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Risk Assessments for Invasive Plants: A Midwestern U.S. Comparison

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Several states in the Midwestern United States are using risk assessment to determine the invasiveness of introduced plant species, and each assessment process is different. This may lead to differences in results for the same species between states, creating concern about credibility by those using the assessments. In this study, risk assessments for six Midwestern states were compared, examining format, content, and assessment committee membership. Case studies were conducted for four species for which at least five of the six states in the study completed a risk assessment; results were compared in the context of general differences in assessment content and those specific to each species. Furthermore, 14 species for which only four of the six states completed assessments were briefly examined for outcome differences only, and possible reasons for these inconsistencies. Overall, differences in assessments did not result in incompatible conclusions for the species compared, suggesting that unique assessments in each state can provide consistent and credible results. We propose that these Midwestern states share species resources with each other to further improve consistency between the assessments.

Nomenclature: cutleaf teasel, *Dipsacus laciniatus* L.; Japanese barberry, *Berberis thunbergii* DC.; Amur honeysuckle, *Lonicera maackii* (Rupr.) Herder; Oriental bittersweet, *Celastrus orbiculatus* Thunb.

Key words: Invasive species, Midwest, risk assessment.

Although invasive plant species in general are widely recognized as a threat to biodiversity and drivers of ecosystem change in areas around the world, recognizing and determining the invasiveness of a given species is not a simple matter. Basic information about a given species' biology and distribution may not be available. Furthermore, the definition of an invasive species itself has varied (Colautti and MacIsaac 2004; Colautti and Richardson 2009; Daehler 2001; Davis and Thompson 2000, 2001; Elton 1958; Mack et al. 2000). Definitions often include some sort of geographic criterion (e.g., a species is not native to the ecosystem or the continent under consideration) and some include criteria for spread or impact, or both, on native species or ecosystems (Valery et al. 2008). Additionally, the Federal Executive Order (1999) on Invasive Species (1999) expanded these definitions by also considering harm to the economy and harm to human health.

The intrinsic difficulty in classifying a species as invasive has resulted in the creation of invasive plant assessments. These procedures evaluate the likelihood of introduction and establishment, extent of existing populations, dispersal potential, and possible harmful effects resulting from invasion of the species under evaluation. Assessment findings can inform policy makers and educate stakeholders. In the United States, the U.S. Department of Agriculture (USDA) Animal Plant Health Inspection Service conducts weed risk assessments (WRAs) using a tool to identify plants with invasive potential that have not been previously documented or have very limited distribution within the United States (Koop et al. 2012). Additionally, individual states may opt to conduct their own invasive plant assessments,

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Management Implications

Risk assessments are conducted to measure the invasiveness of introduced plant species. As defined in this paper, Type I assessments are primarily used for education and management and Type II assessments to guide policy. In Indiana, a Type I state, the completed assessments were shared with land managers to help prioritize control efforts and with the nursery and landscape industry to recommend which species should not be sold commercially. Educational brochures sharing the assessment results were widely disseminated from 1996 to 2014, and articles on the assessment results were published in the Indiana Nursery and Landscape Association's journal. Discussions with land managers indicate that risk assessments did change some management goals, although often site-specific factors weighed more heavily in choosing control goals than the species' rank (e.g., a medium-risk species present in small quantities may be controlled before a high-risk species present in large quantities). There are no data on the impacts of the risk assessments on commercial sales or spread of invasive plant species in Indiana.

Wisconsin is a Type II state and used its assessments as a tool to recommend regulatory status for each species assessed. Information about the rule and the species to be included was shared widely with stakeholders and the general public before and after the rule went into effect. Although there had been extensive outreach on invasive plants for years, the media and organizations picked up the news of the new regulation and made it available to many more people. The Wisconsin Department of Natural Resources created a field guide to provide identification and control information on all of the regulated plants, and over 35,000 copies have been purchased. Many nurseries and landscapers were aware of the species to be regulated and stopped growing, ordering, or designing with them before the rule went into effect. The public began reporting garden center sales of regulated plants, leading to their removal from their stock. All of these efforts have led to greatly increased prevention of the spread of regulated species. Prohibited plants have become a priority for land managers, with efforts being made to contain and, where possible, eradicate these species at all known locations statewide.

Risk assessments provide a solid foundation for education and for regulation, but do not guarantee reduction in invasive plant introduction and spread without significant follow-up.

usually for species that threaten the state's natural and agricultural resources. Some states follow the federal WRA protocol, whereas other states develop assessment protocols and processes specific to their needs.

In general, invasive plant assessments are of two types: status assessments, which are used for determining whether nonnative plant species already occurring in natural areas are invasive, or risk assessments, which identify species that do not currently occur in natural areas but are likely to become invasive in the future (Gordon and Gantz 2008). Most of the assessments being conducted in the Midwestern United States are hybrids of risk and status assessments, allowing users to examine invasiveness both for species that are already present and species that have not yet become invasive in the state in question. We will use the term "risk assessment" to refer to these hybrid assessment tools in this paper.

Each state has created its own risk assessment process for its own purposes and with its particular stakeholders. The assessment process includes the development and use of a tool or tools for assessing invasiveness, as well as a protocol for conducting assessments with the tool(s), including the number and types of people involved, the types of information considered in the assessments, and review and approval of completed assessments. For some states, lists have regulatory authority, whereas other state lists are used for advisory or educational purposes, indicating which plants should be targeted for management or not recommended for planting.

Because invasive species have a variety of impacts on the ecosystems they invade, there is no standard way to examine the extent or the magnitude of the impacts of a particular invasive species (Valery et al. 2008). As a result, each assessment protocol includes a distinct set of criteria for determining whether a species is currently invasive in that state. These criteria are weighted differently by different protocols, and the assessment processes are completed in different ways, possibly leading to differences in the outcomes of the assessments. These conflicting results have led to confusion and frustration regarding a certain plant species—is it invasive or isn't it?— for the nursery and landscape industry and for the general public in deciding which species should not be bought, sold, or planted in their state.

