WHITEPAPER

Minnesota Invasive Terrestrial Plants & Pests Center

Minnesota's Top Terrestrial Invasive Plants & Pests for Research

An Expanded Prioritization

January 1, 2020
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Cover image: The Gunflint Trail is a 57-mile national scenic byway that cuts through the heart of the Superior National Forest at the edge of the Boundary Waters Canoe Area Wilderness in Cook County, Minnesota.

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EXECUTIVE SUMMARY

The Minnesota Invasive Terrestrial Plants and Pests Center has prioritized 168 terrestrial invasive species that are significant threats to the forests, prairies, wetlands, and agriculture within Minnesota. The highest-priority threats are eligible for research funded by MITPPC.

Among insects and earthworms, eligible species are (1) *Dendroctonus ponderosae;* (2) *Agrilus planipennis* and *A. biguttatus;* (3) *Aphis glycines;* (4) *Amynthas spp.;* (5) *Lymantria dispar dispar* and *L. dispar asiatica* (6) *Halyomorpha halys*; (7) *Scolytus schevyrewi* and *S. multistriatus;* (8) *Popillia japonica;* (9) *Anoplophora glabripennis*; (10) *Eupoecilia ambiguella*; (11) *Helicoverpa armigera*; (12) *Sirex noctilio*; (13) *Drosophila suzuki*; (14) *Spodoptera littoralis*; and (15) *Tetropium fuscum.* Japanese beetle, *Popillia japonica*, became eligible after new information was considered in the assessment.

Among plant pathogens, eligible species are (1) *Ophiostoma novo-ulmi*; (2) *Ceratocystis fagacearum*; (3) *Raffaelea quercivora*; (4) *Globodera pallida* and *Globodera rostochiensis*; (5) *Heterobasidion irregulare*; (6) *Heterodera latipons* and *H. filipjevi*; (7) *Phytophthora ramorum*; (8) *Geosmithia morbida*; (9) *Phyllachora maydis*, (10) *Aster yellows phytoplasma;* (11) *Ralstonia solanacearum,* Race 3, biovar 2; (12) *Cronartium ribicola*; (13) *Hymenoscyphus fraxineus*; (14) *Tilletia controversa* (cereal strain); and (15) *Fusarium virguliforme*. Corn tar spot caused by *Phyllachora maydis* was detected in Minnesota for the first time in 2019 and assessed by MITPPC in the same year.

Among plants, eligible species are (1) *Typha angustifolia*; (2) *Lonicera maackii, L. morrowii, L. tatarica,* and *L. japonica*; (3) *Berberis x ottawensis*; (4) *Centaurea stoebe* ssp. *micranthos* and *C. diffusa*; (5) *Tanacetum vulgare*; (6) *Frangula alnus* and *Rhamnus cathartica*; (7) *Phragmites australis* subsp. *australis*; (8) *Gypsophila paniculata*; (9) *Lupinus polyphyllus*; (10) *Cirsium arvense;* (11) *Microstegium vimineum*; (12) *Cotoneaster lucidus*; (13) *Ailanthus altissima*; (14) *Amaranthus palmeri*; and (15) *Euphorbia esula.* Narrowleaf cattail*, Typha angustifolia,* Amur honeysuckle, *Lonicera maackii*, Japanese honeysuckle, *L. japonica*, a barberry hybrid, *Berberis* x *ottawensis*, diffuse knapweed, *Centaurea diffusa*, baby's breath, *Gypsophila paniculata*, Japanese stiltgrass, *Microstegium vimineum,* large-leaved lupine, *Lupinus polyphyllus*, hedge cotoneaster, *Cotoneaster lucidus*, and tree of heaven, *Ailanthus altissima* were newly nominated since the previous assessment.

This ranking of terrestrial invasive species threats is the most extensive regionally and to our knowledge is second only to national rankings prepared by the Animal and Plant Health Inspection Service of the US Department of Agriculture.

