



United States
Department of
Agriculture

Animal and Plant
Health Inspection
Service

April 23, 2012

Version 1

Background Information on the PPQ Weed Risk Assessment Process and Products

Agency Contact:

Plant Epidemiology and Risk Analysis Laboratory
Center for Plant Health Science and Technology

Plant Protection and Quarantine
Animal and Plant Health Inspection Service
United States Department of Agriculture
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

1. Introduction to PPQ Weed Risk Assessment

1.1. Authority

PPQ regulates noxious weeds under the authority of the Plant Protection Act (7 U.S.C. § 7701-7786, 2000) and the Federal Seed Act (7 U.S.C. § 1581-1610, 1939). A noxious weed is “any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment” (7 U.S.C. § 7701-7786, 2000). The PPQ weed risk assessment (Koop et al., 2012) was developed to evaluate the weed risk potential of a plant species and to determine whether or not it is a candidate for listing as a Federal Noxious Weed. Federal noxious weeds are plant taxa prohibited or restricted from entering the United States or moving through it (interstate). For transparency with stakeholders, Federal noxious weeds are listed under the Federal Noxious Weed regulations (7 CFR § 360, 2012). Except for plant species unlikely to contaminate import or export pathways, most Federal noxious weeds are co-listed as noxious weed seeds (see 7 CFR § 361, 2012).

1.2. Risk Analysis Framework

PPQ WRA is consistent with international guidelines

Plant Protection and Quarantine’s (PPQ) weed risk assessment (WRA) model and process are consistent with the general guidance provided by international and North American standards for risk assessment (IPPC, 2009: ISPM Nos. 2 & 11; NAPPO, 2008: RSPM No. 32). The weed risk assessments prepared by the PERAL Weed Team contain information relevant for the initiation, species categorization, and risk assessment phases. These phases correspond to Stage 1 (initiation) and Stage 2 (risk assessment) of risk analysis (IPPC, 2009: ISPM No. 2).

Initiation A weed risk assessment can be initiated for any number of reasons, including, but not limited to, evaluation for listing or delisting Federal Noxious Weeds or plants for propagation that are designated as “Not Authorized Pending Pest Risk Analysis” (NAPPRA) (APHIS, 2011). In each assessment, we note the reason for initiation, and provide other relevant background information.

We combine species categorization and risk assessment

One of the steps of risk assessment is species categorization, in which the plant is evaluated to determine whether it has the characteristics of a quarantine species or a regulated non-quarantine species (IPPC, 2009: ISPM No. 2). The intent of this phase is to identify (i.e., screen out) species that clearly do not meet these definitions before subjecting them to a potentially lengthy risk assessment process. However, because some plants that do not have evidence of spread or impact (harm) elsewhere later become noxious

weeds (IPPC, 2009: ISPM No. 2; Whitney and Gabler, 2008), PPQ subjects most plants to the full weed risk assessment process to evaluate their risk potential based on their inherent biological traits (e.g., Mack, 1996; Reichard, 2001). Essentially, we combine the categorization and risk assessment phases, and use the risk assessment as a screening tool to categorize the potential risk and status of the species.

PPQ WRAs do not make policy recommendations The PPQ WRA process does not make policy or management recommendations. Instead, it categorizes weed risk and relates a species' risk scores to the reference dataset of species with known weediness/invasiveness in the United States. This process results in one of three possible conclusions: "Low Risk," "Evaluate Further," and "High Risk." While these conclusions are not official policy recommendations, the analytical and statistical methodologies behind them support management decisions of allowing entry for Low Risk species, denying entry for High Risk species, and evaluating further other species as appropriate. This yields results similar to outcomes reached using other weed risk assessment systems (e.g., Pheloung et al., 1999; Reichard and Hamilton, 1997).

Plant Protection and Quarantine does risk management separately PPQ program managers use weed risk assessments to evaluate what Federal action may be appropriate. If regulatory action is prudent, program managers evaluate which risk mitigation options would reduce risk to an acceptable level. This risk management process corresponds to Stage 3 of risk analysis (IPPC, 2009). For cultivated plants not yet present in the United States, most management decisions will be to either allow or exclude entry. Agency policy and management decisions about weeds are summarized and communicated separately in risk management documents.

1.3. Usage and meaning of "Invasive" terminology

Confounded weed terminology Terminology in the weed/invasive plant literature is confounded, as words such as "weed" and "invasive" have inconsistent and subjective meanings (Richardson et al., 2000). Development and validation of the PPQ WRA model required some flexibility in terminology, particularly at different phases of the work. As with other studies that have developed and/or tested WRA systems (e.g., Gordon et al., 2008), we relied on information available in the literature to identify plants belonging to three categories of invasiveness: non-invaders, minor-invaders, and major-invaders. In this usage, invader broadly refers to a species' overall ability to establish, spread, and cause negative impacts (i.e., harm); and includes several components of risk recognized by the standard setting body of the International Plant Protection Convention (IPPC, 2009: ISPM No. 11).

