious species (Bhardwaj and Eckert, 2001). Diploid *B. umbellatus* is fertile and self-compatible (Johnson et al., 2008; Krahulcová & Jarolímová, 1993). Hand-pollination trials under greenhouse conditions found *B. umbellatus* to be highly self-fertile (Eckert et al.,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			2000). Flowers are fully self-compatible but require insect visitation for pollination and do not spontaneously self-fertilize (Brown and Eckert, 2005); however, Bhardwaj and Eckert (2001) report that there is some overlap in male and female sexual phases in nature, indicating that it is possible for individuals to self-pollinate in the wild.
ES-12 (Requires specialist pollinators)	n - negl	0	*Butomus umbellatus* is pollinated by insects; the most common pollinator is the European honey bee, but other general pollinators like other bees, flies, and wasps have also been witnessed (Hackett and Monfils, 2014; Bhardwaj and Eckert, 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 - low	1	Shoots emerge in late March or early April and are well established by May (Hackett and Monfils, 2014). Plants bloom from June to August (Hackett and Monfils, 2014). Seeds collected in August do not immediately germinate in natural populations, but after a cold stratification seeds germinated in the spring (Hroudova and Zakravsky, 2003). Bulbils quickly germinate on the soil or water surface and produce new plants (Shaw, 2015). Given this timeline, we answered "b", with alternate answers of "c" for the Monte Carlo simulation.
ES-14 (Prolific reproduction)	y - negl	1	We found somewhat conflicting evidence regarding the magnitude of seed production for *B. umbellatus*, but in all cases, the values were above our threshold of 5,000 for an herbaceous species. A single plant produces, on average, over 7,000 seeds (cited in Krahulcová & Jarolímová (1993), original report unavailable). Diploid populations produce a mean of greater than 20,000 seeds per plant per year (Brown and Eckert, 2005). Individual plants produce 20-50 flowers, each with six carpels that produce about 200 seeds (Parkinson et al., 2010); this produces about 24,000-60,000 seeds per plant. While the literature does not agree on the number of seeds produced per plant, each account exceeds the threshold for this question (>5,000 seeds/m^2), therefore we answered yes.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y – low	1	The transportation of plant fragments is the main vector of introduction to new waterways (Indiana Department of Natural Resources, 2013), and anglers and boaters spread this species between water bodies (Pennsylvania Natural Heritage Program, 2016; USDA Forest Service, 2007). Waterfowl hunters may contribute to spread by using it in construction of hunting blinds (University of Wisconsin-Stevens Point, 2014). We weren't able to find any information regarding viability of plant fragments, or size necessary to regenerate a plant fragment. We answered yes, due to anecdotal information, but with high uncertainty without further knowledge of regeneration rates or requirements.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	? - max	0	We found no evidence that *B. umbellatus* acts as a contaminant. However, *B. umbellatus* is sold as a water garden plant (Wicklein's Water Gardens and Native Plants, 2016; AAA Pond Supply, 2016; AquariumPlants.com, 2016), and aquatic plants are likely to act as contaminants when moved through the horticulture trade (Maki and Galatowitsch, 2004). Therefore, we are answering unknown.
ES-17 (Number of natural	3	2	Fruit and seed description for questions ES-17a through ES-

Question ID	Answer - Uncertainty	Score	Notes (and references)
dispersal vectors)			17e: Flowers produce dark brown fruit that is about 1 cm in length and is filled with tiny seeds (Indiana Department of Natural Resources, 2013; Invasive Plant Atlas of New England, 2015). Seed length is estimated to be about 1.5 mm, based on photographs taken by Steve Hurst (USDA NRCS PLANTS Database, Bugwood.org). See cover photo for image of seeds. Plants may reproduce and spread in four different ways: 1) seeds; 2) vegetative bulbils formed in the inflorescence; 3) vegetative bulbils formed on the side of rhizomes; and, 4) rhizome fragments from large plants (Johnson et al., 2008). Triploid populations are only capable of vegetative reproduction (Eckert et al., 2003).