I. INTRODUCTION

More than 300 terrestrial invasive species occur in Minnesota[1], and more are on the way. This document describes which invasive species pose the greatest threats to Minnesota's forests, prairies, wetlands, and agriculture and how those rankings were determined. 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 research proposals from MITPPC.

The lists in this report do not supersede agency regulatory lists or management priorities. For example, the Noxious Weed Advisory Committee for the Minnesota Department of Agriculture has a risk assessment process to determine the appropriate regulatory status for harmfult plants that may threaten the state. Existing risk assessments were consulted as the species in this prioritization were evaluated.

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 has been provided from the Environment and Natural Resources Trust Fund. The enabling legislation requires that research undertaken by the MITPPC should be focused on a 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. 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 have a history of competing with, or parasitizing, valued plants. For our purposes, invasive 'pests' include non-native pathogens, insects, earthworms, mites, mollusks, or vertebrates that can harm valued plants. Non-native pathogens that affect human or animal health are beyond the scope of MITPPC

[1] Minnesota Invasive Species Advisory Council (2019) MISAC ratings of invasive species of concern to Minnesota. Available on-line at: mninvasives.org/species-lists (Accessed 15 April 2020).

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 current proritization reflects multiple years of effort. MITPPC has applied the Analytical Hierarchy Process (AHP) to systematically evaluate threats posed by a wide array of terrestrial invasive species. AHP is a general method developed by decision scientists to make prioritzations consistent and transparent. The process has been used by many agencies and organizations to facilitate complex decision making. From the outset, MITPPC's version of AHP was designed to be expandable, so that additional species could be added or time, and responsive, so that new information about previously assessed species could be incorporated into the ranking.

MITPPC's approach to AHP followed four general steps: (1) selecting species for evaluation; (2) selecting criteria by which to compare species and determining the importance of those criteria; (3) establishing consistent measurement standards for each criterion; (4) reviewing information sources to assign a rating to each criterion for each species; (5) analyze the results to determine a ranking for each species. An overview of the procedures is provided here. A forthcoming technical document will describe the process in greater detail.

Selecting species for review. The initial list of invasive species for ranking was compiled in 2015 by fifteen experts were identified, six from the faculty at the University of Minnesota and nine program managers from partner agencies (Section II). Experts were assigned to one of three panels on insects, plants, or pathogens. Each panel was asked to use their professional opinions to identify approximately 40 invasive species that posed the greatest threats to the Minnesota. In total, the panelists identified 124 terrestrial invasive species of greatest concern for Minnesota's agriculture, forests, wetlands, or prairies. In 2017, MITPPC made a general call for additional terrestrial invasive species to be evaluated.

Selecting and weighing criteria to compare species. In brief, the fifteen-member panel engaged in facilitated discussions about what makes an invasive species a threat to the state. The panel identified 17 criteria to measure the "unmanaged biological threat" that each species poses to Minnesota. Each criterion (listed in Section III) had to be relevant to all invasive species under consideration. 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. The threat a species poses to the state was affected more by the potential impact the species might have than on its likelihood of invasion. Operational defnitions for each criterion were developed, including descriptions for three or more qualitative ratings (e.g., high, medium, and low) to distinguish levels of threat that a species might pose.

Ratings for each species. From 2015 to 2016, a team of six graduate students was hired to assemble and summarize published information about the 124 species with respect to the 17 criteria. Note: the intent of the literature review was not to provide a comprehensive review for each species but to provide justification for each rating. Simple tables summarized the 2,108 ratings, and bibliographies summarize the literature that was consulted. The expert panels were provided with the tables and given an opportunity to adjust the ratings on species for which they had expertise. Since 2017, assessment documents that provided the rationale for each ranking were prepared for newly nominated species, the first for jumping worms, *Amynthas* spp. In 2019, a postdoctoral scientist was hired by MITPPC to prepare similar, scientifically rigorous assessments. An additional 46 species were arbitrarily selected from the list of nominated species with preference given to those species that had been nominated multiple times.

