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Guidelines for the USDA-APHIS-PPQ Weed Risk Assessment Process

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Table of Contents

List of Tables

List of Figures

Section 1: Introduction to the PPQ Weed Risk Assessment

The United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ) conducts weed risk assessments (WRAs) to evaluate the risk potential of a plant taxon becoming weedy or invasive and to assess where it might establish in the United States. Article IV.2 of the International Plant Protection Convention (IPPC, 1997) indicates that national plant protection organizations are responsible for conducting pest risk analyses to protect the plant resources of their country. USDA-APHIS-PPQ is the national plant protection organization for the United States and is responsible for safeguarding U.S. plant resources from pests including noxious weeds. The national regulatory authority to conduct WRAs is provided in Title IV – Plant Protection Act of 2000 (7 U.S.C. § 7701-7786).

In this document, we provide guidance for conducting WRAs using the PPQ WRA process. The document should be useful to risk analysts, as well as to customers, stakeholders, and trading partners interested in understanding our methodology and products. PPQ WRAs are initiated to address a variety of issues and situations; however, one of the primary reasons we conduct a PPQ WRA is to determine whether or not a plant taxon is a candidate for listing as a Federal Noxious Weed. A Federal Noxious Weed is defined as “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). Federal Noxious Weeds are taxa prohibited or restricted from entering into or moving interstate within the United States. For transparency, Federal Noxious Weeds are listed as part of the Federal Noxious Weed regulations (7 CFR § 360). Except for plant species unlikely to contaminate import or export pathways, most Federal Noxious Weeds are also listed as Noxious Weed Seeds, which are weed species that are regulated in agricultural and vegetable seed entering or moving through the United States in commerce (see 7 CFR § 361). Any person or organization can petition PPQ to list a plant taxon as a Federal Noxious Weed, which may initiate a WRA. PPQ prioritizes taxa for evaluation based on the current demand for WRAs.

Risk analysis framework

The PPQ WRA process is consistent with international standards for phytosanitary measures (ISPMs) (ISPM Nos. 2 and 11), as well as regional (North American) standards for phytosanitary measures (RSPMs) (RSPM No. 32) for pest risk analysis (IPPC, 2011, 2013b; NAPPO, 2008). These standards identify three stages of pest risk analysis: Stage 1, initiation; Stage 2, risk assessment; and Stage 3, risk management (IPPC, 2011). PPQ WRAs address Stages 1 (initiation) and 2 (risk assessment). Stage 3 (risk management) is beyond the scope of a PPQ WRA.

PPQ WRAs can be initiated for different reasons, such as:

- determining whether a plant taxon is a candidate for listing as a Federal Noxious Weed
- evaluating plant taxa:

- that have been designated by PPQ as "Not Authorized Pending Pest Risk Analysis" (i.e., NAPPRA)
- that are newly detected or that have expanded their geographic range in the United States
- that are exhibiting invasive traits elsewhere in the world
- when there is stakeholder concern of their risk potential
- that have been requested for import as either a commodity for consumption or a plant for planting

One of the steps in pest risk analysis is categorization, during which taxa are evaluated to determine whether they meet the defining criteria to be considered quarantine or regulated non-quarantine pests (IPPC, 2011). The purpose of categorization is to identify (i.e., screen out) species that do not meet these definitions before subjecting them to a lengthier risk analysis. However, because plant taxa for which there is no evidence of spread or impact elsewhere in the world can later become pest plants (IPPC, 2011; Whitney and Gabler, 2008), PPQ evaluates the risk potential for all plant taxa based on their inherent biological traits and behavior outside of their native range (e.g., Mack, 1996; Reichard, 2001). Essentially, in the PPQ WRA, categorization and risk assessment are combined into one process and used as a screening tool to categorize the status and potential risk of the plant taxon.

The PPQ WRA predictive model (Koop et al., 2012) is a major component of the overall PPQ WRA process and evaluates the risk potential of a plant taxon. The term "WRA model" or "model" is used to refer to the predictive logistic regression model that quantifies a plant taxon's ability to escape, establish, spread, and cause harm. The terms "PPQ WRA" or "WRA process" refer to the overall process for evaluating a plant taxon's risk profile, including the portion evaluated by the predictive model.

The completed PPQ WRA does not include policy or risk management recommendations. It categorizes risk and relates the risk scores obtained during the assessment to the dataset of plant taxa used to develop and validate the predictive logistic regression model (Koop et al., 2012). Based on the plant taxon's risk scores, the PPQ WRA categorizes the risk as either "low risk," "evaluate further" (moderate risk), or "high risk." Because most policy decisions for cultivated plants are to either allow or deny entry into the United States, we recommend that taxa with a moderate risk potential (i.e., those with a risk categorization of "evaluate further") be further assessed by some other process to help inform policy and decision makers.

While the conclusions from the PPQ WRA are not official policy recommendations, the analytical and statistical methodologies behind these conclusions support management decisions of allowing entry to low risk taxa, denying entry to high risk taxa, and further evaluating other taxa as appropriate. The three possible outcomes of the PPQ WRA are similar to those of other weed risk assessment models (e.g., Pheloung et al., 1999; Reichard and Hamilton, 1997). Risk managers in APHIS-PPQ use results from PPQ WRAs in conjunction with other information to decide what Federal action may be appropriate.

In general, if regulatory action is prudent for a pest, risk managers determine which mitigation options might reduce risk to an acceptable level. This risk management process corresponds to

Stage 3 of pest risk analysis (IPPC, 2011). For plant taxa not yet present in the United States, most management decisions will be to either allow or deny them entry. Agency policy and management decisions are summarized and communicated separately in a risk management document.

Usage and meaning of the term "invasive"

Terminology in the weed/invasive plant literature is inconsistent and imprecise, as words such as "weed" and "invasive" have subjective and sometimes ambiguous meanings (Richardson et al., 2000). As with other studies that have developed and/or tested WRA models (e.g., Gordon et al., 2008), Koop et al. (2012) relied on information available in the literature to identify U.S. plant taxa belonging to three categories of invasiveness: non-invaders, minor-invaders, and major-invaders. In this usage, "invader" broadly refers to a taxon's overall ability to establish, spread, and cause negative impacts (i.e., harm) and includes several components of risk recognized and used by the International Plant Protection Convention in its international standards pertaining to pest risk analysis (IPPC, 2011; IPPC, 2013b).

In the PPQ WRA, the Establishment/Spread and the Impact Potential of a plant taxon are evaluated as two separate risk elements. The risk scores for these two elements are used by the predictive model to characterize the overall invasive potential of the species, in the broadest sense. When evaluating establishment/spread, a stricter definition of the term "invasive" is adopted (referring to a taxon's capacity to escape, establish, reproduce, and spread throughout a landscape (Richardson et al., 2000). However, at the end of the PPQ WRA process, when the scores for both risk elements are considered, a broader definition of the term "invader" is used, because risk scores are related back to the plant dataset used to develop and validate the WRA model (Koop et al., 2012).

If introduced into the United States, we predict that low-risk plant taxa are likely to remain non-invaders or non-weeds, while high-risk taxa are likely to become major-invaders or major-weeds after some indeterminate period[1]. Taxa classified as Evaluate Further typically have intermediate risk scores between those of low- and high-risk plants. They pose a moderate risk and are likely to become minor-invaders or minor-weeds—that is, species likely to escape and naturalize but not expected to become widely naturalized or cause widespread harm.

[1] The period of time after a species is introduced but before it behaves invasively is generally referred to as the lag phase of invasion (Kowarik, 1995).

Section 2: Overview and Interpretation of the PPQ Weed Risk Assessment (WRA)

A PPQ WRA has three major analytical components:

- assessment of the plant taxon's Establishment/Spread and Impact Potential (i.e., its invasive potential)
- evaluation of the sensitivity of the Establishment/Spread and impact risk scores to uncertainty
- determination of the areas in the United States suitable for establishment by the taxon

The PPQ WRA is conducted in a Microsoft Excel workbook (see Fig. 1), while the final report is written in Microsoft Word. In the report we describe the plant taxon's risk profile and discuss the information considered in the evaluation. The report includes the following information and sections: 1) title page, 2) background and species information, 3) written and graphic summaries of the analysis, 4) discussion, 5) literature cited, and 6) a copy of the answers and justifications from the Excel workbook, including all evidence considered.

During the development of a WRA, we gather scientific evidence and other information for answering a series of questions that characterize the risk posed by the plant taxon. Most questions require an answer of yes (= y), no (= n), or unknown (= ?). A handful of questions require multiple-choice answers of a, b, c, etc. The questions are organized into the following four risk elements:

- Establishment/Spread (ES) Potential – 23 questions
- Impact (Imp) Potential – 18 questions
- Geographic (Geo) Potential – 3 variables with 36 questions total
- Entry (Ent) Potential – 12 questions

See Appendix A for a complete list of the questions for each risk element. Questions that are more strongly associated (i.e., predictive) with invasiveness and weed potential are more heavily weighted in the PPQ WRA (Koop et al., 2012). As part of the process, risk analysts are required to qualitatively categorize the uncertainty associated with each answer. Uncertainties are categorized as negligible (= negl), low, moderate (= mod), high, or maximum (= max) based on the quantity and quality of the evidence supporting each answer.

For the ES and Imp risk elements, the Excel workbook automatically assigns a pre-determined score for each given answer, and then sums the scores to produce an overall score for that risk element. Risk elements have the following score ranges: ES = -25 to 32, Imp = 1.0 to 5.1, Ent = 0 to 1. We do not assign scores to the Geographic Potential risk element. Instead, we use the answers to the Geo questions to answer three questions under ES and develop a map of the potential distribution of the species in the United States (see below and Process 4).

Question ID	Question	Answer	Uncer-tainty	Score	Notes (and references)
Establishment / Spread Potential					
ES-1	Select one: (A) Introduced elsewhere long ago (>75 years) but not escaped; (B) Introduced recently (<75 years) but not escaped; (C) Never introduced elsewhere; (D) Escaped/Casual; (E) Naturalized; (F) Invader.			???	Naturalized and spreading in Australia ({Parsons, 2001 #1220}).
ES-2	Is the species highly domesticated (y, n, or ?).	n	low	0	This species is cultivated ({Page, 2006 #5119}), but we found no evidence of domestication.
ES-3	Congeneric weed (y, n, or ?).			???	
ES-4	Shade tolerant at some stage of life cycle (y, n, or ?).	?	max		Unknown
ES-5	Climbing or smothering growth habit (y, n, or ?).	y	negl	1	Species is an herbaceous vine ({NRCS, 2013 #11020}).
ES-6	Forms dense thickets (y, n, or ?).	y	negl	2	Forms dense thickets of up to an acre in size in natural and disturbed environments ({Bossard, 2000 #9400;Weber, 2003 #394}).

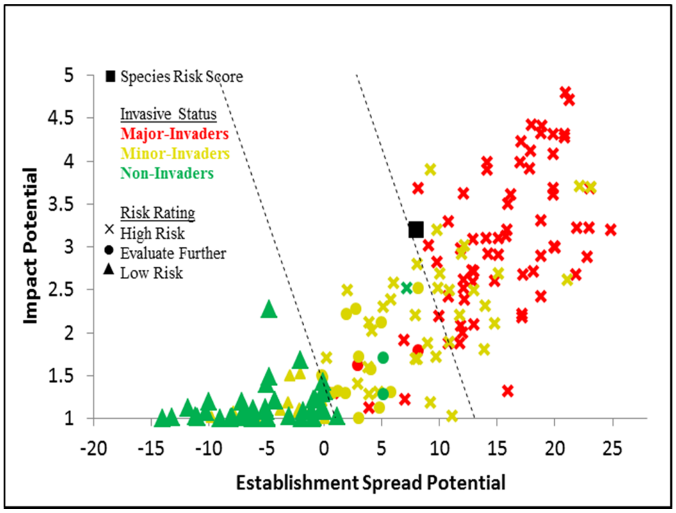
Figure 1. Sample excerpt from the workbook of an in-progress WRA. Evidence is organized under the "Notes (and references)" column for each of the questions. Once enough evidence has accumulated for any given question, the risk analyst enters an answer and uncertainty level ("Answer" and "Uncertainty" columns, respectively).

The predictive model

At the core of the PPQ WRA is a logistic regression risk model that describes the risk potential of the plant taxon being assessed. The model uses the risk scores from the Establishment/Spread and Impact risk elements to determine the likelihood that a given plant taxon will be a non-, minor-, or major-invader (Appendix B). These likelihoods are probabilities that sum to one (or 100 percent, depending on how they are expressed) for any given plant taxon and are automatically calculated by the workbook.

During the development of the PPQ WRA model, decision or risk thresholds were selected that maximized the model's ability to correctly identify non-, minor-, and major-invaders while minimizing predictive errors. These thresholds can be expressed in terms of either the probabilities of invasiveness themselves (Appendix C) or the original risk scores for ES and Imp (Fig. 2). The decision thresholds create three risk rating regions that summarize the outcome of the predictive model: Low Risk, Evaluate Further (moderate risk), or High Risk.

In the PPQ WRA product (i.e., the Word document), the ES and Imp risk scores for the plant taxon under assessment are superimposed on a graph displaying the risk scores obtained for the 204 plant species used to develop and validate the PPQ WRA model (Koop et al., 2012). The decision thresholds that separate the Low Risk, Evaluate Further, and High Risk regions are also shown on the graph for reference (diagonal dashed lines in Fig. 2). This graph is one of the principal analytical outputs of the WRA.



Risk Potential. The taxon's risk score (black square) is plotted in the risk space. The other data represent the risk scores for the 204 species used to develop and test the PPQ WRA model and are plotted for reference. The color of these symbols represents the known behavior of these species in the United States: non-invaders are green, minor-invaders are yellow, and major-invaders are red. The symbol used for each species corresponds to the outcome of the WRA model (Low Risk, Evaluate Further, or High Risk). All species that were categorized as Evaluate Further (those in the middle region of the graph) underwent secondary screening,

Figure 2. Risk space of the PPQ WRA model as determined by the risk scores for Establishment/Spread and Impact Potential. Diagonal dashed lines represent the risk decision thresholds between Low Risk (left), Evaluate Further (moderate risk) (middle), and High Risk (right).

Secondary screening

Plant taxa that receive a risk rating of Evaluate Further (i.e., those with moderate risk potential) are subjected to a secondary screening that helps to reclassify some of the taxa as either High or Low risk. This process helps risk managers as they evaluate possible management options for these moderate-risk taxa (i.e., should the taxa be prohibited or should they be allowed entry into the United States?). During secondary screening, plant traits that are strongly associated with plant invasiveness are examined.

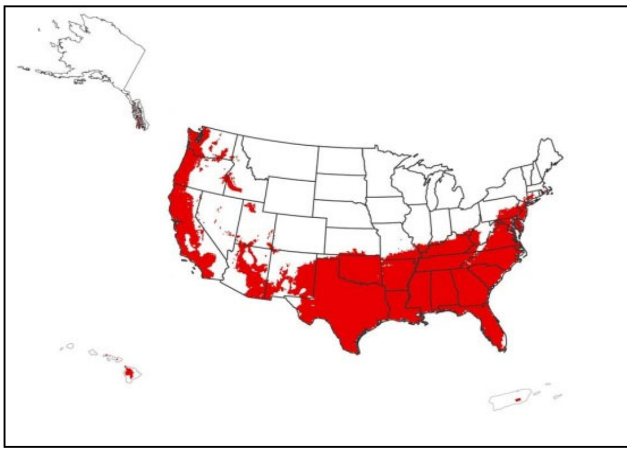
While many different approaches can be taken with taxa that present a moderate risk (e.g., Mack, 1996), the design of the secondary screening tool in the PPQ WRA is similar to the one developed for the Hawaiian WRA process (Daehler et al., 2004). The tool uses a short decision tree containing six questions associated with plant invasiveness that are based on life-history traits and behavior elsewhere in the world. The list of questions and a graph of the secondary screening decision tree are found in Appendix D. In the PPQ WRA, the results of secondary screening are reported immediately after the results of the primary risk model. It should be noted that even after secondary screening, some plant taxa may still remain in the Evaluate Further category.

Geographic potential

Unlike most other WRA models, the PPQ WRA does not consider climatic suitability within the Establishment/Spread or Impact risk elements (i.e., within the predictive model). The United States (including its territories) is climatically diverse because of its large size and the distribution of its land area across different latitudes. As such, we designed the WRA process to be climatically neutral so the model would not be biased against smaller climatic regions (e.g., tropical forests, Mediterranean) of the United States. Thus, the risk ratings reported by the model represent baseline ratings for the plant taxon's 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 (IPPC, 2013b). For this reason, the PPQ WRA reports the geographic potential of a plant taxon separately so that risk managers can make decisions appropriate for their jurisdiction (e.g., national, state, local).

The PPQ WRA addresses geographic potential using three variables—plant hardiness to minimum winter temperatures (plant hardiness zones), Köppen-Geiger climate classes, and mean annual precipitation bands. For each variable, specific values or ranges of climatic compatibility are determined by examining the global distribution of the taxon. These values or ranges are evaluated in a series of 36 yes/no questions (see Section 3, Process 4).

Using geographic information system (GIS) software, we use the information to generate a map of the United States where suitable values for each climatic variable jointly occur (Fig. 3). We report the map and the percentage of the United States that is climatically suitable for the taxon in the WRA. Although all of the United States' territories are considered when estimating the percentage of U.S. area that is suitable, only the map for Puerto Rico is displayed. Work is underway to compare the accuracy and precision of this tool to that of other climate-matching tools.