In the PPQ WRA, we evaluate the establishment/spread and impact potential of a species as two separate risk elements. In the first risk element where we evaluate establishment/spread, we adopt a stricter definition of the term

‘invasive’ that refers to a species’ capacity to escape, establish, reproduce, and spread throughout a landscape (*sensu* Richardson et al., 2000). However, at the end of the PPQ WRA process when we consider scores for both risk elements, we return to the broad usage of the term invader because we relate a species’ risk scores back to the dataset that was used to develop and test the WRA model (Koop et al., 2012). If introduced into the United States, Low Risk plants are likely to become non-invaders, while High Risk plants are likely to become major-invaders. Species classified as Evaluate Further typically have risk scores intermediate between those of Low- and High Risk plants. They present a moderate risk potential and are likely to become minor-invaders.

2. Guide for Interpretation of WRA Results

WRAs provide three major products describing a species’ risk profile

The PERAL Weed Team uses the PPQ WRA process to evaluate the risk potential of a species becoming weedy or invasive, and where it may establish in the United States. Our current analytical process features three major components that help risk analysts and risk managers evaluate a species’ risk profile: 1) assessment of the species’ invasive potential (*sensu lato*); 2) evaluation of the sensitivity of the risk scores to uncertainty; and 3) determination of the areas in the United States suitable for species establishment.

PPQ weed risk assessments are conducted in a Microsoft Excel file that contains a series of mostly yes/no questions that are answered for every species. Questions are organized into four risk elements: establishment/spread potential, impact potential, geographic potential, and entry potential (Appendix A). Unless otherwise indicated, each question requires an answer of either ‘y’ or ‘n’ for yes and no, ‘?’ for the unknowns, or a letter from a to f. Answers receive scores from -5 to +5, depending on the question; questions that are more strongly associated with invasiveness/weediness are more heavily weighted. For each risk element, the scores are summed and reported, or used in some other fashion to evaluate the risk posed by each species. How this information is used in the risk assessment is described below. After a species is assessed, a summary of the results, and the answers and their supporting evidence is compiled in a Microsoft Word file that we refer to as the weed risk assessment.

In this section, we describe the WRA process in enough detail to help readers understand our WRA products and their results.

2.1 Assessment of the species’ establishment/spread and impact potential

Scores for establishment/spread and impact (harm)

At the core of the PPQ WRA is a logistic regression risk model (Appendix B) that assesses the risk potential of the species. The model was developed

potential are used in a logistic regression model and validated using 204 plants with known weed/invasive (noxious) behavior in the United States (non-invaders, minor-invaders, and major-invaders) (Koop et al., 2012). It uses the risk scores from the establishment/spread and impact risk elements to determine the likelihood a given species will be a non-, minor-, and major-invader (*sensu lato*). These likelihoods are probabilities that sum to one for any given species, and are reported in the WRA.

ROC curve analysis was used to set decision thresholds for risk categories Because most management decisions for plants will be to either allow or exclude entry, we used cutoff scores determined by Receiver Operating Characteristic (ROC) curve analysis (Appendix C) on the probability scores to categorize the overall risk of plant introduction (i.e., Low Risk, Evaluate Further, or High Risk) and facilitate management decisions. ROC curve analysis is an analytical tool used in decision making that maximizes the predictive ability of a model while minimizing false-positive and false-negative errors (Caley and Kuhnert, 2006; Metz, 1978).

In the WRA, we report risk scores used in the logistic regression model. Risk scores can range from -25 to 32 for the establishment/spread risk element, and from 1.0 to 5.1 for the impact risk element. Higher scores indicate greater risk. Descriptions associated with each risk element highlight the risk factors that contributed to that score and provide additional information not considered in the risk model, but may be relevant for risk managers. For comparison, the establishment/spread and impact risk scores are plotted on a graph with the scores for the 204 species used in model development (Appendix D). The decision thresholds that separate the Low Risk, Evaluate Further, and High Risk regions are also plotted for reference.

Secondary screening of species classified as Evaluate Further Species classified as Evaluate Further by the model are species with intermediate (i.e., moderate) risk scores, and are subjected to a secondary screening tool (Appendix E). With this tool, we examine specific traits that are strongly correlated with plant invasive status in the United States. The tool was designed to help risk managers evaluate management options for these species by focusing on our strongest predictors of risk. However, even after secondary screening, some species may remain in the Evaluate Further category. If a species is subjected to secondary screening, the result of this analysis is reported after the result for the primary risk model.

2.2 Uncertainty

Uncertainty is described for every question in the WRA Uncertainty is a fundamental part of risk analysis because our knowledge of the factors contributing to risk is rarely perfect. For every question in the WRA, analysts report their level of uncertainty in the answer in terms of negl (negligible), low, mod (moderate), high, or max (maximum). These are qualitative descriptors of uncertainty and describe the degree to which some other answer may be correct. An uncertainty level of max is only used for

questions that cannot be answered with the evidence (the unknowns).

The index of uncertainty ranges between 0 and 1 For the establishment/spread and impact risk elements, we report an index of uncertainty that describes the overall level of uncertainty associated with that risk element. The index ranges from zero to one, where a one corresponds to maximum uncertainty (i.e., all questions answered as unknown) and a zero corresponds to perfect knowledge. The index considers the uncertainty rating given by the analyst to each question and the relative weight of each question in the risk element. For the 204 species used to validate and test the WRA model, the mean uncertainty index for both risk elements was 0.17. Scores lower and higher than 0.17 represent lower and higher levels of uncertainty associated with a risk element.

