University of Minnesota

Twin Cities Campus

Minnesota Invasive Terrestrial Plants and Pests Center

College of Food, Agricultural and Natural Resource Sciences

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Dear Friends,

The Minnesota Invasive Terrestrial Plants and Pests Center is excited to share the preliminary results of the prioritized, top-124 terrestrial invasive species threats to our state. The goal of this analysis was to identify the "worst of the worst" invasive plants, insects, and pathogens that threaten valued plants in Minnesota's prairies, forests, wetlands, and agriculture. The results will be used to set MITPPC's funding priorities for research at the University of Minnesota, including the Research and Outreach Centers across the state. Much of that research funding was made available through Minnesota's Environment and Natural Resources Trust Fund.

The rankings are the outcome of a structured process. That process involves careful thinking about what it means for any terrestrial invasive species to be the greatest threat to the entire state. That thinking leads to the development of common criteria to measure the degree of threat posed by every species and to assessments of the relative importance of each criterion. We then consult published references and scientific experts to assign ratings to each criterion for each species. Some "math" happens to convert the ratings to priority scores so that all species can be compared and ranked. Before the ranks are finalized, though, we seek your input.

The attached white paper summarizes the rankings of each of the species, the criteria that were considered to compare the species, the ratings that were assigned to each criterion for each species, and a bibliography of literature consulted. This is not meant to be a technical document. We are happy to share any technical details with those who might be interested.

We have three questions for you. First, do you have any additional information or experience to share that might affect the ratings that were assigned to each species? Please note that the ratings for each criterion have specific operational definitions that may not be intuitive. (The definitions are included in this document.) Second, of the 124 taxa that are listed here, which five do you think are the greatest threat to Minnesota? Lastly, would you recommend any additional terrestrial invasive species that are not on this list to be added next year as we update the list? Please go to www.mitppc.umn.edu to provide your feedback. All responses must be received by noon on July 29, 2016.

We wish to thank the faculty and graduate students at the University of Minnesota and valued colleagues at the Minnesota Department of Agriculture and the Minnesota Department of Natural Resources who contributed to this process. We thank you for your interest in MITPPC and your efforts to help the Center succeed.

Sincerely

Robert C. Venette, Ph.D.
Director, MITPPC



Minnesota's Top 124 Terrestrial Invasive Plants and Pests: Priorities for Research

Science-based solutions to protect Minnesota's prairies, forests, wetlands, and agricultural resources

College of Food, Agricultural and Natural Resource Sciences

UNIVERSITY OF MINNESOTA

Contents

I. Introduction

This white paper, "Minnesota's Top 124 Terrestrial Invasive Plants and Pests: Priorities for Research," describes the outcome of efforts to identify which invasive species pose the greatest threats to Minnesota's forests, prairies, wetlands, and agriculture. This information will be used to set funding priorities for the Minnesota Invasive Terrestrial Plants and Pests Center (MITPPC) at the University of Minnesota. Funding needs for research on terrestrial invasive species far exceed the resources that are currently available. Thus, a fair, consistent, and transparent process to determine priorities for future research is essential. Those priorities will be reflected in regular requests for proposals.

We welcome your feedback on this white paper. Specifically, we would like to know whether you have any information that could change the criteria ratings that were assigned to each pest (see Sections VII, VIII, and IX). If you would like to propose a change a rating, please be consistent with the definitions and measurement standards that were provided in Section X and provide reference citations or detailed descriptions to support your proposed change. We would also like to know which species among the 124 described here that you would prioritize for research. Lastly, as there are many more than 124 terrestrial invasive threats to the state, we would like to know which additional species should be evaluated next year. Please submit all feedback through the on-line form at mitppc.umn.edu.

What is the MITPPC? The MITPPC was established in the College of Food, Agricultural, and Natural Resource Sciences at the University of Minnesota with support from the Minnesota legislature to "research and develop effective measures to prevent and minimize the threats posed by terrestrial invasive plants, pathogens, and pests, including weeds and pests, in order to protect the state's native prairies, forests, wetlands, and agricultural resources" (ML 2014, Ch. 312, Art. 13, Sec. 44, Subd. 2). Significant funding was provided from the Environment and Natural Resources Trust Fund. The enabling legislation requires that research undertaken by the MITPPC should be focused on the prioritized species list.

What do we mean by 'invasive terrestrial plants and pests'? For MITPPC, 'invasive' refers to those species that are not native to Minnesota's ecosystems and have the potential to cause economic, environmental, and/or social harms. We focus on those invasive species that dwell primarily on the land, though some species of concern readily move in or along water. During the start-up of MITPPC, we will focus on those invasive species that may affect the abundance or health of valued plants, especially those growing in prairies, forests, wetlands, and/or agriculture. Invasive plants include those "weeds" that compete with, or parasitize, valued plants. For our purposes, invasive 'pests' include non-native pathogens, insects, earthworms, mites, mollusks, vertebrates that can harm valued plants.

Why invest in invasive species research? Terrestrial invasive species cost Minnesotans approximately $3 billion annually in lost productivity and increased management costs. They threaten the integrity of ecosystems that provide wildlife habitat, clean water, and fresh air. Every ecosystem in every corner of the state is vulnerable to invasion. Thus, many Minnesotans are actively working to prevent or limit damage from terrestrial invasive species. Research is needed to provide those individuals with new technologies and techniques to ensure management goals are achieved or to provide confidence that current management approaches are effective.

How was the prioritization done? The Minnesota Invasive Terrestrial Plants and Pests Center undertook an expansive research prioritization to systematically evaluate threats posed by a wide array of terrestrial invasive insects, plants, and plant pathogens. Fourteen panelists were identified, six from the faculty at the University of Minnesota and eight program managers with advanced degrees from partner agencies (Section II). In total, these panelists identified over 120 significant invasive plants, pathogens, or insects that threaten Minnesota's agriculture, forests, wetlands, or prairies. An Analytical Hierarchy Process (AHP) was used to rank these threats. AHP is a form of multi-criteria decision analysis that makes the process of selecting the highest priority threats consistent and transparent. AHP has been used by many agencies and organizations to facilitate complex decision making. In brief, the fourteen member panel engaged in facilitated discussions about criteria by which terrestrial invasive plants and pests should be considered a high threat and the relative importance of each criterion.

The panel identified 17 criteria to measure the "unmanaged biological threat" that each species poses to Minnesota. These criteria were based on the panelists' previous experiences with invasive species and interpretations of published literature. Each criterion (listed in Section III) had to be relevant to all invasive species that have invaded, or might invade, the state. As part of the AHP, the relative importance of each criterion was determined by a questionnaire submitted to all panelists. Panelists were presented with the criteria in pairs and asked which of the two options was more important (on a scale of 1-7) to determine the unmanaged threat a species might pose to the state. Responses from the panel were analyzed with Comparion Core software, and results presented to the panelists. Each of the 17 criteria were not equally important (Section III). More emphasis was placed on the impact that an invasive species might have than on its likelihood of invasion.

A team of six graduate students (Section II) was then hired to assemble published information about the 124 species and provide summaries of that information with respect to the 17 criteria. MITPPC's

Director evaluated the information and assigned initial ratings based on measurement standards for each criterion (Sections VII, VIII, and IX). Those ratings were used in the AHP to compare and rank all 124 species.
The prioritization panel reconvened to review the rankings from the AHP. Panelists examined the results, verified or revised ratings, and readjusted priorities assigned to criteria as needed. The rankings in this document represent the outcome of the revised information.

Why this process? Our broad challenge is to identify research priorities that transcend the goals and values of any individual or institution in the state so that research from MITPPC has benefits for multiple stakeholders. The challenge is difficult because the priorities are derived from differing opinions on invasive species. Our hope is that MITPPC's priorities will be consistent with, though perhaps not identical to, many priorities of other individuals and institutions.

There is no perfect approach to prioritization. Some have suggested, "Why not vote?" Voting can appeal to a sense of democracy, but the outcome reflects who voted. This process is limited to the options available at the time the vote occurs and can lead to substantially different priorities from one vote to another. A new threat cannot easily be considered a priority until a new vote is taken. Further, as more is learned about the biology and behavior of these species, the potential impact of that research on opinions and subsequent priorities is not always clear.

We chose the AHP for three primary reasons. Firstly, the nature of the process forces the discussion from which species should be most important (perhaps for unknown reasons) to which attributes make a species important. We believe this exercise provides greater transparency in the decision-making process. Secondly, AHP easily allows for additional threats to be considered in the future without undoing the original work. We believe such an approach provides flexibility to our prioritizations over time while maintaining some consistency. Lastly, AHP allows us to easily revise priority scores and rankings as new information is gathered about these threats.