Geographic Potential. Geographic potential is determined from the plant taxon's distribution in the world, and is based on three climatic variables: plant hardiness to minimum winter temperatures, Köppen-Geiger climate classes, and mean annual precipitation bands. The area shown in red represents the U.S. area where all three climatic variables are suitable for the taxon. This is typically a conservative estimate, as the actual U.S. area suitable is likely to be smaller when other limiting variables are considered. Furthermore, the area where a species is likely to become invasive is likely to be even smaller.

Figure 3. Map of the United States, including Alaska, Puerto Rico, and Hawaii, showing the areas estimated as suitable for establishment for the plant taxon under assessment. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

Entry potential

If a plant taxon is already present in the United States, or if a permit for its entry has been requested, evaluation of this risk element is not necessary. In all other instances, the PPQ WRA examines the entry potential of the plant taxon under consideration. This risk element evaluates the likelihood that a taxon will enter, whether intentionally or accidentally, as a pathway contaminant. The entry potential risk element consists of 12 questions that evaluate the number of pathways with which a plant taxon is or may be associated. Taxa that are cultivated elsewhere or positively valued by society are more likely to enter than other less-valued taxa. The risk score for this element ranges from 0 to 1, with higher scores indicating a higher likelihood of entry.

Uncertainty

Uncertainty is a fundamental component of risk because our knowledge of the factors contributing to risk is rarely perfect. Unlike most other WRA systems, in the PPQ WRA assessors explicitly categorize uncertainty for every answer and risk element, and we also evaluate the sensitivity of the final risk rating to uncertainty. This feature of the PPQ WRA provides risk managers and policy-makers additional information for decision-making.

Summary of uncertainty

As risk analysts answer the questions in the WRA based on the available evidence, they rate their degree of uncertainty for each question. Uncertainty is categorized as negligible (= negl), low, moderate (= mod), high, or maximum (= max). Maximum uncertainty is reserved for questions that cannot be answered with the available evidence [i.e., those that are answered as unknown (?)]. These uncertainty ratings express our degree of confidence in the answers, but also simultaneously express our belief that some other answer may be correct.

The overall level of uncertainty associated with the ES, Imp, and Ent risk elements is also summarized using an index of uncertainty that is automatically calculated and reported in the workbook. The index ranges from 0 to 1, and reflects the uncertainty rating for each question (as categorized by the risk analyst) as well as the relative weight of each question in the risk element. During the PPQ WRA model development and validation (Koop et al., 2012), the average uncertainty index for the Establishment/Spread and impact risk elements was about 0.17. In the final WRA products, the uncertainty index is reported for each risk element.

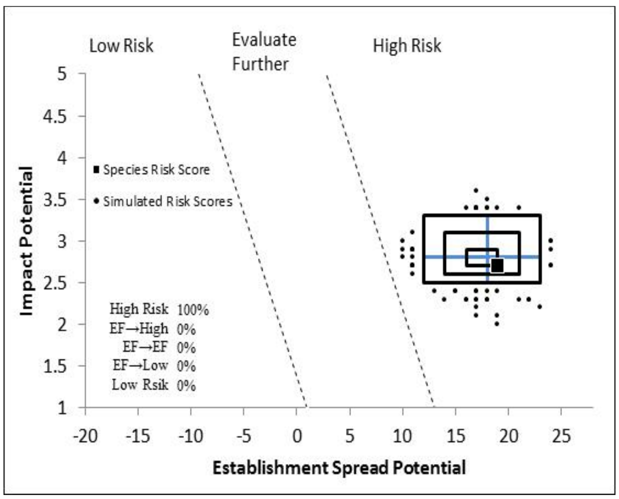
Although uncertainty is also categorized for each question in the Geographic Potential risk element, currently no index of the overall level of uncertainty is generated for this risk element. However, significant sources of uncertainty of this risk element are reported in a written summary.

Uncertainty Analysis

The sensitivity of a taxon's risk scores to uncertainty, and therefore to the final conclusion of the model, is evaluated using a stochastic (probabilistic) simulation that is conducted with the software program @Risk. The stochastic simulation automatically generates new outcomes (i.e., new WRA risk scores) by choosing different answers (e.g., no vs. yes) for each question of the PPQ WRA. The new answer is selected based on the original answer and its associated level of uncertainty. As such, answers with higher uncertainty ratings are more likely to change during the simulation than answers with lower uncertainty ratings. For questions that were answered as unknown, the stochastic simulation randomly selects an answer based on an equal likelihood of occurrence. The process creates new simulated risk assessments and automatically calculates their risk scores.

The stochastic simulation generates 5,000 sets of simulated risk scores. As demonstrated in Figure 4, we graph simulated risk scores in relation to the original risk score for the plant taxon under assessment. The distributions for 50, 95, and 99 percent of the simulated scores are shown as boxes, while the remaining 1 percent are plotted as outlying points. The original risk score that was derived by the analyst is shown as a solid black square. For additional information on uncertainty in the PPQ WRA see Section 3, Process 6.

All simulated risk scores categorized as Evaluate Further (moderate risk) are subjected to secondary screening to determine their final risk category. The uncertainty analysis includes an inset that lists the percentages of simulations (out of 5,000) corresponding to each of the five possible outcomes of the assessment, following secondary screening: 1) High Risk, 2) Evaluate Further → High Risk, 3) Evaluate Further → Evaluate Further, 4) Evaluate Further → Low Risk, and 5) Low Risk (Fig. 4).



Uncertainty analysis. Model simulation results (N=5,000) for uncertainty around the risk score (filled black square) for a species. The blue "+" symbol represents the medians of the simulated risk scores. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent. The remaining 1 percent of the outcomes are shown as outliers outside of the boxes. The inset shows the final risk outcomes for the simulated risk scores [High Risk, Evaluate Further (EF), and Low Risk]. All simulated risk scores classified as Evaluate Further undergo secondary screening; their final risk classification is also shown.

Figure 4. Sample results of an uncertainty analysis for a plant taxon. Simulated risk scores are plotted in the same Establishment/Spread potential (x-axis) and Impact Potential (y-axis) risk space as the original risk score that was derived by the risk analyst.

The larger the distribution of points and boxes around the original risk score, the greater the uncertainty in the WRA. Distributions that are located entirely inside one of the three risk regions (Low Risk, Evaluate Further, or High Risk) indicate that despite the associated uncertainty, the conclusion reached during the PPQ WRA is analytically robust. Distributions of simulated risk scores that are centered over the original risk score are "balanced," indicating that the impact of uncertainty has no net direction relative to the original score. Most of the time, the center of the distribution will be slightly off-center from the original score, as shown in Figure 4. Such a scenario is common and usually not a concern. However, an original risk score that is located outside of the three boxes indicates a significant amount of uncertainty associated with the assessment. Addressing the uncertainty in the analysis will likely bring the two closer together, either by moving the original risk score towards the center of the uncertainty distribution (as is usually the case) or coalescing the uncertainty distribution over the original risk score, or perhaps a little of both. In an ideal WRA, the uncertainty distribution is small, centered over the original risk score, and entirely located within one region of risk, and all simulated assessments result in the same conclusion as the original assessment.

The final product

A summary of the PPQ WRA results, including pertinent graphs and maps, answers to the questions, uncertainties, supporting evidence, and general information about the plant taxon, is compiled in a Microsoft Word document. The final report is about 15-20 pages long and includes the following sections:

- **Title page.** Identifies the plant taxon using scientific and common names and provides one or more images.
- **Background and species information.** Describes the WRA initiating event, the taxon's global distribution, and its status in the United States.
- **Analysis**
    - Provides narrative summaries of each of the risk elements assessed (Establishment/Spread, Impact, Geographic, and, if applicable, Entry Potential).
    - Reports values for risk scores, uncertainties, and probabilities of invasiveness.
    - Includes figures summarizing the analytical results of the model (geographic potential, risk potential compared to that of the taxa used to validate the model, and results of the uncertainty analysis).
- **Discussion.** Summarizes the final conclusions from the assessment and presents additional information relevant to decision-makers.
- **Literature cited.** A list of all references and evidence considered.
- **Appendix A.** A copy of the data from the Excel worksheet containing the WRA questions and their answers, uncertainties, scores, and associated evidence.

Section 3: Conducting the PPQ WRA

In this section, we provide guidance to risk analysts on how to conduct a WRA using the PPQ WRA process. The processes in this section satisfy the requirements of Stage 1 (Initiation) and Stage 2 (Risk Assessment) of the three stages of pest risk analysis described in international and regional standards for pest risk analysis: ISPM No. 2 (IPPC, 2011), ISPM No. 11 (IPPC, 2013b), and RSPM No. 32 (NAPPO, 2008).

Before beginning work on a PPQ WRA, ensure you have the following basic documents and tools:

- This guidelines document: *Guidelines for the USDA-APHIS-PPQ Weed Risk Assessment Process*, Version 1
- The Microsoft Excel workbook file: *Form E-300 WRA guidelines and template.xlsx*. Save this file to an appropriate folder and rename it with the scientific name of the plant taxon being assessed (i.e., "Genus species.xlsx"). The majority of your assessment will be conducted within this workbook. Here, we refer to this document as the Excel workbook or simply as the workbook. The workbook has multiple worksheets, so if we write "worksheet," we are referring to a particular section of the workbook.
- Word-processing software, such as Microsoft Word.
- The Microsoft Word document: *Form E-301 WRA Document Template.docx*. Save this file to an appropriate folder and rename it with the scientific name of the plant taxon being assessed (i.e., "Genus species.docx"). You will present and summarize the results of the WRA in this document. Here, we will refer to this document as the Word template or simply as the template.
- @Risk software. This program is used to evaluate the sensitivity of the risk assessment to uncertainty.
- ArcGIS software. This program is used to generate a map (optional) of the areas in the United States suitable for taxon establishment.

PPQ WRAs are completed using the following eight processes, which are generally conducted in the order in which they are listed:

- Process 1: Gathering background information
- Process 2: Gathering the evidence
- Process 3: Answering the questions and describing uncertainty
- Process 4: Assessing geographic potential
- Process 5: Assessing entry potential
- Process 6: Uncertainty analysis
- Process 7: Finalizing and reviewing the analysis in the Excel Workbook
- Process 8: Assembling the WRA

Process 1: Gathering background information

During this process, familiarize yourself with the taxon being evaluated and begin gathering background information that will be needed for the "Species Information" section in the Word template. Process 1 includes verifying the identity of the taxon, listing synonyms and common names, and documenting the initiating event for the WRA (i.e., why the WRA is being conducted). In this process, we also check online databases to get an overview of the global and U.S. distribution of the taxon. To complete this process, follow the guidance in sections 1-1 to 1-6.

1-1. Verifying taxon identity and listing synonyms and common names

Determine the appropriate taxonomic level of analysis. Although species is the most typical taxonomic level for analysis, other levels may be more appropriate or necessary, particularly for cultivated plants. The use of a taxonomic level above (e.g., genus) or below (e.g., cultivar) the species level should be supported by sound rationale. For example, industry may wish to import an apparently non-invasive cultivar of a generally recognized invasive species. In this case, the WRA should evaluate the taxon at the cultivar level.

Verify the taxonomic identity to ensure that the scientific name being used is valid. The identity of the plant taxon and any synonyms should be determined using the following accepted, internationally recognized sources.

- For taxonomic issues or inconsistencies, search for the scientific name in:
  - Germplasm Resources Information Network (GRIN). United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program (NGRP). https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch.aspx?language=en. Note: We typically try to follow taxonomy and nomenclature given by GRIN.
  - The PLANTS Database (PLANTS). United States Department of Agriculture, Natural Resources Conservation Service (NRCS), The National Plant Data Center. http://plants.usda.gov.
  - Kartesz, J. T. The Biota of North America Program (BONAP), North American Vascular Flora, Taxonomic Data Center, Chapel Hill, NC. http://bonap.net/tdc.
- If you find inconsistencies or the taxon is not listed in the above sources, sources, expand your search to other sources, such as those listed below. If necessary, consider contacting taxon-specific experts, or the experts with GRIN, PLANTS, or BONAP.
  - The Plant List, a working list of all plant species. Royal Botanic Gardens, Kew and Missouri Botanical Garden http://www.theplantlist.org/.
  - Relevant flora and taxonomic treatments
  - Integrated Taxonomic Information System. http://www.itis.gov/.
  - VASCAN, Database of Canadian vascular plants http://data.canadensys.net/vascan/search?lang=en

In the "Species Information" section in the Word template, add the information listed in the bullets below. As you conduct the WRA, you will likely revise and amend this information. This information may also be entered at the bottom of the "Screening Tool" worksheet in the workbook and later transferred to the Word template during Process 7.

- *Taxon, authority, and common name*. Record this information at the top of the "Species Information" section in the Word template (i.e., the heading). If you use a name different than the one provided by GRIN, explain why under "Synonyms." List the primary English common name of the taxon. GRIN will often have numerous common names. If the taxon occurs in the United States, use the most prevalent U.S. common name. If it is not present in the United States, use the most representative name. The species, authority, and common name will be required elsewhere in the Word template (e.g., cover page).

- *Plant family*. Plant family is usually straightforward. However, different taxonomic systems may treat and organize plant genera among families variably. In such cases, we typically follow GRIN taxonomy.
- *Synonyms.* If the taxon has few synonyms (e.g., less than six), list them all. However, if it has numerous synonyms, list only the relevant ones, including the basionym (the original, validly published name of the plant taxon). Relevant synonyms are those that would be encountered or used today or in the recent past, or those that were used in the evidence you provided in the WRA. If the plant taxon is currently being referred to by multiple scientific names in the literature, identify the names and describe who is using those synonyms. Indicate whether or not you used these additional synonyms in the literature search.
- *Common name(s).* Only list the major English common names and any other names that were relevant for the WRA. After each name, provide at least one citation documenting the use of that name.

1-2. Familiarize yourself with the plant taxon

Before beginning the main literature review for the WRA, spend a few minutes familiarizing yourself with the taxon. Consider the taxon's size, life form (herb, vine, tree, grass, etc.), life cycle (annual, perennial), and preferred natural habitats. Find this information through a general web search (e.g., Google or Bing), taxonomic treatments, or species factsheets. We also recommend searching for images of the taxon on the internet. A basic understanding of the taxon will help you evaluate the evidence.

1-3. Documenting the initiating event

Under "Initiation" in the "Species Information" section of the Word template, describe in a few sentences why the WRA is being conducted. Cite emails and/or discussions that resulted in the initiation. Include the name and affiliation of the requestor.

For examples of why a PPQ WRA may be initiated, see Section 1 (under "Risk analysis framework") above.

1-4. Briefly review the foreign and U.S. distribution of the taxon

Understanding the foreign and U.S. distribution of a taxon is important for risk managers who must make regulatory or operational decisions, but it is also important for risk analysts conducting the assessment. Taxa that are present in the United States will require additional evaluation to determine the extent and nature of their U.S. distribution. Information required for this circumstance is best obtained while conducting the risk assessment and is described under Process 2.

During Process 1, it is sufficient to review a species' distribution by visiting a few online databases. This information will help prepare the analyst for the depth of evaluation that will be needed under Process 2.

Briefly review the species' distribution by visiting the GRIN, PLANTS, and BONAP databases identified in section 1-1. In addition, visit the Global Biodiversity Information Facility (GBIF), which maintains records on plant distribution. For records associated with global positioning system coordinates, GBIF maps occurrences (e.g., Figure 5). During Process 4 (Assessing the geographic potential), the analyst will download the distribution records from GBIF.

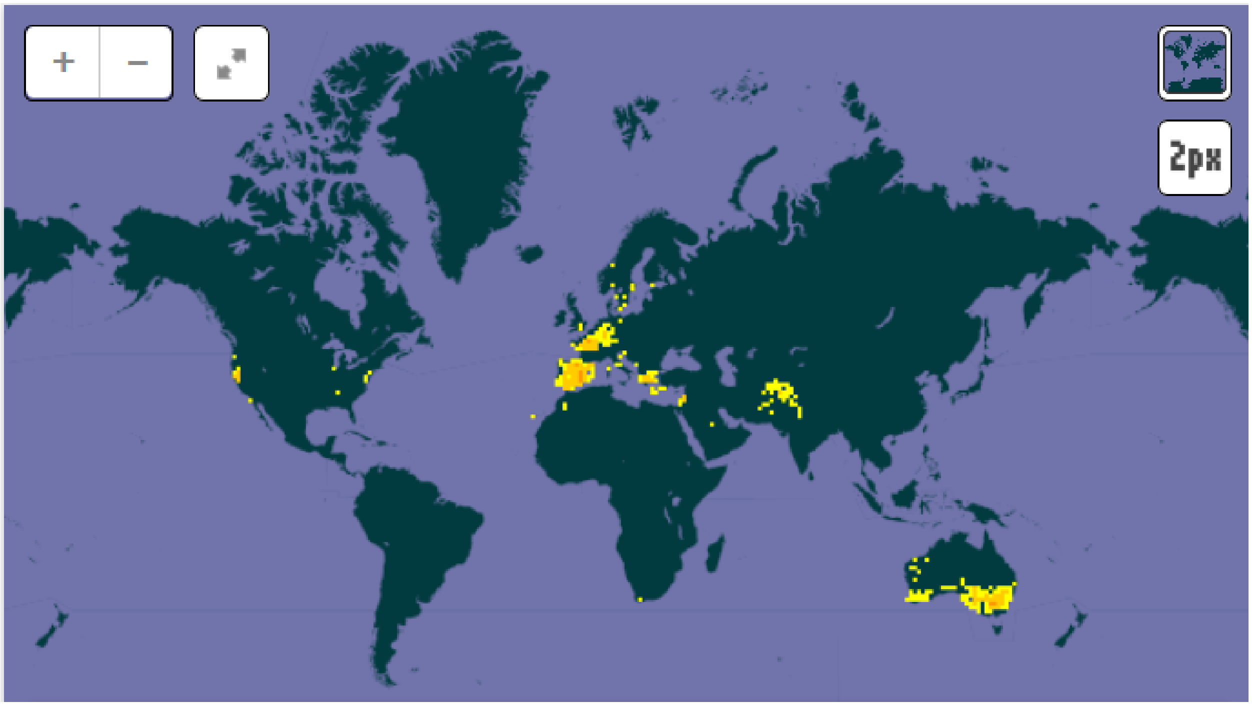


Figure 5. GBIF map of the plant records associated with point occurrences for *Heliotropium europaeum.*

Process 2: Gathering the evidence

Although PPQ WRAs are summarized in a narrative format, the assessment itself is highly structured and uses a set of specific questions to evaluate risk. Specific evidence is required to answer the questions in the PPQ WRA. In Process 2, we gather the evidence needed to answer these questions, as well as to describe the taxon's U.S. distribution and status. During this process, we may also discover additional information relevant to the taxonomy and foreign distribution of the species.