Analyzing results. All results were analyzed with Comparion software by Expert Choice. In 2016, results were reviewed by the expert panels. Panelists examined the results, verified or revised ratings, and readjusted priorities assigned to criteria as needed. The interim rankings were made available for public comment for 30 days. In 2019, results were reviewed by Center staff.

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 our democratic tendencies, but the outcome only reflects those 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 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 confidently determining whether an understudied species might pose a threat.

We fully intend to update the priorities on a regular basis, ideally no later than every other year. The updates will allow us to consider more species and to review new information that may affect our threat scores. The process will be refined for completeness and accuracy. 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 from 2015-2016 to this prioritization process.

Insects

- **Mark Abrahamson**, Pest Detection and Response Unit Supervisor, Plant Protection Division, Minnesota Department of Agriculture
- **Angie Ambourn**, Research Scientist, 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 student assistants in 2015-2016 (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)

Graduate student assistants in 2017-2018

- **Amy Kendig,** Ph.D., Department of Ecology and Evolutionary Biology, UMN
- **Matt Hill, M.S.,** Department of Forest Resources, UMN

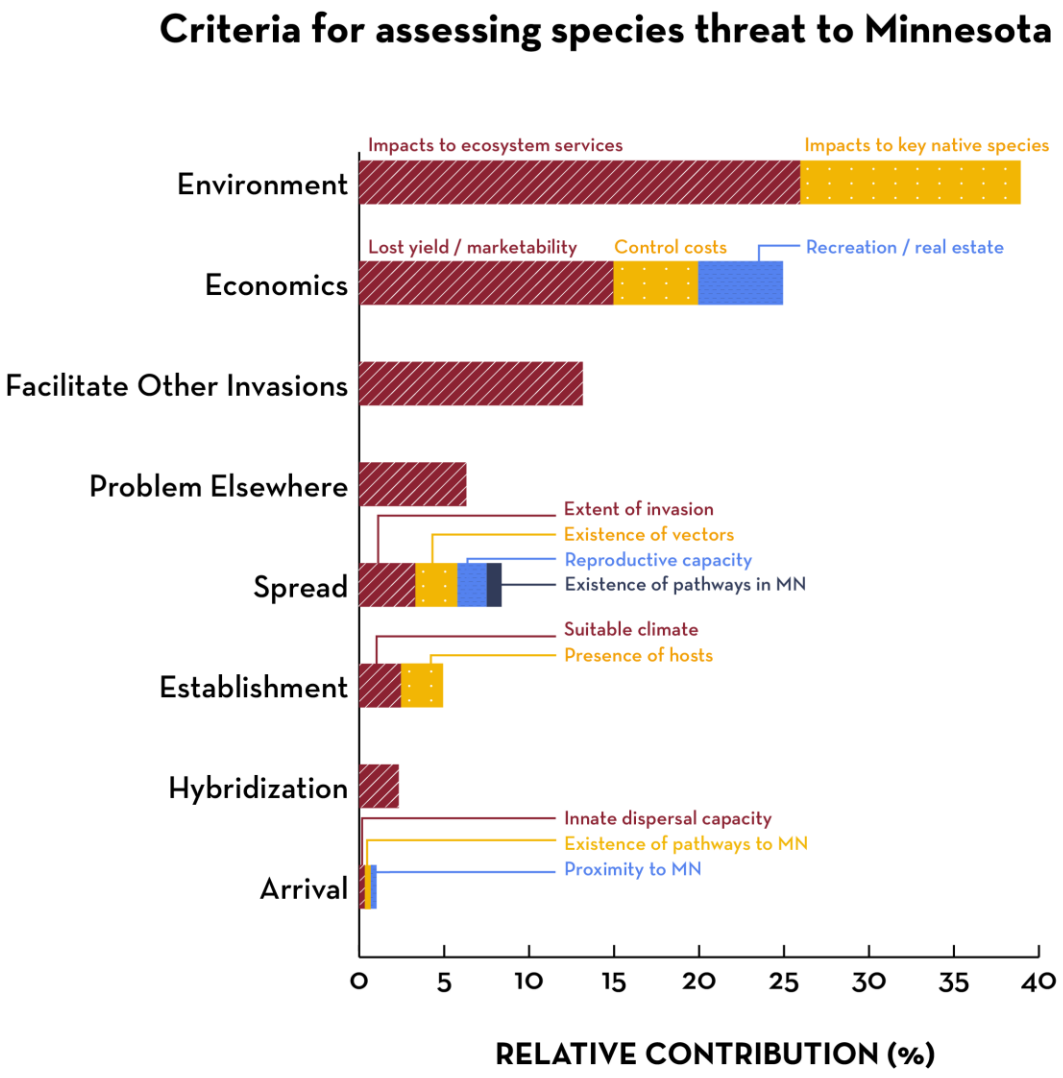
MITPPC staff assessor (2019-2020)