AHP has some limitations. The most significant issue is that the process does not work well for species that might be threats to the state, but experts are highly uncertain. We relied on an expert-driven process to identify the top terrestrial-invasive-species threats to Minnesota, and we trust those judgements. A separate process could be developed to pre-screen species, for example, some European species that are not yet in North America, to determine if enough is known to consider them a legitimate threat to the state. In addition, AHP provides a single score for each invasive species without a "margin of error." The margin of error can be important when the quality of information is highly variable from species to species. There is certainly some margin for error in each of the priority scores that reflects limits to our knowledge about these species. The scores are a reflection of the best available information, and are useful for priority setting. However, our knowledge about these species and how they might affect the entire state can be limited, especially for species that are new to the region. The process is most useful for structuring a research program to respond to known threats, not for determining whether some species might pose a threat.

We fully intend to update the priorities on a regular basis, no later than every other year. The updates will allow us to consider more species and to review new information that may affect out threat scores. Managing biological invasions is a dynamic process, so our prioritizations must be flexible to a degree.

II. Prioritization Panel members

We thank the following individuals for their extensive, valuable contributions to this prioritization process.

Insects

- Mark Abrahamson, Pest Detection and Response Unit Supervisor, Plant Protection Division, Minnesota Department of Agriculture
- Brian Aukema,*McKnight-Land Grant Professor and Associate Professor, Department of Entomology, UMN
- Robert Koch, Assistant Professor and Extension Entomologist, Department of Entomology, UMN
- Val Cervenka, Forest Health Program Coordinator, Division of Forestry, Minnesota Department of Natural Resources

Pathogens

- Robert Blanchette, Professor, Department of Plant Pathology, UMN
- Susan Burks, Invasive Species Program Coordinator, Minnesota Department of Natural Resources
- Kathryn Kromroy, Research Scientist, Minnesota Department of Agriculture
- Deborah Samac,* Adjunct Professor, Department of Plant Pathology, UMN (USDA-ARS Plant Science Research)
- Brian Schwingle, Forest Health Specialist, Minnesota Department of Natural Resources

Plants

- Roger Becker, Professor, Department of Agronomy and Extension Agronomist, UMN
- Monika Chandler, Biological control and terrestrial invasive plant early detection, Minnesota Department of Agriculture
- Anthony Cortilet, Noxious Weed Law, Minnesota Department of Agriculture
- Rebecca Montgomery,* Associate Professor, Department of Forest Resources, UMN
- Laura Van Riper, Terrestrial Invasive Species Coordinator, Minnesota Department of Natural Resources

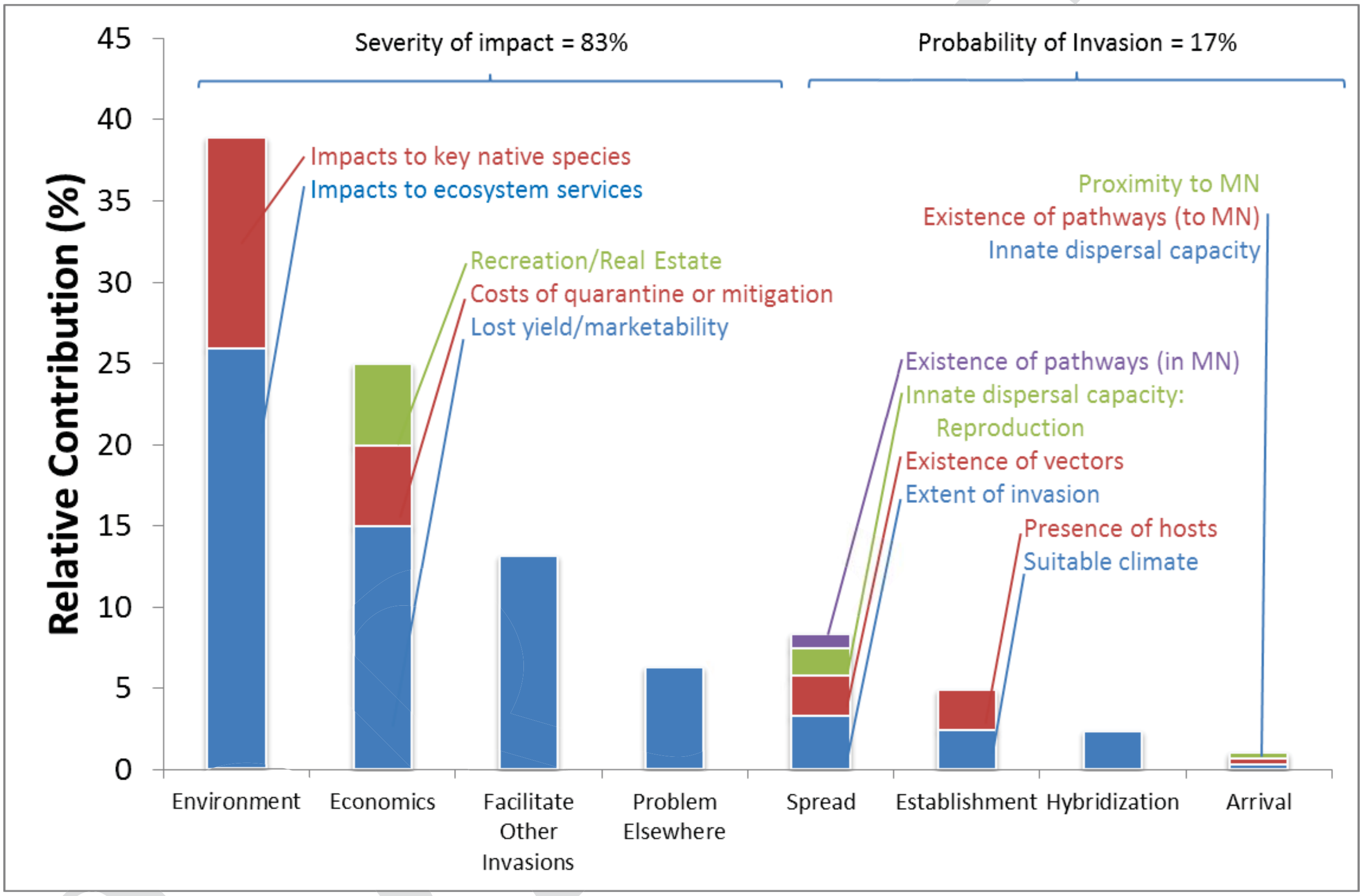
*Panel chair

Graduate students (degree being pursued; home department)

- Aaron David, Ph.D., Department of Ecology, Evolution, and Behavior, UMN
- Genevieve Furtner, M.B.S., College of Continuing Education, UMN
- Melissa Peck, M.S., Department of Natural Resource Science Management, UMN
- Derik Olson, M.S., Department of Forest Resources, UMN
- Ashley Reichard, M.S., Department of Natural Resource Science Management, UMN
- Roxanne Sage, M.S., Département de Biologie, Chimie et Géographie, Université du Québec à Rimouski (UQAR)

III. Seventeen criteria, and their relative importance, to assess the threat a terrestrial invasive species poses to Minnesota

The graph below shows the relative contribution of each criterion to the final priority score. The priority score measures the level of threat posed by different terrestrial invasive species to Minnesota. In general, the seven criteria associated with the severity of impact contributed 83% to the final priority scores. The ten criteria associated with the probability of invasion contributed 17% to the final priority scores.



IV. Prioritized list of terrestrial invasive insects

This list describes the ranked order of terrestrial invasive insects that threaten Minnesota and is organized from greatest statewide threat (highest priority) to least threat (lowest priority).