We recommend that new analysts begin with section 2-1. Experienced analysts already familiar with the PPQ WRA may begin with section 2-2.

2-1. Familiarizing yourself with the questions and the Excel workbook

Before starting your first PPQ WRA, we recommend that analysts review the WRA questions and their associated question-specific guidance. An understanding of the questions and the kind of evidence required to answer them is critical for compiling the most useful evidence and for completing the assessment in a timely manner. This also helps reduce analyst subjectivity. A list of the questions and their associated guidance is provided in Appendices E through G. The questions and their guidance are also found in the “Screening Tool” worksheet of the workbook, where the guidance for each question is embedded as a comment; hover your mouse over the cell containing the question to see a pop-up with the guidance.

The question-specific guidance provides a detailed description of the kind of evidence required to answer each question. It describes the evidence required for yes and no responses, and indicates when a question can be answered as no based on a lack of evidence or when using congeneric information would be inappropriate. The guidance also includes definitions, clarification of complex issues, lists of recommended resources, suggestions for search criteria, and full examples of answered questions. There is a large amount of information in the question-specific guidance, so it is important to carefully read it before you begin working on a WRA. Analysts usually become very comfortable with the material only after completing 3-5 assessments.

We also recommend that all new analysts familiarize themselves with the content and structure of the workbook. In Table 1 we list all of the worksheets in the workbook and briefly describe their content or purpose.

Table 1. Descriptions of worksheets within the PPQ WRA Excel workbook.

Worksheet	Description
Revision History	The WRA process is managed under a quality management system to ensure that all products are of the highest quality and are based on sound science. Under the quality management system, some documents are controlled and must be approved by the appropriate staff member before they can be used. The workbook is a controlled document; its version, effective date, and approver are recorded here. This worksheet also provides a history of the revisions to the workbook.
Screening Tool	All of the questions in the WRA and their associated guidance are located in this worksheet. Columns for recording the evidence, answer, and uncertainty for each question are provided (see Processes 2 and 3). Near the bottom of the worksheet are cells reporting risk scores, probabilities of invasiveness, and overall model results. A block of gray cells is also provided for the analyst to record general information about the taxon, the assessment, and his or her name and affiliation. The references used to support the WRA are recorded below that block of cells.
Risk Score Plot	This worksheet contains two graphs that we use in our WRA products. The top graph (the risk score plot) is automatically updated as the analyst answers questions in the “Screening Tool” worksheet. The bottom graph contains the results from uncertainty analysis; it is automatically populated when the analyst enters the 5,000 simulated risk scores from the stochastic simulation (see Process 6).

Worksheet	Description
Uncertainty	This worksheet contains the stochastic model used by the software program @Risk for the uncertainty analysis (see Process 6). Analysts do not need to enter or change any information in this worksheet. It is password protected to avoid accidental changes to its content. If you do not have @Risk installed and open on your computer, many of the cells on this worksheet will report errors. This is normal and can be ignored.
LUT	This is the Look-Up Table (LUT) for determining what score to assign to answer choices. Analysts do not need to enter or change anything in this worksheet. It is also password protected.
Notes	Analysts can record additional information on this worksheet that does not correspond to any of the specific questions on the "Screening Tool" worksheet.
Climate Worksheet	This is a blank worksheet that the analyst can print and used for taking notes during analysis of a taxon's geographical potential (Process 4).
GBIF Data	Data downloaded from the GBIF database is recorded in this worksheet (Process 4).
Maps	This worksheet records a few pieces of information related to the geographical potential analysis. In addition, the analyst inserts a copy of the final map showing the regions of the United States that are suitable for the taxon's establishment (Process 4).
TableForWord	PPQ WRAs are conducted in the Microsoft Excel workbook but are reported in a Word document. This worksheet automatically duplicates the information from the Screening Tool worksheet into a format that the analyst can paste into Word (Process 7).

2-2. General approach to evidence gathering

We recommend gathering evidence source by source and not question by question. In other words, as you read each source and find information relevant to a particular question, record that evidence in the "Notes (and references)" column of the "Screening Tool" worksheet of the workbook. Consider quoting from the source rather than paraphrasing when the source is particularly compelling or useful. Try to read each source only once.

Focus on gathering sources that provide direct evidence. Direct evidence answers the question without the need for any indirect or circumstantial evidence, inferences, or assumptions. For example, for the question "Is the taxon shade adapted?" evidence stating "This species is adapted to shade and can survive under low light conditions for extended periods" is considered direct evidence. In contrast, evidence stating "This taxon is a pioneer and early successional species" is not direct evidence, but could be interpreted to suggest that the taxon is not shade adapted because pioneer and early successional species are generally light-demanding taxa. This latter type of evidence, while valid, is indirect or circumstantial, and usually associated with higher uncertainty.

During Process 2, enter only relevant information in the “Notes (and references)” column for each question. Do not answer the question or categorize the uncertainty until you have completed the majority of the literature search or have difficulty finding relevant new information. When you have accumulated enough evidence to inform a particular question, answer it and categorize the level of uncertainty in the “Answer” and “Uncertainty” columns of the “Screening Tool” worksheet as described under Process 3.

2-3. Reviewing the literature

General literature search. Consult the types of resources listed below (in whatever order you choose) to gather the majority of the evidence for the plant taxon being assessed. Although we list them first, note that much of the world’s knowledge on invasive species is not published in peer-reviewed journals. Gather evidence from different sources and locations where the taxon occurs. Include information on impacts and invasive behavior from anywhere in the world, including information from the WRA area if it occurs there. In general, try to find two to four references for each question; reduce uncertainty by using more sources if the evidence is weak or has discrepancies. A broad evidence base should strengthen the assessment and lower your uncertainty.

- **Major electronic journal databases and search engines** (e.g., CAB Abstracts, BIOSIS, Web of Science, AGRICOLA, SCOPUS). These can be used to find primary literature (e.g., research articles) on the taxon. The introduction/background and methods sections of articles that do not initially appear relevant often provide useful information on biology and invasive species status.
- **Major weed/invasive species books and guides** (e.g., Holm et al., 1997; Weber, 2003). These works often summarize pest biology, impacts, management strategies, and ongoing efforts on control.
- **Proceedings** (e.g., Brunel, 2005; Veitch et al., 2011). These are collections of seminars and posters presented at meetings, workshops, and conferences. They include general and taxon-specific information on research, policy, and management information. Proceedings are usually available online.
- **Pest databases and other factsheets** (e.g., CABI, 2013a, 2013b; ISSG, 2013).
- **General references (books, textbooks) on biological invasions or weeds** (e.g., Booth et al., 2003; Radosevich and Holt, 1984). Although these infrequently provide detailed taxon-specific accounts, they sometimes contain important information.
- **Regional plant lists** (e.g., Acevedo-Rodríguez and Strong, 2012; Space and Flynn, 2002). These lists of native and/or exotic taxa occurring in a region are useful for determining presence/absence of a plant taxon in a region or country and, for some types of questions, are sometimes the only references available.
- **Annotated plant lists** (e.g., Randall, 2007; Verloove, 2006; Waterhouse, 1993). These can provide additional information, such as taxon status (casual, naturalized, invasive), date of introduction or naturalization, distribution within a region, pathways/vectors, life form, and habitats invaded (natural, agricultural, etc.).
- **Floras** (e.g., eFloras, 2013). These are botanical treatments of native and naturalized taxa in a region. They usually include dichotomous keys for identification, detailed botanical descriptions, and information on status, habitats, distribution, and whether a taxon is native or naturalized. They can be useful for determining plant life form, taxonomy,

family, and fruit/seed morphology. Floras usually provide information needed for the general botanical description of the taxon under the "Species Information" section of the WRA template.

- **Herbaria** (e.g., Univ. of California, 2014; Univ. of Florida, 2014). These are collections of pressed and dried plants that are often labeled with information from the collection sites. Because herbarium records often precede published distribution information by years to decades, they are useful for identifying additional regions of occurrence and for evaluating status in an area (e.g., casual, naturalized, invasive) and possible impacts.
- **Gardening compendia** (e.g., Bailey and Bailey, 1976; Foulis, 2001). These provide horticultural information and may help determine taxon popularity and date of introduction.
- **Gardening websites and forums** (e.g., Dave's Garden, 2014; GardenWeb, 2014). These sites can contain plant horticultural factsheets, which give information on plant behavior and general growing conditions (light/shade, soil, plant hardiness zones). They are useful for determining cultivation status and for finding evidence of anthropogenic impacts and control.
- **Google Scholar** (http://scholar.google.com). This search engine focuses on scientific literature, including peer-reviewed articles, proceedings, and reports. It can provide very useful and timely information. Results may overlap with electronic journal database results, but Google Scholar is useful for finding more recent publications and reports that are not available in other databases. Links to full-text PDF documents are sometimes available.
- **General internet search engines** (e.g., Google, Bing). This type of search is good for finding information from local or state weed managers, university extension agencies, and non-scientific sites (e.g., forums, gardening sites, invasive species sites).
- **Other WRAs** (e.g., Univ. of Hawaii, 2014; DEPI, 2014). WRAs prepared by other governments or groups can be very useful to fill in gaps and verify other information.

If you need more evidence to answer the questions after conducting a general literature search as described above, conduct more specific searches or search at the genus level.

Specific searches. Conduct question-specific searches using the recommended resources and keywords for a given question (e.g., taxon name + breeding system + mating system). These resources and keywords are available within the question-specific guidance of this document (see Appendices E through G). However, we do not recommend searching for more than an hour to fill in gaps in information after the general literature search, because such information may not be available and it may not alter the outcome of the WRA. Questions can always be answered as unknown or no (based on a lack of evidence) as appropriate. If, after completing the WRA and running the uncertainty simulation, it becomes apparent that additional evidence would make a difference in the outcome of the WRA, then consider further, targeted searches.

Congeneric searches. We can use information from closely related taxa (i.e., congeners) to fill in some information gaps, particularly for "simple" biological traits that are relatively well conserved within taxonomic groups. For example, fruit type is generally well conserved within plant genera, making it likely that most members of a given genus will have the same fruit type and dispersal mechanisms. However, we advise against using congeneric evidence for questions about more complex processes. For example, congeneric evidence should not be used to answer questions about a taxon's invasiveness, weediness, impact, and other "behaviors," as they are determined by complex interactions of multiple factors (e.g., species traits, environmental features, and human processes). In the question-specific guidance (Appendices E, F, G, and H), we clarify for which questions it is appropriate to use congeneric information. As a general rule, we try to limit the use of congeneric evidence to only a few questions in any given WRA, because the assessment should focus on the specific taxon.

2-4. Gathering evidence on U.S. distribution and status of the plant taxon

As you gather evidence for the WRA questions, document information relevant to the U.S. distribution and status of the taxon. Specifically, determine if the taxon is naturalized or cultivated in the United States. If it is naturalized, describe that distribution and any efforts to control or manage the species. Although that information does not affect the outcome of the assessment (i.e., the risk score and rating), it is part of the background information on the taxon and is likely to be critical information for decision-makers when setting policies or prioritizing resources for weed management. Specific issues that should be addressed and suggested resources for addressing them include:

- ***Extent of U.S. cultivation.*** Is the plant taxon cultivated in the United States, and if so, what is the extent of cultivation? Decision-makers consider the extent of cultivation when deciding whether or not a taxon should be regulated, because regulatory programs are likely to be ineffective against widely cultivated or distributed taxa. The extent of cultivation varies widely and can be evaluated in several ways (Fig. 6). If the taxon is cultivated in the United States, consider whether it is cultivated commercially or only privately. Taxa that are offered in major retail stores (e.g., Lowe's, Home Depot, Walmart) or grown and distributed by major commercial growers (see below) can be considered widely cultivated. Also consider visiting online gardening forums and seed exchange websites to gauge the amount of interest and private trading. Finally, consider the number of cultivars that are available for the taxon, which can indicate how extensively it is cultivated. Examples of sources for this information include:
  - Major commercial growers, distributors, and retail stores:
    - Monrovia: http://www.monrovia.com/plant-catalog/
    - Green Leaf: http://greenleafnursery.com/index.cfm/fuseaction/plants.main/index.htm
    - Bailey Nurseries: http://www.baileynurseries.com/imagelibrary/gallery/
    - San Marcos Growers: http://www.smgrowers.com/index.asp
    - Lowe's Home Improvement: http://www.lowes.com/cd_Lowes+Plant+Guide_253427968_?url=plantsearch.aspx
  - National and regional plant finder databases are good sources to determine if a given taxon is commercially propagated at regional or local levels.
    - Backyard Gardener: http://www.backyardgardener.com/Plant-Index/
    - Plant Information Online: https://plantinfo.umn.edu/
    - Florida and U.S. Gulf Coast: http://www.plantfinder.com/
  - Major U.S. and North American horticultural references are useful as well.

        - Hortus [e.g., Bailey, L. H., and E. Z. Bailey. 1976. Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada (revised and expanded by The Staff of the Liberty Hyde Bailey Hortorium). Cornell University. 1290 pp.] (Compare listings among the different editions to determine whether a taxon was introduced recently.)
        - Dirr, M. 1998. Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation and Uses. Stipes Pub., Champaign, Illinois. 1187 pp.
        - Online Plant Guide: http://www.onlineplantguide.com/Index.aspx
    - Online Gardening Forums
        - Dave's Garden: http://davesgarden.com/guides/pf/
        - GardenWeb: http://forums.gardenweb.com/forums/
    - Garden Collections
        - Missouri Botanical Garden: http://www.livingcollections.org/mobot/Home.aspx
        - Fairchild Tropical Garden: http://www.fairchildgarden.org/science-conservation-/plant-collections/tropical-fruit-collection/list-of-living-plants
        - The Arnold Arboretum: http://arboretum.harvard.edu/plants/plant-inventory/
    - General internet search engines (e.g., Google, Bing): You can also do a general internet search with the keyword "buy" + the taxon name to generate a list of places selling the plant online.
- ***Naturalized distribution in the United States.*** Is the taxon naturalized in the United States, and if so, what is the extent of its distribution and invasive status? In how many and which states is it naturalized? If only a few occurrences exist, you should verify if the plant taxon is truly naturalized or if the occurrences represent escaped or cultivated plants. Recommended sources to address this issue include the following:
    - Kartesz, J. T. The Biota of North America Program (BONAP). North American Plant Atlas, Taxonomic Data Center, Chapel Hill, North Carolina. http://bonap.net/tdc.
    - The PLANTS Database. United States Department of Agriculture, Natural Resources Conservation Service (NRCS), The National Plant Data Center. http://plants.usda.gov.
    - EDDMapS: Early Detection and Distribution Mapping System. The University of Georgia, Center for Invasive Species and Ecosystem Health. http://www.eddmaps.org/. Not all observations in EDDMapS have been verified, which raises the uncertainty surrounding the data.
- ***Management and regulatory status in the United States***. Is the plant taxon being managed or regulated in the United States, and if so, what is being done? The scope of this evaluation is very broad and includes action taken by any state, private, or public entity, including private landowners and other Federal agencies. For instance, do any states list the taxon as a Noxious Weed? Is it on advisory lists or targeted for control by Federal agencies, such as the U.S. Forest Service, the U.S. Fish and Wildlife Service, or the Department of Transportation? Likewise, is it on advisory lists or targeted for control by groups such as invasive plant or exotic pest plant councils? We generally do not

contact stakeholders and experts for this type of information, but that may be warranted if you find conflicting information in the literature.

Some preliminary sources for this information include those listed below. Other sources that provide more detailed information will likely appear during the literature review.

- PPQ. 2010. Federal Noxious Weed List (http://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/weedlist.pdf). United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (PPQ). Normally, the taxon being assessed would not already be listed as a Federal Noxious Weed, but we listed this resource here in the rare case that you need to consult it.
- The BONAP and PLANTS databases linked above. However, these databases may not have the most up-to-date information on state weed lists, and they sometimes confound noxious weed lists with noxious seed lists.
- The National Plant Board's page on Regulated Noxious Weeds (http://nationalplantboard.org/laws-and-regulations/state-regulated-noxious-weeds/). This page contains links to state and federally regulated weeds.
- State Noxious-Weed Seed Requirements Recognized in the Administration of the Federal Seed Act (http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5090172). United States Department of Agriculture, Agricultural Marketing Service.
- Least Wanted: Alien Plant Invaders of Natural Areas (http://www.nps.gov/plants/alien/fact.htm). United States Department of the Interior, National Park Service, Plant Conservation Alliance, Alien Plant Working Group.
- Invasive Plant Atlas of the United States (http://www.invasive.org/weedus/index.html). Collaborative project between the National Park Service, the University of Georgia Center for Invasive Species and Ecosystem Health, the Invasive Plant Atlas of New England and the Lady Bird Johnson Wildflower Center.
- National Association of Exotic Pest Plant Councils (EPPCs) (http://www.naeppc.org/). This organization is a coalition of state and regional Exotic Pest Plant Councils (EPPCs) and Invasive Plant Councils (IPCs). This site has links to the websites for U.S. EPPCs and IPCs.