We examined and compared the status assessment protocols used in six states in the Midwestern United States (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin) to look for similarities and differences in the criteria used for determining invasiveness, in order to identify the potential reasons for differences in outcomes among states. These states all have active, ongoing assessment processes, and because of their geographic proximity, there is a high likelihood that a species that is invasive in one state may also be invasive in a nearby state. However, there is a wide range of climate zone variation between the states that might also lead to different rates of invasion between states.

Materials and Methods

Because the risk assessments for the Midwestern states were created with differing purposes of education or regulation, the assessments were separated into two main categories based on these goals to facilitate comparison:

- Type I: Those created strictly to assess invasiveness.
- Type II: Those created strictly to inform policy regarding species that may be invasive.

Possible outcomes for each risk assessment reflect the nature of these goals (Table 1). Although the actual terminology may differ, Type I assessments produce three main types of results: invasive, not very invasive, and need more

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Table 1. The assessment outcomes for each state; each outcome has been defined for a better understanding of the implications of that outcome.

Outcome	Implication
Indiana	
Very high	Very highly invasive
High	Highly invasive
Medium	Moderately invasive
Low	Not very invasive
Caution	Not enough information to determine invasiveness
Michigan	
High	Highly invasive
Medium	Moderately invasive
Low	Not very invasive
Insignificant	Not invasive
Ohio	
Invasive	Invasive
Pending further review	Will be reviewed again for invasiveness (higher score than not invasive)
Not known to be invasive	Not invasive (based on currently available information)
Insufficient data	Not enough information to determine invasiveness
Illinois	
Recommend for regulation	Recommend to list as exotic weed
Do not recommend for regulation	Do not recommend to list as exotic weed
Postpone decision	Not enough information to complete the assessment
Minnesota	
Prohibit/Eradicate noxious weed	Must be eradicated statewide; all importation, sale, and transportation of the plant is prohibited
Prohibit/Control noxious weed	Must be managed to prevent spreading; all importation, sale, and transportation of plant is prohibited
Restricted noxious weed	Importation, sale, transportation prohibited
Specially regulated plant	Plant is allowed, but subject to varying management requirements
Do not list	No regulation or management
Watch	Not enough information to complete the assessment
Wisconsin	
Prohibited	Transport, possession, transfer, and introduction of plant illegal; control required
Restricted	Transport, transfer, and introduction of plant illegal; control not required
Prohibited/Restricted	Split-listed within state; depends on location
Non-Restricted	Invasive, but not illegal to transport, possess, transfer, or introduce the plant
Caution/Watch	Not enough information to complete the assessment at this time

information to assess invasiveness. Type II outcomes include regulated plant species, nonregulated plant species, and insufficient information available to make a regulatory determination (Table 2). As shown by the dates in Table 2, the assessments were completed over a long range of time because different states started their assessment processes at different times; it is likely that states starting later made use of earlier states' assessment documents when making their own.

We first compared content of the assessment protocols used in Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin (Table 3). We then analyzed the assessment results in depth for four species that represent different growth forms and frequency of use in the ornamental trade and have been assessed by at least five of the six states. Cutleaf teasel (*Dipsacus laciniatus* L.) is an herbaceous plant not commonly sold for ornamental uses. Japanese bar berry (*Berberis thunbergii* DC.) is an ornamental shrub that is frequently sold and planted. Amur honeysuckle [*Lonicera maackii* (Rupr.) Herder] is also an ornamental shrub, although not as commonly sold as Japanese barberry. Oriental [Asian] bittersweet (*Celastrus orbiculatus* Thunb.) is a vine sold for ornamental use. This comparison was limited to plants widely accepted as invasive because of the limited number and nature of assessments completed by Illinois and Ohio in the short period of time that they have been conducting assessments. Species assessed by four of the six states were also examined for consistency of outcome and

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Table 2. An explanation of outcomes for all six states. The top part of the table shows the outcomes from Type I states sorted into three categories of similar responses. The bottom part shows Type II state responses sorted into three categories of similar responses.

Outcome	State rankings		
Type I	Indiana	Michigan	Ohio
Invasive	Very high High Medium	High Medium	Invasive
Not very invasive	Low	Low Insignificant	Pending further review Not known to be invasive
Need more information	Caution	(None)	Insufficient data
Type II	Illinois	Minnesota	Wisconsin
Some regulation	Recommend for regulation	Prohibited/Eradicate noxious weed Prohibited/Control noxious weed Restricted Noxious weed Specialty Regulated plant	Prohibited Restricted Prohibited/Restricted
No regulation	Do not recommend for regulation	Do not list	Non-Restricted
Need more information	Postpone decision	Watch	Caution

are briefly discussed. The Appendix (http://dx.doi.org/10.1614/IPSM-D-15-00018.S1) contains a complete list of all assessments completed for terrestrial invasives in all six states from which we selected the species for this comparison.

Results and Discussion

The format of assessments differs substantially across the six states. Indiana, Michigan, and Ohio have Type I assessments, while Illinois, Minnesota, and Wisconsin have Type II assessments. Indiana and Ohio use a quantitative approach; points are given for responses to each criterion, and these are totaled for a final score within predetermined ranges that correspond to outcomes. Wisconsin and Illinois utilize an assessment form similar to the point system assessments of Ohio and Indiana, but it is simply a guide for discussion procedures that follow. Michigan uses a point system to assign various categorical ranks, which convert to invasive potential and the impacts of the plant in each of four separate ecological regions. Minnesota does not use a point system, and instead employs a flow chart where responses to questions lead to further questions until a suggested outcome is reached. Both point and nonpoint systems have benefits and drawbacks. Point systems are objective and transparent, but the point totals at or near action thresholds may be difficult to interpret or accept as fact. They are, however, easy to update when new information becomes available about the species' impacts or distribution, for example. Nonpoint systems involved a discussion among stakeholders, and therefore can more easily address nuanced concepts such as human value. The assessments are less transparent, though, and they cannot be easily updated with new information. The benefits and drawbacks of both point and nonpoint systems are summarized in Table 4.