Rank	Scientific name	Common name	Priority Score
1	*Dendroctonus ponderosae*	mountain pine beetle	100.00
2	*Agrilus planipennis*	emerald ash borer	96.45
3	*Aphis glycines*	soybean aphid	88.81
4	*Halyomorpha halys*	brown marmorated stink bug	84.75
5	*Lymantria dispar dispar*	gypsy moth, European	84.75
6	*Lymantria dispar asiatica*	gypsy moth, Asian	84.73
7	*Scolytus schevyrewi*	banded elm bark beetle	84.30
8	*Scolytus mulistriatus*	European elm bark beetle	81.38
9	*Anoplophora glabripennis*	Asian longhorned beetle	76.65
10	*Eupoecilia ambiguella*	European grape berry moth	76.20
11	*Helicoverpa armigera*	old world bollworm	74.64
12	*Sirex noctilio*	Sirex woodwasp	74.05
13	*Drosophila suzuki*	spotted wing drosophila	73.76
14	*Spodoptera littoralis*	Egyptian cottonworm	73.14
15	*Agrilus biguttatus*	oak splendor beetle	72.71
16	*Tetropium fuscum*	brown spruce longhorned beetle	71.92
17	*Ips typographus*	European spruce bark beetle	70.56
18	*Chrysodeixis chalcites*	golden twin spot moth	70.05
19	*Adelges picea*	balsam woolly adelgid	69.70
20	*Diabrotica speciosa*	cucurbit beetle	69.47
21	*Pityophthorus juglandis*	walnut twig beetle	66.17
22	*Autographa gamma*	silver Y moth	65.33
23	*Rhizotrogus majalis*	European chafer	65.21
24	*Leguminivora glycinivorella*	soybean pod borer	64.90
25	*Tipula oleracea*	European craneflies	64.08
26	*Epiphyas postvittana*	light brown apple moth	63.76
27	*Popillia japonica*	Japanese beetle	63.36
28	*Tipula paludosa*	European craneflies	62.47
29	*Coleophora laricella*	larch casebearer	61.43
30	*Acrolepiopsis assectella*	leek moth	61.08
31	*Orgyia pseudotsugata*	Douglas fir tussock moth	60.76
32	*Contarinia nasturtii*	swede midge	58.31
33	*Agrilus sulicollis*	European oak borer	57.17
34	*Lycorma delicatula*	spotted lanternfly	55.95
35	*Tomicus piniperda*	European shoot beetle	53.92
36	*Lilioceris lilii*	lily leaf beetle	53.60
37	*Operophtera brumata*	winter moth	52.73
38	*Lobesia botrana*	European grapevine moth	51.99
39	*Pyrrhalta viburni*	viburnum leaf beetle	51.81
40	*Yponomueta malinellus*	apple ermine moth	45.63

By virtue of appearing on this list, each species is a credible threat to one or more communities or ecosystems in the state. Other threats exist, so this list will be updated annually. This list is only intended to direct research at the University of Minnesota to discover new management tools to prevent or mitigate the impacts from the most threatening species.

V. Prioritized list of terrestrial invasive plant pathogens

This list describes the ranked order of terrestrial invasive plant pathogens that threaten Minnesota and is organized from greatest statewide threat (highest priority) to least threat (lowest priority).

Rank	Scientific name	Common name	Priority Score
1	*Ophiostoma novo-ulmi*	Dutch elm disease	84.24
2	*Ceratocystis fagacearum*	oak wilt	81.97
3	*Raffaelea quercivora*	Japanese oak wilt	81.10
4	*Heterobasidium irregulare*	Annosum root rot	78.92
5	*Phytophthora ramorum*	sudden oak death	72.94
6	*Geosmithia morbida*	thousand cankers disease	72.90
7	*Aster yellows phytoplasma*	aster yellows	71.51
8	*Arceuthobium americanum*	dwarf mistletoe	70.98
9	*Ralstonia solanacearum* (Race 3, biovar 2)	brown rot	70.92
10	*Cronartium ribicola*	white pine blister rust	70.72
11	*Hymenoscyphus fraxineus (pseudoalbidus)*	ash dieback	70.20
12	*Tilletia controversa* (cereal strain)	Dwarf bunt	69.23
13	*Fusarium virguliforme*	soybean sudden death	68.02
14	*Phytophthora infestans*	late blight	67.33
15	*Fusarium graminearum*	Fusarium head blight	66.09
16	*Amylostereum areolatum*	associate fungus to Sirex woodwasp	65.90
17	*Phytophthora alni* ssp. *alni*	alder disease	65.45
18	*Harpophora maydis*	late wilt of corn	64.04
19	*Ophiognomonia clavigigenti-juglandacearum*	butternut canker	63.92
20	*Fusarium euwallaceae*	dieback; wilt	63.42
21	*Phakospora pachyrhizii*	soybean rust	63.06
22	*Urocystis agropyri*	wheat flag smut	62.12
23	*Plasmodiophora brassicae*	club root	62.08
24	*Candidatus phytoplasma mali*	apple proliferation phyoplasma	61.87
25	*Pseudoperonospora cubensis*	Downy mildew of cucurbits	61.62
26	*Ditylenchus dipsaci*	stem and bulb nematode	60.90
27	*Clavibacter michigensis ssp. nebraskensis*	Goss's wilt	60.61
28	*CGMMV*	Cucumber green mottle mosaic virus	59.49
29	*Phytophthora kernoviae*	dieback of several woody plants	59.32
30	*Lachnellula willkommii*	European larch canker	59.04
31	*Gibberlla circinata (anamorph = Fusarium circinatum)*	pitch canker	58.78
32	*Curtobacterium flaccumfaciens*	bacterial wilt	55.46
33	*Plasmopara obducens*	Impatiens downy mildew	52.49
34	*Phytophthora austrocedri*	juniper dieback	52.48
35	*Phytophthora alni* ssp. *uniformis*	alder disease	50.96
36	*Phytophthora hedraiandra*	beech, azalea, and Viburnum dieback	50.41
37	*Phytophthora cinnamomi*	ink disease on chestnut and oak	49.61
38	*Peronospora belbahrii*	basil downy mildew	46.34
39	*Clavibacter michigenensis* ssp. *michigenensis*	bacterial wilt of tomato	43.94

By virtue of appearing on this list, each species is a credible threat to one or more communities or ecosystems in the state. Other threats exist, so this list will be updated annually. This list is only intended to direct research at the University of Minnesota to discover new management tools to prevent or mitigate the impacts from the most threatening species.

VI. Prioritized list of plants (weeds)

This list describes the ranked order of terrestrial invasive plants that threaten Minnesota and is organized from greatest statewide threat (highest priority) to least threat (lowest priority).

Rank	Scientific name	Common name	Priority Score
1	*Centaurea stoebe* ssp. *micranthos*	spotted knapweed	93.35
2	*Tanacetum vulgare*	common tansy	91.39
3	*Lonicera morrowii*	Morrow's honeysuckle	89.55
4	*Frangula alnus*	glossy buckthorn	86.73
5	*Phragmites australis* ssp. *australis*	European common reed	86.32
6	*Lonicera tatarica*	Tatarian honeysuckle	85.14
7	*Rhamnus cathartica*	European buckthorn	84.38
8	*Cirsium arvense*	Canada thistle	82.76
9	*Euphorbia esula*	leafy spurge	79.05
10	*Pastinaca sativa*	wild parsnip	78.86
11	*Polygonum cuspidatum*	Japanese knotweed	78.28
12	*Phalaris arundinacea*	reed canarygrass	78.18
13	*Carduus acanthoides*	spiny plumeless thistle	77.39
14	*Coronilla varia*	crown vetch	77.32
15	*Alliaria petiolata*	garlic mustard	76.38
16	*Berberis thunbergii*	Japanese barberry and hybrids	74.87
17	*Celastrus orbiculatus*	oriental bittersweet	74.87
18	*Polygonum sachalinense*	Japanese knotweed	74.47
19	*Vincetoxicum nigrum*	black dog-strangling vine, black swallowwort	74.16
20	*Amaranthus palmeri*	Palmer amaranth	73.72
21	*Berberis vulgaris*	common barberry and hybrids	72.84
22	*Acer platanoides*	Norway maple	71.85
23	*Centaurea debeauxii*	meadow knapweed	71.69
24	*Linaria dalmatica*	Dalmatian toadflax	71.58
25	*Melilotus officinalis*	yellow sweetclover	71.49
26	*Centaurea solstitialis*	yellow star thistle	71.46
27	*Kochia scoparia*	Mexican fireweed	71.30
28	*Melilotus alba*	white sweetclover	70.33
29	*Humulus japonicus*	Japanese hops	70.09
30	*Cynoglossum officinale*	houndstongue	69.68
31	*Rosa multiflora*	multiflora rose	69.26
32	*Berteroa incana*	hoary alyssum	69.09
33	*Lotus corniculatus*	birdsfoot trefoil	68.72
34	*Heracleum mantegazzianum*	giant hogweed	64.95
35	*Hieracium auranticum*	orange hawkweed	60.52
36	*Hieracium caespitosum*	meadow hawkweed	60.46
37	*Cardamine impatiens*	narrowleaf bittercress	57.73
38	*Caragana arborescens*	Siberian peashrub	57.16
39	*Euonymus alatus*	winged burning bush	56.39
40	*Digitalis lanata*	Grecian foxglove	56.00
41	*Dipsacus fullonum*	common teasel	55.59
42	*Dipsacus laciniatus*	cutleaf teasel	55.59
43	*Conium maculatum*	poison hemlock	54.15
44	*Daucus carota*	Queen Anne's lace, wild carrot	52.84
45	*Torilis japonica*	Japanese hedge-parsley	48.01

By virtue of appearing on this list, each species is a credible threat to one or more communities or ecosystems in the state. Other threats exist, so this list will be updated annually. This list is only intended to direct research at the University of Minnesota to discover new management tools to prevent or mitigate the impacts from the most threatening species.