ES-17a (Wind dispersal)	? - max		Long distance dispersal of seeds occurs by wind or over ice (Johnson et al., 2008). We are unsure what the author means by this, but as seeds are extremely small, we answered unknown.
ES-17b (Water dispersal)	y - negl		Seeds and bulbils are moved by water currents (White et al., 1993). Bulbils and fragments spread via water (Johnson et al., 2008). Seeds, bulbils, and rhizomes are moved by water currents (Stuckey, 1968).
ES-17c (Bird dispersal)	y - high		Birds spread seed (Johnson et al., 2008). Seed dispersal over long distances is possible on the feathers of water birds (Hroudová and Zákravský, 1993).
ES-17d (Animal external dispersal)	y - high		*Butomus umbellatus* fragments are used by muskrats to build lodges, and this fragmentation contributes to spread (Gaiser et al., 1949; University of Wisconsin-Stevens Point, 2014). We are using higher uncertainty here because it is unclear which characteristics (i.e. size, part of plant that is fragmented) determine fragment viability.
ES-17e (Animal internal dispersal)	n - mod		We found no evidence that propagules of *B. umbellatus* can survive internal passage or are spread by animals through gut passage
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	Seeds are long-lived (White et al., 1993). Because we were unable to find additional information regarding seed dormancy and longevity of this species, we are answering unknown.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - high	1	*Butomus umbellatus* has the ability to spread via rhizome fragments (Johnson et al., 2008). Rhizome fragments from large plants (Johnson et al., 2008; Hacket and Monfils, 2014) contribute to the spread of the plant and are one of the main ways for triploid populations to spread (Eckert et al., 2003). Mechanical harvesting of the plant has not curbed population growth, but rather has contributed to its spread in water bodies as fragments disperse (Pelican River Watershed District, 2016).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - negl	0	We found no evidence that this species is resistant to herbicides, and it is not listed by Heap (2013) as a weed that is resistant to herbicides. Herbicides that were found to be effective to manage *B. umbellatus* include Endothall; Flumioxazin; Triclopyr + 2, 4-D amine; Diquat; Glyphosate; Imazamox; Imazapyr; Fluridone; Topramezone; Fluridone; Imazamox; Imazapyr; Penoxsulam; and Triclopyr (Hackett and Monfils, 2014).
ES-21 (Number of cold hardiness zones suitable for its survival)	8	0	

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
ES-22 (Number of climate types suitable for its survival)	7	2	
ES-23 (Number of precipitation bands suitable for its survival)	8	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - low	0	It is unlikely that *B. umbellatus* tissues contain or produce allelopathic chemicals (Dietz, 2015). Allelopathic effects have not been documented for this species (Wisconsin Department of Natural Resources, 2016).
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this species is parasitic. Furthermore, *B. umbellatus* does not belong to a family known to contain parasitic plants (Heide-Jorgensen, 2008; Bhardwaj and Eckert, 2001; Brown and Eckert, 2005).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	? - max		*Butomus umbellatus* is capable of forming dense mats that could affect the availability of light, nutrients, and dissolved gasses in invaded sites (Manitoba Purple Loosestrife Project, 2006; GLANSIS, 2012). Infestations could also result in increased water temperatures and altered nutrient flows and/or sedimentation rates (GLANSIS, 2012). The ecological effects of this species are not well-studied, and are acknowledged as an area needing more research (White et al., 1993; Johnson et al., 2008). Speculations regarding effects of this species reflect ecological effects associated with a dense growth form. Since *B. umbellatus* does grow in dense populations, we believe that it is likely to change ecosystem processes in ways associated with this growth form. Therefore, we answered unknown, since this species' growth form suggests that it may have these effects, but the effects have not been studied or confirmed in the field.