The committees (formal or informal) that review the risk assessments differ in each state, with members having various backgrounds and qualifications. For instance, the horticultural industry (through the Illinois Green Industry Association) and natural land management interests are represented in the Illinois assessments through equal representation on a 16-member voting board. Indiana's committee has both self-appointed members who are land managers or natural resource agency staff, and members who are appointed to represent particular groups, like the Indiana Nursery and Landscape Association. Minnesota has a Noxious Weeds Advisory Committee reporting to the Commissioner of Agriculture. The member organizations are specified in state statute. Organizations include government agencies, conservation and agricultural organizations, the horticultural industry, and others. Ohio specifies formal requirements for its five assessment team members, who are appointed by the Ohio Invasive Plants Council, and also includes input from the Ohio Nursery and Landscape Association. In Wisconsin, many stakeholders are involved in the conversation, including land managers, botanists, tribal, nursery, and agricultural representatives. Both Indiana and Wisconsin vary the composition of the assessment committee based on the type of species being assessed to assure inclusion of experts on that species. Differences in backgrounds of the committee members in the focus states may contribute to discrepancies in results, because qualifications and experiences likely impact each reviewer's knowledge and opinions of invasive plants. These differences are especially important to consider for states that use Type II

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assessments and rely on committee conversations to determine whether a species will be recommended for regulation.

Similar characteristics of invasive plants are measured by each assessment but constitute different proportions of the assessment criteria. These differences are noted in Figure 1, which reveals the relative proportions of questions relating to the five major topics covered within the assessments for each state: distribution/current invasion status; establishment and expansion capabilities; ecological impacts; socioeconomic and cultural impacts; and prevention, control and management options. Additionally, Figure 2 illustrates the differences in weighting of similar topics between the point system assessments used by Indiana and Ohio (the two quantitative systems). Indiana uses two different assessments: one for species in trade (Invasive Plant Species Assessment Work Group [IPSAWG] Assessment Tool) and one for species not in trade (Indiana Non-Native Plant Invasiveness Ranking Form [INPIRF]). Specific differences between assessment tools are discussed below for individual species.

Given the differences in the construction and completion of the assessments, the results from the assessments for the four case study species are fairly consistent. The completed Type I risk assessments found Amur honeysuckle, cutleaf teasel, Japanese barberry, and Oriental bittersweet to be invasive. The completed Type II risk assessments recommended regulation of the four species, although the specific levels of regulation varied.

Minnesota and Wisconsin did not recommend the same level of regulation across all species assessed. Minnesota lists cutleaf teasel and Oriental bittersweet as Prohibited/Eradicate, while Wisconsin lists these species as Restricted. This difference was largely based upon the limited abundance and distribution of these species in Minnesota, where eradication is feasible, compared with broad distribution in Wisconsin, where eradication is not feasible. Minnesota has designated specific Japanese barberry cultivars as Specially Regulated Plants for a 3-yr production phase-out followed by a Restricted designation for these cultivars. Wisconsin recommended that the same Japanese barberry cultivars be designated Restricted with similar practical implications. Amur honeysuckle was recommended as Restricted in Minnesota but is split-listed as Prohibited/Restricted in Wisconsin. The outcomes in each state for each species, as well as the dates the assessments were completed, are summarized in Table 5.

Differences between assessment content and protocol for a single species were common among the states, especially in regard to treatment of cultivars and outcomes. The results for each species are presented below.

Amur Honeysuckle. Amur honeysuckle is an Asian shrub that was formerly very popular in trade but is now sold much less frequently than Japanese barberry. This plant was assessed by all six states: alone in Michigan, Minnesota, Ohio, and Wisconsin and with other species and hybrids of Eurasian bush honeysuckle in Illinois and Indiana.

The assessments for Amur honeysuckle were completed over 11 yr, from 2003 to 2014. Earlier completion dates are associated with fewer sources. The most significant contradictions occurred in suitable habitat; for instance, some states did not include any wetland-type habitats while others did. This could be because some states reviewed multiple species at a time, which increased the ecological amplitude of invasion, whereas other states assessed a single species at a time, reducing the number of habitats potentially invaded. Additional differences include dispersal abilities (intentional human-mediated noted only by Michigan and Ohio) and human health effects, because some states do not explicitly address human health impacts in their assessments.

Amur honeysuckle produced very similar results from each state, especially across the Type I states. The Type II states all regulate the plant in some capacity; Illinois recommended Amur honeysuckle for regulation, Minnesota recommended it as restricted, and Wisconsin listed it as prohibited and restricted. Wisconsin split-listed Amur honeysuckle depending on location within the state, making it illegal in all of Wisconsin to transport, transfer, and introduce Amur honeysuckle. In those areas where it is not yet established, it is listed as prohibited to encourage control and eradication.

Cutleaf Teasel. Cutleaf teasel is a monocarpic perennial plant native to southern Europe and southwestern Asia that is minimally in trade for horticultural use. This plant was assessed by five states—individually in Indiana, Ohio, and Wisconsin and with common teasel (*Dipsacus fullonum* L.) in Illinois and Minnesota.

The assessments were completed from 2007 until 2014, and it is likely that available information concerning cutleaf teasel and its spread increased within this time period. The most notable differences in information were observed for hybridization potential (ranging from unknown to unlikely to probable), probability of long-distance dispersal (low or high), ability to go undetected (low to medium), and inconsistent information presented for impacts on ecosystem processes and human health. Type I states do not include economic benefits in their assessments, and this also resulted in differences between assessments.

While specific information present in the assessments may reflect the individual interests and environments of the states, inherent properties of cutleaf teasel itself should not vary across states. The distribution of the species in the state can result in differences in regulation in

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Table 3. The criteria considered by each state in its assessment, separated into five broad topics, each with subtopics that are divided into specific criteria. An "x" indicates that the criterion is explicitly covered in the assessment, an "I" indicates that the criterion is incorporated into the assessment through another general/broad question, and a blank space indicates that the criterion was neither explicitly covered nor incorporated into the assessment. Indiana has two tools, IPSAWG (Invasive Plant Species Assessment Work Group) and INPIRF (Indiana Nonnative Plant Invasiveness Ranking Form), used for plants in trade and not in trade, respectively.