VII. Terrestrial invasive insects (alphabetically by common name): criteria ratings to determine threat to Minnesota.

	apple ermine moth	Asian longhorned beetle	balsam woolly adelgid	banded elm bark beetle	brown marmorated stink bug
Criterion	*Yponomueta malinellus*	*Anoplophora glabripennis*	*Adelges picea*	*Scolytus schevyrewi*	*Halyomorpha halys*
Proximity to MN	Medium	Medium	Medium	Very High	Very High
Existence of pathways (to MN)	Medium	Medium	Medium	High	High
Innate dispersal capacity	Moderate	Low	Mly-Low	Mly-Low	Mly-Low
Climatic suitability	High	High	Medium	Medium	Medium
Presence of hosts	Low	High	High	High	High
Hybridization/host shift	High	Low	Low	Low	Low
Existence of pathways (in MN)	Medium	Medium	Medium	High	High
Dispersal capacity: Reproduction	Low	Low	High	High	High
Extent of invasion	Mly-Low	Low	Mly-Low	Moderate	Moderate
Existence of non-human vectors	Negligible	Negligible	High	Negligible	Negligible
Problem elsewhere	Medium	High	Medium	High	High
Impacts to yield or marketability	Low	Medium	Medium	Low	High
Quarantine or mitigation costs	Medium	High	Medium	Medium	High
Impacts to recreation or real estate	Low	High	Low	Low	Medium
Conseq. to native species	1	4	2	3	2
Conseq. to ecosystem services	0	1	2	3	1
Facilitate other invasions	Low	Low	Low	High	Medium

	brown spruce longhorned beetle	cucurbit beetle	Douglas fir tussock moth	Egyptian cottonworm	emerald ash borer
Criterion	*Tetropium fuscum*	*Diabrotica speciosa*	*Orgyia pseudotsugata*	*Spodoptera littoralis*	*Agrilus planipennis*
Proximity to MN	Medium	Low	Medium	Low	Very High
Existence of pathways (to MN)	Medium	Low	Medium	Low	High
Innate dispersal capacity	Mly-Low	Mly-Low	Mly-Low	Very High	Mly-Low
Climatic suitability	High	Low	Medium	High	High
Presence of hosts	High	High	Medium	High	High
Hybridization/host shift	Low	Low	Low	Low	High
Existence of pathways (in MN)	Medium	Medium	Medium	Medium	High
Dispersal capacity: Reproduction	Low	High	Medium	High	Low
Extent of invasion	Mly-Low	Mly-Low	Low	High	High
Existence of non-human vectors	Negligible	Negligible	Negligible	Negligible	Negligible
Problem elsewhere	Medium	High	Medium	High	High
Impacts to yield or marketability	High	High	Low	High	Low
Quarantine or mitigation costs	High	High	Low	High	High
Impacts to recreation or real estate	Medium	Low	Medium	Low	High
Conseq. to native species	3	1	3	2	4
Conseq. to ecosystem services	0	0	2	0	3
Facilitate other invasions	Low	Medium	Low	Low	High

Terrestrial invasive insects: criteria ratings to determine threat to Minnesota (cont.)

	European chafer	European craneflies	European craneflies	European elm bark beetle	European grape berry moth
Criterion	*Rhizotrogus majalis*	*Tipula oleracea*	*Tipula paludosa*	*Scolytus mulistriatus*	*Eupoecilia ambiguella*
Proximity to MN	High	Medium	High	Very High	Low
Existence of pathways (to MN)	Medium	Medium	Medium	High	Low
Innate dispersal capacity	Mly-Low	Mly-Low	Low	Mly-Low	Mly-Low
Climatic suitability	High	Low	Negligible	Medium	High
Presence of hosts	High	High	High	High	Medium
Hybridization/host shift	Low	Low	Low	Low	Low
Existence of pathways (in MN)	Medium	Medium	Medium	High	Medium
Dispersal capacity: Reproduction	Low	High	Medium	High	High
Extent of invasion	Mly-Low	Low	Low	Moderate	Moderate
Existence of non-human vectors	Negligible	Negligible	Negligible	Negligible	Negligible
Problem elsewhere	High	High	High	Medium	High
Impacts to yield or marketability	Medium	Medium	Medium	Low	Medium
Quarantine or mitigation costs	High	High	High	Medium	High
Impacts to recreation or real estate	Medium	Medium	Medium	Low	Low
Conseq. to native species	2	2	2	3	2
Conseq. to ecosystem services	0	0	0	3	0
Facilitate other invasions	Low	Low	Low	High	High

	European grapevine moth	European oak borer	European shoot beetle	European spruce bark beetle	golden twin spot moth
Criterion	*Lobesia botrana*	*Agrilus sulicollis*	*Tomicus piniperda*	*Ips typographus*	*Chrysodeixis chalcites*
Proximity to MN	Medium	Medium	Very High	Low	High
Existence of pathways (to MN)	Medium	Medium	High	Medium	Medium
Innate dispersal capacity	Mly-Low	Low	Mly-Low	Mly-Low	Low
Climatic suitability	Low	Medium	High	Medium	Medium
Presence of hosts	Medium	High	High	High	High
Hybridization/host shift	Low	Low	Low	Low	Low
Existence of pathways (in MN)	Medium	Medium	Medium	Medium	Medium
Dispersal capacity: Reproduction	High	Low	Low	Low	High
Extent of invasion	Low	Low	Low	Mly-Low	Moderate
Existence of non-human vectors	Negligible	Negligible	Negligible	Negligible	Negligible
Problem elsewhere	High	Medium	High	High	High
Impacts to yield or marketability	Low	Low	Low	Low	Low
Quarantine or mitigation costs	Medium	Low	Low	High	High
Impacts to recreation or real estate	Low	Low	Low	Medium	Low
Conseq. to native species	2	2	3	3	2
Conseq. to ecosystem services	0	1	0	1	0
Facilitate other invasions	Low	Medium	Low	Medium	High

Terrestrial invasive insects: criteria ratings to determine threat to Minnesota (cont.)

Criterion	gypsy moth, Asian *Lymantria dispar asiatica*	gypsy moth, European *Lymantria dispar dispar*	Japanese beetle *Popillia japonica*	larch casebearer *Coleophora laricella*	leek moth *Acrolepiopsis assectella*
Proximity to MN	Low	Very High	Very High	Very High	High
Existence of pathways (to MN)	Medium	High	High	High	Medium
Innate dispersal capacity	Mly-Low	Mly-Low	Mly-Low	Mly-Low	Mly-Low
Climatic suitability	High	High	High	High	High
Presence of hosts	High	High	High	High	Low
Hybridization/host shift	Medium	Medium	Low	Low	Low
Existence of pathways (in MN)	Medium	High	High	High	High
Dispersal capacity: Reproduction	Medium	Medium	Low	Low	High
Extent of invasion	Very High	High	Very High	High	Mly-Low
Existence of non-human vectors	Negligible	Negligible	Negligible	Negligible	Negligible
Problem elsewhere	High	High	Medium	High	Medium
Impacts to yield or marketability	Low	Low	Low	Low	Low
Quarantine or mitigation costs	High	High	High	Low	Low
Impacts to recreation or real estate	Medium	Medium	Medium	Low	Low
Conseq. to native species	3	3	2	3	2
Conseq. to ecosystem services	3	3	1	1	0
Facilitate other invasions	Medium	Medium	Low	Low	High

Criterion	light brown apple moth *Epiphyas postvittana*	lily leaf beetle *Lilioceris lilii*	mountain pine beetle *Dendroctonus ponderosae*	oak splendor beetle *Agrilus biguttatus*	old world bollworm *Helicoverpa armigera*
Proximity to MN	Medium	High	High	Low	Medium
Existence of pathways (to MN)	Medium	Medium	High	Medium	Medium
Innate dispersal capacity	Low	Mly-Low	Mly-Low	Mly-Low	Very High
Climatic suitability	Negligible	High	Medium	High	High
Presence of hosts	High	High	High	High	High
Hybridization/host shift	High	Low	High	Low	High
Existence of pathways (in MN)	Medium	Medium	Medium	High	Medium
Dispersal capacity: Reproduction	High	Medium	Low	Low	High
Extent of invasion	Low	High	Moderate	Moderate	Moderate
Existence of non-human vectors	Negligible	Negligible	Negligible	Negligible	Negligible
Problem elsewhere	High	Medium	High	High	High
Impacts to yield or marketability	Low	Low	Medium	Low	High
Quarantine or mitigation costs	Low	Medium	Medium	High	High
Impacts to recreation or real estate	Low	Low	High	Medium	Low
Conseq. to native species	2	2	3	3	2
Conseq. to ecosystem services	0	0	4	1	0
Facilitate other invasions	High	Low	High	Medium	Low

Terrestrial invasive insects: criteria ratings to determine threat to Minnesota (cont.)