Monte Carlo simulation indicates what other risk scores are possible based on the uncertainties In each WRA, we evaluate the sensitivity of a species' risk scores and the model's results to uncertainty using a Monte Carlo simulation. Essentially, we are interested in determining what the risk score would have been if we had answered some of the questions differently. The Monte Carlo simulation generates new outcomes (i.e., new risk assessments) by sometimes choosing new answers for each question based on the original answer and its associated level of uncertainty. Answers for which there was relatively little uncertainty are unlikely to change, whereas answers with higher levels of uncertainty are more likely to change. This simulation is run 5000 times and the results are plotted on a graph in relation to the original risk scores for the species (shown as a black square). The distributions for 50, 95, and 99 percent of the simulated risk scores are shown as boxes, while the remaining 1 percent of the scores are shown as outlying points. The median values for the establishment/spread (E/S) and impact (Imp) risk scores are shown as a blue "+" symbol. All of the simulated risk scores categorized as "evaluate further" are subjected to secondary screening to determine their final risk category. The percentages of simulations corresponding to each of the five possible outcomes (Low Risk; Evaluate Further → Low Risk; Evaluate Further → Evaluate Further; Evaluate Further → High Risk; and High Risk) are shown in a figure in each WRA. For reference, the results of a Monte Carlo simulation are shown in Appendix F.

2.3 Geographic Potential

The climatic suitability of the United States is assessed separately Unlike most other weed risk assessment systems, the PPQ WRA does not consider climatic suitability within the establishment/spread or impact risk elements (i.e., the predictive model). This was intentional so that the risk model would not be biased against one climatic region of the United States or another. Relative to many other countries, the United States (including its territories) is geographically and climatically diverse due not only to its large land area but also to how that land area is distributed across latitudes. Thus by necessity, the PPQ WRA is geographically neutral and the risk

rating reported by the model represents a baseline rating of the species capacity to establish, spread, and cause harm. However, consideration of whether an organism can establish in a given climatic region is still a fundamental part of pest risk assessment. For this reason, the PPQ WRA reports the geographic potential of a species separately so that risk managers can make whatever decision is appropriate for their jurisdiction (e.g., national, state, local).

Three climate variables are used to determine which regions of the United States are suitable for species establishment

In the geographic potential risk element, the PPQ WRA evaluates climatic suitability using three variables: plant hardiness to minimum winter temperatures, precipitation, and Köppen-Geiger climate classes. For each of variable, the specific values or ranges to which a species is adapted are determined by examining where the species occurs elsewhere in the world. Using GIS, this information is then used to produce a map of the region of the United States where suitable values of each variable occur jointly. The map and the percentage of the United States that is climatically suitable are reported in the WRA. Although there are many other more sophisticated climate-matching tools available, we consider this simple tool suitable for our rapid screening process. Work is underway to compare the accuracy and precision of our tool to that of several other climate matching tools.

2.4 Entry Potential

Most species of plants that enter the United States are intentionally imported for cultivation, processing, or consumption. If a species is already present in the United States, or if it will be intentionally introduced in the near future, assessment of this risk factor is not necessary. However, in cases where it is deemed necessary, the PPQ WRA process also evaluates a species' entry potential. The entry potential risk element consists of about a dozen questions that evaluate the likelihood a species will enter either intentionally or accidentally as a contaminant of a pathway. Species that are cultivated elsewhere or are positively valued by society are more likely to enter than other species. The risk score for entry potential can range from zero to one, with higher scores indicating a higher likelihood of entry. The associated index of uncertainty can also range from zero to one, where higher values indicate greater uncertainty. These two values and a summary of the entry potential assessment are reported in the WRA document.

2.5 Discussion

In the discussion section of each assessment, we briefly review the available evidence and report our final conclusion. We also introduce additional information that may be relevant to managers in decision making, but is not considered by the risk model. A copy of the full weed risk assessment that was conducted on our Microsoft Excel spreadsheet is available upon request.