	State						
Criteria	IL	IN	IN2	MI	MN	OH	WI
Broad topics							
Distribution/current invasion status	x	x	x	x	x	x	x
Establishment and expansion capabilities: a life history	x	x	x	x	x	x	x
Ecological impacts	x	x	x	x	x	x	x
Socioeconomic and cultural impacts	x	x		x	x		x
Prevention, control, and management options	x	x	x	x	x		x
Specific question/criteria and subtopics							
Distribution/current invasion status							
Distribution							
What is the native range of the species?			x	x	I		x
What is current known state distribution?	x	x	x	x	x	x	x
What is current known U.S. distribution?	x		x	x	I	x	I
In how many regions in state is it established?	I	I	x	x		x	I
What is the proportion of potential range invaded?							x
Is the genotype nonnative?	I	I	I	I	x	I	I
Is species native to state?	I	I	I	x	x	I	x
What is known abundance?	I	I		I		I	x
Presence in natural areas							
Does species occur in any natural areas of state?	I	x		I	I	x	I
Does it only occur in natural state areas due to persistence from cultivation?		x	I	x	I	x	
Does species persist without cultivation?		I	x	x	I	I	
Self-replicating popns outside cultivation and alters aspect of natural ecosystem?		I	I	I	I	x	I
Is species invasive only when natural disturbance regime disrupted?		x	I	x		I	I
Has species persisted after colonization when natural regime restored?		x		I		I	
Habitat and climate areas							
What is the native habitat of the species?	I			I			x
What is the habitat invaded in the state?	I	I	x	I	I	I	x
Is the species established in similar habitat?	I		I	I		I	x
What is the conservation significance of the habitats threatened?				I		x	x
What is the native climate of the species?	I		x		I		I
Is the species established in similar climate?	I		x	I	x	x	x
What is ecological range of species?	x	I					x
Regulation and identification in other places							
Is the species identified as a problem in another state?	I		I	x	x	x	x
Plant listed as invasive in adjoining state or nearby state?	x			x	I	x	I
Has species been regulated by other state/entity?	x			I	I		x
Does plant occur in state and listed as "noxious" federally or state-wide?	I			x		x	x
Is the plant illegal to sell anywhere?	I			I			x
Establishment and expansion capabilities: a life history							
General plant characteristics							
What type of plant is this?	x	I	I	x	I	I	x
Distinguishing characteristics aiding in survival?	I	I	I	I	I	I	x
Is it able to go undetected?	x						x
Habitat and climate requirements							
Is there evidence of new populations of species in state in recent period?	I	x					
What types of habitat can it invade and establish?	I	I	I	I	I	x	I

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Table 3. Continued.

Criteria	State						
	IL	IN	IN2	MI	MN	OH	WI
What are the germination requirements?		x	x	x	x	I	I
How competitive is species for limiting factors?	I	x	x	I	x	I	I
What is the growth vigor?	I	I	x	I	I	I	I
What climate restrictions does this plant have?			I				x
How will climate change effect where this species can establish?							x
Mode(s) of reproduction							
What is the mode of reproduction (vegetative vs. seed or both)?	I	x	x	x	x	x	x
Does vegetative reproduction maintain population?		x	I	x	x	x	I
Does species have vegetative regeneration?		I	x	I	I	I	x
What is the frequency of sexual reproduction?		x		x	x	x	I
How many seeds or propagules does a mature plant make (or per area)?	x	x	x	x	x	x	I
How long are seeds viable?	x	x	x	x	x		x
Is the plant self-fertile?		I		I	x		I
Does it have hybridization potential?	x	I	x		x	x	x
Dispersal							
Pathways of dispersal (intentional and unintentional)?	x	x	x	x	I	I	x
What is the potential for long-distance dispersal?	I	x	x	x	x	x	I
Maturation and reproductive period							
Can it complete its reproductive cycle in the concerned area?		x		I			I
How long is the flowering period?		I		I		x	I
What is the generation/maturation time?	I	I		I	x	x	x
Invasion							
What is the known rate of invasion?	x	x					x
What is the estimated rate of invasion?		x					
Do natural controls exist in state to effectively prevent spread?	I				x		I
Other species in the genus invasive?	I	I	x	I	I	I	I
Ecological impacts							
Changes induced in the receiving ecosystem by the species							
Does it alter ecosystem/community structure?	x	x	x	x	x	I	x
Does it reduce native species richness or diversity? (Competition)	x	I	x	x	x	x	x
Displaces native vegetation?	I	x	x	I	x	x	x
Has it negatively affected state or federal listed plants or animals?	I	x	I	x	I	x	I
Does it alter ecosystem/community functions and processes?	x	x	x	x	x	x	x
In which/ how many habitat types is plant invasive?	I	x	x	x		x	x
Do impacts only occur under a few, identifiable, environmental conditions?		x					
What level of disturbance areas does species invade? (Succession)	I	I	x	x		x	I
Invasive species' contributing properties							
What is population density of species?	I	I	x	I		x	I
Does it have allelopathic properties?	x	I	I	I	x	I	x
Hybridizes with native state plants or commercially available plants? (Gene pool)	I	x			x	x	I
Toxic to wildlife?		I	x		x	I	I
Plant has potential to harbor pests or be alternative host?			x		x		I
Socioeconomic and cultural impacts							
General commercial values							
Does species cause significant financial losses in any sector?	I	I		I	x		x
Any commercial value?	I	x		I	I		x
Are there many commercial growers in the state?	I	x		I	I		I
Do growers rely on species for significant portion of their production in state?	I	x		x	I		I
Is it utilized state-wide?	I	x		I	I		I
Is it sold in retail stores?	I	x	I	x	x		I

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Table 3. Continued.