Imp-N2 (Changes habitat structure)	y - low	0.2	The large amount of underground rhizomes can harm fish and other wildlife by destroying food sources and habitats (Pennsylvania Natural Heritage Program, 2016). *Butomus umbellatus* can adversely impact native fish species by forming dense stands in waters previously unvegetated or sparsely vegetated by aquatic plants (Hackett and Monfils, 2014; Parkinson et al., 2010).
Imp-N3 (Changes species diversity)	y - low		*Butomus umbellatus* forms monospecific stands (Johnson et al., 2008) and can displace native riparian vegetation (USDA Forest Service, 2007). It replaced native vegetation within the St. Lawrence River (Roberts, 1972) and threatens native littoral species like *Zizania aquatica* (wild rice) (Brown and Eckert, 2005). Dietz (2014) found that *B. umbellatus* litter actually increased species diversity, and the presence of *B. umbellatus* nodules had no effect on species diversity. This is an area where more research is necessary, since the evidence we were able to find is somewhat vague and conflicting. However, we are answering “yes,” with low uncertainty, because there is evidence that this species displaces vegetation and forms monospecific stands in certain circumstances.
Imp-N4 (Is it likely to affect federal Threatened and	y - high	0.1	As temperatures cool in the fall and winter months, *B. umbellatus* stalks fall to the bottom of the riverbed but do not

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
Endangered species?)			decompose. This allows pike eggs, another introduced and invasive species, to cling to the leaves and stems. Through this, the eggs are anchored and protected from suffocating in the mud. Once hatched, these fish prey on native species, including T&E species of salmon and steelhead within the Pacific Northwest (Bannister, 2014). This indirect effect of *B. umbellatus* is a threat to T&E species, so we answered yes to this question. We used high uncertainty, however, because there is a need for further research into the ecological effects of this species (White et al., 1993; Johnson et al., 2008).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	? - max	0.1	*Butomus umbellatus* is already present in counties in Washington and Iowa (Kartesz, 2014) that are designated as globally outstanding ecoregions (Ricketts et al., 1999). As reviewed under Imp-N1 and Imp-N2, *B. umbellatus* may have the potential to negatively impact ecosystems processes, habitat structure, and species diversity. Therefore, we are answering unknown, as it is likely this species will affect globally outstanding ecoregions, but the broad effects assessed by the question have not been shown to be characteristic of this species. We are answering “unknown” as opposed to “no” because the full ecological effects of this species have not been fully studied and are not well understood.
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 - mod	0.6	In 2013, Salish Kootenai College in Montana utilized a $28,500 grant funded by the Montana Department of Natural Resources and Conservation to research the effectiveness of bare-ground application in controlling *B. umbellatus* in natural areas (Montana Department of Natural Resources and Conservation, 2013). The Minnehaha Creek Watershed District, in conjunction with Waterfront Restoration, LLC, are conducting a pilot program to determine the effectiveness of hand removal for *B. umbellatus* populations in Lake Minnetonka, Minnesota, "to promote the growth of native plants" (Waterfront Restoration, LLC, 2012). This evidence of control leads to an answer of "c", with alternate answers of "b" for the Monte Carlo simulation. We used moderate uncertainty because it was somewhat difficult to find control programs that specifically targeted natural systems, indicating that this species may not always be regarding as a weed of this system.
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - mod	0	We found no evidence that this species affects personal property, human safety, or public infrastructure.
Imp-A2 (Changes or limits recreational use of an area)	y - negl	0.1	It can interfere with recreational activities such as swimming and boating (Pennsylvania Natural Heritage Program, 2016). *Butomus umbellatus* stands provide habitat for the intermediate hosts (e.g. great pond snail – *Lymnaea stagnalis* L.) of the swimmer’s itch parasite (*Austrobilharzia variglandis*) (Hackett and Monfils, 2014; Parkinson et al., 2010). Dense populations along lake shores inhibit boating, fishing, and swimming (Jacobs et al., 2011; Parkinson et al., 2010). *Butomus umbellatus* can crowd shallow ponds and lakes, interfering with safe swimming and boating areas. Near-shore fishing has also seen impacts, as well as environmentally and economically

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
			important reservoirs that experience water level fluctuations (Bannister, 2014).