Extent of Cultivation	Level of Cultivation		Public Interest in gardening forums	Number of Cultivars
Widely Cultivated	Commercial	Sold by major retail stores such as Walmart, Lowe's, Home Depot	Dozens of comments	Dozens or more
		Grown by major plant distributors such as Monrovia, Green Leaf, Bailey, San Marcos Growers		
		Offered by only local, small, or specialized nurseries	Some comments	Some cultivars
	Private	Maintained by only specialty or private collectors		
Limited Cultivation		Only present in botanical gardens	A few	A few
Not Cultivated		Not cultivated	No public comments	None

Figure 6. Framework for considering the extent of a taxon's cultivation in the United States.

Process 3: Answering the questions and describing Uncertainty

Most of the evidence gathered during Process 2 will pertain to the WRA questions contained in the "Screening Tool" worksheet in the workbook. In Process 3, we use this evidence to answer the WRA questions and qualitatively describe the uncertainty associated with the answers. Although we present general guidance for this process in three separate sections below, risk analysts will usually be completing all of these sections concurrently. You should familiarize yourself with all the guidance below before starting this process. For further information related to each question, refer to the question-specific guidance (Appendices E, F, G, and H).

3-1. Presenting and evaluating the evidence

In this section, we provide general guidance on how to organize, present, and evaluate the evidence so that your answers and uncertainty ratings are well and clearly supported. The gathered evidence should be placed in the "Notes (and references)" column of the "Screening Tool" worksheet in the Excel workbook. Because the text in this column will form part of the final Word document, present the evidence in complete sentences, organized in an intuitive way, and properly cited. Review the evidence and ensure that it is assigned to the appropriate question.

Present the strongest evidence first. Present the strongest evidence first, unless the nature of the question or the evidence suggests some other order is more appropriate. Direct evidence is stronger than indirect evidence. If you have strong evidence from multiple sources and uncertainty is negligible, consider deleting weaker evidence to keep the notes succinct.

Use direct quotations or paraphrase, as appropriate. For expediency, we sometimes present the evidence by quoting from the literature. This has the added benefit of capturing the source's wording. However, when you need to report evidence from many different sources, paraphrasing may be more concise and understandable. In such instances, citing multiple sources in a single sentence is good practice.

Provide citations for all evidence. Cite **all** published literature and information from databases, webpages, government documents, and personal communications. Citations help ensure transparency and allow readers to locate the original source if needed.

Address each question as precisely as possible. Eliminate information that is not directly related to the question to keep the evidence as succinct as possible and to avoid confusing the reader. For example, the evidence "Taxon X reduces species diversity, lowers crop yield, and hinders navigation" should be split up among the appropriate questions. Thinking critically about what the different questions are asking is important. Although some questions are related or build on each other, you should not use the same evidence to answer multiple questions, because each one addresses a different risk factor. If the distinction between different questions is not apparent to you, carefully read the guidance or consult with the team.

Limit the number of inferences. The PPQ WRA is an evidence-based process, meaning that the evidence answers the questions, not the analyst. If direct evidence is not available to support an answer, the analyst can make inferences using indirect and circumstantial evidence. An inference is a conclusion drawn by connecting indirect pieces of evidence in a logical manner. However, analysts should limit the number of inferences as overusing them will weaken the assessment and may have a significant impact on the final risk score of the species. In general, we recommend limiting the use of inferences to those questions that have the word "likely" in them (i.e., ES-15, ES-16, Imp-N4, Imp-N5, and Imp-P3), but inferences can be used elsewhere as appropriate. When you make an inference, be sure to make it clear that this is the case (e.g., state that the evidence suggests X because of Y and Z…).

Do not use speculation or suppositions to support positive answers. A supposition is an opinion or statement based on incomplete evidence. For example, for the question "Does the taxon change species diversity?," answering yes would be inappropriate if we only knew that the taxon being assessed is a vine and that some other species of vines have reduced biodiversity. In this case, the analyst would be speculating, because not all vine species reduce biodiversity. When reasonable, you can use speculation to justify an answer of "unknown" when a lack of evidence would otherwise suggest a response of no (see additional guidance below). For example, the following would be appropriate: "Although we found no direct evidence that taxon X reduces biodiversity, this taxon is spreading aggressively into undisturbed forests [citation]. Because it is very similar to its congeners Y and Z, which have been shown to reduce biodiversity [citation(s)], we answered this question as unknown." Compare this example with the one given at the beginning of the paragraph.

Provide an explanation for your answer when the evidence is conflicting. Sometimes the evidence is conflicting because it supports different answers. In these cases, organizing and clearly presenting all of the evidence is important. When evaluating each piece of evidence, consider its overall weight. Consider the evidence's quality, source, independence, and specificity to the taxon and question at hand, as well as how many pieces of evidence support one answer versus another. The evidence may support a single, best answer, but if not—if it equally supports two or more choices—answer the question as unknown. Regardless of the outcome, provide an explanation for the choice and the associated uncertainty.

Do not over-interpret any given piece of evidence. It can be easy to read too much into any piece of evidence or to overuse it for multiple questions. For example, a regional list of invasive taxa may classify a taxon as a "transformer." Based on the definition of that term in the source, the analyst may be tempted to use the information to answer questions about impacts on ecosystem processes, habitat structure, and species diversity. However, unless the source specifically mentions that the taxon had *all* of those impacts, this would be over-interpreting the evidence. In this case, we only know for certain that the taxon had at least one of those impacts. The analyst should not ignore the evidence that the taxon is considered a "transformer," but will have to decide how best to use that evidence (e.g., for a question for which much less other relevant information was found). For the other questions where the evidence could also apply, it would be appropriate to state, "This taxon is considered a transformer, but it was not clear what specific impacts it is having. Consequently we answered unknown for this question about changes to ecosystem processes, but assumed that the taxon is changing biodiversity (see Imp-N3)."

Use evidence relating to weeds and invasive plants with caution. As explained in the Introduction, these terms are inconsistently defined and used. Within the scope of answering the assessment questions, we follow Richardson et al.'s (2000) concept of an invasive species as one that can establish, naturalize, and spread, regardless of the type of system in which it is present. This definition does not consider harm the taxon may be causing. A weed, on the other hand, has negative impacts or is perceived as problematic. Its ability to naturalize and spread is not relevant for assessing impact. Thus, within the scope of the WRA questions, these terms are distinct and address only one of the risk elements each: invasiveness gives information about Establishment/Spread Potential, while weediness gives information about Impact Potential (Table 2). When compiling and evaluating the available evidence, carefully consider how each source uses the terms "weed" and "invasive plant." As a general rule, the analyst should not use the term "weed" in evidence presented under Establishment/Spread Potential or the term "invasive plant" in evidence presented under Impact Potential.

Table 2. Comparison of the terms "invasive plant" and "weed" as they relate to the PPQ WRA.

Term	Definition	Relevant WRA Section
"Invasive plant"	A plant capable of establishing, naturalizing, and spreading, regardless of the type of system in which it is present	Establishment/Spread Potential
"Weed"	A plant taxon that has negative impacts or is perceived to be problematic by people	Impact Potential

Indicate the use of congeneric data. A congener is a species that is in the same genus as the taxon being assessed. In the PPQ WRA, data from congeners with similar life forms and biology can be used to support weak or incomplete evidence from the taxon being evaluated. Congeneric data can also be used when specific data in unavailable. When using such information, the source(s) must identify the congener(s), and the evidence must be clear and reasonably certain. Statements/facts about an entire genus (e.g., "the genus *Vaccinium* produces fleshy fruits that are dispersed by birds") are *not* considered congeneric information and may be used as direct evidence for every taxon within the genus.

Limit the use of congeneric data to answer Impact Potential questions. Generally, congeneric information can be used to support a yes or no answer for Establishment/Spread Potential risk element questions, because many of those questions concern relatively simple biological traits that may be well conserved among members of a genus (e.g., fruit type, life form). In contrast, Impact Potential questions focus on the consequences of complex interactions of traits and the invaded environment. Therefore, analysts should **not** use evidence from congeners to support yes answers to Impact Potential questions for the species being evaluated. However, you can use congeneric evidence to support answers of no and unknown when reasonable. For example, if the taxon is not well known and you think it could have certain impacts based on its similarity to congeners that have these impacts, answer unknown and provide your reasoning. Use of congeneric information is allowed in this fashion in the Impact Potential risk element, because in this element answers of no and unknown are scored as 0. We discuss a few other exceptions to the use of congeneric information for the Impact Potential risk element in the question-specific guidance (Appendix F).

3-2. Answering the questions

After you have evaluated the evidence for a given question and have presented and organized it succinctly, you are ready to answer. Enter your answer (i.e., y, n, ?, a, b, c, d, e, or f) in the "Answer" column of the "Screening Tool" worksheet. We recommend that you enter answers using the keyboard, but you can also select them using the dropdown menu within each answer cell. All answers must be entered exactly as specified and in lowercase without periods. Do not cut and paste answers from one question to another, as that can alter formulas associated with specific cells. Once you enter an answer, the spreadsheet displays the risk score associated with that question in the "Score" column. The spreadsheet also maintains a running sum of the risk scores for each risk element in the "Risk Score Summary" section near the bottom of the "Screening Tool" worksheet (cells E127 through E134; Fig. 7).

	A	B	C	D	E
126	**Risk Score Summary**				
127		Establishment/Spread Potential		0.10	19
128		Impact Potential		0.10	2.7
129		General			0.1
130		Natural Areas Impact			0
131		Anthropogenic Impact			0
132		Production Impact			1.6
133		Geographic Potential		N/A	N/A
134		Entry Potential		0.00	1
135		Number of questions remaining to be answered:	0		
136		Number of missing or incorrect uncertainties:	0		
137		Secondary Screening Score	7		
138					
139		Probability (Major-Invader) =	0.877		
140		Probability (Minor-Invader) =	0.119		
141		Probability (Non-Invader) =	0.004		
142		Model Result =	High Risk		
143		Secondary Screening =	Not Applicable		

Figure 7. Example of the "Risk Score Summary" section (cells A126-E134) of the "Screening Tool" worksheet.

Based on the available evidence, one of four scenarios will emerge for each answer. We discuss these below, as well as particular concerns with multiple-choice questions.

Answering based on good evidence. In this scenario, direct or indirect evidence sufficiently supports a given response, and the answer should be clear.

Answering when conflicting evidence exists. You found direct/indirect evidence, but it is conflicting, and choosing a particular answer is difficult. In these cases, answering unknown is appropriate. Sometimes, though, the conflicting information represents variation in taxon biology, where some varieties or populations possess a trait and others do not (e.g., self-compatibility). In such cases, answering unknown is reasonable, but so may be answering yes or no depending on whether you are taking a conservative or liberal approach. The important thing to do is to explain your approach in the "Notes (and references)" column.

The other two scenarios involve a lack of evidence, and the analyst must answer either no or unknown. Below we provide some general guidance for these two scenarios, but when no information is found, see Appendices E through G for detailed guidance for each question.

Answering no based on a lack of evidence. When the plant trait or behavior being evaluated is readily observable and the taxon is relatively well known, answering no based on a lack of evidence may be appropriate. This approach is based on the assumption that if the taxon had a given trait or caused some kind of impact, it would have been reported in the literature. For example, although no source specifically states that daffodils are not parasitic or that they have been tested and found not to be parasitic, you can reasonably answer that they are not parasitic because daffodils are relatively well studied and well known. The same reasoning applies to other questions, including those in the Impact Potential risk element. For example, consider a well-known, widely distributed, woody vine taxon that is only established in natural systems. Questions relating to impact in agricultural systems could be answered as no with low uncertainty because for a well-known taxon such impacts would likely have already been reported if they were valid. As the knowledge base about a taxon decreases, you should use higher levels of uncertainty with these types of answers until, ultimately, answering unknown would be more appropriate.

Answering unknown based on a lack of evidence. When no or little information has been found and the plant trait being evaluated is not readily observable, or the taxon is not well studied or well known, answering unknown is likely most appropriate. For example, for the question “Is the plant self-compatible?” an analyst should answer unknown when no information has been found because that trait is not readily observed or easily tested. A similar approach should be taken when the taxon is new to science, is generally not well known or well studied, or has never or only recently been introduced outside of its native range. One practical consequence of answering unknown is that all possible answers for that question are considered equally likely (which affects the uncertainty analysis). In the question-specific guidance (Appendices E, F, G, and H), we identify those questions for which a response of unknown is appropriate when information is unavailable.

Questions with multiple-choice answers. Five questions in the PPQ WRA require the analyst to choose among multiple-choice answers (Table 3). Except for ES-13, these questions relate to the behavior of a taxon elsewhere (ES-1) or how it is perceived by people (Imp-N6, Imp-A4, and Imp-P6). Choose the best answer from the available evidence. Because analysts can usually find information that rules out one or more possible answers, we think answering unknown is not ideal for these questions. However, answering unknown may be appropriate when the taxon is a new organism without a long history in either cultivation or the wild. This includes taxa that recently formed naturally through hybridization or polyploidization, or were artificially created by traditional breeding or other modern techniques. Answering unknown is appropriate for those taxa because they have not yet had an opportunity to behave in an invasive or weedy manner.

Importantly, for your answer to multiple-choice questions, you must enter two alternate choices in the “Screening Tool” worksheet (see cells I27-K33). These alternate choices are used in the uncertainty analysis (Process 6). For the “2nd choice,” choose the second most likely answer, and choose the third most likely answer for the “3rd choice.” For any given question, the two alternate choices must be different from the original answer, but they do not have to be different from each other; if no other option makes sense as the “3rd choice,” use the same answer as that for “2nd choice.” At the end of the evidence that is presented in the “Notes (and references)” column for multiple-choice questions, list the alternate choices so that this information is carried over into the Word document (e.g., The alternate choices for the stochastic simulation were “d” and “e”).

Table 3. Multiple-choice questions in the PPQ WRA.

Risk Element Question	Possible Answers
ES-1 (Establishment/Spread status outside its native range)	a to f
ES-13 (Minimum generation time)	a to d
Imp-N6 (Environmental/natural areas weed)	a to c
Imp-A4 (Weed of anthropogenic systems)	a to c
Imp-P6 (Weed of production systems)	a to c

3-3. Determining uncertainty ratings for questions

Uncertainty is a fundamental part of pest risk analysis because our knowledge of the factors contributing to risk is rarely complete or clear. This applies to the evidence available to evaluate the risk factors, but also to the risk models themselves, which may not consider all of the factors associated with risk. In the former case, sources of uncertainty include missing or incomplete information, inconsistent or conflicting data, and dated or erroneous information. Because of the quantity and quality of the available evidence, risk analysts are not always completely confident in the answers they choose. For the sake of transparency, risk analysts are compelled to report uncertainty in pest risk assessments (IPPC, 2011, 2013b) and consider how it may affect the results of the assessment.

In the PPQ WRA, we consider uncertainty at three different levels. First, we report the uncertainty associated with each answer. Second, we calculate static estimates of the overall levels of uncertainty associated with each risk element. Finally, using a stochastic simulation, we evaluate the sensitivity of the final outcome of the predictive model to uncertainty. We provide guidance for categorizing question-level uncertainty and summarizing it for the risk elements below, and guidance for conducting the stochastic simulation in Process 6.

Uncertainty ratings in the PPQ WRA. For every answer in the PPQ WRA, the analyst must rate the level of uncertainty associated with their answer as either negligible (= negl), low, moderate (= mod), high, or maximum (= max). These qualitative descriptors describe your confidence in the answers based on the quality and quantity of the evidence. When evaluating uncertainty, analysts should consider the following factors: evidence quality, source of the evidence, availability of quantitative information, complexity of the trait being evaluated, independence of sources, expert opinion, use of congeneric information, conflicting information, and whether inferences and assumptions were necessary. As a general rule, the availability of quantitative data, multiple independent sources, and peer-reviewed sources should lower uncertainty (Fig. 8). In contrast, uncertainty should increase if evidence is unavailable, or if answers are based on conflicting evidence, congeneric information, "low quality" or non-peer-reviewed sources, or analyst interpretations. Conjecture, speculation, and untested hypotheses are not considered evidence, but where appropriate they may be used to support particular answers, albeit with much higher levels of uncertainty.

Some additional points about the uncertainty associated with the use of congeneric information are worth making. First, using evidence about congeners with similar biology is inherently more uncertain. Consequently, when an answer is based solely on congeneric information, the analyst should increase the uncertainty by at least one level. In contrast, if there is some evidence about the taxon being assessed and it is weak, information from several congeners might be used to reduce uncertainty. This can be done for both the Establishment/Spread and Impact Potential risk elements. Finally, increasing uncertainty may be appropriate if one uses descriptions that apply to the entire genus (e.g., the genus *Vaccinium* produces fleshy fruits that are dispersed by birds).

As a general rule, if a single piece of direct evidence for the taxon from a reputable or peer-reviewed source supports a particular answer, start with low uncertainty. Then, consider how the other factors summarized in Figure 8 affect the level of uncertainty. When the answer is clear-cut, the uncertainty level is likely to be low or negligible. Still, only use negligible uncertainty when the evidence is very strong and leaves very little doubt. When the answer is not so clear-cut, usually because of conflicting, indirect, or congener-based evidence, the uncertainty level is more likely to be moderate or high (see below).