Criteria	State						
	IL	IN	IN2	MI	MN	OH	WI
What are socioeconomic effects (direct or indirect) of restricting species use?	I	I		I	I		x
Would the control of a species add costs to a sector?	I	I		I	I		x
Is a noninvasive, alternative plant commercially available?	x				x		
Agriculture							
How is the species introduced into agricultural systems?	I			x	I		I
What is the ability to invade agricultural systems?	I			x	I		
Colonizes ditches, grassy swales, and riparian zones?	x			I			
During what part of production cycle for agriculture does species harm?	I			x			
What is impact on crop production?	I	I		x	x		I
Nuisance in crop fields?	x			I	I		
Is the plant sold as a crop within the state?	x	I		x	I		I
Sold for beneficial agricultural uses?	x	I		x	I		I
Sold for forage?	x	I		x	I		x
Horticulture							
How is the species introduced into horticultural systems?	I			x	I		
What is the ability to invade horticultural systems?	I			x			I
During what part of production cycle for horticulture does species harm?				x			
What is impact on horticultural production?	I	I		x	I		I
Nuisance in lawns, turf areas, and gardens?	x			x	I		
Widespread economic value in horticulture?	x	I		I	I		I
Widespread cultural value in horticulture?	x	I		I	I		I
Many retail seed outlets in the state?	I	x		I	I		I
Sold for ornamental purposes?	x	I		I	I		I
Has commercially available varieties that have been proven to be sterile?	x				I		I
Has it provided crop, turf, or feed source of significant income?	I	x		x			I
Is the plant sold horticulturally as a fruit, vegetable, herb, or ornamental?	I	I		x	I		I
Has the plant resulted in commercial income from turf in the state?	I	I		x			I
Managed and constructed landscapes							
How extensive is the plant in managed forests?				x			I
Does the species affect production in managed forests?	I			x	x		I
Is the plant desirable in managed forests?	I			x	I		I
At what stage in its life does species have an impact in managed forests?				x			I
Are there silvicultural treatments that can alter presence of species?				x	I		
How is the species introduced into managed forests?	I			x	I		I
Has the plant resulted in commercial income from forestry in the state?	I	I		x	I		I
Is the species desirable in managed landscapes?	I			x			I
How extensive is the plant in managed landscapes?	I			x			I
Does the species alter the aesthetics of managed landscapes?				x	I		I
Has an effect on desirable plant composition in managed landscapes?	I			x	I		I
How is the species introduced into managed landscapes?	I			x	I		I
Where in managed landscapes is the species found?	I			x			
Is the species desirable in constructed habitat systems?	I			x			
What is the ability of species to invade constructed habitat systems?				x			
What is the impact on constructed habitat systems?	I			x			
During what stage does species have negative impact on constructed habitat?				x			
How is the species introduced into constructed habitat?	I			x			
Is the plant used in landscaping?	I			x	I		I
Is the plant used in erosion control?	x			x			x
Is the plant used in wildlife management practices?	I			x			I

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Table 3. Continued.

Criteria	State						
	IL	IN	IN2	MI	MN	OH	WI
Safety							
Sold for medicinal purposes?	x						x
Has potential to negatively impact human health?	x				x	I	x
Blocks views on transportation rights-of-way?	x						
Increases fire intensity, increases risk of escape?	x					I	I
Recreation and culture							
Does the plant contribute to recreation?	I			x			
Does the plant inhibit water vehicle use?	x						
Does the plant inhibit hiking?	x						
Does the plant inhibit hunting and fishing?	x						
Does the plant inhibit swimming?	x						
Does the plant limit aesthetic of natural vistas and viewsheds?	x			I			
Does the plant reduce property value?	x						
Prevention, control, and management options							
Historic intervention							
Are there current management activities for this species in the state?	I			x			
Has the species been successfully eradicated anywhere else?	x	I	I	I	I		I
Is further site restoration usually necessary?	I	x		x			
Will resurveying or retreating be necessary?	I	x	I	x	I		I
State prevention							
What is the responsiveness to prevention efforts?					x		x
What are the costs of prevention?							x
State control							
Are there effective control measures?	x	x	I	x	x		x
What is the minimum effort for control?	I	I	x	I	I		x
What are the costs of control?	x	x		x			x
Are control measures legal?	I			x			I
Can species be eradicated or controlled on a state-wide basis?	I	I	I		x		I
Evaluation of species for control							
Propagules numerous and long-lasting or spread widely or spread far?	I	x	I	I	I	I	I
Age of reproduction is early in life span?	I	x		I		I	I
In how many sites is the species established?	I	x	I	I			I
How large is the area to be managed?	I	x	I				
Is the species difficult to control without damage to native species?	I	x		x	I		x
Does the species provide more overall benefit than negative impacts?	I	I		I	x		I
Costs of prevention or control vs. costs of allowing invasion to occur?							x
Efficacy of monitoring?							x
How to address legal and landowner issues?							x

Type II states. One outcome difference noted is the listing of Prohibited/Eradicate Noxious Weed in Minnesota but the Restricted label in Wisconsin. Minnesota is aiming to eliminate the plant, because it has limited distribution in Minnesota, whereas Wisconsin has not made possession illegal, because of its widespread distribution and abundance, which makes complete eradication infeasible. Overall, results were similar across states; all of the states either listed this species as invasive (Type I) or had some level of regulation (Type II).

Japanese Barberry. Japanese barberry is a shrub native to Japan widely sold for landscaping in the United States. It has many dozens of named varieties, cultivars, and hybrids that are available in the industry. The plant was assessed alone in two states (Indiana and Michigan) and with cultivars in Ohio, Wisconsin, and Minnesota.

Indiana used the fewest sources, perhaps because it was the first to complete the Japanese barberry assessment (in 2007), although the assessment was recently updated; Ohio used the largest number of resources, at 37. Notable

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Table 4. A comparison of the strengths and weaknesses of assessment protocols that assign points (Type I) and that do not assign points (Type II).