3. Literature Cited

- 7 CFR § 360. 2012. Code of Federal Regulations, Title 7, Part 360, (7 CFR §360 - Noxious Weed Regulations). United States Government.
- 7 CFR § 361. 2012. Code of Federal Regulations, Title 7, Part 361, (7 CFR §361 - Importation of Seed and Screenings under the Federal Seed Act). United States Government.
- 7 U.S.C. § 1581-1610. 1939. The Federal Seed Act, Title 7 United States Code § 1581-1610.
- 7 U.S.C. § 7701-7786. 2000. Plant Protection Act, Title 7 United States Code § 7701-7786.
- APHIS. 2011. Plants for planting whose importation is not authorized pending pest risk analysis: Notice of availability of data sheets for taxa of plants for planting that are quarantine pests or hosts of quarantine pests. Federal Register 76(143):44572-44573. Last accessed September 12, 2011, <http://www.gpo.gov/fdsys/>.
- Caley, P., and P. M. Kuhnert. 2006. Application and evaluation of classification trees for screening unwanted plants. *Austral Ecology* 31(5):647-655.
- Gordon, D. R., D. A. Onderdonk, A. M. Fox, and R. K. Stocker. 2008. Consistent accuracy of the Australian weed risk assessment system across varied geographies. *Diversity and Distributions* 14:234–242.
- IPPC. 2009. International standards for phytosanitary measures: 1-32. International Plant Protection Convention (IPPC) and the Food and Agriculture Organization of the United Nations, Rome. 432 pp.
- Koop, A., L. Fowler, L. Newton, and B. Caton. 2012. Development and validation of a weed screening tool for the United States. *Biological Invasions* 14(2):273-294.
- Mack, R. N. 1996. Predicting the identity and fate of plant invaders: Emergent and emerging approaches. *Biological Conservation* 78:107-121.
- Metz, C. E. 1978. Basic principles of ROC analysis. *Seminars in Nuclear Medicine* 8:283-298.
- NAPPO. 2008. NAPPO regional standards for phytosanitary measures: RSPM#32: Pest risk assessment for plants for planting as quarantine pests. North American Plant Protection Organization (NAPPO), Ottawa, Canada. 16 pp.
- Pheloung, P. C., P. A. Williams, and S. R. Halloy. 1999. A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management* 57:239-251.
- Reichard, S. 2001. The search for patterns that enable prediction of invasion. Pages 10-19 *in* R. H. Groves, F. D. Panetta, and J. G. Virtue, (eds.). *Weed Risk Assessment*. CSIRO, Collingwood, Australia.
- Reichard, S. H., and C. W. Hamilton. 1997. Predicting invasions of woody

- plants introduced into North America. *Conservation Biology* 11(1):193-203.
- Richardson, D. M., P. Pyšek, M. Rejmanek, M. G. Barbour, F. D. Panetta, and C. J. West. 2000. Naturalization and invasion of alien plants: Concepts and definitions. *Diversity and Distributions* 6:93-107.
- Whitney, K. D., and C. A. Gabler. 2008. Rapid evolution in introduced species, 'invasive traits' and recipient communities: challenges for predicting invasive potential. *Diversity and Distributions* 14(4):569-580.

4. Appendices

Appendix A. Questions and scoring used in the PPQ weed risk assessment.

Establishment/Spread Potential	
ES-1	Select one: A). Introduced elsewhere long ago (>75 years) but not escaped (-5). B). Introduced recently (<75 years) but not escaped (-2). C). Never introduced elsewhere (0). D). Escaped/Casual (0). E). Naturalized (2). F). Invader (5).
ES-2	Is the species highly domesticated (y=-3, n=0, or ?=0).
ES-3	Congeneric weed (y=1, n=0, or ?=0).
ES-4	Shade tolerant at some stage of life cycle (y=1, n=0, or ?=0).
ES-5	Climbing or smothering growth habit (y=1, n=0, or ?=0).
ES-6	Forms dense thickets (y=2, n=0, or ?=0).
ES-7	Aquatic (y=1, n=0, or ?=0).
ES-8	Grass (y=1, n=0, or ?=0).
ES-9	Nitrogen-fixing woody plant (y=1, n=0, or ?=0).
ES-10	Produces viable seed or spores (y=1, n=-1, or ?=0).
ES-11	Self-compatible or apomictic (y=1, n=-1, or ?=0).
ES-12	Requires specialist pollinators (y=-1, n=0, or ?=0).
ES-13	Minimum generative time: A). less than 1 (multiple generations per year) (2). B). 1 year (annual-1 gen per year) (1). C). 2or3 years (0). D). >3years (-1). ?=0.
ES-14	Prolific seed/spore production (see scoring guide) (y=1, n=-1, or ?=0).
ES-15	Propagules likely to be dispersed unintentionally by people (y=1, n=-1, or ?=0).
ES-16	Propagules likely to disperse in trade as contaminants and hitchhikers (y=2, n=-1, or ?=0).
ES-17 ^a	No. natural dispersal vectors (none=-4, one=-2, two=0, three=2, four or five=4). We consider up to five possible dispersal vectors: wind, water, bird, animal internal, animal external. These correspond to the same five in the Australian weed risk assessment (questions 7.04-7.08).
ES-18	Evidence that a persistent (>1yr) propagule bank (seed bank) is formed (y=1, n=-1, or ?=0).
ES-19	Tolerates/benefits from mutilation, cultivation or fire (y=1, n=-1, or ?=0).
ES-20	Is resistant to some herbicides or has potential to acquire herbicide resistance (y=1, n=0, or ?=0).
ES-21	Number of USDA cold hardiness zones suitable for survival (out of 13) (zero-three=-1, four-nine=0, ten-thirteen=1).
ES-22	Number of climate types suitable for survival (out of 12) (zero-two=-2, three=0, four-twelve=2).