If you select an answer of "no" based on a lack of evidence, start with moderate uncertainty. Then, consider the other factors described in section 3-2 under "Answering 'no' based on a lack of evidence" (Fig. 8) to determine the uncertainty level, as follows:

- If the taxon is very well known because it either has been extensively studied or is widely cultivated, consider reducing uncertainty.
- If limited information exists on the taxon, consider increasing uncertainty.
- If the trait or biology being evaluated is simple or straightforward, consider reducing uncertainty.
- If the biology is more complex, not readily observable, or not likely to be reported, consider increasing uncertainty.
- If reasonable speculation suggests that the answer may or could be yes, but you found no direct or indirect evidence to support a yes response, increase uncertainty.
- If a lot of uncertainty exists, and you think yes and no seem equally likely, then answer unknown with maximum uncertainty.

We think that it is generally inappropriate to assign negligible uncertainty when an answer is based on a lack of evidence.

Assuming analysts follow the general rules for assigning uncertainty, you do not need to explain in every case why you chose a particular level of uncertainty. However, if the situation for any given question is complex, unclear, or involves conflicting information, you should explain at the end of the evidence why you chose that particular level of uncertainty. This explanation not only ensures transparency in risk assessment, but also identifies opportunities for reducing uncertainty in the future.

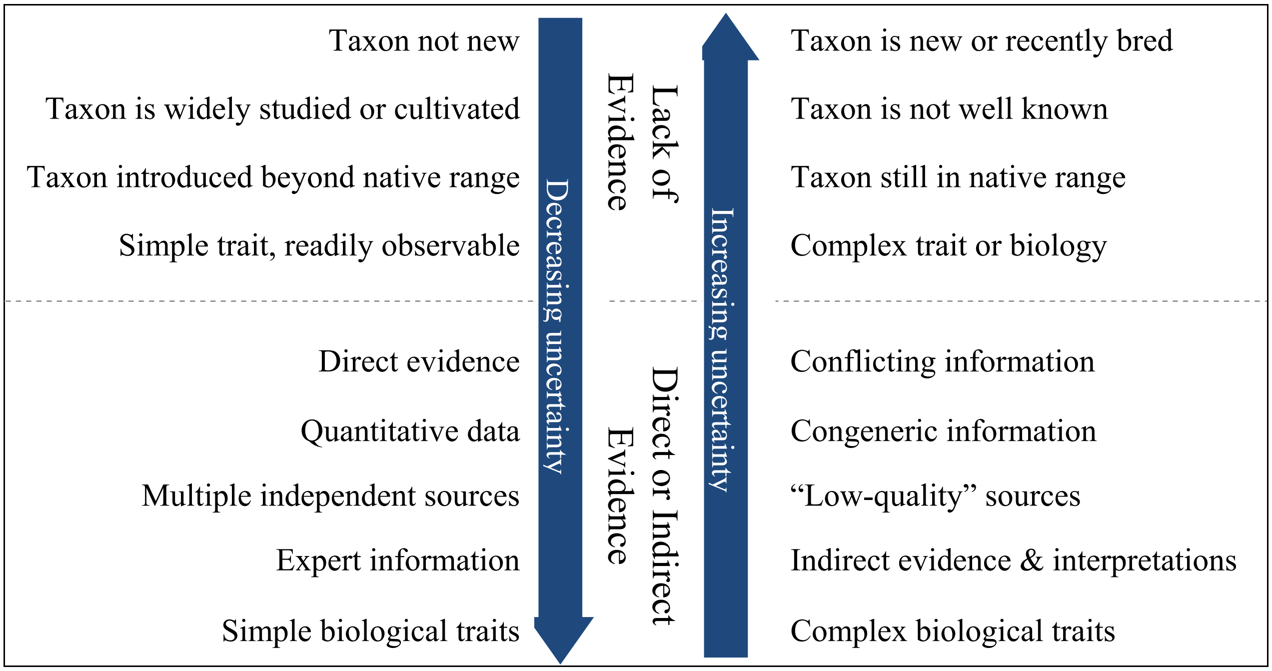


Figure 8. The general impact of factors on the level of uncertainty associated with an answer.

3.4. Entering the level of uncertainty

Just as when entering answers into cells, we recommend typing the uncertainty rating (negl, low, mod, high, or max) into the cell in the “Uncertainty” column of the “Screening Tool,” but you can also select it from the dropdown box within the cell. To ensure that the workbook formulas function properly, enter the uncertainties in lowercase text exactly as indicated and do not use periods with the abbreviations. The workbook automatically tracks how many uncertainty ratings have not been entered (cell C136 in Fig. 7). If an uncertainty rating has been entered but was not written correctly (e.g., “negl.” instead of “negl” or with spaces before/after the rating), then it will count as an incomplete entry.

Besides their qualitative meaning for analysts, the uncertainty ratings also describe the likelihood of an alternative answer being correct. For the purpose of calculating an index of uncertainty for each risk element (see next section), we assigned each uncertainty rating a probability value that represents that likelihood (Table 4). If the uncertainty rating is maximum (only possible when a question is answered as unknown), then all possible answers for the question are equally likely. For the purpose of conducting a stochastic simulation of the impacts of uncertainty (see Process 6), we also assigned each uncertainty rating a probability distribution around the static probabilities (Table 4). We did this primarily because the static probability values were arbitrarily chosen. Overall, the static probabilities and their associated ranges represent probabilities from near zero (negligible uncertainty) to a 50 percent chance (high uncertainty). A detailed explanation and validation of our uncertainty model is forthcoming (Caton et al., in review).

Table 4. Uncertainty ratings used to describe question-level uncertainty in the PPQ WRA. The probability associated with a rating represents our belief that some other answer is correct.

	Probability that an alternative answer is correct	
Uncertainty Level	**Probability**	**Range**
Negligible (=negl)	0.001	0 to 0.005
Low	0.01	0.005 to 0.05
Mod (=mod)	0.1	0.05 to 0.175
High	0.25	0.175 to 0.5
Max (=max)	All answer choices are equally likely	

3.5. The index of uncertainty

We estimate the overall level of uncertainty associated with each risk element—Establishment/Spread, Impact, and Entry Potential—with a calculated "index of uncertainty." The index accounts for both the uncertainty associated with each question and the weight of each question in the risk element score. Questions that are weighted more heavily in the WRA model (i.e., have potentially greater score values) contribute more to the index. The index of uncertainty is unit-less and ranges between 0 and 1. A value of 1 indicates maximum uncertainty and reflects a situation in which all of the questions have been answered as unknown. A value of 0 represents complete certainty. The index for each risk element is calculated automatically in the workbook and is presented in the "Uncertainty" column of "Risk Score Summary" section (cells D127-D134) of the "Screening Tool" worksheet (Fig. 7).

In the risk element summaries of the Word template, we report the index of uncertainty for the Establishment/Spread, Impact, and Entry Potential risk elements. However, because readers may not understand what this index means, we conclude each written summary by describing the level of uncertainty in the following manner: "We had a [very low, low, average, high, or very high] level of uncertainty for this risk element." We defined the value ranges for the different categories based on data for the 204 species that were used to develop and validate the PPQ WRA model. The uncertainty score distributions for the Establishment/Spread and Impact Potential risk elements were very similar and had an average index of about 0.17 (Caton et al., in review). The thresholds were chosen based on the 20th, 40th, 60th, and 80th percentiles of these distributions (Table 5). Until the Entry Potential risk element is validated, we are assuming that the score distribution for its index of uncertainty will be similar to that of the other two risk elements.

Table 5. Thresholds for different qualitative levels of uncertainty for the Establishment/Spread and Impact Potential risk elements.

Index of Uncertainty Score Range	Qualitative Description of the Level of Uncertainty
Index < 0.07	Very low
0.07 ≥ Index < 0.13	Low
0.13 ≥ Index < 0.20	Average
0.20 ≥ Index < 0.26	High
Index ≥ 0.26	Very High

3-6. Tracking the process in the spreadsheet

As noted above, the "Screening Tool" worksheet tracks how many questions and uncertainties remain to be answered (see cells C135 and C136; Fig. 7). These cells will remain highlighted red until all the questions and uncertainties have been entered, including the 10 alternate answers to the five multiple-choice questions.

Process 4: Assessing geographic potential

Predicting the geographic potential (i.e., areas with suitable habitat for establishment and spread) of a plant taxon is an important component of any WRA, as climatological factors affect the ability of a taxon to establish in any given area. We assess geographic potential in the PPQ WRA using Proto3, an additive, raster-based[2] prototype model, in ArcGIS. Proto3 uses variables from three global datasets (climate layers) representing plant hardiness zones, mean annual precipitation (in 10-inch bands), and Köppen-Geiger climate classes to predict where a given taxon may find suitable habitat in the United States and its territories. Analysts use a variety of sources to gather georeferenced presence data (data with latitude/longitude coordinates) and plant taxon occurrences that do not have specific coordinates (reported occurrences). Using the data and the spatial layers, Proto3 creates a map of the United States where the layers overlap.

Figure 9 provides an overview of the Proto3 model. In spatial analysis terms, the response variable (derived from georeferenced and reported occurrence data for the taxon) informs the creation of the predictor variables (using the three climatic spatial layers), which are run through the model algorithm in ArcGIS to produce the predicted map. In other words, we provide data, create new layers, combine them, and generate a predicted map, as further described in the sections below.

[2] A raster provides data in the form of cells or pixels. In the case of our geographic potential assessment, it treats the map area as a grid and associates data with each cell.

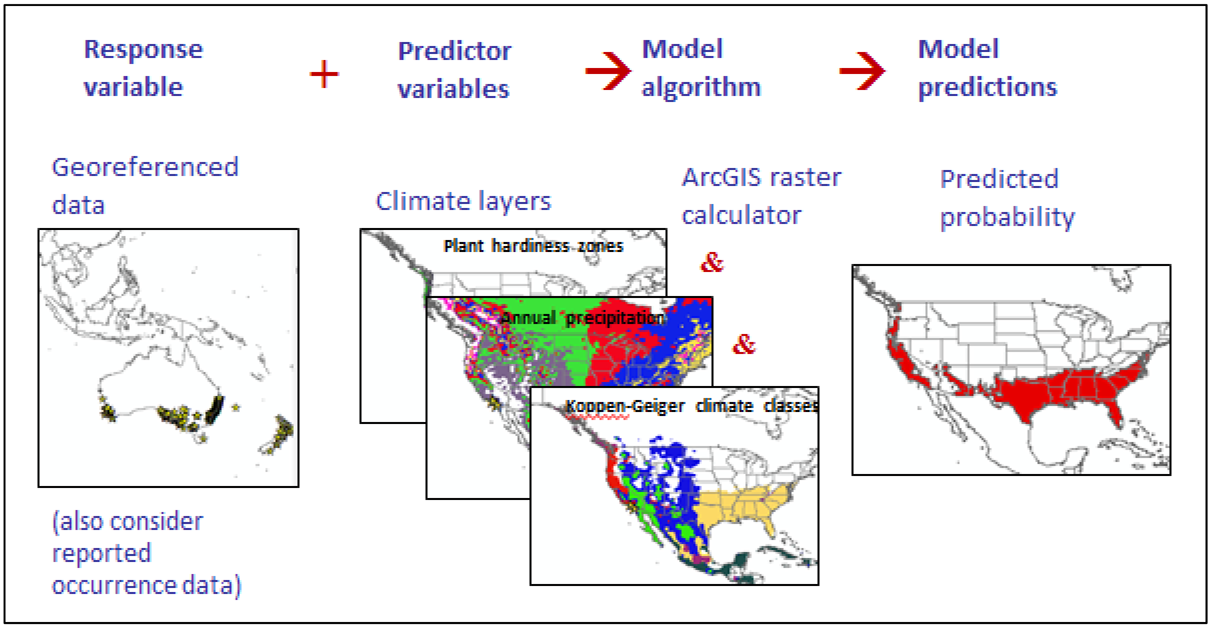


Figure 9. Overview of the PPQ Proto3 model for assessing the geographic potential of a plant taxon.

Our plant hardiness zone and annual precipitation datasets were provided through the North Carolina State University/Animal and Plant Health Inspection Service Plant Pest Forecasting System. These datasets were generated using Climate Forecast System Reanalysis (CFSR) base data (Saha et al., 2010), following the procedures outlined in Magarey et al. (2008). We use two data sets for each variable, one representing 30-year averages and the other representing 10-year averages. We use the 30-year datasets to gather the data for the Proto3 model to answer the questions in the Geographic Potential section of the Excel workbook and the 10-year datasets to produce the predictive maps. Many of the global data points representing plant distribution were recorded over several decades, and the 30-year datasets capture a broad range of climatic variance during those decades. The 10-year datasets represent more recent estimations of minimum temperatures and mean precipitation. Using the 10-year maps to produce our predictive maps allows us to provide a current estimation of potential distribution and incorporate climate change into our model. The Köppen-Geiger climate class dataset is an adaptation of a raster made available online by Peel et al. (2007). The original dataset contained 32 climate classes that we reclassified to represent 12 specific but more broadly defined classes as described by Espenshade et al. (1995) (e.g., tropical rainforest, desert, tundra).

The guidance in the following sections is an overview of the process for evaluating geographic potential. We provide instructions for downloading the data and creating the Proto3 maps in a detailed instruction manual, which is available upon request. Beyond this general guidance, if priorities allow we can also train analysts on how to gather the georeferenced and reported occurrence data and run the model in ArcGIS.

4-1. Gathering and preparing the data for input into ArcGIS

Gather data about the distribution of the taxon from a variety of sources. At the start of the WRA process, we recommend that you download all occurrences from the Global Biodiversity

Information Facility (GBIF) (see section 1-4). This database provides two types of records: georeferenced data (with latitude and longitude coordinates) and reported occurrence data (local or regional occurrences without specific coordinates). Copy all of these data into the GBIF worksheet of the Excel workbook, and take note of where the taxon is reported to occur throughout the world, including countries, provinces, states, cities, etc. These data supplement georeferenced points and improve the assessment of the taxon's known global distribution, particularly if that distribution was not captured in the GBIF database. The more precise the location data, the lesser the uncertainty.

After reviewing the majority of the literature for the taxon, begin assessing geographic potential by organizing and cleaning the GBIF data you downloaded to the workbook. Remove duplicates and reports of plants under cultivation and ensure that geographic coordinates match countries. As mentioned above, we can provide detailed work instructions for this in a separate instruction manual (Assessing Geographic Potential Instruction Manual) upon request.

4-2. Adding georeferenced and reported occurrence data to ArcMap
To conduct the geopotential evaluation, you need access to a computer with ArcGIS software and a map document that contains all datasets needed for the analysis. We provide each analyst with their own folder and map document in ArcMap, and the analyst creates new datasets for each taxon assessed.

Import the georeferenced data (latitude/longitude coordinates—called "xy" data in ArcGIS) contained in the GBIF worksheet into an ArcMap document. The coordinates show up on the map as points scattered across the globe. Polygons outlining country, province, state, or county boundaries can be created on the map to represent the occurrence data. These layers, which represent the global distribution of the taxon, are then used to answer the questions related to the taxon's presence in a given climatic region.

4-3. Assessing the global distribution of a taxon
Three climatic variables are used to assess the geographic potential of a plant taxon: plant hardiness zones, Köppen-Geiger climate classes, and mean annual precipitation[3]. In this step, you will overlay the data layers describing the taxon's global distribution over each of the three climate maps to determine where (in which hardiness zones, climate classes, and precipitation bands) the taxon can occur. You will then answer yes or no to each Geographic Potential question in the "Screening Tool" worksheet and describe your uncertainty as negligible, low moderate, or high. Provide evidence for your answers in the "Notes (and references)" column. For example, if you have evidence that your taxon occurs in a given Plant Hardiness Zone in four countries, list those countries in the comment field. Note that you cannot answer "unknown" in the geographic potential analysis; make the best determination for a yes or no answer based on the available evidence. Question-specific guidance is available in Appendix G.

When evaluating the uncertainty associated with each question in this element, consider the type of data available (georeferenced or reported occurrences), the quantity of points for any given climate layer (i.e., zone, band, class), if the data are available from multiple countries, and if the

[3] There are 13 Plant Hardiness Zones, ranging from Zone 1 in the coldest climates to Zone 13 in the tropics. We use 12 climate classes in the Köppen-Geiger dataset. Mean annual precipitation is represented by 11 ten-inch bands.

data are consistent with the overall biology of the taxon. For example, if a climate class has five points in each of three different countries, you might reasonably answer yes with negligible uncertainty. If only a few points exist, but the taxon being present in that zone or class seems reasonable, based on the biological traits of the taxon and its native distribution, answer yes with low uncertainty.

Using the reported occurrence data is more art than science and requires the analyst's expertise. For example, if evidence indicates that the taxon is found in China or Russia, answering yes for every climate class or Zone in those large countries would likely overestimate the true distribution. Consider other evidence and biological traits encountered while answering questions for the predictive model. For example, are there extreme temperatures under which the taxon cannot survive? This is good evidence to support an answer of no. A specific search for the taxon in a given province may help to narrow down a large area by providing county-level occurrence data. Although time-consuming, using the reported occurrence data in addition to georeferenced points in the assessment may often give a more accurate representation of the area at risk. The use of the reported occurrences (i.e., data without georeferenced points) distinguishes our Proto3 method from other spatial analyses that depend strictly on georeferenced data. Occasionally, the reported occurrence data will not add any new information, in which case only the georeferenced data will be used in the Proto3 analysis.

4-4. Conducting Proto3 analysis
Once all questions are answered, follow the Weed Team's Assessing Geographic Potential Instruction Manual to complete the Proto3 analysis and create the map specific to the plant taxon. The general process is as follows:

1. Create global maps for each of the three climate variables (Plant Hardiness Zones, Köppen-Geiger climate classes, mean annual precipitation) representing areas where the taxon could establish.
2. Create a new map in which the three variables overlap.
3. Create a U.S.-centric map and calculate the predicted area (in square miles or square kilometers).
4. Record the area in the Maps worksheet in the Excel workbook. The spreadsheet automatically estimates the percentage of the U.S. area that is suitable for establishment.
5. Create an image (in appropriate software, e.g., PowerPoint) of your predicted areas for use in the WRA Word document.