Strength	Weakness
Point systems	
Objective	Point totals at or near action thresholds may be problematic
Facilitates species comparisons	Difficult to assign points to nuanced concepts such as human values
Transparent	Can be reductionist
Easy to update as new information becomes available	Requires that all decisions fall into discrete categories, which can be difficult at times
Nonpoint systems	
Logical process guides decision-making	Subjective
Nuanced concepts such as human values can be addressed in detail	Difficult to compare species assessments
Plants are evaluated on a continuum of invasiveness, rather than using artificial thresholds	May not be transparent
	Updating assessments with new information may be more difficult

differences in information between states involve suitable habitats (wet, dry, or both), hybridization potential (none to regular hybridization), seed viability (less than a year by Indiana and Wisconsin, up to 10 yr by Michigan), ability to reduce biodiversity (not cited by Indiana), ecosystem structure changes (not cited by Indiana), and effective control methods (differing reports on fire and biological controls), as well as differences in the inclusion of human health impacts and dispersal ability. Given that the basic biology of the species does not vary from state to state, we expected to find better consistency in the answers to questions related to the plant's biology.

Despite the differences in assessment content, the results are relatively similar across all four states for Japanese barberry. Indiana, Michigan, and Ohio all found the species to be highly invasive; Minnesota listed Japanese barberry as a Specially Regulated Plant, so that cultivars with the greatest seed production will be phased out of sale; Wisconsin has also proposed that the parent species and certain cultivars be restricted and phased out of sale. The economic and cultural values placed on Japanese barberry in Minnesota and Wisconsin resulted in the allowance of continued sale and use of certain barberry cultivars within these states.

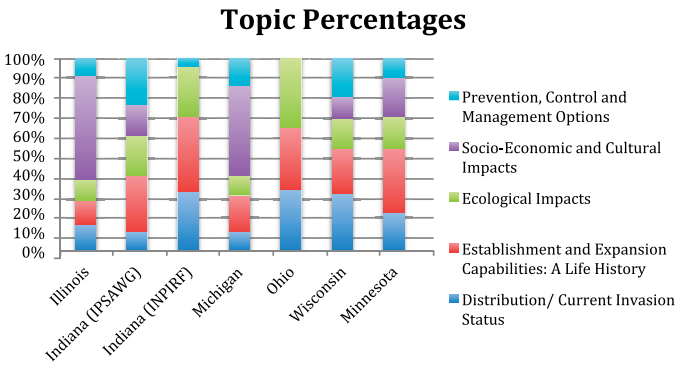


Figure 1. Topics by proportion. These stacking bar charts show the relative number of questions asked by each state by topic, as seen in the legend. (Color for this figure is available in the online version of this article.)

Oriental (Asian) Bittersweet. Oriental bittersweet is a vine native to temperate regions of eastern Asia; it is sold for planting, and cut stems with ripe fruits are used for decorations. Five of the six states (Michigan excluded) have completed an assessment for Oriental bittersweet.

Differences in information used may be attributed to increasing information published during the span of completion, from 2003 to 2014, and to assessment formats. Minnesota's flow chart system can advance a species to the next evaluation step without answering all possible questions. For example, a significant negative impact of a species can advance that species before all possible impacts are documented. The most significant differences regarded hybridization potential (not evaluated by Minnesota, because the species had already advanced in the flow chart process before questions about hybridization were reached), dispersal ability (long-distance, water-mediated dispersal, and human dispersal not noted by Illinois and Ohio), seed production (estimates from nonprolific to prolific) and varying accounts of seed viability, as well as no evaluation of impacts on ecosystem processes for this particular species by Minnesota and no finding of impact on ecosystem processes by Indiana. The Minnesota flow chart system advanced this species because of the potential of significant financial losses to the forestry sector, so documentation of all possible impacts was not required in the flow chart. Additional differences between states occur because Type I state assessment tools do not include criteria on effective control methods or human health impacts, resulting in different information presented in assessments. Although environments, infestation levels, and purposes for listing within

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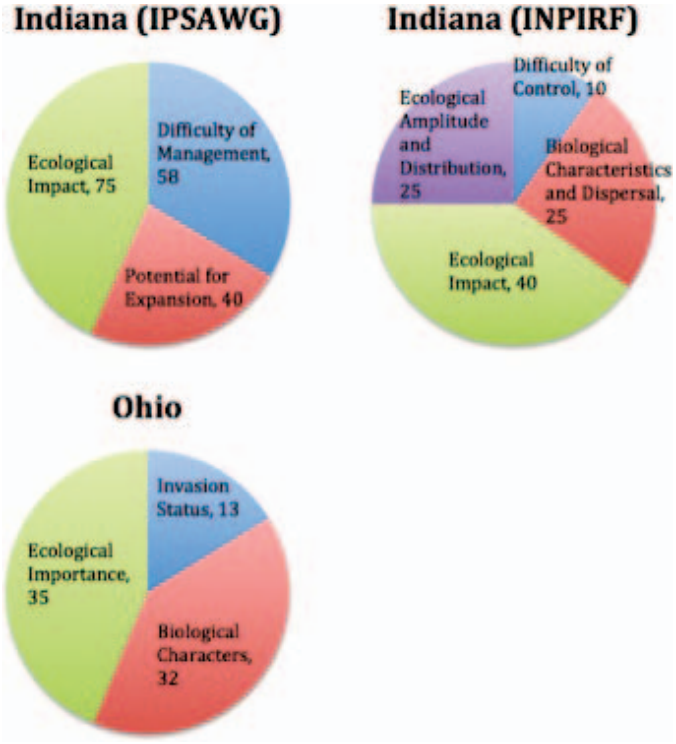


Figure 2. Point system assessments weighting. These pie charts show the relative proportion of points each assessment from Indiana and Ohio allocates to each section of their assessment(s). For both IPSAWG (Invasive Plant Species Assessment Work Group) and INPIRF (Indiana Non-Native Plant Invasiveness Ranking Form) tools, Ecological Impact receives the most possible points. For Ohio, Ecological Importance has the most possible points. (Color for this figure is available in the online version of this article.)

states may vary, the inherent properties of Oriental bittersweet itself should be fairly constant; therefore, inconsistent information may be indicative of the resources available and the known species distributions at the time of assessment completion.