- **Amy Morey,** Ph.D., Department of Entomology, UMN

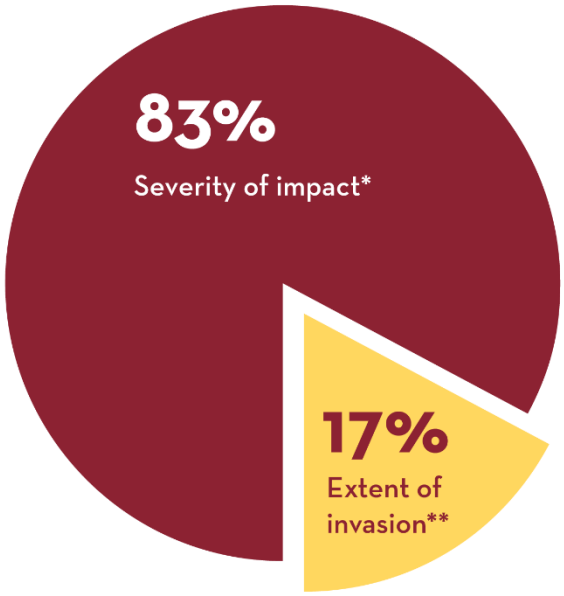
III. PRIORITIZATION CRITERIA OVERVIEW

17 criteria, and their relative importance, to assess the threat terrestrial invasive species pose 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.



Criteria for assessing species threat to Minnesota



*Includes Environment, Economics, Facilitate Other Invasions, Problem Elsewhere

**Includes Spread, Establishment, Hybridization, Arrival

IV. PRIORITIZED LIST

Terrestrial invasive insect and earthworm species

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).

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 periodically. 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. Highlighted species are eligible currently for research funding.

- Full breakdowns of the criteria ratings of each insect, plant and pathogen species considered in our process can be viewed online at : https://z.umn.edu/mitppcprioritytable
- **Note:** For species assessed in 2015-2016, references to support ratings are given in accompanying bibliographies within the link above. For species that were evaluated after 2016, complete narratives are provided to more clearly explain the rationale for each rating.