ES-23	Number of precipitation bands suitable for survival (out of 11) (zero-four=-1, five-seven=0, eight-eleven=1).
-------	---

Impact Potential

Imp-G1	Allelopathic (y=0.1, n=0, or ?=0).
Imp-G2	Parasitic (y=0.1, n=0, or ?=0).
Imp-N1	Change ecosystem processes and parameters that affect other species? (y=0.4, n=0, or ?=0).
Imp-N2	Change community structure? (y=0.2, n=0, or ?=0).
Imp-N3	Change community composition? (y=0.2, n=0, or ?=0).
Imp-N4	Likely to affect any federal Threatened and Endangered plant species? (y=0.1, n=0, or ?=0).
Imp-N5	Likely to affect any globally outstanding ecoregions? (y=0.1, n=0, or ?=0).
Imp-N6	For conservation/natural areas, choose the best answer. A). Plant not a weed (0); B). Plant a weed but no evidence of control efforts (0.2); C). Plant a weed and evidence of control efforts (0.6).
Imp-A1	Impacts human property, processes, civilization, or safety? (y=0.1, n=0, or ?=0).
Imp-A2	Changes or limits recreational use of an area? (y=0.1, n=0, or ?=0).
Imp-A3	Outcompetes, replaces or otherwise affects desirable plants and vegetation? (y=0.1, n=0, or ?=0).
Imp-A4	For urban/suburban areas, choose the best answer. A). Plant not a weed (0); B). Plant a weed but no evidence of control efforts (0.1); C). Plant a weed and evidence of control efforts (0.4).
Imp-P1	Reduces crop/product yield? (y=0.4, n=0, or ?=0).
Imp-P2	Lowers commodity value? (y=0.2, n=0, or ?=0).
Imp-P3	Is it likely to impact trade? (y=0.2, n=0, or ?=0).
Imp-P4	Reduces the quality or availability of irrigation, or strongly competes with plants for water? (y=0.1, n=0, or ?=0).
Imp-P5	Toxic to animals, including livestock/range animals and poultry (y=0.1, n=0, or ?=0).
Imp-P6	For production systems, choose the best answer. A). Plant not a weed (0); B). Plant a weed but no evidence of control efforts (0.2); C). Plant a weed and evidence of control efforts (0.6).

Geographic Potential

For each of the three variables below, determine which zones, classes, or bands are suitable for species establishment.

Plant cold hardiness zones	
Geo-Z1	Zone 1 (below -50°F or below -45.6°C)
Geo-Z2	Zone 2 (-50 to -40°F, or -45.6 to -40.0°C)
Geo-Z3	Zone 3 (-40 to -30°F, or -40.0 to -34.4°C)
Geo-Z4	Zone 4 (-30 to -20°F, or -34.4 to -28.9°C)

Geo-Z5	Zone 5 (-20 to -10°F, or -28.9 to -23.3°C)
Geo-Z6	Zone 6 (-10°F to 0°F, or -23.3 to -17.8°C)
Geo-Z7	Zone 7 (0 to 10°F, or -17.8 to -12.2°C)
Geo-Z8	Zone 8 (10 to 20°F, or -12.2 to -6.7°C)
Geo-Z9	Zone 9 (20 to 30°F, or -6.7 to -1.1°C)
Geo-Z10	Zone 10 (30 to 40°F, or -1.1 to 4.4°C)
Geo-Z11	Zone 11 (40 to 50°F, or 4.4 to 10°C)
Geo-Z12	Zone 12 (50 to 60°F, or 10 to 15.6°C)
Geo-Z13	Zone 13 (above 60°F, or above 15.6°C)

Köppen-Geiger climate classes

Geo-C1	Tropical rainforest
Geo-C2	Tropical savanna
Geo-C3	Steppe
Geo-C4	Desert
Geo-C5	Mediterranean
Geo-C6	Humid subtropical
Geo-C7	Marine west coast
Geo-C8	Humid continental warm summers
Geo-C9	Humid continental cool summers
Geo-C10	Subarctic
Geo-C11	Tundra
Geo-C12	Icecap

10-inch precipitation bands (measurement in cm)

Geo-R1	0-10 inches (0-25 cm)
Geo-R2	10-20 inches (25-51 cm)
Geo-R3	20-30 inches (51-76 cm)
Geo-R4	30-40 inches (76-102 cm)
Geo-R5	40-50 inches (102-127 cm)
Geo-R6	50-60 inches (127-152 cm)
Geo-R7	60-70 inches (152-178 cm)
Geo-R8	70-80 inches (178-203 cm)
Geo-R9	80-90 inches (203-229 cm)
Geo-R10	90-100 inches (229-254 cm)

Entry Potential

Ent-1	Plant already here (y=1, n=0). STOP IF YES
Ent-2	Plant proposed for entry, or entry is imminent (y=1, n=0). STOP IF YES
Ent-3	Choose the best answer: (a) not cultivated or positively valued; (b) not cultivated, but positively valued or potentially beneficial; (c) cultivated, but no evidence of trade or resale; (d) cultivated with evidence of trade or resale
Ent-4	Entry as a contaminant
Ent-4a	Plant present in Canada, Mexico, Central America, the Caribbean or China (y, n, ?).

Ent-4b	Contaminant of plant propagative material (except seeds) (y, n, ?).
Ent-4c	Contaminant of seeds for planting (y, n, ?).
Ent-4d	Contaminant of ballast water (y, n, ?).
Ent-4e	Contaminant of aquarium plants or other aquarium products (y, n, ?).
Ent-4f	Contaminant of imported landscape products (y, n, ?).
Ent-4g	Contaminant of containers, packing materials, trade goods, equipment or conveyances (y, n, ?).
Ent-4h	Contaminants of fruit, vegetables, or other products for consumption or processing (y, n, ?).
Ent-4i	Contaminant of some other pathway? Be specific in the notes column and choose one of the following letters representing the appropriate risk score, relative to the other pathways in which the species may enter as a contaminant: (a) 0; (b) 0.01; (c) 0.02; (d) 0.03; (e) 0.04; (?)
Ent-5	Likely to enter through natural dispersal (y, n, ?).