The results of Oriental bittersweet assessments are reconcilable with one another. Indiana found the plant to be highly invasive, and it was assessed as invasive in Ohio; Illinois recommended it for regulation, Minnesota listed it as Prohibited/Eradicate, and Wisconsin restricted it. Minnesota is trying to eliminate the plant, whereas Wisconsin intends to minimize the spread, because eradication is not feasible in Wisconsin because of its current extent. The findings of invasiveness for the Type I states are consistent with regulatory actions in the Type II states.

Additional Species. For 14 additional species, four or more states had completed risk assessments as of September 2015. Although not compared in detail, the outcomes of the risk assessments for these species can be divided into four categories: (1) species that are highly invasive across the region and therefore have similar outcomes (eight species); (2) species with invasiveness patterns that vary with location in their range (two species); (3) species with outcomes that vary based on the influence of economic value (one species); and (4) species that are new to the region and have limited information (three species). These species are discussed in detail below, and the results are condensed in Table 6.

Species That Are Highly Invasive across the Region. When a nonnative species has already caused widespread infestations, a risk assessment is not predictive, but it often serves to document the rationale for listing the species as invasive in a particular state. Tree-of-heaven [*Ailanthus altissima* (P. Mill.) Swingle] is a widespread invasive tree in much of the region, especially in urban areas and along roadsides. Tree-of-heaven was assessed as highly invasive in Indiana, invasive in Ohio, and restricted in Minnesota and Wisconsin, which are essentially equivalent findings that it is invasive in all four states. Alder buckthorn (*Frangula alnus* P. Mill.), European buckthorn (*Rhamnus cathartica* L.), garlic mustard [*Alliaria petiolata* (Bieb.) Cavara & Grande], and multiflora rose (*Rosa multiflora* Thunb. ex Murr.) are also widespread in the region and have the same risk assessment outcomes in each state as tree-of-heaven does. Garlic mustard was also assessed at a high level of invasiveness in Michigan. Purple loosestrife (*Lythrum salicaria* L.) and common reed [*Phragmites australis* (Cav.) Trin. ex Steud.] have consistent assessment results, with two exceptions: *Lythrum* is listed as a prohibited/control noxious weed in Minnesota, meaning that it is actively managed in the state; and *Phragmites* is listed as prohibited in some parts of Wisconsin, where it is not yet as abundant, and restricted in others. These abundant nonnative plants have been assessed as invasive in all four states for which risk assessments have been completed. Multiflora rose, purple loosestrife, and the buckthorns are all designated exotic weeds in Illinois, so they were not put through Illinois' risk assessment process. A seventh species, Japanese knotweed (*Polygonum cuspidatum* Sieb. & Zucc.), was assessed at high invasiveness in Indiana, recommended for regulation in Illinois, restricted in Wisconsin, and specially regulated in Minnesota, where it can be still be sold with a caution label that advises against planting it in riparian areas or floodplains. These outcomes are all consistent with the widespread invasive nature of Japanese knotweed.

Species with Invasiveness Patterns That Vary with Location in Their Range. A few species have different assessment results in different states, likely resulting from difference in performance at the edge of the species' range, which has also led to different planting frequencies in different states. Japanese honeysuckle (*Lonicera japonica* Thunb.), for instance, has been more heavily planted in the southern part of the

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Table 5. Outcomes of risk assessments for each species are listed according to state. Blank squares indicate the species has not been assessed.

Species	Assessment					
	IL	IN	MI	MN	OH	WI
Cutleaf teasel	Recommend for regulation, Dec 9, 2014	High, Sep 21, 2012		Prohibited/Eradicate, May 20, 2011	Invasive, Dec 31, 2014	Restricted, Aug 21, 2007
Japanese barberry		High, May 25, 2007	High, Mar 13, 2009	Specially regulated, Feb 24, 2014	Invasive, Mar 1, 2015	Proposed restricted, Dec 16, 2011
Amur honeysuckle	Recommend for regulation, Nov 12, 2013	High, Aug 7, 2003	High, Mar 5, 2009	Restricted, Dec 17, 14	Invasive, May 1, 2014	Prohibited/Restricted, Sep 6, 2007
Oriental bittersweet	Recommend for regulation, Feb 26, 2014	High, Dec 17, 2003		Prohibited/Eradicate, Feb 3, 2011	Invasive, May 1, 2014	Restricted, Sep 6, 2007

Midwest, because the more northern states are at the edge of the plant hardiness zone for this species. Though Japanese honeysuckle is present in Wisconsin, Michigan, and Minnesota, it has not reached the high abundances seen in natural areas in Illinois, Indiana, and Ohio (EDDMapS, 2015). As a result, it was assessed as high on the invasiveness scale for Indiana and Invasive in Ohio, but only medium invasiveness in Michigan and prohibited in Wisconsin, a designation that indicates its distribution is still small enough that they are working to contain it. Japanese honeysuckle is already a designated exotic weed in Illinois, so a risk assessment was not conducted there. In Minnesota, no risk assessment has been done. Japanese honeysuckle has only been reported in one county (EDDMapS, 2015) in Minnesota, and there are no Minnesota herbarium specimens of this species.

Russian-olive (*Elaeagnus angustifolia* L.) was heavily planted in the western part of the region for use as a windbreak and wildlife food and cover. In this part of the region, it regularly escapes cultivation and was assessed as restricted in Wisconsin and recommend for regulation in Illinois. In the eastern part of the region, autumn-olive (*Elaeagnus umbellata* Thunb.) was planted more frequently for the same purposes because it was more successful in this part of the species range than Russian-olive. The relatively few Russian-olives that were planted in the eastern Midwest have shown limited invasiveness, and therefore received an assessment outcome of medium in Indiana, and in Ohio was assessed as invasive but received a very low score (48, whereas below 45 is considered not invasive), whereas autumn-olive scored 63.

Species with Outcomes That Vary Based on the Influence of Economic Value. One of these species is still commonly sold and planted in the Midwest, and states have approached these risk assessments in different ways, leading to different outcomes.