RANK	COMMON NAME	SCIENTIFIC NAME (PRIORITY SCORE)
1	Mountain pine beetle	*Dendroctonus ponderosae* (96.71)
2	Flat-headed borers; emerald ash borer, oak splendor beetle	*Agrilus planipennis* (93.28); *Agrilus biguttatus* (70.32)
3	Soybean aphid	*Aphis glycines* (85.89)
4	Jumping worm	*Amynthas spp* (84.11)
5	Gypsy moth; European, Asian	*Lymantria dispar dispar* (81.97); *Lymantria dispar asiatica* (81.95)
6	Brown marmorated stink bug	*Halyomorpha halys* (81.96)
7	Elm bark beetles; banded, European	*Scolytus schevyrewi* (81.53); *Scolytus multistriatus* (78.71)
8	Japanese beetle	*Popillia japonica* (75.12)
9	Asian longhorned beetle	*Anoplophora glabripennis* (74.13)
10	European grape berry moth	*Eupoecilia ambiguella* (73.69)
11	Old world bollworm	*Helicoverpa armigera* (72.18)
12	Sirex woodwasp	*Sirex noctilio* (71.61)
13	Spotted wing drosophila	*Drosophila suzuki* (71.33)
14	Egyptian cottonworm	*Spodoptera littoralis* (70.74)
15	Brown spruce longhorned beetle	*Tetropium fuscum* (69.55)
16	European spruce bark beetle	*Ips typographus* (68.24)
17	Swede midge	*Contarinia nasturtii* (68.07)
18	Golden twin spot moth	*Chrysodeixis chalcites* (67.75)
19	Balsam wooly adelgid	*Adelges picea* (67.41)

20	Cucurbit beetle	*Diabrotica speciosa* (67.19)
21	Walnut twig beetle	*Pityophthorus juglandis* (64.00)
22	Silver Y moth	*Autographa gamma* (63.19)
23	European chafer	*Rhizotrogus majalis* (63.07)
24	Soybean pod borer	*Leguminivora glycinivorella* (62.77)
25	European craneflies	*Tipula oleracea* (61.98)
26	Light brown apple moth	*Epiphyas postvittana* (61.67)
27	European craneflies	*Tipula paludosa* (60.42)
28	Spotted lanternfly	*Lycorma delicatula* (60.18)
29	Larch casebearer	*Coleophora laricella* (59.41)
30	Leek moth	*Acrolepiopsis assectella* (59.07)
31	Douglas fir tussock moth	*Orgyia pseudotsugata* (58.76)
32	European oak borer	*Agrilus sulicollis* (55.29)
33	European shoot beetle	*Tomicus piniperda* (52.14)
34	Lily leaf beetle	*Lilioceris lilii* (51.84)
35	Winter moth	*Operophtera brumata* (51.00)
36	European grapevine moth	*Lobesia botrana* (50.28)
37	Viburnum leaf beetle	*Pyrrhalta viburni* (50.10)
38	Apple ermine moth	*Yponomueta malinellus* (44.13)

V. PRIORITIZED LIST

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).

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. Highlighted species are eligible currently for research funding.

- Full breakdowns of the criteria ratings of each insect, plant and pathogen species considered in our process can be viewed online at : https://z.umn.edu/mitppcpriorititytable
- **Note:** For species assessed in 2015-2016, references to support ratings are given in accompanying bibliographies within the link above. For species that were evaluated after 2016, complete narratives are provided to more clearly explain the rationale for each rating.

RANK	COMMON NAME	SCIENTIFIC NAME
1	Dutch elm disease	*Ophiostoma novo-ulmi* (81.47)
2	Oak wilt	*Ceratocystis fagacearum* (79.27)
3	Japanese oak wilt	*Raffaelea quercivora* (78.44)
4	Potato cyst nematodes	*Globodera pallida;* (70.39) *Globodera rostochiensis* (77.72)
5	Annosus root rot	*Heterobasidion irregulare* (76.33)
6	Cereal cyst nematodes	*Heterodera latipons;* (68.49) *H. filipjevi* (74.08)
7	Sudden oak death	*Phytophthora ramorum* (70.54)
8	Thousand cankers disease	*Geosmithia morbida* (70.5)
9	Corn tar spot	*Phyllachora maydis* (69.41)
10	Aster yellows	*Aster yellows phytoplasma* (69.15)
11	Potato brown rot	*Ralstonia solanacearum, Race 3, biovar 2* (68.59)
12	White pine blister rust	*Cronartium ribicola* (68.39)
13	Ash dieback	*Hymenoscyphus fraxineus* (67.89)
14	Dwarf bunt of wheat	*Tilletia controversa (cereal strain)* (66.95)
15	Soybean sudden death	*Fusarium virguliforme* (65.78)
18	Late blight	*Phytophthora infestans* (65.11)
19	Fusarium head blight	*Fusarium graminearum* (63.92)
20	Associate fungus to Sirex woodwasp	*Amylostereum areolatum* (63.73)
21	Alder root rot	*Phytophthora alni ssp alni* (63.3)