Final notes
The area in red (Fig. 9) represents an estimate of areas in which the climate may be conducive for the establishment of a given taxon. Other variables may further limit where a taxon can establish. Alternately, the taxon may be able to establish in microhabitats not represented by the predictive map. If a taxon were to establish in the predicted range, it is unlikely that it would become invasive throughout the entire range as climate and other variables may be more limiting towards the periphery of its range.

Proto3 is a simple climate-matching analysis; other, more detailed tools are available. We validated the Proto3 model using species naturalized in the United States and, using the same data, compared the accuracy of the Proto3 model to three other species distribution models that are more complex [MaxEnt and CLIMEX (Match Climate), and a process model known as the Thornley Transport Resistance Model]. The results from this initial study showed that Proto3 performed as well than these modeling systems and can be used for assessing geographic potential (Magarey et al., *in review*).

Process 5: Assessing entry potential

The entry potential section of the PPQ weed risk assessment has not yet been validated; this risk element may change considerably once that happens.

The entry potential section consists of 14 questions that assess the likelihood that the plant taxon will enter the United States intentionally for cultivation, accidentally as a contaminant, or through natural dispersal. Taxa that are cultivated elsewhere or are positively valued by society are more likely to enter than other, less valued, taxa. The risk score for this element ranges from 0 to 1, with higher scores indicating a higher likelihood of entry.

If a taxon is already present in the United States, or if a permit for its entry has been requested, the analyst only answers the first (Ent-1) and potentially the second (Ent-2) question for this risk element. Assessing the entire risk element is not necessary in such cases, because after answering yes to either Ent-1 or Ent-2 the Excel workbook automatically sets all other scores as not applicable and thereby prevents the analyst from answering any more questions.

If the taxon is present in the United States but has a limited naturalized distribution or is not widely cultivated, evaluating entry potential may be prudent. In such cases, you can answer no to Ent-1 and Ent-2 and explain in the "Notes (and references)" column why you are fully evaluating the entry potential. Alternatively, you can answer yes to Ent-1 or Ent-2 and not answer the rest of the questions while still providing evidence for all the questions in the "Notes (and references)" column. The evidence will be available to risk managers if they deem it helpful for their decision-making process.

Sources and information used elsewhere in the WRA will be useful to answer the questions in the Entry Potential risk element.

- To answer Ent-1, use the references listed under Process 1-4 to verify the U.S. distribution of the plant taxon.
- Review your evidence from ES-1 (Establishment and spread status outside native range), ES-2 (Is the species highly domesticated?), ES-15 (unintentional spread by human activity), ES-16 (contaminant of agricultural products), ES-17 (dispersal vectors), and Imp-P3 (trade impacts).

For guidance and information related to each question, refer to the question-specific guidance (Appendix H).

Process 6: Uncertainty analysis

In Process 6, we conduct a stochastic simulation to evaluate the sensitivity of the risk scores to uncertainty in the assessment—specifically, uncertainty in the answers to the questions in the Establishment/Spread and Impact Potential risk elements. A stochastic simulation is a computational technique in which repeated random samples are taken from a dataset to evaluate how likely an outcome or score is. Here, we refer to the stochastic simulation as the uncertainty analysis. In the case of the PPQ WRA, the uncertainty analysis helps us evaluate what would happen to the risk scores if we chose a slightly different set of answers. Hence, the analysis allows us to evaluate what other risk scores are likely given the uncertainty in the WRA. The greater the uncertainty in the WRA, the wider the range of possible risk scores around the original analyst-derived score. For a full explanation of how we developed and tested the underlying uncertainty model see Caton et al. (in review).

In the uncertainty analysis, the software stochastically determines if each answer has changed based on its uncertainty rating. The greater the question uncertainty, the more likely the chosen answer will change to an alternate answer. After determining which answers are changing, the simulation chooses new answers, based on their likelihoods. For yes/no questions, the new answer is simply the opposite, while for multiple-choice questions the two alternate answers are equally likely. If a question was answered as unknown, all answer choices for that question are equally likely. After all answers have been determined, the model calculates the new risk scores, determines the outcome of the assessment, and runs the secondary screening analysis if necessary. It repeats this process 5,000 times, and we graph the resulting simulated risk scores and ratings outcomes, as well as the analyst-derived risk score. Appendix I describes the uncertainty analysis in greater detail.

Before beginning the uncertainty analysis, ensure that all questions have been answered and all uncertainty ratings correctly filled by referring to cells C135 and C136 (Fig. 7) in the "Screening Tool" worksheet.

PPQ uses the software program @Risk to conduct the uncertainty analysis. This program is installed as an add-in for Microsoft Excel and must be purchased separately from the software company Palisade. The specific stochastic model that PPQ uses to conduct the uncertainty analysis is already built into the workbook in the "Uncertainty" worksheet. If the correct software is already installed, the analyst only needs to select "Start simulation" from the menu under the @Risk tab in the workbook to run the analysis. Appendix J provides specific work instructions for conducting the analysis, which takes only five minutes. If you are running the uncertainty analysis for the first time on a given computer or previously ran @Risk using different settings, you may need to reset a few simulation settings as described in Appendix I. Because several of the worksheets in the workbook are password protected to prevent accidental changes to the formulas, you will need to enter the password "test" when prompted by @Risk. Entering this password within an @Risk simulation does not unprotect the worksheets; rather, it gives the software permission to access them.

Once the @Risk simulation has completed, incorporate the relevant data from the output into the "Risk Score Plot" worksheet following the guidance in Appendix J. We built this worksheet to automatically graph the results of the simulation. We developed a standard method for displaying the results in the Establishment/Spread and Impact Potential risk space (Fig. 10). The results from the 5,000 iterations are displayed as 50th, 95th, and 99th percentile boxes, with the remaining 1 percent of the simulated risk scores plotted as outliers. The median values for the Establishment/Spread and Impact Potential risk scores are shown as a blue cross within these boxes. The original risk score that was determined by the analyst is plotted as a solid black square, along with the two decision thresholds that separate the risk ratings. For transparency, we also report the percentage of the 5,000 simulated risk scores that resulted in each of five possible outcomes, incorporating the results from the secondary screening: 1) Low Risk, 2) Evaluate Further → Low Risk, 3) Evaluate Further → Evaluate Further, 4) Evaluate Further → High Risk, and 5) High Risk.

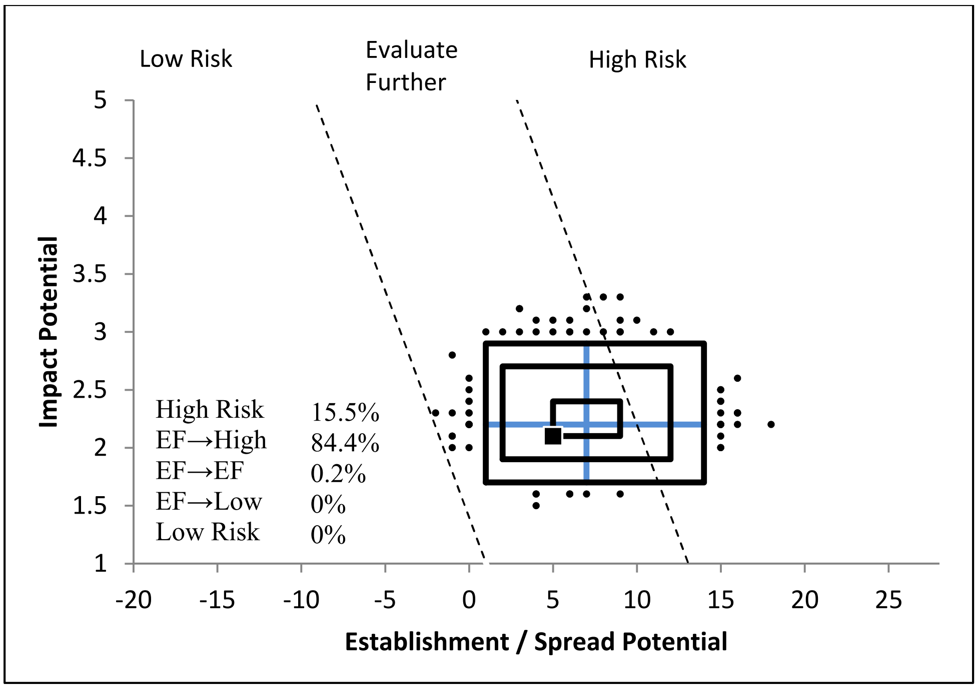


Figure 10. Model simulation results (N=5,000) for uncertainty around the risk score for *Hakea europaeum.*

At a quick glance, the figure summarizing the results of the uncertainty analysis provides several key pieces of information important for risk analysts and decision-makers to consider. Analysts may use this information to determine when additional information is needed to reduce uncertainty. Decision-makers may use this information for making regulatory decisions or determining the strength of mitigation measures:

- *The overall size of the boxes*. Box sizes depend upon the amount of uncertainty in the assessment. They correlate well with the index of uncertainty, so that greater uncertainty gives larger boxes, and vice versa. Greater uncertainty for one risk element or the other will produce less square, more elongated rectangular boxes (Fig. 11).
- *The location of the analyst-derived risk score relative to the center of the distribution of simulated risk scores*. Ideally, the WRA has low uncertainty and the analyst-derived risk score will be located near the intersection of the medians (blue lines). However, this

seems to rarely be the case. Often, the risk score is located off-center, usually left and below, and sometimes outside some or all of the percentile boxes (Fig. 11). This is expected and merely indicates that if you take uncertainty into account, picking a slightly different set of answers, the new risk scores tend to increase. If additional information changed one or more answers, the new risk score would likely move toward the center of the distribution. However, additional information may only reduce the uncertainty in the WRA, giving smaller and more centered boxes around the original risk score (Caton et al., in review).

- *The distribution of the simulated risk scores with respect to the decision thresholds*. Regardless of the amount of uncertainty in a WRA, if the original risk score and all of the simulated risk scores are located within either the Low Risk or High Risk regions of the graph, then the conclusion from the WRA is well supported. If the results do not meet these criteria, then consider the next bullet.
- *The dominant risk rating outcome for the simulated risk scores*. The inset in the uncertainty figure displays the percentage of the 5,000 iterations among the different possible outcomes (i.e., ratings). If distributions cross one or both decision thresholds or are located entirely within the Evaluate Further risk region, these results are important to examine. If the most frequent outcome coincides with the original risk rating, then the original rating is statistically robust. If they differ, then the results are somewhat conflicted. During validation of the uncertainty model (Caton et al., in review), 13 percent of the 204 species analyzed had dominant outcomes in the uncertainty analysis that did not support the original risk rating. Sometimes it may not be possible to resolve the conflict; in such cases, noting the discrepancy for decision-makers to consider is prudent and acceptable.

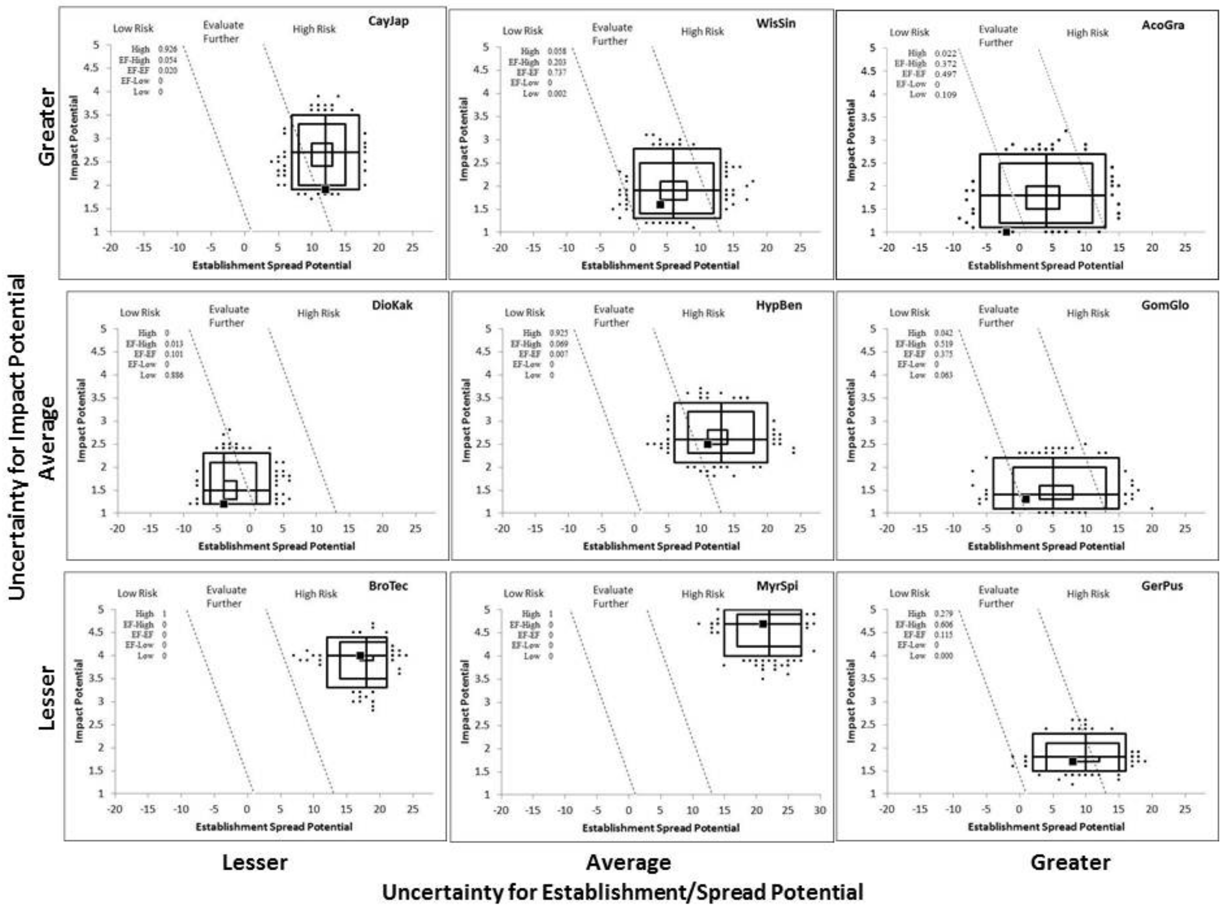


Figure 11. Representative uncertainty analysis charts for different levels of uncertainty in Establishment/Spread Potential (x-axis) and Impact Potential (y-axis).

Process 7: Finalizing and assembling the WRA

At this point, you should have answered all of the questions in the predictive WRA model, evaluated the sensitivity of the final risk rating to uncertainty, determined where in the United States the taxon is likely to establish, and if applicable, evaluated its likelihood for entry. In Process 7, you will review the final outcome of the assessment and formally finalize the analysis using the Word template.

7-1. Reviewing the final outcome of the assessment in the Excel workbook

Before finalizing the WRA Word template, review the results in the workbook as outlined in the following bullets.

- Review the final results of the WRA model as shown by cells C139 to C143 on the “Screening Tool” worksheet. All of these results are automatically calculated by cell formulas. The three probabilities of invasiveness (cells C139 to C141) are the direct results from the logistic regression model that predicts weed risk (see Appendix B). Once all of the questions have been answered, the result is automatically calculated in the worksheet (C142, Fig. 7), including the result of the secondary screening tool (C143, Fig. 7) if the primary result was Evaluate Further. As part of the secondary screening process (see Appendix D), we calculate the “Secondary Screening Score,” which is displayed in cell C137.

- Consider the results from the previous bullet as well as the two figures on the “Risk Score Plot” worksheet. Are these results consistent with the accumulated evidence? In other words, do the results make sense based on the overall weight and diversity of evidence? If not, then review the evidence, answers, and uncertainties to determine if some of the questions were answered too liberally or conservatively.
- Consider the final risk rating from the WRA model (i.e., cell C142 or C143, depending on if the secondary screening was necessary, Fig. 7) and the dominant risk outcome from the uncertainty analysis (e.g., see Fig. 4). If they differ, consider reviewing the literature a little more extensively to see if you can reduce uncertainty for some key questions. Contacting experts who have experience with the taxon under field conditions may be helpful. Additional analysis may not be necessary if you think the final risk rating and the dominant outcome from the uncertainty analysis are likely to lead to a particular decision by policy managers. Consulting with the policy managers—even before finalizing the WRA—may also be prudent, to determine their comfort level and understanding of the information presented.
- Review the map showing the geographic potential of the taxon in the United States (e.g., see Fig. 3). Does the map seem reasonable with respect to the general biology and adaptations of the taxon? If not, review the evidence and the answers for the geographic potential risk element and revise the map accordingly.
- Evaluate the final risk rating of the WRA. Was it expected, or do you think the risk was over- or underestimated? Is the result consistent with the weight of the evidence? In other words, do the risk scores and the final model result make sense? If necessary, review the assessment and determine if you were too conservative or too liberal with your answers. Consider whether high uncertainty might have affected the results.
- If you change any of the answers or uncertainties, you will need to re-run the uncertainty analysis.

7-2. Preparing and finalizing the WRA Word document

The results of the work conducted in the workbook, as well as background information on the taxon, are presented and summarized in a WRA document. It includes the cover page, introduction, taxon information, summary of the analysis, analytical results, discussion section, literature cited, and appendix of the data from the workbook. If you have not already done so, save a copy of the template that is used to create the document to your computer and rename it with the scientific name of the plant taxon being assessed (i.e., Genus species.docx). The template provides some standard text, such as section headings and the introduction text, that is applicable to all WRAs and therefore does not need to be modified. The green highlighted areas in the template indicate places where the analyst needs to fill in information for their particular WRA. These highlighted areas provide instructions as to what needs to be entered in that section of the document. Complete each section of the template by following the instructions in the template itself as well as the instructions provided below. As you enter information in the template, delete the instructional text and remove any green highlights.