Appendix B. Logistic regression model formulas

Below are the formulas for the logistic regression model of the probabilities (P) of being a major-invader, minor-invader, and non-invader. E/S and Imp refer to the risk scores from the Establishment/Spread and Impact risk elements. All three probabilities sum to 1 for each plant.

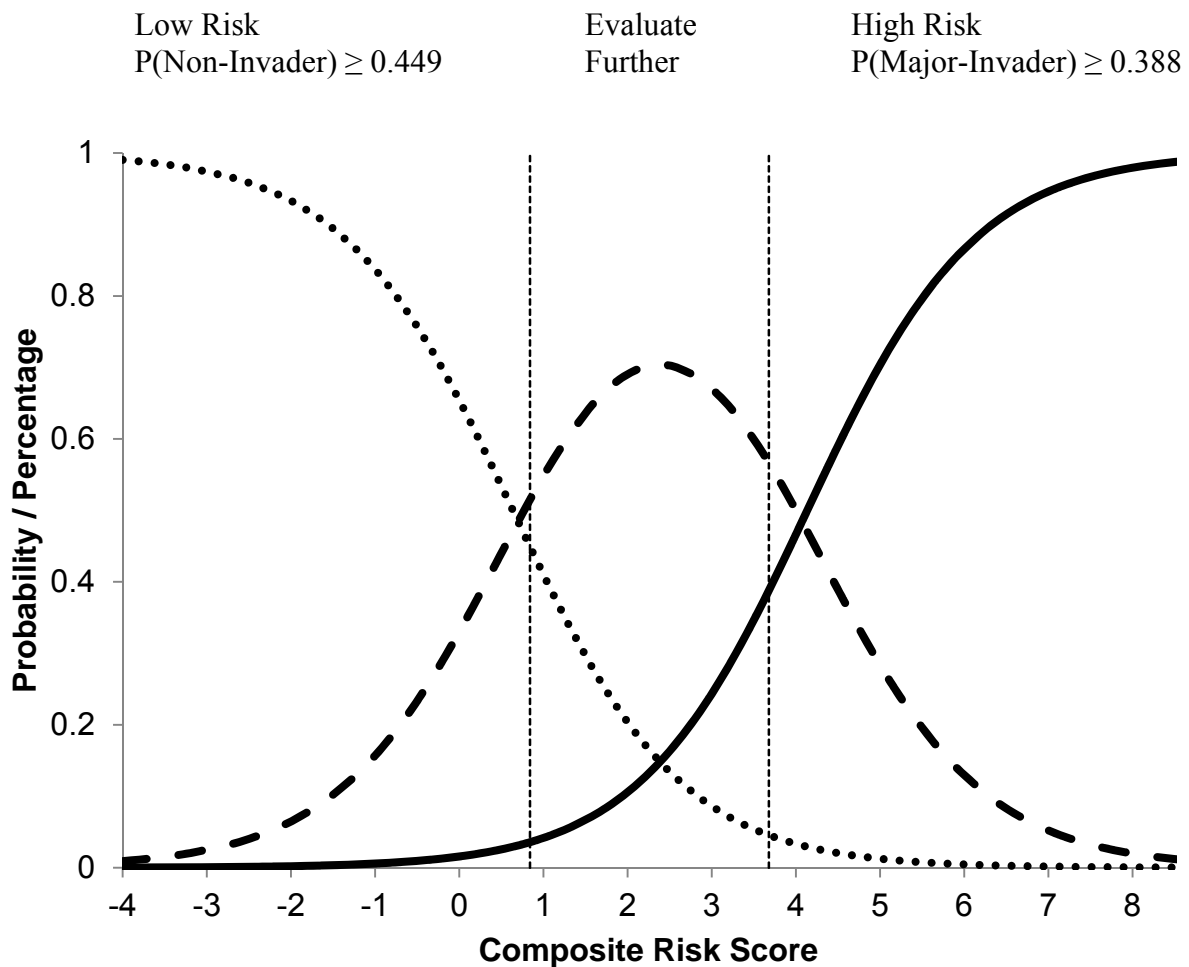
$$P(Maj - I) = \frac{1}{1 + e^{(4.1348 - (0.2356 \times E/S) - (0.6019 \times Imp))}}$$

$$P(Min - I) = \frac{1}{1 + e^{(0.6366 - (0.2356 \times E/S) - (0.6019 \times Imp))}} - P(Maj - I)$$

$$P(Non - I) = 1 - \left(\frac{1}{1 + e^{(0.6366 - (0.2356 \times E/S) - (0.6019 \times Imp))}} \right)$$