22	Diplodia tip blight	*Diplodia pinea* (62.41)
23	Late wilt of maize	*Harpophora maydis* (61.93)
24	Butternut canker	*Ophiognomonia clavigigenti-juglandacearum* (61.81)
25	Boxelder dieback	*Fusarium euwallaceae* (61.34)
26	Soybean rust	*Phakospora pachyrhizi* (60.98)
27	Flag smut of wheat	*Urocystis agropyri* (60.08)
28	Cereal cyst nematode	*Heterodera cicero* (60.06)
29	Club root	*Plasmodiophora brassicae* (60.04)
30	Apple proliferation	*Candidatus phytoplasma mali* (59.84)
31	Downy mildew of cucurbits	*Pseudoperonospora cubensis* (59.6)
32	Stem and bulb nematode	*Ditylenchus dipsaci* (58.89)
33	Goss's wilt	*Clavibacter michigensis subsp. Nebraskensis* (58.62)
34	Cucumber green mottle mosaic virus	*CGMMV* (57.54)
35	Dieback of several woody plants	*Phytophthora kernovae* (57.37)
36	European larch canker	*Lachnellula willkommii* (57.1)
37	Pitch canker	*Gibberlla circinata (anamorph = Fusarium circinatum)* (56.85)
38	Light leaf spot	*Pyrenopeziza brassicae* (54.6)
39	Bacterial wilt	*Curtobacterium flaccumfaciens* (53.63)
40	Impatiens downy mildew	*Plasmopara obducens* (50.77)
41	Juniper dieback	*Phytophthora austrocedri* (50.75)
42	Alder disease	*Phytophthora alni ssp uniformis* (49.29)
43	Beech, azalea and Viburnum dieback	*Phytophthora hedraiandra* (48.76)
44	Ink disease on chestnut and oak	*Phytophthora cinnamomic* (47.98)
45	Bacterial wilt of tomato	*Clavibacter michigenensis subsp. Michigenensis* (42.49)
46	Basil downy mildew	*Peronospora belbahrii* (41.54)

VI. PRIORITIZED LIST

Terrestrial invasive 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).

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. Highlighted species are eligible currently for research funding.

- Full breakdowns of the criteria ratings of each insect, plant and pathogen species considered in our process can be viewed online at : https://z.umn.edu/mitppcprioritytable
- **Note:** For species assessed in 2015-2016, references to support ratings are given in accompanying bibliographies within the link above. For species that were evaluated after 2016, complete narratives are provided to more clearly explain the rationale for each rating.

RANK	COMMON NAME	SCIENTIFIC NAME
1	**Narrowleaf cattail**	*Typha angustifolia* (100)
2	**Honeysuckles**	*Lonicera maackii, L. morrowii, L. tatarica, L. japonica* (95.59)
3	**Ottawa barberry**	*Berberis x ottawensis (B. thunbergii x B. vulgaris)* (93.21)
4	**Knapweeds** (spotted, diffuse)	*Centaurea stoebe subsp. micranthos; C. diffusa* (90.28)
5	**Common tansy**	*Tanacetum vulgare* (88.38)
6	**Buckthorn** (glossy, common)	*Frangula alnus, Rhamnus cathartica* (83.88)
7	**European common reed**	*Phragmites australis subsp. australis* (83.49)
8	**Baby's breath**	*Gypsophila paniculata* (83.42)
9	**Large-leaved lupine**	*Lupinus polyphyllus* (81.97)
10	**Canada thistle**	*Cirsium arvense* (80.04)
11	**Japanese stiltgrass**	*Microstegium vimineum* (79.84)
12	**Hedge cotoneaster**	*Cotoneaster lucidus* (78.76)
13	**Tree of heaven**	*Ailanthus altissima* (78.24)
14	**Palmer amaranth**	*Amaranthus palmeri* (77.44)
15	**Leafy spurge**	*Euphorbia esula* (76.45)
16	**St. John's wort**	*Hypericum perforatum* (76.33)
17	**Wild parsnip**	*Pastinaca sativa* (76.27)