Taxon background information. When making regulatory decisions, decision-makers consider basic information about the taxon that is presented on the cover page and in the “Species

Information" section of the Word template. At this point in the WRA process, you will have probably already completed recording some of this information (i.e., taxonomy, common names, and the initiating event in the "Species Information" section), as instructed in Process 1 (Gathering Background Information). If you did not already fill out this information in the Word template, refer back to Process 1, sections 1-1 and 1-3 for guidance on doing this. Otherwise, finalize the "Species Information" section and prepare the cover page by following the guidance below as well as that contained in the template. Ensure that all information is appropriately cited.

- On the cover page, ensure that the current scientific name and most representative English common name are included. Also, include one or more images that show the life form, habit, and/or habitat of the taxon. These images should complement the taxon's botanical description (see below). If available, include an image of a population of the taxon that represents the kind of impacts it may be having. Caption image(s) and credit them to the appropriate source. Many websites will provide guidance on how exactly to acknowledge the source. Only use images that are under a common license agreement or that you have obtained permission to use.
- In "Species Information," incorporate any additional information on taxonomy, including taxon name, family, synonyms, and common names that you may have come across as you gathered evidence for the rest of the WRA process.
- In "Botanical description," in one to three sentences, provide a concise botanical description of the taxon so that someone not familiar with it will have a general understanding of what kind of plant was assessed [e.g., size, life form (herb, vine, tree, grass), life cycle (annual, perennial), preferred habitats] (see Process 1-2 for further guidance). Cite a couple of references, preferably floras, where the reader can obtain a full botanical description. Consider the following botanical description as an example: "*Heliotropium europaeum* is an erect or semi-prostrate branched annual growing 10 to 50 cm tall and produces a well-developed taproot (Holm et al., 1997; Parsons and Cuthbertson, 2001). It is relatively hairy, produces flowers in indeterminate scorpioide cymes, and has a somewhat offensive odor when crushed (Parsons and Cuthbertson, 2001). For a full description see Zhengyi et al. (2014)."
- In "Foreign distribution and status," briefly describe the taxon's foreign distribution distinguishing between its native origin, introduced range, and naturalized/invasive range. If the number of countries of distribution is not too large, list all of them. When appropriate, instead of listing individual countries, you can describe the taxon's range in terms of regions (e.g., "this species is native to sub-Saharan Africa"). State whether the taxon has been moved beyond its native range. The information in this section will be somewhat redundant with the evidence used to answer question ES-1. Ensure that they are consistent with each other. State whether the taxon is cultivated beyond the United States and cite a few references. Also, briefly describe whether it is regulated or managed elsewhere.
- In "U.S. distribution and status," summarize all of the information relating to U.S. distribution, cultivation, and management (see Process 2-4 for detailed guidance on gathering this information) in a single paragraph. This section is meant to be a summary for decision-makers and risk managers. If the plant taxon is not present in the United States, state that it is not known to be present and cite the major sources of information used to determine this. If the taxon is present in the United States, state when, how, and why it was introduced, if this information is readily available. If cultivated, describe the

extent to which it is cultivated. Describe if it is naturalized, and if any states or other agencies, groups, or individuals are managing it. List the states where it is naturalized. If it is naturalized in many states, you can simply describe the region (e.g., the southeast) along with the number of states in that region where it occurs. If appropriate, describe any uncertainty relating to the status of the taxon. State whether additional research or evaluation is necessary to address any significant uncertainty. Additional details on status in the United States can be provided elsewhere in the WRA.

- In "WRA area," identify the area in relation to which the WRA is conducted [definition modified from that for "PRA area" (IPPC, 2013a)]. Because the predictive model was developed for the entire United States and because the WRA is geographically neutral (as explained in Section 2), the WRA area is always the entire United States, even if it is initiated for a particular state or region. If the WRA was conducted for another region of the world outside of the United States, identify that region here[4].

Risk element summaries
In the "Establishment/Spread Potential" and "Impact Potential" sections, provide a small summary highlighting the traits that contributed the most to the taxon's risk score. Add other information related to the risk element that you think should be considered by decision-makers and risk managers but was not covered under any of the questions in the risk element. Additionally, include a brief statement or discussion about the amount of uncertainty for each risk element. For example, "We had a very low amount of uncertainty for this risk element," or "We had a high amount of uncertainty for this risk element due to…." Refer to Table 5 (Process 3) to determine the appropriate qualitative descriptions to use for your taxon's uncertainty scores. Finally, add the risk scores and the uncertainty index scores where indicated in the template. These scores can be found in the Risk Score Summary section of the "Screening Tool" worksheet.

In "Geographic Potential," provide the estimated percentage of the United States suitable for establishment of the taxon and list the climate zones and classes that make up that predicted distribution. As needed, discuss any major sources of uncertainty in the analysis. For instance, in cases where there was a lot of uncertainty for a given hardiness zone, climate class, or precipitation band and a different answer would have affected the area of the predicted distribution, discuss the source of the uncertainty and how you addressed it. Providing a narrative explanation of such uncertainties is important for this risk element, because—unlike for the other risk elements—we cannot calculate an index of uncertainty for it. To help explain how other environmental variables may limit the predicted distribution for the taxon, describe its preferred habitats. For example, "This taxon is restricted to lake shores and other riparian areas," or "Its habitats include hot, dry, low-lying areas, and savanna woodlands."

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[4] Because the predictive model of the PPQ WRA is not restricted to any given geographic region, it may be used anywhere in the world, provided that a climate-matching analysis confirms the WRA area is suitable for establishment by the plant taxon under assessment. Many of the questions in the PPQ WRA were derived from the Australian WRA, which has proven to be reasonably accurate for a number of regions around the world (Gordon et al., 2008). Thus, we expect that the PPQ WRA will perform similarly. However, some of the individual questions in our process may not be as predictive of invasive status in the foreign country as they are for the United States due to unique ecological processes that influence species invasiveness in other biogeographic regions.

In “Entry Potential,” if a full assessment of this risk element was not necessary (that is, you answered yes for either Ent-1 or Ent-2), enter the following standard text: “We did not assess the entry potential of *Taxon X* because it is already present in the United States (citations).” Also, delete the line containing the placeholders for the entry potential risk score and uncertainty index. If the entry potential risk element was fully assessed, then follow the same guidance as that provided above for the “Establishment/Spread Potential” and “Impact Potential” sections.

For Figure 1 (Predicted distribution of [Taxon] in the United States): Go to the “Maps” worksheet, copy the image showing the predicted U.S. distribution of the taxon, and then paste this image into the box for Figure 1. [This map image is produced in ArcGIS based on the detailed instructions provided in the separate geographic potential instruction manual (as mentioned in Process 4).] Resize the image as needed to fit the box.

Results
In the “Results” section, enter the following information:

- The model probabilities for the taxon being a major-invader, minor-invader, and non-invader. These probabilities can be found in the “Risk Score Summary” section of the “Screening Tool” worksheet (see cells C139-141). In the workbook, these probabilities are presented as decimal numbers. When adding them to the template, be sure to change these to percentages (e.g., 0.972 → 97.2%).
- The Risk Result from the logistic regression model, which is either Low Risk, Evaluate Further, or High Risk. This result is indicated in the “Risk Score Summary” section of the “Screening Tool” worksheet (see cell C142).
- If the result from the logistic regression model was Evaluate Further, under the result of the Secondary Screening enter Low Risk, Evaluate Further, or High Risk; otherwise, enter Not Applicable. The appropriate result is indicated in the “Risk Score Summary” section of the “Screening Tool” worksheet (see cell C143).
- For Figure 2 (Taxon risk score): Go to the “Risk Score Plot” worksheet and copy the chart that contains the risk score for the taxon plus the scores from the 204 species used to develop and validate the WRA model (i.e., the top chart in the worksheet). In the template, select “Paste special” → “JPEG paste” from the menu to paste this chart into the designated space. If needed, add a border to the chart and/or resize the chart to best fit the space.
- For Figure 3 (Model simulation results for uncertainty): Go to the “Risk Score Plot” worksheet and copy the chart that contains the taxon’s risk score and the results from the uncertainty analysis (i.e., the bottom chart in the worksheet). In the Word template, select “Paste special” → “JPEG paste” from the menu to paste this chart into the designated space. If needed, add a border to the chart and/or resize the chart to best fit the space. If possible, fit Figures 2 and 3 on the same page.

Discussion
In “Discussion,” provide a summary and discussion of the overall result of the WRA, including the impact of uncertainty on the final conclusion. As part of this summary, be sure to refer to Figures 2 and 3 [e.g., “The result of the weed risk assessment for [Taxon] is High Risk (Fig. 2)” and “Overall, we are very confident in our determination of high risk based on the results of our uncertainty simulation (Fig. 3)”]. Additionally, describe any other information that may be useful

for risk managers and decision-makers to consider as they evaluate risk management options, including information that may suggest a different regulatory response than that indicated by the overall risk result. While we do not make any policy or management recommendations for regulating or deregulating species, we can make some suggestions on how to proceed with taxa that have a risk result of Evaluate Further. In general, this discussion section consists of one or two paragraphs and no more than three.

Literature Cited
In "Literature Cited," provide citations for all references cited in the WRA document, including those cited in Appendix A (see below). PPQ analysts should refer to instructions in the template for details on how to insert and format these references into the document. For all other analysts, we highly recommend that you use some sort of reference management software (e.g., EndNote) to manage your references and create the literature cited section.

WRA Appendix
The last section of the Word template is Appendix A, which is a table of all the risk element questions and their associated answers, uncertainty scores, risk scores, and evidence/notes contained in the "Screening Tool" worksheet. The worksheet "TableForWord" formats this information so it can be copied into Appendix A from the spreadsheet. The only difference in content is that the text for most of the questions is abbreviated; otherwise, the answers, uncertainties, and notes are copied over exactly as they were entered.

Follow these instructions for creating Appendix A (which are essentially the same as those provided in the template): Open the "TableForWord" worksheet in the workbook. Select the entire cell range that starts from the header row and ends with the last row under Entry Potential. Copy and paste that block of cells into the designated location in the template. You will most likely need to adjust the column widths to format it properly. When modifying column width, make sure you select the "+" symbol that appears when you hover over the left-top corner of the table to modify the entire table. Ensure the main header row (row1) repeats at the top of every page (right click the first row and select "Repeat as header" from Word's table menu). Always scroll through to make sure everything is formatted properly. The font should be Times New Roman, size 10.

Review the evidence for misspellings, grammatical errors, and clarity of writing. Because the evidence was not entered in a word-processing program, you will likely revise many of the entries in the appendix. Once you revise the text in the template, copy the cells corresponding to the evidence column, and paste them back over the cells in the workbook in the "Screening Tool" tab to ensure your edits are archived there as well. Pasting over the cells will likely change their formatting (i.e., font, cell wrapping), but this should not be a concern. Also, because the spacing between risk element sections in the workbook and the appendix is different, you will need to copy and paste the information for each risk element individually. Once you have copied over the information in the workbook, format the bibliography in the document using EndNote (or another reference management tool) so that references in the appendix are formatted and included in the bibliography. Once the reference section is finalized, copy it and paste it into the "Screening Tool" worksheet at cell H164.

Final steps
As part of reading through and reviewing the WRA document, check that all the green highlighted instructions in the template have been deleted. Also, ensure that the green highlighted header on the cover page ("Form E-301…") and Appendix B (Revision History) have been deleted. As noted above in Process 2, the PPQ WRA process is managed under a quality management system, and the template is one of the controlled documents in this system, so its version, effective date, and approver are recorded in the cover page header, and the revision history is recorded in Appendix B. Once the template is copied to create a WRA document for a particular taxon (i.e., a new WRA packet), this header and Appendix B should be deleted from the copy.

7-3. Peer review of the final WRA product
After you have completed the final WRA product (the workbook and the document), the product should undergo peer review. Peer review is vital to ensuring high quality-analyses by helping to identify potential mistakes in judgment and interpretation of the literature, to guard against bias, to maintain consistency between WRAs, and to improve clarity of the product. In PPQ, WRAs are produced by the Plant Epidemiology and Risk Analysis Laboratory (PERAL). All PERAL WRA products undergo scientific review by at least one weed risk analyst who has been trained in the PPQ WRA process, and are also reviewed by the PERAL editor and the PERAL assistant director (or their designee).

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Appendices

List of Appendices

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

Appendix B. Logistic regression model formulas.

Appendix C. Logistic regression model and decision thresholds for low risk, evaluate further, and high risk.

Appendix D. Secondary screening tool of the PPQ WRA.

Appendix E. Question-specific guidance and examples for the risk element Establishment/Spread Potential.

Appendix F. Question-specific guidance and examples for the risk element Impact Potential.

Appendix G. Question-specific guidance and examples for the risk element Geographic Potential.

Appendix H. Question-specific guidance and examples for the risk element Entry Potential.

Appendix I. Conceptual process for the uncertainty analysis in the PPQ WRA.

Appendix J. Work instructions for performing an uncertainty analysis (a stochastic simulation) using @Risk.

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

A1. Establishment/Spread Potential

Code	Question
ES-1	What is the taxon's establishment and spread status outside its native range: (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown. (a = -5, b = -2, c = 0, d = 0, e = 2, f = 5, ? = 0)
ES-2	Is the species highly domesticated? (y = -3, n = 0, or ? = 0)
ES-3	Are there any congeners that are considered significant weeds? (y = 1, n = 0, or ? = 0)
ES-4	Is it shade tolerant at some stage of its life cycle? (y = 1, n = 0, or ? = 0)
ES-5	Is the plant a vine or scrambling plant, or does it form tightly appressed basal rosettes? (y = 1, n = 0, or ? = 0)
ES-6	Does the taxon form dense thickets, patches, or populations? (y = 2, n = 0, or ? = 0)
ES-7	Is the taxon an aquatic plant? (y = 1, n = 0, or ? = 0)
ES-8	Is the taxon a grass (Poaceae)? (y = 1, n = 0, or ? = 0)
ES-9	Is the taxon a nitrogen fixing woody plant? (y = 1, n = 0, or ? = 0)
ES-10	Does the taxon produce viable seed or spores? (y = 1, n = -1, or ? = 0)
ES-11	Is the taxon self-compatible or apomictic? (y = 1, n = -1, or ? = 0)
ES-12	Does the taxon require specialist pollinators that are not present in the WRA area? (y = -1, n = 0, or ? = 0)
ES-13	What is the taxon's minimum generation time? Choose one: (a) less than a year with multiple generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) unknown. (a = 2, b = 1, c = 0, d = -1, ? = 0)
ES-14	Is the taxon a prolific seed producer? (y = 1, n = -1, or ? = 0)
ES-15	Are propagules likely to be dispersed unintentionally by human activity? (y = 1, n = -1, or ? = 0)
ES-16	Are propagules likely to be dispersed as contaminants or hitchhikers of any agricultural, forestry, or horticultural products? (y = 2, n = -1, or ? = 0)
ES-17	What is the number of natural dispersal vectors as described by ES-17a through ES-17e? (none = -4, one = -2, two = 0, three = 2, four or five = 4)
ES-17a	Are propagules wind dispersed? (y, n, ?)
ES-17b	Are propagules water dispersed? (y, n, ?)
ES-17c	Are propagules dispersed by birds? (y, n, ?)
ES-17d	Are propagules dispersed by other animals (externally)? (y, n, ?)
ES-17e	Are propagules dispersed by other animals (internally)? (y, n, ?)

ES-18	Is there evidence that a persistent (>1 year) seed bank (or other propagules) is formed? (y = 1, n = -1, or ? = 0)
ES-19	Does the taxon tolerate or benefit from mutilation, cultivation, or fire? (y = 1, n = -1, or ? = 0)
ES-20	Does the taxon have resistance to some herbicides or demonstrate potential to acquire herbicide resistance? (y = 1, n = 0, or ? = 0)
ES-21	Adaptive potential: Number of plant hardiness zones (out of 13) suitable for survival. (zero to three = -1, four to nine = 0, ten to thirteen = 1)
ES-22	Adaptive potential: Number of Köppen-Geiger climate classes (out of 12) suitable for survival. (zero to two = -2, three = 0, four to twelve = 2)
ES-23	Adaptive potential: Number of annual precipitation bands (out of 11) suitable for survival. (zero to four = -1, five to seven = 0, eight to eleven = 1)

A2. Impact Potential

Code	Question
Imp-G1	Is the taxon allelopathic? (y = 0.1, n = 0, or ? = 0)
Imp-G2	Is the taxon parasitic, and does it have potential hosts in the WRA area? (y = 0.1, n = 0, or ? = 0)
Imp-N1	Does the taxon change ecosystem processes and parameters? (y = 0.4, n = 0, or ? = 0)
Imp-N2	Does the taxon change habitat structure? (y = 0.2, n = 0, or ? = 0)
Imp-N3	Does the taxon change species diversity? (y = 0.2, n = 0, or ? = 0)
Imp-N4	Is the taxon likely to affect Federal Threatened & Endangered species? (y = 0.1, n = 0, or ? = 0)
Imp-N5	Is the taxon likely to affect any U.S. globally outstanding ecoregion? (y = 0.1, n = 0, or ? = 0)
Imp-N6	What is the taxon's weed status in natural systems? Choose one: (a) Taxon not a weed; (b) taxon a weed but no evidence of control; (c) taxon a weed and evidence of control efforts. (a = 0, b = 0.2, c = 0.6, ? = 0)
Imp-A1	Does the taxon negatively impact personal property, human safety, or public infrastructure? (y = 0.1, n = 0, or ? = 0)
Imp-A2	Does the taxon change or limit recreational use of an area? (y = 0.1, n = 0, or ? = 0)
Imp-A3	Does the taxon affect desirable and ornamental plants and vegetation? (y = 0.1, n = 0, or ? = 0)
Imp-A4	What is the taxon's weed status in anthropogenic systems? Choose one: (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts. (a = 0, b = 0.1, c = 0.4, or ? = 0)
Imp-P1	Does the taxon reduce crop or commodity yield? (y = 0.4, n = 0, or ? = 0)
Imp-P2	Does the taxon lower commodity value? (y = 0.2, n = 0, or ? = 0)
Imp-P3	Does the taxon impact or is it likely to impact trade? (y = 0.2, n = 0, or ? = 0)

Imp-P4	Does the taxon affect the quality or availability of irrigation, or strongly compete with plants for water? (y = 0.1, n = 0, or ? = 0)
Imp-P5	Is the taxon toxic to animals? (y = 0.1, n = 0, or ? = 0)
Imp-P6	What is the taxon's weed status in production systems? Choose one: (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts. (a = 0, b = 0.2, c = 0.6, ? = 0)

A3. Geographic Potential
For each of the three climate variables below, determine which hardiness zones, climate classes, or precipitation bands are suitable for species establishment. Select either y or n.