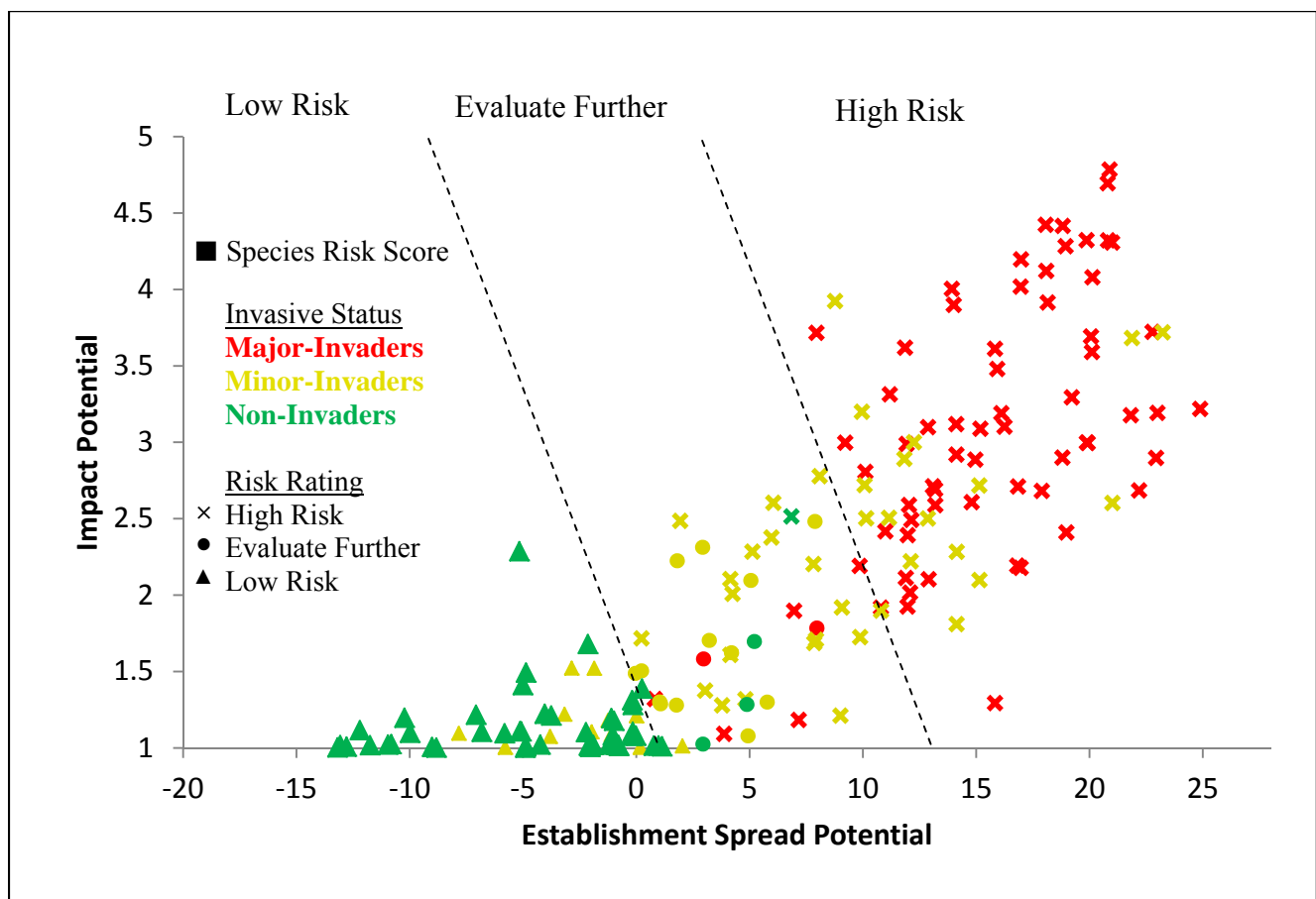
Appendix C. Logistic regression model and cutoff scores

In the diagram below, we present the logistic regression model for the probabilities of being a non-invader (dotted line), minor-invader (dashed lined), and major-invader (solid line) as a function of the composite risk score. Composite Risk Score refers to a linear combination of the risk scores for the establishment/spread (E/S) and impact (Imp) risk elements. It is used in determining the probabilities and is calculated as $(0.2356 \times E/S) + (0.6019 \times Imp)$. The vertical lines are the cutoff scores used by the model to determine the outcome of the model (Low Risk, Evaluate Further, or High Risk). The cutoff scores were calculated by Receiver Operating Characteristic (ROC) curve analysis. This analysis maximizes the probabilities of accurately identifying non- and major-invaders, while minimizing errors. In the analysis, we assumed that the cost of a false-positive and false-negative error were equal. If the probability of being a non-invader is ≥ 0.449 (composite risk score ≤ 0.841), then the species is classified as Low Risk. If the probability of being a major-invader is ≥ 0.388 (composite risk score ≥ 3.769), then the species is classified as High Risk. All other species are classified as Evaluate Further pending secondary screening.