Criterion	silver Y moth *Autographa gamma*	Sirex woodwasp *Sirex noctilio*	soybean aphid *Aphis glycines*	soybean pod borer *Leguminivora glycinivorella*	spotted lanternfly *Lycorma delicatula*
Proximity to MN	Low	Medium	Very High	Low	Medium
Existence of pathways (to MN)	Medium	Medium	High	Low	Medium
Innate dispersal capacity	Very High	Mly-Low	Very High	Mly-Low	Mly-Low
Climatic suitability	Medium	High	High	Medium	Low
Presence of hosts	High	High	High	High	High
Hybridization/host shift	Low	Low	High	Low	Low
Existence of pathways (in MN)	Low	Medium	Medium	Low	Medium
Dispersal capacity: Reproduction	High	Medium	High	High	Low
Extent of invasion	Moderate	Moderate	Very High	Moderate	Mly-Low
Existence of non-human vectors	Negligible	Negligible	Negligible	Negligible	Negligible
Problem elsewhere	High	Medium	High	High	Medium
Impacts to yield or marketability	High	Low	High	High	Medium
Quarantine or mitigation costs	High	Medium	High	High	Medium
Impacts to recreation or real estate	Low	Medium	Low	Low	Low
Conseq. to native species	1	3	2	1	2
Conseq. to ecosystem services	0	1	0	0	0
Facilitate other invasions	Low	High	High	Low	Low

Criterion	spotted wing drosophila *Drosophila suzuki*	swede midge *Contarinia nasturtii*	viburnum leaf beetle *Pyrrhalta viburni*	walnut twig beetle *Pityophthorus juglandis*	winter moth *Operophtera brumata*
Proximity to MN	Very High	High	High	Medium	Medium
Existence of pathways (to MN)	High	Medium	Medium	Medium	Medium
Innate dispersal capacity	Low	Mly-Low	Mly-Low	Mly-Low	Mly-Low
Climatic suitability	High	High	High	Medium	High
Presence of hosts	High	Low	High	Medium	High
Hybridization/host shift	Medium	Low	Low	High	High
Existence of pathways (in MN)	High	Medium	Medium	Medium	Medium
Dispersal capacity: Reproduction	High	High	Medium	Low	Low
Extent of invasion	Very High	Mly-Low	Mly-Low	Mly-Low	Low
Existence of non-human vectors	Negligible	Negligible	Negligible	Negligible	Negligible
Problem elsewhere	High	High	Medium	Medium	Medium
Impacts to yield or marketability	High	Medium	Low	Low	Low
Quarantine or mitigation costs	Medium	Low	Medium	Medium	Low
Impacts to recreation or real estate	Low	Low	Low	Low	Low
Conseq. to native species	2	2	2	3	3
Conseq. to ecosystem services	0	0	0	0	0
Facilitate other invasions	Low	Low	Low	High	Low

VIII. Terrestrial invasive pathogens (alphabetically by disease among bacteria, fungi, nematodes, oomycetes, parasitic plants, and viruses): criteria ratings to determine threat to Minnesota.

	Bacteria				
	apple proliferation phyoplasma	aster yellows	bacterial wilt of dry beans	bacterial wilt of tomato	brown rot
Criterion	*Candidatus phytoplasma mali*	*Aster yellows phytoplasma*	*Curtobacterium flaccumfaciens*	*Clavibacter michigenensis* ssp. *michigenensis*	*Ralstonia solanacearum*, Race 3, biovar 2
Proximity to MN	Low	High	Very High	Very High	Medium
Existence of pathways (to MN)	Medium	High	Medium	High	High
Innate dispersal capacity	Low	Low	Low	Low	Mly-Low
Climatic suitability	Medium	High	High	High	Medium
Presence of hosts	Low	High	High	Low	Low
Hybridization/host shift	Low	Low	Medium	Low	Medium
Existence of pathways (in MN)	Medium	Medium	Medium	Medium	Medium
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	High	Very High	Moderate	Moderate	Moderate
Existence of non-human vectors	High	High	Negligible	Negligible	Negligible
Problem elsewhere	Medium	Medium	Medium	Medium	High
Impacts to yield or marketability	High	High	Medium	Low	High
Quarantine or mitigation costs	Medium	Medium	Medium	Low	High
Impacts to recreation or real estate	Low	Low	Low	Low	Low
Conseq. to native species	1	2	1	1	2
Conseq. to ecosystem services	0	0	0	0	0
Facilitate other invasions	Low	Low	Low	Low	Low

	Bacteria	Fungi			
	Goss's wilt	Annosum root rot	ash dieback	associate fungus to Sirex woodwasp	boxelder dieback; wilt
Criterion	*Clavibacter michigensis* ssp. *nebraskensis*	*Heterobasidium irregulare*	*Hymenoscyphus fraxineus (pseudoalbidus?)*	*Amylostereum areolatum*	*Fusarium euwallaceae*
Proximity to MN	Very High	Very High	Low	Medium	Medium
Existence of pathways (to MN)	High	High	Low	Medium	Medium
Innate dispersal capacity	Low	Mly-Low	Mly-Low	Mly-Low	Low
Climatic suitability	Medium	High	High	High	Negligible
Presence of hosts	High	High	High	Medium	High
Hybridization/host shift	Low	High	Low	Low	High
Existence of pathways (in MN)	High	High	Medium	Medium	Medium
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Very High	Mly-Low	Moderate	Mly-Low	Mly-Low
Existence of non-human vectors	Negligible	Negligible	Negligible	Medium	Medium
Problem elsewhere	Medium	High	Medium	Medium	Medium
Impacts to yield or marketability	High	Medium	Medium	Low	Low
Quarantine or mitigation costs	Low	Medium	High	Low	Low
Impacts to recreation or real estate	Low	Medium	Medium	Low	Low
Conseq. to native species	1	3	4	3	2
Conseq. to ecosystem services	0	2	0	0	0
Facilitate other invasions	Low	Low	Low	High	High

Terrestrial invasive plant pathogens: criteria ratings to determine threat to Minnesota (cont.)

	Fungi				
	butternut canker	Dutch elm disease	Dwarf bunt	European larch canker	Fusarium head blight
Criterion	*Ophiognomonia clavigigenti-juglandacearum*	*Ophiostoma novo-ulmi*	*Tilletia controversa (cereal strain)*	*Lachnellula willkommii*	*Fusarium graminearum*
Proximity to MN	Very High	Very High	Medium	Medium	Very High
Existence of pathways (to MN)	High	High	Medium	Medium	High
Innate dispersal capacity	Mly-Low	Mly-Low	Low	Mly-Low	Mly-Low
Climatic suitability	High	High	High	High	High
Presence of hosts	Medium	High	High	Medium	High
Hybridization/host shift	Low	High	Low	Low	Low
Existence of pathways (in MN)	High	High	Medium	Medium	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	High	Very High	Moderate	Mly-Low	Very High
Existence of non-human vectors	Medium	Medium	Negligible	Negligible	Negligible
Problem elsewhere	Medium	Medium	Medium	High	Medium
Impacts to yield or marketability	Low	Low	High	Medium	High
Quarantine or mitigation costs	Low	Medium	High	Low	High
Impacts to recreation or real estate	Low	Medium	Low	Low	Low
Conseq. to native species	4	4	2	2	1
Conseq. to ecosystem services	1	1	0	0	0
Facilitate other invasions	Low	High	Low	Low	Low

	Fungi				
	Japanese oak wilt	oak wilt	pitch canker	soybean rust	soybean sudden death
Criterion	*Raffaelea quercivora*	*Ceratocystis fagacearum*	*Gibberlla circinata (anamorph = Fusarium circinatum)*	*Phakospora pachyrhizii*	*Fusarium virguliforme*
Proximity to MN	Low	Very High	Medium	High	Very High
Existence of pathways (to MN)	Medium	High	Medium	High	High
Innate dispersal capacity	Mly-Low	Mly-Low	Mly-Low	Low	Low
Climatic suitability	High	High	Negligible	High	High
Presence of hosts	High	High	Medium	High	High
Hybridization/host shift	Low	Low	Low	Low	Low
Existence of pathways (in MN)	Medium	High	Medium	Medium	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Moderate	High	Mly-Low	Mly-Low	High
Existence of non-human vectors	Medium	Medium	Medium	Negligible	Negligible
Problem elsewhere	High	Medium	High	Medium	High
Impacts to yield or marketability	Medium	Medium	Low	High	High
Quarantine or mitigation costs	High	High	Medium	High	High
Impacts to recreation or real estate	Medium	High	Medium	Low	Low
Conseq. to native species	2	3	3	1	1
Conseq. to ecosystem services	0	2	0	0	0
Facilitate other invasions	High	Low	Low	Low	Low

Terrestrial invasive plant pathogens: criteria ratings to determine threat to Minnesota (cont.)