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - low	0	We found no evidence that this taxon affects ornamental plants and vegetation.
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	Due to the "tremendous" impact on recreation, landowners with *B. umbellatus* populations attempt to control them using various methods, including raking, cutting, laying bottom materials to prevent settling/growth of new individuals, and inappropriate/incorrect herbicide applications (Johnson et al., 2008). Mechanical harvesting of *B. umbellatus* in Minnesota in the Detroit Lakes system was undertaken by the Minnesota Department of Natural Resources to improve boating and swimming. However, mechanical harvesting proved ineffective and the program was cancelled (Pelican River Watershed District, 2016). We answered "c" to this question given the active role of citizens and government in controlling *B. umbellatus* in anthropogenic systems. 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)	n - low	0	We found no evidence that this species reduces crop or commodity yield.
Imp-P2 (Lowers commodity value)	n - low	0	We found no evidence that this species lowers commodity value.
Imp-P3 (Is it likely to impact trade?)	n - low	0	We found no evidence that this species is regulated in any country outside of North America, or that any countries require phytosanitary certificates for import (APHIS, 2016). Therefore, this species is unlikely to impact trade.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - negl	0.1	*Butomus umbellatus* grows prolifically in irrigation canals and can impede the distribution of irrigation water. An infested irrigation canal system in Idaho must be chained every two or three years to reduce densities and increase water delivery and availability (Parkinson et al., 2010). Dense populations growing within irrigation ditches reduce water availability and flow (Jacobs et al., 2011). *Butomus umbellatus* growth can block drainage ditches and irrigation canals and cause serious damage to agriculture if water is not reaching the crops or being drained from them properly (Bannister, 2014).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - negl	0	We found no evidence that this species is toxic to animals. Further, *B. umbellatus* was used at one time to aid in the elimination of worms from horses and cattle (Montana Weed Control Association, 2016). The roots of *B. umbellatus* have been said to be roasted and eaten in Asia (Montana Weed Control Association, 2016).
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]	c - low	0.6	*Butomus umbellatus* is classified as a weed of rice in India (Moody, 1989). Companies that provide surface water irrigation for agriculture in *B. umbellatus* invaded areas can spend over $60,000 per year battling *B. umbellatus*, not including the costs of chemical treatment (Hackett and Monfils, 2014). The manager of the Aberdeen-Springfield Canal Irrigation System in Idaho estimates that properly managing *B.*

Question ID	Answer - Uncertainty	Score	Notes (and references)
			umbellatus in this system would increase the costs to farmer shareholders by 8% a year (Rice and Dupuis, 2009). We answered "c" given the cost of managing this species in production systems. Alternate answers for the Monte Carlo simulation are both "b".
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2015).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that this species exists in or could survive in this plant hardiness zone.
Geo-Z2 (Zone 2)	n - low	N/A	We found no evidence that this species exists in or could survive in this plant hardiness zone.
Geo-Z3 (Zone 3)	y - low	N/A	Canada, Finland, Kazakhstan, and Russia.
Geo-Z4 (Zone 4)	y - negl	N/A	Canada, Finland, Norway, and the United States: New York and Vermont.
Geo-Z5 (Zone 5)	y - negl	N/A	Belarus, Estonia, Finland, and the United States: Illinois, New York, and Maine.
Geo-Z6 (Zone 6)	y - negl	N/A	Afghanistan, Austria, Canada, and the United States: Connecticut, Michigan, New York, and Ohio.
Geo-Z7 (Zone 7)	y - negl	N/A	Austria, India, Poland, Slovenia, Sweden, and the United states: Connecticut and Washington.