18	Japanese knotweed	*Polygonum cuspidatum* (75.71)
19	Reed canarygrass	*Phalaris arundinacea* (75.61)
20	Spiny plumeless thistle	*Carduus acanthoides* (74.84)
21	Crown vetch	*Coronilla varia* (74.78)
22	Korean barberry	*Berberis koreana* (74.77)
23	Cow parsley	*Anthriscus sylvestris* (74.48)
24	False spiraea	*Sorbaria sorbifolia* (74.19)
25	Garlic mustard	*Alliaria petiolata* (73.87)
26	Turkish wartycabbage	*Bunais orientalis* (73.3)
27	Russian olive	*Elaeagnus angustifolia* (72.88)
28	Japanese barberry	*Berberis thunbergii* (72.41)
29	Oriental bittersweet	*Celastrus orbiculatus* (72.41)
30	European swamp thistle	*Cirsium palustre* (72.4)
31	Giant knotweed	*Polygonum sachalinense* (72.02)
32	Periwinkle	*Vinca minor* (71.92)
33	Black swallowwort	*Vincetoxicum nigrum* (71.72)
34	Kudzu	*Pueraria montana* (71.12)
35	Common barberry	*Berberis vulgaris* (70.44)
36	Ground ivy	*Glechoma hederacea* (70.14)
37	White mulberry	*Morus alba* (69.67)
38	Norway maple	*Acer platanoides* (69.49)
39	Meadow knapweed	*Centaurea debeauxii* (69.34)
40	Dalmatian toadflax	*Linaria dalmatica* (69.22)
41	Yellow sweet clover	*Melilotus officinalis* (69.14)
42	Yellow star thistle	*Centaurea solstitialis* (69.11)
43	Mexican fireweed	*Bassia scoparia* (68.96)
44	American dwarf mistletoe	*Arceuthobium americanum* (68.8)
45	Black caraway	*Carum carvi* (68.8)
46	Sweetclover	*Melilotus alba* (68.02)
47	Japanese hop	*Humulus japonicus* (67.79)
48	Houndstongue	*Cynoglossum officinale* (67.39)
49	Multiflora rose	*Rosa multiflora* (66.99)
50	Hoary alyssum	*Berteroa incana* (66.81)
51	Bird's-foot trefoil	*Lotus corniculatus* (66.46)
52	Amur maple	*Acer ginnala* (66.32)
53	Porcelain vine	*Ampelopsis brevipedunculata* (63.64)
54	Giant hogweed	*Heracleum mantegazzianum* (62.81)
55	Yellow archangel	*Lamiastrum galeobdolon* (61.25)
56	Ussurian pear	*Pyrus ussuriensis* (58.78)
57	Garlic chives	*Allium tuberosum* (58.63)
58	Orange hawkweed	*Hieracium auranticum* (58.53)