	Fungi			Nematodes	Oomycetes
	thousand cankers disease	wheat flag smut	white pine blister rust	stem and bulb nematode	alder disease
Criterion	*Geosmithia morbida*	*Urocystis agropyri*	*Cronartium ribicola*	*Ditylenchus dipsaci*	*Phytophthora alni* ssp. *alni*
Proximity to MN	Medium	Medium	Very High	Very High	High
Existence of pathways (to MN)	Medium	Medium	High	High	Medium
Innate dispersal capacity	Low	Mly-Low	Moderate	Mly-Low	Mly-Low
Climatic suitability	Low	High	High	Medium	Medium
Presence of hosts	Medium	High	High	High	Low
Hybridization/host shift	High	Low	Low	Low	High
Existence of pathways (in MN)	Medium	Medium	High	High	Medium
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Mly-Low	Mly-Low	Very High	Moderate	Mly-Low
Existence of non-human vectors	Medium	Negligible	Negligible	Low	Low
Problem elsewhere	Medium	High	Medium	Medium	Medium
Impacts to yield or marketability	Low	Medium	Low	Medium	Low
Quarantine or mitigation costs	Medium	Medium	Low	Medium	Low
Impacts to recreation or real estate	Low	Low	Medium	Low	Low
Conseq. to native species	3	2	4	2	4
Conseq. to ecosystem services	1	0	2	0	2
Facilitate other invasions	High	Low	Low	Low	Low

	Oomycetes				
	alder disease	basil downy mildew	beech, azalea, and Viburnum dieback	club root	dieback of several woody plants
Criterion	*Phytophthora alni* ssp. *uniformis*	*Peronospora belbahrii*	*Phytophthora hedraiandra*	*Plasmodiophora brassicae*	*Phytophthora kernovae*
Proximity to MN	High	Very High	Very High	Very High	Low
Existence of pathways (to MN)	High	High	High	High	Medium
Innate dispersal capacity	Mly-Low	Low	Mly-Low	Mly-Low	Mly-Low
Climatic suitability	Medium	High	Medium	High	High
Presence of hosts	Low	Low	Low	Low	High
Hybridization/host shift	High	High	Medium	Low	Medium
Existence of pathways (in MN)	Medium	Medium	High	High	Medium
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Mly-Low	Moderate	Mly-Low	Mly-Low	Mly-Low
Existence of non-human vectors	Low	Negligible	Low	Low	Low
Problem elsewhere	Medium	Medium	Medium	High	Medium
Impacts to yield or marketability	Low	Low	Low	Medium	Low
Quarantine or mitigation costs	Low	Low	Low	Medium	Medium
Impacts to recreation or real estate	Low	Low	Low	Low	Medium
Conseq. to native species	2	1	2	2	3
Conseq. to ecosystem services	0	0	0	0	0
Facilitate other invasions	Low	Low	Low	Low	Low

Terrestrial invasive plant pathogens: criteria ratings to determine threat to Minnesota (cont.)

	Oomycetes				
	Downy mildew of cucurbits	Impatiens downy mildew	ink disease on chestnut and oak	juniper dieback	late blight
Criterion	*Pseudoperonospora cubensis*	*Plasmopara obducens*	*Phytophthora cinnamomi*	*Phytophthora austrocedri*	*Phytophthora infestans*
Proximity to MN	Very High	Very High	Medium	Low	Very High
Existence of pathways (to MN)	High	High	Medium	High	High
Innate dispersal capacity	Low	Mly-Low	Mly-Low	Mly-Low	Mly-Low
Climatic suitability	High	High	Negligible	Medium	High
Presence of hosts	Low	Low	High	Low	Low
Hybridization/host shift	Low	Low	Medium	Medium	Low
Existence of pathways (in MN)	High	High	Medium	Medium	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Mly-Low	Mly-Low	Mly-Low	Mly-Low	Very High
Existence of non-human vectors	Negligible	Negligible	Low	Low	Negligible
Problem elsewhere	Medium	Medium	Medium	Medium	High
Impacts to yield or marketability	High	Medium	Low	Low	High
Quarantine or mitigation costs	High	Medium	Low	Low	High
Impacts to recreation or real estate	Low	Low	Low	Low	Low
Conseq. to native species	1	1	2	3	1
Conseq. to ecosystem services	0	0	0	0	0
Facilitate other invasions	Low	Low	Low	Low	Low

	Oomycetes		Parasitic plants	Viruses
	late wilt of corn	sudden oak death	dwarf mistletoe	Cucumber green mottle mosaic virus
Criterion	*Harpophora maydis*	*Phytophthora ramorum*	*Arceuthobium americanum*	*CGMMV*
Proximity to MN	Low	Medium	High	Medium
Existence of pathways (to MN)	Medium	High	High	Medium
Innate dispersal capacity	Low	Mly-Low	Low	Mly-Low
Climatic suitability	Low	Low	High	High
Presence of hosts	High	Low	Medium	Low
Hybridization/host shift	Low	Medium	Low	Low
Existence of pathways (in MN)	High	High	Medium	Medium
Dispersal capacity: Reproduction	High	High	Low	High
Extent of invasion	Mly-Low	Mly-Low	Mly-Low	Moderate
Existence of non-human vectors	Negligible	Low	High	Medium
Problem elsewhere	High	Medium	High	High
Impacts to yield or marketability	High	Medium	Medium	Medium
Quarantine or mitigation costs	High	Medium	Medium	High
Impacts to recreation or real estate	Low	Low	Low	Low
Conseq. to native species	1	4	3	1
Conseq. to ecosystem services	0	2	0	0
Facilitate other invasions	Low	Low	Medium	Low

IX. Terrestrial invasive plants (alphabetically by common name): criteria ratings to determine threat to Minnesota.

	birdsfoot trefoil	black dog-strangling vine, black swallowwort	Canada thistle	common barberry	common tansy
Criterion	*Lotus corniculatus*	*Vincetoxicum nigrum*	*Cirsium arvense*	*Berberis vulgaris*	*Tanacetum vulgare*
Proximity to MN	Very High	Very High	Very High	Very High	Very High
Existence of pathways (to MN)	High	High	High	Medium	High
Innate dispersal capacity	Low	Low	Mly-Low	Low	Mly-Low
Climatic suitability	High	High	High	High	High
Presence of hosts	High	Medium	High	High	High
Hybridization/host shift	Low	Low	High	High	High
Existence of pathways (in MN)	High	Medium	High	Medium	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Very High	Mly-Low	Very High	Mly-Low	High
Existence of non-human vectors	High	Negligible	Negligible	High	Low
Problem elsewhere	Medium	Medium	Medium	Medium	Medium
Impacts to yield or marketability	Low	Low	High	Low	Medium
Quarantine or mitigation costs	Medium	Medium	High	Low	Medium
Impacts to recreation or real estate	Low	Low	Low	Low	Low
Conseq. to native species	2	4	3	4	4
Conseq. to ecosystem services	1	1	0	0	2
Facilitate other invasions	Medium	High	Medium	High	High

	common teasel	crown vetch	cutleaf teasel	Dalmatian toadflax	European buckthorn
Criterion	*Dipsacus fullonum*	*Coronilla varia*	*Dipsacus laciniatus*	*Linaria dalmatica*	*Rhamnus cathartica*
Proximity to MN	Very High	Very High	Very High	Very High	Very High
Existence of pathways (to MN)	High	High	High	High	High
Innate dispersal capacity	Mly-Low	Low	Mly-Low	Low	Mly-Low
Climatic suitability	High	High	High	High	High
Presence of hosts	High	High	High	Medium	High
Hybridization/host shift	High	Low	High	High	High
Existence of pathways (in MN)	Medium	High	Medium	High	High
Dispersal capacity: Reproduction	High	Medium	High	High	High
Extent of invasion	Mly-Low	Very High	Mly-Low	Moderate	Very High
Existence of non-human vectors	Negligible	Low	Negligible	Negligible	High
Problem elsewhere	Medium	Medium	Medium	Medium	Medium
Impacts to yield or marketability	Low	Low	Low	Medium	Low
Quarantine or mitigation costs	Low	Low	Low	Low	High
Impacts to recreation or real estate	Low	Low	Low	Low	Medium
Conseq. to native species	3	3	3	4	3
Conseq. to ecosystem services	0	2	0	0	1
Facilitate other invasions	Low	High	Low	Medium	High

Terrestrial invasive plants: criteria ratings to determine threat to Minnesota (cont.)