Geo-Z8 (Zone 8)	y - negl	N/A	Afghanistan, Canada, France, Romania, Spain, Sweden, and the United Kingdom.
Geo-Z9 (Zone 9)	y - negl	N/A	Denmark, France, Ireland, the Netherlands, Spain, and the United Kingdom.
Geo-Z10 (Zone 10)	y - low	N/A	France, Ireland, Portugal, Spain, and the United Kingdom.
Geo-Z11 (Zone 11)	n - negl	N/A	We found no evidence that this species exists in or could survive in this plant hardiness zone.
Geo-Z12 (Zone 12)	n - negl	N/A	We found no evidence that this species exists in or could survive in this plant hardiness zone.
Geo-Z13 (Zone 13)	n - negl	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 in or could survive in this climate class.
Geo-C2 (Tropical savanna)	n - low	N/A	One point in India, however we found no evidence in the literature that this species could survive in this climate class, therefore we are answering "no".
Geo-C3 (Steppe)	y - mod	N/A	Several points in Afghanistan and Spain.
Geo-C4 (Desert)	n - low	N/A	One point in Afghanistan, however we found no evidence in the literature that this species could survive in this climate class, therefore we are answering "no."
Geo-C5 (Mediterranean)	y - negl	N/A	France, Greece, Portugal, Spain, Turkey, and the United States: Washington.
Geo-C6 (Humid subtropical)	y - negl	N/A	France, Germany, Italy, and Romania.
Geo-C7 (Marine west coast)	y - negl	N/A	Belgium, Canada, Denmark, France, Ireland, the Netherlands, Spain, and the United Kingdom.
Geo-C8 (Humid cont. warm sum.)	y - negl	N/A	Canada and the United States: Connecticut, Illinois, Ohio, and Michigan.
Geo-C9 (Humid cont. cool	y - negl	N/A	Canada, Germany, Russia, Spain, and the United States:

Question ID	Answer - Uncertainty	Score	Notes (and references)
sum.)			Massachusetts, New York, and Ohio.
Geo-C10 (Subarctic)	y - negl	N/A	Canada, Finland, Germany, Norway, Russia, and Sweden.
Geo-C11 (Tundra)	n - low	N/A	We found no evidence that this species exists in or could survive in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that this species exists in or could survive in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - low	N/A	We found no evidence that this species exists in or could survive in this rain band.
Geo-R2 (10-20 inches; 25-51 cm)	y - low	N/A	Afghanistan, Italy, Kazakhstan, and Spain.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Armenia, Canada, Greece, Italy, Russia, Syria, and Turkey.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Canada, France, Greece, Spain, and Turkey.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Canada, Denmark, France, Ireland, the United Kingdom, and the United States: Connecticut, Illinois, New York, and Ohio.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Canada, France, Greece, Ireland, Serbia, the United Kingdom, and the United States: Connecticut.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Germany, Spain, and the United Kingdom.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Many points in the United Kingdom.
Geo-R9 (80-90 inches; 203-229 cm)	y - low	N/A	Canada, the United Kingdom, and the United states.
Geo-R10 (90-100 inches; 229-254 cm)	n - high	N/A	We found no evidence that this species exists in this rain band. As an aquatic plant it may be able to survive, but given that it is an emergent and not submerged species, it is unclear how excess rain will affect growth. Therefore, while we are answering "no", we are using high uncertainty.
Geo-R11 (100+ inches; 254+ cm)	n - high	N/A	We found no evidence that this species exists in this rain band. As an aquatic plant it may be able to survive, but given that it is an emergent and not submerged species, it is unclear how excess rain will affect growth. Therefore, while we are answering "no", we are using high uncertainty.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	This species was first observed in the United States within Lake Champlain, New York, in 1929 (Muenscher, 1930).
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	

Question ID	Answer - Uncertainty	Score	Notes (and references)
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	