59	**Meadow hawkweed**	*Hieracium caespitosum* (58.48)
60	**Swallowwort**	*Chelidonium majus* (57.22)
61	**Valerian**	*Valeriana officinalis* (57.1)
62	**Creeping bellflower**	*Campanula rapunculoides* (56.38)
63	**Narrowleaf bittercress**	*Cardamine impatiens* (55.83)
64	**Siberian peashrub**	*Caragana arborescens* (55.28)
65	**Burning bush**	*Euonymus alatus* (54.54)
66	**Grecian foxglove**	*Digitalis lanata* (54.16)
67	**Wild teasel**	*Dipsacus fullonum* (53.76)
68	**Cutleaf teasel**	*Dipsacus laciniatus* (53.76)
69	**Balfour's touch-me-not**	*Impatiens balfourii* (52.97)
70	**Poison hemlock**	*Conium maculatum* (52.37)
71	**Wild carrot**	*Daucus carota* (51.1)
72	**Korean mountain ash**	*Sorbus alnifolia* (46.73)
73	**Japanese hedge-parsley**	*Torilis japonica* (46.43)
74	**Bristley bellflower**	*Campanula cervicara* (41.05)

VII. PRIORITIZATION CRITERIA

Definitions and measurement standards

Expert panels identified 17 criteria that affect the threat an invasive species poses to Minnesota. Operational standards for each criterion are given here. The standards guide the selection of appropriate ratings for each criterion. The ratings are converted to scores, and the scores adjusted for the relative importance of the criterion to determine overall threat. These standards help to ensure consistency when comparing diverse species.

ARRIVAL

Proximity to Minnesota

The probability of arrival in Minnesota depends upon its 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.

RANKING	
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 acknowledge that pathways may exist, even if they are difficult to conceive.

RANKING	
High	Pathways for arrival of the pest in Minnesota are known to occur
Medium	Pathways for the 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. Measured dispersal distances take precedence over meals of dispersal.

RANKING	
Very High	Maximum recorded dispersal >500 km per year (or moves in low level jets/ upper atmosphere)
High	Maximum recorded dispersal 250-500 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 & PERSISTENCE

Sustainability of Minnesota Climate

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

RANKING	
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 addresses the chances that an invading species will find host plants (or suitable soils for weeds) near the point of arrival. 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.

RANKING	
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

Some invasive species can mate with closely related species and produce viable hybrids. In some cases, the hybrids have been found to be better adapted to local conditions that the original invasive species. In addition, some species, particularly insects and pathogens, over time have increased the number of plants upon which they can develop. The ability to produce viable hybrids with other species or to shift hosts increases the risk that an invasive species poses. This criterion assumes that hybridization or host shifts are always possible, even if not yet demonstrated. Thus, the lowest rating for the criterion is low instead of none.

RANKING	
High	Species 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 genus or species

SPREAD

Existence of Pathways

This criterion relates to the movement of the pest within the state, not the arrival of the species into the state. Here, we accept the fact that pathways may exist, even if they are difficult to conceive.

RANKING	
High	Pathways for arrival of the pest in Minnesota are known to occur
Medium	Pathways for the 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

Dispersal Capacity-Reproduction 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.

RANKING	
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.

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

RANKING	
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.

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

Impact to Yields & 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…

RANKING	
High	>$5 million
Medium	$5 million to 0.5 million
Low	<$0.5 million

Annual costs of quarantine or other mitigation are…

RANKING	
High	>$5 million
Medium	$5 million to 0.5 million
Low	<$0.5 million

Annual Impacts to recreation or real estate are…

RANKING	
High	>$5 million
Medium	$5 million to 0.5 million
Low	<$0.5 million
None	$0

Consequences to Native Species

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

RANKING	
Could reasonably be expected to affect federally listed Threatened and Endangered Species	5
Could directly, negatively impact pollinator	4
Causes local loss of native species	4
Lowers density of native species (empirical support)	3
Infection to native fauna or flora	2
Consumes native fauna or flora	2
Production of toxic substances including allelochemicals	2
Lowers density of native species (presumed due to dense thicket or vining)	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.

RANKING
Modification 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
Interferes with carbon sequestration

Facilitate Other Invasions

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

RANKING	
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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