Criterion	European common reed *Phragmites australis* ssp. *australis*	garlic mustard *Alliaria petiolata*	giant hogweed *Heracleum mantegazzianum*	giant knotweed *Polygonum sachalinense*	glossy buckthorn *Frangula alnus*
Proximity to MN	Very High	Very High	High	Very High	Very High
Existence of pathways (to MN)	High	High	Medium	High	High
Innate dispersal capacity	Mly-Low	Low	Mly-Low	Mly-Low	Mly-Low
Climatic suitability	High	High	High	High	High
Presence of hosts	High	High	Medium	High	High
Hybridization/host shift	High	Low	High	High	Low
Existence of pathways (in MN)	High	High	Medium	High	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Very High	High	Mly-Low	Mly-Low	Very High
Existence of non-human vectors	High	Low	Negligible	Negligible	High
Problem elsewhere	Medium	Medium	Medium	Medium	Medium
Impacts to yield or marketability	Low	Low	Low	Low	Medium
Quarantine or mitigation costs	Medium	Medium	Medium	Medium	High
Impacts to recreation or real estate	Medium	Low	Medium	Low	Low
Conseq. to native species	4	4	2	4	3
Conseq. to ecosystem services	4	2	2	3	1
Facilitate other invasions	Low	Medium	Low	Low	High

Criterion	Grecian foxglove *Digitalis lanata*	hoary alyssum *Berteroa incana*	houndstongue *Cynoglossum officinale*	Japanese barberry *Berberis thunbergii*	Japanese hedge-parsley *Torilis japonica*
Proximity to MN	Very High	Very High	Very High	Very High	Very High
Existence of pathways (to MN)	High	High	High	High	High
Innate dispersal capacity	Mly-Low	Low	Low	Low	Mly-Low
Climatic suitability	High	High	High	High	High
Presence of hosts	High	Medium	Medium	High	High
Hybridization/host shift	High	Low	High	High	Medium
Existence of pathways (in MN)	High	High	High	High	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Mly-Low	Very High	High	Moderate	Moderate
Existence of non-human vectors	Negligible	Negligible	Low	High	Low
Problem elsewhere	Medium	High	Medium	Medium	Medium
Impacts to yield or marketability	Low	Medium	Low	Low	Low
Quarantine or mitigation costs	Low	Medium	Low	Medium	Low
Impacts to recreation or real estate	Low	Low	Low	Low	Low
Conseq. to native species	3	2	3	4	1
Conseq. to ecosystem services	0	1	0	1	0
Facilitate other invasions	Low	Low	High	Medium	Low

Terrestrial invasive plants: criteria ratings to determine threat to Minnesota (cont.)

Criterion	Japanese hops *Humulus japonicus*	Japanese knotweed *Polygonum cuspidatum*	leafy spurge *Euphorbia esula*	meadow hawkweed *Hieracium caespitosum*	meadow knapweed *Centaurea debeauxii*
Proximity to MN	Very High	Very High	Very High	Very High	Very High
Existence of pathways (to MN)	High	High	High	High	High
Innate dispersal capacity	Mly-Low	Mly-Low	Low	Mly-Low	Low
Climatic suitability	Medium	High	High	High	High
Presence of hosts	Medium	High	High	Medium	Medium
Hybridization/host shift	Low	High	High	High	High
Existence of pathways (in MN)	High	High	High	High	Medium
Dispersal capacity: Reproduction	High	High	Medium	High	High
Extent of invasion	Mly-Low	Moderate	Very High	Moderate	Mly-Low
Existence of non-human vectors	Negligible	Negligible	Low	Negligible	Negligible
Problem elsewhere	High	High	Medium	Medium	High
Impacts to yield or marketability	Low	Low	High	Low	Medium
Quarantine or mitigation costs	Low	Medium	High	Low	Low
Impacts to recreation or real estate	Low	Low	Medium	Low	Low
Conseq. to native species	4	4	3	3	4
Conseq. to ecosystem services	0	3	0	1	1
Facilitate other invasions	High	Low	Low	Low	Low

Criterion	Mexican fireweed *Kochia scoparia*	Morrow's honeysuckle *Lonicera morrowii*	multiflora rose *Rosa multiflora*	narrowleaf bittercress *Cardamine impatiens*	Norway maple *Acer platanoides*
Proximity to MN	Very High	Very High	Very High	Very High	Very High
Existence of pathways (to MN)	High	High	High	High	High
Innate dispersal capacity	Mly-Low	Mly-Low	Mly-Low	Mly-Low	Low
Climatic suitability	High	High	High	High	High
Presence of hosts	High	High	High	High	High
Hybridization/host shift	Low	High	High	High	Medium
Existence of pathways (in MN)	High	High	High	High	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Moderate	Very High	High	Moderate	Mly-Low
Existence of non-human vectors	Medium	High	High	Low	Negligible
Problem elsewhere	Medium	Medium	Medium	Medium	Medium
Impacts to yield or marketability	Medium	Medium	Low	Low	Medium
Quarantine or mitigation costs	Medium	Medium	High	Low	Low
Impacts to recreation or real estate	Low	Low	Low	Low	Low
Conseq. to native species	3	4	3	3	3
Conseq. to ecosystem services	0	1	1	0	1
Facilitate other invasions	Medium	High	Low	Low	Medium

Terrestrial invasive plants: criteria ratings to determine threat to Minnesota (cont.)

Criterion	orange hawkweed *Hieracium auranticum*	oriental bittersweet *Celastrus orbiculatus*	Palmer amaranth *Amaranthus palmeri*	poison hemlock *Conium maculatum*	Queen Anne's lace, wild carrot *Daucus carota*
Proximity to MN	Very High	Very High	High	Very High	Very High
Existence of pathways (to MN)	High	High	High	High	High
Innate dispersal capacity	Mly-Low	Low	Mly-Low	Low	Mly-Low
Climatic suitability	Medium	High	High	High	High
Presence of hosts	Medium	High	High	Medium	Medium
Hybridization/host shift	High	High	High	Low	Low
Existence of pathways (in MN)	High	High	Medium	Medium	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	High	Moderate	High	Low	High
Existence of non-human vectors	Negligible	High	High	High	Low
Problem elsewhere	Medium	Medium	Medium	Medium	Medium
Impacts to yield or marketability	Low	Low	High	Low	Low
Quarantine or mitigation costs	Low	Medium	High	Low	Low
Impacts to recreation or real estate	Low	Low	Low	Low	Low
Conseq. to native species	3	4	1	3	2
Conseq. to ecosystem services	1	1	1	0	0
Facilitate other invasions	Low	Medium	Low	Low	Low

Criterion	reed canarygrass *Phalaris arundinacea*	Siberian peashrub *Caragana arborescens*	spiny plumeless thistle *Carduus acanthoides*	spotted knapweed *Centaurea stoebe* ssp. *micranthos*	Tatarian honeysuckle *Lonicera tatarica*
Proximity to MN	Very High	Very High	Very High	Very High	Very High
Existence of pathways (to MN)	High	High	High	High	High
Innate dispersal capacity	Mly-Low	Low	Mly-Low	Low	Mly-Low
Climatic suitability	High	High	High	High	High
Presence of hosts	High	High	High	High	High
Hybridization/host shift	High	Low	High	High	High
Existence of pathways (in MN)	High	High	High	High	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Very High	High	Very High	Very High	Very High
Existence of non-human vectors	High	Negligible	Negligible	High	High
Problem elsewhere	High	Medium	Medium	Medium	Medium
Impacts to yield or marketability	Low	Low	Medium	High	Medium
Quarantine or mitigation costs	Medium	Low	Low	High	Medium
Impacts to recreation or real estate	Low	Low	Low	Medium	Low
Conseq. to native species	4	2	3	4	4
Conseq. to ecosystem services	2	1	0	2	0
Facilitate other invasions	Low	Low	High	Low	High

Terrestrial invasive plants: criteria ratings to determine threat to Minnesota (cont.)