Callery pear (*Pyrus calleryana* Dcne.) is a commonly sold and planted tree species that was assessed as Invasive in Ohio and high invasiveness in Indiana. Illinois, however, did not recommend Callery pear for regulation, primarily because it is such an important species in trade in Illinois that it was not possible to get consensus on its invasiveness from the diverse group of partners involved in the assessment process. In Wisconsin, where Callery pear has only been reported as invasive in natural areas in one county, the risk assessment outcome was caution.

Species That Are New to the Region and Have Limited Information. For species that are relatively new to the Midwest, the assessment outcomes are variable for two reasons. First, there is not as much information available in the scientific literature about the characteristics and impacts of these species, making it difficult to answer the

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Table 6. Species for which four states have completed risk assessments as of August 2014 and the results. Only four states had assessed garlic mustard at the start of this study.

Common name	Latin name	IL[a]	IN[b]	MI[c]	MN[d]	OH[e]	WI[f]	No. of completed assessments
Tree of heaven	*Ailanthus altissima*		H		R[g]	I	R	4
Porcelainberry	*Ampelopsis brevipedunculata*		C		PE[g]	P	P	4
Black swallowwort	*Cynanchum louiseae*/*Vincetoxicum nigrum* L. Moench		H		PE	I	P/R	4
Russian-olive	*Elaeagnus angustifolia*	R	M			I	R	4
Alder buckthorn	*Frangula alnus*/*Rhamnus frangula* L.		H		R	I	R[h]	4
Japanese honeysuckle	*Lonicera japonica*		H	M		I	P	4
Purple loosestrife	*Lythrum salicaria*		H		PC	I	R	4
Common reed	*Phragmites australis* ssp. *australis*		H		R[g]	I	P/R	4
Japanese knotweed	*Polygonum cuspidatum*/*Fallopia japonica* (Houtt.) Dcne.	R	H		S		R	4
Callery pear	*Pyrus calleryana*	N	H			I	C	4
Lesser celandine	*Ranunculus ficaria*	R	C			I	P	4
European buckthorn	*Rhamnus cathartica*		H		R	I	R	4
Multiflora rose	*Rosa multiflora*		H		R	I	R	4
Garlic mustard	*Alliaria petiolata*		H	H	R	I	R	5

[a] Illinois assessment results: R, recommended for regulation; N, not recommended for regulation.

[b] Indiana assessment results: L, low risk of invasion; M, medium risk of invasion; H, high risk of invasion; C, caution (not enough information).

[c] Michigan assessment results: I, insignificant risk of invasion; L, low risk of invasion; M, medium risk of invasion; H, high risk of invasion.

[d] Minnesota assessment results: PE, Prohibited/Eradicate noxious weed; PC, Prohibited/Control noxious weed; R, Restricted noxious weed; S, Specially Regulated noxious weed; C, county noxious weed; N, no listing.

[e] Ohio assessment results: I, invasive; P, pending further review; N, not known to be invasive; ID, insufficient data.

[f] Wisconsin assessment results: P, Prohibited; R, Restricted; P/R, Prohibited/Restricted; N, nonregulated, but assessed; C, caution.

[g] Regulatory status recommended for 2017.

[h] Cultivar exemptions exist.

assessment questions adequately. Second, these species are more abundant in some areas than in others, because they have not yet spread across the region. In areas where they are more abundant, they are more likely to be assessed as invasive. Four species fall into this category: porcelainberry (*Ampelopsis brevipedunculata* Maxim. Trautv.), which is prohibited in Minnesota and Wisconsin, pending further review in Ohio, and a caution species in Indiana; black swallowwort (*Cynanchum louiseae* Kartesz & Gandhi), which has a rank of high invasiveness in Indiana, invasive in Ohio, and prohibited in Minnesota and Wisconsin; and lesser celandine (*Ranunculus ficaria* L.), which is recommended for regulation in Illinois and is invasive in Ohio, prohibited in Wisconsin, and a caution species in Indiana.

Despite the differences between the six Midwestern states' invasive plant assessment processes, consensus is strong on the invasiveness of the four case study species. The differences in the intent of the assessments (e.g., regulation vs. education), timing of the assessments, reported abundance and distribution of a species in each state, and assessors' access to information regarding the species are responsible for different content in the assessments but did not result in irreconcilable conclusions. Indeed, this seems to demonstrate the robustness of the assessment processes—minor differences in content between states' assessments do not cause significantly different conclusions.

Although there is overall consistency, greater variation in results exists for Type II compared with Type I states, because the regulatory category depends in part on the current distribution and the feasibility of management of the species in the state, which varies between states. Additionally, the social and economic impacts of listing play a greater role in discussions in Type II states than point-based assessments of the Type I states.

Although it might be preferable for all states to use the exact same process for invasive plant assessments for

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consistency's sake, it is infeasible given the different purposes for assessment, as well as varying regulatory processes and the diverse partnerships that have pursued assessments in each state. In each case, partners came together and developed criteria and weighting systems considered appropriate and acceptable to the partners involved in the process. Fortunately, our case studies indicate that the different processes are providing similar results.

These four case study species represent species with a great deal of published information on their biology, distribution, and impacts. The 14 additional species that were assessed by four rather than five states reveal that, while overall the states' assessments produce complementary results, there are predictable differences in some species' outcomes. Such differences include performance of the species in different parts of its range, the economic importance of certain species in particular areas, and a lack of information about the distribution and impacts of less well-known species. Differences such as those above may lead to predictable differences in risk assessment outcomes for a particular species; however, these differences are not a reflection of inherent differences in risk assessments.

A clear way that all states could strengthen the credibility and accuracy of their assessments is by sharing sources of information on each species to assure the best information available is being used. This will be implemented by posting literature citations on the Midwest Invasive Plant Network website (http://MIPN.org). Furthermore, representatives from all states mentioned in this study are communicating to ensure transparency across state protocols and to share data and literature on newly spreading plant species that may be more difficult to assess.

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