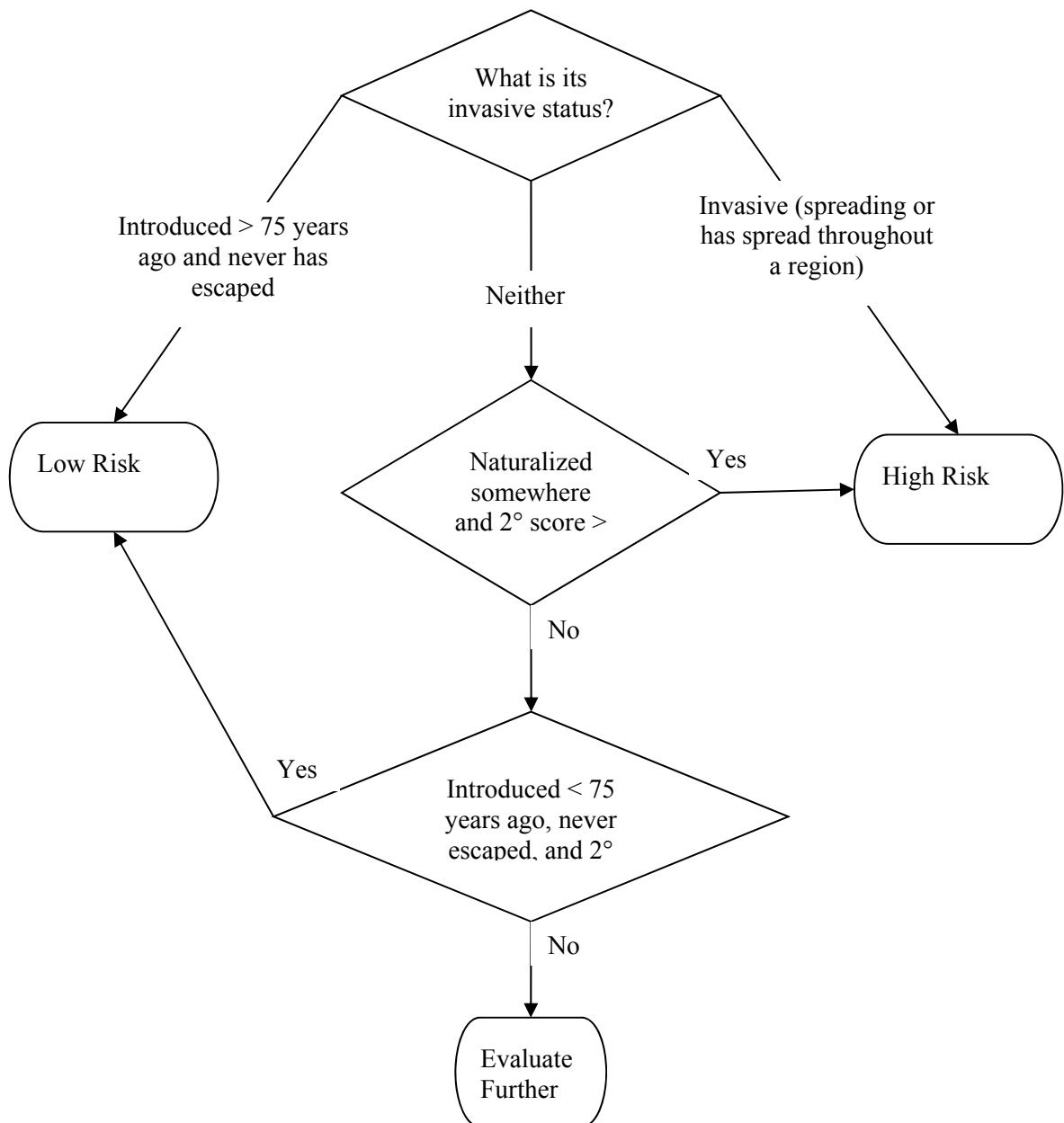
Appendix D. Risk score reference dataset.

Risk score distribution for the 204 species used to develop (N=102) and test (N=102) the PPQ WRA model. Marker color corresponds to the a priori classification for a species (major-, minor-, and non-invader). Marker type (triangle, circle, and x) corresponds to the conclusion of the assessment after using the logistic regression model and the secondary screening, if applicable. The dashed lines represent the decision thresholds from Appendix C but expressed in terms of the establishment/spread and impact risk scores instead of probabilities of invasiveness. Although not shown in this graph, the species' risk score, which is determined in a risk assessment, is plotted as a black square.



Appendix E. Secondary screening system.

This system uses key questions that were strongly associated with invasive status in the United States. The first is question E/S-1 from the WRA model, and refers to the species invasive status anywhere in the world, including in the United States. Following that, the left and right paths correspond to two of the status options from E/S-1. In the central diamond, the secondary score is the sum of the scores for six questions from the WRA model: 1) prolific reproduction; 2) minimum generation time; 3) shade adapted; 4) commodity contaminant; 5) number of natural dispersal vectors; and 6) forms dense thickets.



Appendix F. Example of a Monte Carlo analysis of the sensitivity of the species' risk score to uncertainty.

The figure below shows an example of a Monte Carlo analysis. The distribution of all 5000 simulated risk scores is plotted in relation to the observed risk score determined by the analyst. For clarity, the distribution of the central 50, 95, and 99 percent of the risk scores are represented by the small, medium, and large boxes, respectively. Score medians for each variable are shown by the blue lines (+). The percentages of simulations corresponding to each of the five possible outcomes [Low Risk; Evaluate Further (EF) → Low Risk; Evaluate Further → Evaluate Further; Evaluate Further → High Risk; and High Risk] are shown at the bottom left of the figure.