Criterion	white sweetclover *Melilotus alba*	wild parsnip *Pastinaca sativa*	winged burning bush *Euonymus alatus*	yellow star thistle *Centaurea solstitialis*	yellow sweetclover *Melilotus officinalis*
Proximity to MN	Very High	Very High	Very High	High	Very High
Existence of pathways (to MN)	High	High	High	Medium	High
Innate dispersal capacity	Low	Low	Mly-Low	Low	Low
Climatic suitability	High	High	High	Low	High
Presence of hosts	High	High	High	High	High
Hybridization/host shift	High	Low	Low	High	Medium
Existence of pathways (in MN)	High	High	High	Medium	High
Dispersal capacity: Reproduction	High	High	High	High	High
Extent of invasion	Very High	Very High	Mly-Low	Low	Very High
Existence of non-human vectors	Negligible	Low	High	High	Negligible
Problem elsewhere	High	High	Medium	Medium	High
Impacts to yield or marketability	Low	Low	Low	Low	Low
Quarantine or mitigation costs	Low	Medium	Low	Medium	Medium
Impacts to recreation or real estate	Low	Low	Low	Medium	Low
Conseq. to native species	3	3	3	4	3
Conseq. to ecosystem services	2	1	0	2	2
Facilitate other invasions	Low	High	Low	Low	Low

X. Definitions and measurement standards for each criterion

ARRIVAL

Proximity to Minnesota

The probability of arrival depends upon proximity among other factors. A pest that already occurs in Minnesota with a limited distribution, is likely at greater risk of arriving in other parts of the state than a pest not yet in Minnesota or not in North America.

Very High: Pest is known to occur in Minnesota.
High: Pest occurs in Wisconsin, Iowa, South Dakota, North Dakota, Manitoba, or Ontario
Medium: Pest occurs in North America
Low: Pest is not known to occur in North America

Existence of Pathways

The probability of arrival depends also upon the existence of pathways to bring the pest to Minnesota. Here, we accept the fact that even though a potential pathway may not be conceivable, there may exist unconceivable pathways and therefore the scale does not include negligible risk.

High: Pathways for arrival of the pest in Minnesota are known to occur.
Medium: Pathways for arrival of the pest in Minnesota are conceivable, but not known to occur.
Low: Pathways for arrival of the pest in Minnesota are difficult to conceive.

Innate Dispersal Capacity

The innate movement potential of pests depends on natural (e.g., flight, swimming, wind, flowing water, etc.) means of dispersal. This factor does not account for movement by humans or other vectors.

Very High: Maximum recorded dispersal >500 km per year (or moves in low level jets/ upper atmosphere).
High: Maximum recorded dispersal 500-250 km per year.
Moderate: Maximum recorded dispersal 100-250 km per year.
Moderately Low: Maximum recorded dispersal 1-100 km per year. (wind dispersal; flowing water;)
Low: Maximum recorded dispersal <1 km per year (movement through soil; splash dispersal)

ESTABLISHMENT and Persistence

Suitability of Minnesota Climate

Potential geographic distribution of ectothermic (cold-blooded) pests can be estimated based on the availability of suitable climate and nutrition.

High: >40% of Minnesota is predicted to be suitable.
Medium: >20 to 40% of Minnesota is predicted to be suitable.
Low: >0 to 20% of Minnesota is predicted to be suitable.
Negligible: No part of Minnesota is suitable.

Presence of hosts

Likelihood of finding a host is based on the likelihood of the pest finding a host relatively close to the location of introduction. The entire host range of the pest should be considered as well as the geographic distribution of those hosts. Keep in mind that Minnesota has 79,627 square miles (=50,961,280 acres; 206,232 square kilometers) of dry land.

High: >10% of Minnesota with suitable hosts (or habitat for weeds).
Medium: >1 to 10% of Minnesota with suitable hosts (or habitat for weeds).
Low: >0 to 1% of Minnesota with suitable hosts (or habitat for weeds).
Negligible: 0% of Minnesota with suitable hosts (or habitat for weeds).

Hybridization/Host shift

High: Species has been reported to hybridize or has undergone a documented host shift.
Medium: Species in the same genus have been reported to hybridize/shift hosts
Low: Hybridization/Host shifts have not been reported for this species..

SPREAD

Existence of pathways

This criteria relates to the movement of the pest within the state. Here, we accept the fact that even though a potential pathway may not be conceivable, there may exist unconceivable pathways and therefore the scale does not include negligible risk. This criterion is different from the existence of pathways because there the emphasis is on pathways that might bring the species into the state; here the emphasis is on pathways that might move the species within the state.

High: Pathways for movement of the pest within Minnesota are known to occur.
Medium: Pathways for movement of the pest within Minnesota are conceivable, but not known to occur.
Low: Pathways for movement of the pest within Minnesota are difficult to conceive.

Dispersal Capacity-Reproductive Potential

Potential abundance is based on the number of descendants an individual could produce in one year. This annual reproductive potential can be estimated as $r = (n_o/p)^g$, where r is the reproductive potential per year, n_o is the number of male and female offspring produced per female, p is the number of parents required for reproduction (1 or 2) and g is the number of generations per year.

High: Annual reproductive potential (r) of pest is >500 descendants per year.
Medium: Annual reproductive potential (r) of pest is 100 to 500 descendants per year.
Low: Annual reproductive potential (r) of pest is <100 descendants per year.

Extent of invasion

This factor describes the potential extent of the invasion in Minnesota in the next 10 years if the species is already present in the state or if we assumed it arrived at a single point within the next year. It is measured relative to the number of counties that likely have suitable climate and hosts and relative to the dispersal ability (moved by humans or not) of the organism.

Very High: >60 counties likely to have established populations of the pest.
High: 30-60 counties likely to have established populations of the pest.
Moderate: 15-29 counties likely to have established populations of the pest.
Moderately-Low: 7-14 counties likely to have established populations of the pest.
Low: 1-7 counties likely to have established populations of the pest.

Existence of vectors

This factor focuses on non-human vectors that might bring the pest into Minnesota.

High: Vectored by birds or long distance insect migrants
Medium: Vectored by insects or bats
Low: Vectored by other mammals
None: No evidence of any vectors

IMPACT

Problem Elsewhere

This criterion is frequently cited in other pest risk assessment schemes. If a pest has proven to be problematic elsewhere, it is likely to be a pest within a newly invaded area. This criterion simply asks whether a pest has been reported as any time of a problem in areas where it occurs. If the native range of the organism is not known, the highest possible rank for this criterion is Medium.

High: Noted as a problem within its native range and areas where it has invaded
Medium: Noted as problem only in areas where it has invaded
Low: Not reported as a problem elsewhere

Impact to Yields and Marketability

This criterion is meant to focus on the potential economic impact of the pest in the state on yields or marketability of the crop. For this criterion, simplified calculations are appropriate. Consider the total economic value of the plants that might be affected. Consider whether establishment is likely in most or all production areas. Emphasis should be placed on likely losses. If only "worst cases" have been reported in the literature, likely losses statewide might reasonable be assumed to be 50% of those losses.

Annual impacts to yields and marketability are…

High: >$5 million
Medium: $5 million to 0.5 million.
Low: <$0.5 million.

Costs of quarantine or other mitigation (annual)

High: >$5 million
Medium: $5 million to 0.5 million.
Low: <$0.5 million.

Impacts to recreation or real estate (annual)

High: >$5 million
Medium: $5 million to 0.5 million.
Low: <$0.5 million.

Consequences to native species

Assign a score based on the most severe impact that has been documented for the species.

Could reasonably be expected impacts federally listed Threatened and Endangered Species	5
Could directly, negatively impact pollinators	4
Causes local loss of native species	4
Lowers density of native species	3
Infection to native fauna or flora	2
Consumes native fauna or flora	2
Production of toxic substances including allelochemicals	2
Forms dense thickets or grows as a vine	2
Host for recognized pathogens/parasites of native species	1
None of the above apply	0

Consequences to ecosystem services (Scorecard approach)

The items bellow list common ecological services. Here simply count the number of impacts that have been reported for the pest. The maximum possible score is 7 and the minimum score is 0.

Modifications of soil, sediments, nutrient cycling
Alteration of genetic resources
Alteration of biological control
Changes in pollination services
Alteration of erosion regimes
Affects hydrology or water quality (includes effects of management)
Creates a fire hazard

Facilitate other invasions

Invasion by the organism could lead to invasions of other species.

High: The invasive species has facilitated invasions elsewhere.
Medium: The invasive species is a plant or animal that could reasonably be expected to be a host or vector of another invasive species
Low: The species has not been reported to facilitate invasion elsewhere and is not likely to directly aid in the invasion of other species

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