Code	Description
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)

A4. Entry Potential

Code	Question
Ent-1	Is the plant taxon already in the United States? (y=1, n=0) STOP IF YES
Ent-2	Is the plant taxon proposed for import or is its entry imminent (y=1, n=0) STOP IF YES
Ent-3	What is the cultivation status of this plant taxon? Choose the best answer: (a) Neither cultivated or positively valued; (b) Not cultivated, but positively valued or potentially beneficial; (c) Cultivated, but no evidence of trade or resale; (d) Commercially cultivated or other evidence of trade or resale. (a = 0, b = 0.05, c = 0.25, d = 0.5)
Ent-4	Entry as a contaminant
Ent-4a	Is the taxon present in Canada, Mexico, Central America, the Caribbean, or China? (y or n)[5].
Ent-4b	Is the plant taxon a contaminant of propagative plant material (except seed)? (y = 0.4, n = 0, ? = 0)
Ent-4c	Is the plant taxon a contaminant of seeds for planting? (y = 0.4, n = 0, ? = 0)
Ent-4d	Is the plant taxon a contaminant of ballast? (y = 0.3, n = 0, ? = 0)
Ent-4e	Is the plant taxon a contaminant of aquarium plants or other aquarium products? (y = 0.2, n = 0, ? = 0)
Ent-4f	Is the plant taxon a contaminant of imported landscape products? (y = 0.2, n = 0, ? = 0)
Ent-4g	Is the plant taxon a contaminant of containers, packing materials, equipment, conveyances, or non-agricultural products? (y = 0.2, n = 0, ? = 0)
Ent-4h	Is the plant taxon a contaminant of highly processed commodities or fruits, vegetables, grains or other products for consumption? (y = 0.1, n = 0, ? = 0)
Ent-4i	Is the plant taxon a contaminant of some other pathway(s) not covered above? Choose the letter for the risk score that best represents the relative risk for the pathway(s): (a) 0; (b) 0.01; (c) 0.02; (d) 0.03; (e) 0.04.
Ent-5	Is the plant taxon likely to enter the United States through natural dispersal? (y = 0.6, n = 0, ? = 0)

[5] This question is not scored directly. If the taxon is present in one of these regions or countries, then the scores for questions Ent-4b through Ent-4i are doubled.

Appendix B. Logistic regression model formulas

This appendix contains the formulas for the logistic regression model of the probabilities (P) of a taxon being a major-invader (MajI), minor-invader (MinI), and non-invader (NonI). In this usage, an invader is broadly defined to mean a species capable of establishing, spreading, and causing impacts in a broad range of environmental, production, and anthropogenic systems. ES and Imp refer to the risk scores from the Establishment/Spread and Impact Potential risk elements, respectively. The three probabilities sum to 1 for each plant [P(MajI) +P(MinI) +P (NonI) =1]. These probabilities are automatically calculated by the Excel workbook in cells C139 to C141 on the "Screening Tool" worksheet. For additional information on the model or its development, see Koop et al. (2012).

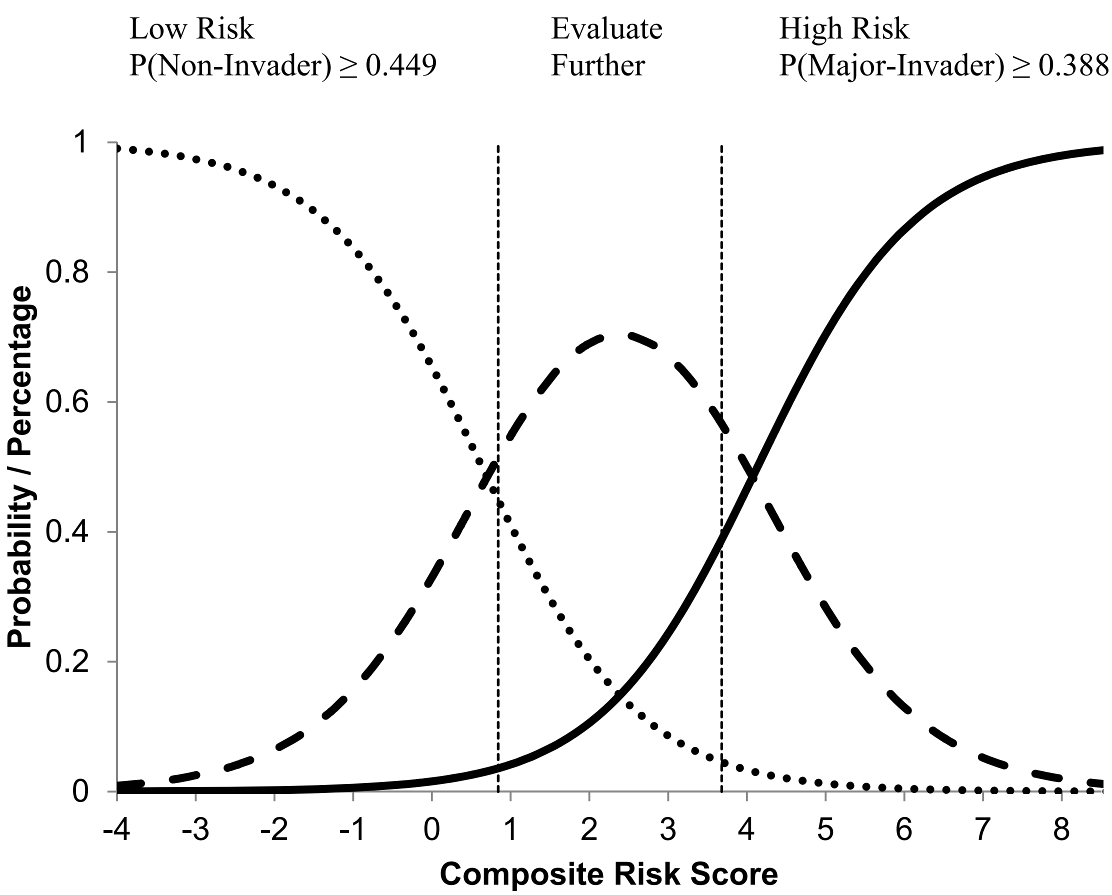
$$P(MajI) = \frac{1}{1 + e^{\left(4.1348 - (0.2356 \times ES) - (0.6019 \times Imp)\right)}}$$

$$P(MinI) = \frac{1}{1 + e^{\left(0.6366 - (0.2356 \times ES) - (0.6019 \times Imp)\right)}} - P(MajI)$$

$$P(NonI) = 1 - \left(\frac{1}{1 + e^{\left(0.6366 - (0.2356 \times ES) - (0.6019 \times Imp)\right)}}\right)$$

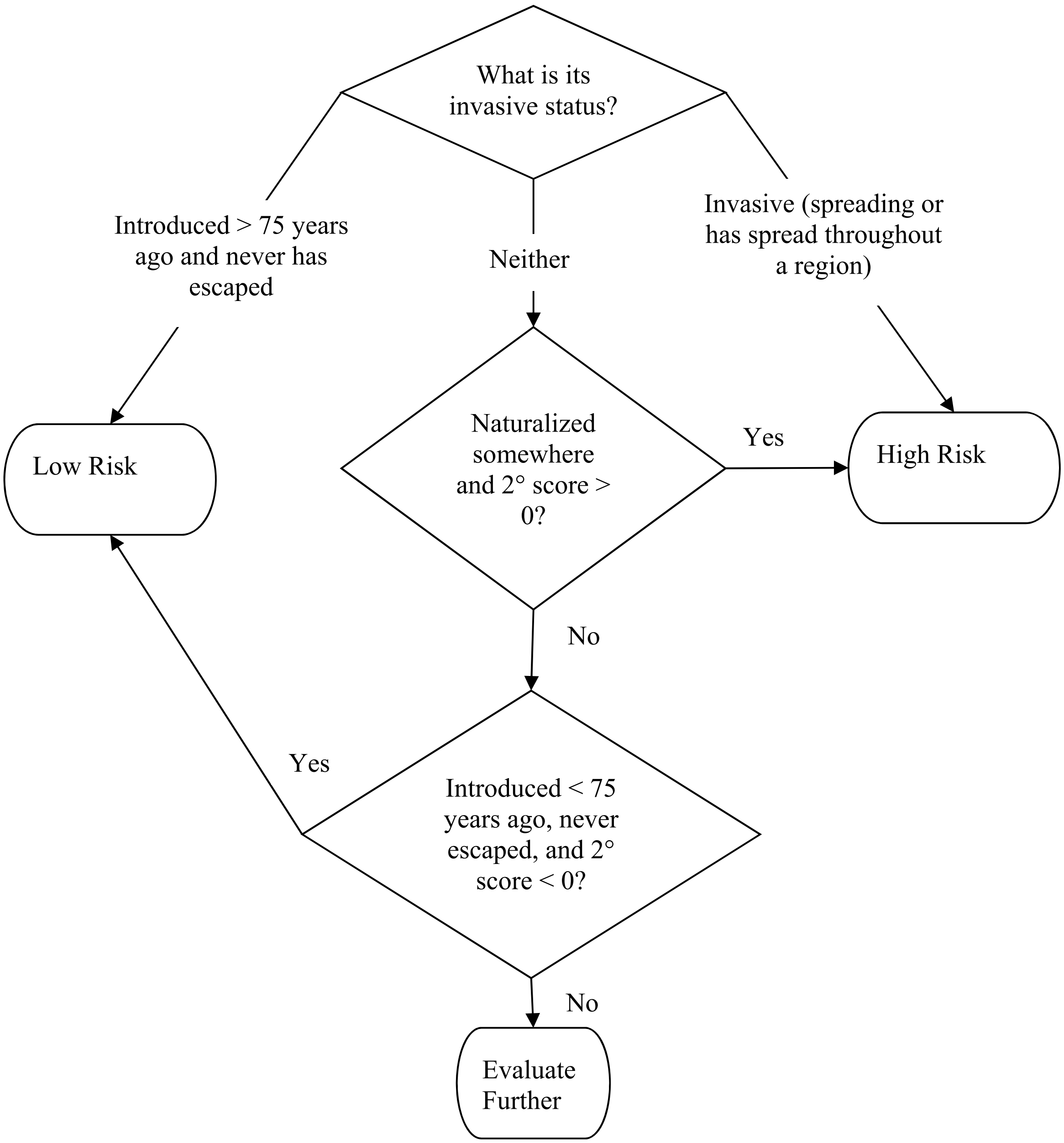
Appendix C. Logistic regression model and decision thresholds for Low Risk, Evaluate Further, and High Risk

In this appendix we present the logistic regression model for the probabilities of being a non-invader (dotted line), minor-invader (dashed line), 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 (ES) and Impact (Imp) Potential risk elements. It is used in determining the probabilities described in Appendix B and is calculated as (0.2356 × ES) + (0.6019 × Imp) (Koop et al., 2012). The vertical lines are the cutoff scores used by the model to determine the outcome of the WRA (Low Risk, Evaluate Further, or High Risk). The cutoff scores were calculated by receiver operating characteristic (ROC) curve analysis (Koop et al., 2012). 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 (occurring when the composite risk score ≤ 0.841), then the species is classified as Low Risk. If the probability of being a major-invader is ≥ 0.388 (occurring when the composite risk score ≥ 3.769), then the species is classified as High Risk. All other species are classified as Evaluate Further pending secondary screening. For additional information on the development of the model see Koop et al. (2012).



Appendix D. Secondary screening tool of the PPQ WRA

The secondary screening tool uses several questions that are strongly predictive of weed risk to determine if some of the taxa classified by the primary model as Evaluate Further should be categorized as High Risk or Low Risk. The first is question ES-1 from the WRA model, which refers to the species' invasive status anywhere in the world, including in the United States. The left and right paths correspond to two of the status options from ES-1. The central and bottom diamonds incorporate two other status options from ES-1. In those diamonds, the secondary score is the sum of the scores for six questions from the WRA model: 1) prolific reproduction (ES-14), 2) minimum generation time (ES-13), 3) shade adapted (ES-4), 4) commodity contaminant (ES-16), 5) number of natural dispersal vectors (ES17), and 6) forms dense thickets (ES-6).


What is its invasive status?
Introduced > 75 years ago and never has escaped
Neither
Invasive (spreading or has spread throughout a region)
Low Risk
Naturalized somewhere and 2° score > 0?
Yes
High Risk
No
Yes
Introduced < 75 years ago, never escaped, and 2° score < 0?
No
Evaluate Further

Appendix E. Question-specific guidance and examples for the risk element Establishment/Spread Potential

The Establishment/Spread Potential risk element evaluates the likelihood the taxon will escape, naturalize, and spread in the area at risk by evaluating numerous factors about the biology of the taxon. It does not consider any evidence about the impact a taxon is or is not causing. The risk score may range from -25 to 32 points, with higher numbers indicating a higher likelihood. Questions usually require an answer of yes (y), no (n), or unknown (?), except where otherwise indicated.

For each question, we provide the question, answer choices, and scoring in bold type followed by the question-specific guidance. As necessary, additional suggestions, definitions, search criteria, and references are provided. One or more examples are also provided. For the examples, the full citations for references are not provided. This omission is intentional.

ES-1 What is the taxon's establishment and spread status outside its native range: (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown. (a = -5, b = -2, c = 0, d = 0, e = 2, f = 5, ? = 0)

<u>Definitions</u>

- Casual: Alien plants "that may flourish and even reproduce occasionally in an area, but which do not form self-replacing populations, and which rely on repeated introductions for their persistence." These taxa are typically called waifs, transients, and occasional escapes, or they may be described as "persisting after cultivation" in the literature (Richardson et al., 2000). Crop plants that appear a season or two after they were planted but do not persist are called volunteers (Gressel, 2005) and are considered casuals in the context of the PPQ WRA.
- Naturalized: "Alien plants that reproduce consistently and sustain populations over many life cycles without direct intervention by humans; they often recruit offspring freely, usually close to adult plants, and do not necessarily invade natural, semi-natural or human-made ecosystems" (Richardson et al., 2000). Many sources use the word "established" as a synonym of "naturalized"; however, other sources consider "established" to refer to plants that are not quite fully naturalized (i.e., surviving, but not reproducing) (Richardson et al., 2000).
- Invasive: "Naturalized plants that produce offspring, often in very large numbers, at considerable distances from parent plants, and thus have the potential to spread over a considerable area" (Richardson et al., 2000). Consider "considerable distances" to be distances of more than 100 meters for taxa spreading by seeds and other propagules, and distances of more than 6 meters every three years for taxa spreading by roots, rhizomes, stolons, or creeping stems (Richardson et al., 2000). Words such as "spreading" and "expanding" are indicative of an invasive species, in the strict sense. Naturalized exotic species that are widely distributed across an area are also likely to be invasive or have been invasive in the past.

Rationale. One of the best predictors of invasiveness (in the strict sense) is a taxon's status where it has been introduced outside of its native range (Caley and Kuhnert, 2006; Reichard, 2001). Review the literature to determine the invasive status of the taxon around the world (see definitions below).

Criteria. If the taxon is relatively new (e.g., recently bred, artificial hybrid, genetically modified organism, new natural hybrid) and has not had sufficient time to express its potential invasiveness (or lack of it) under uncontrolled conditions answer unknown. Because the invasive plant literature uses conflicting terminology to describe a taxon's status, carefully evaluate the evidence by either reading the source's definitions of its terminology or examining the underlying supporting evidence. For example, species described as "widely naturalized throughout the country" or "rapidly spreading" should be considered invasive, unless the evidence suggests otherwise. For the terms listed in choices "d," "e," and "f" we follow Richardson et al.'s (2000) concepts and definitions (see above). For this question, it is not appropriate to use congeneric information.

We recommend that you begin your compiled evidence with a single sentence describing the native distribution. Then describe the status of the species for the countries where it has been introduced. This list does not need to be exhaustive, just representative. Be sure to provide your reasoning or supporting documentation for every country/case as necessary. Because a taxon's status may vary depending on what country it is in, choose the answer that describes its worst status. In other words, if a taxon has not escaped in a country where it is cultivated, but it has become naturalized in another country, choose "e." If a species is invasive in one country and naturalized in five others, choose "f." Evidence that a plant is a weed in a given country is almost always inappropriate for this question and risk element because weediness generally refers to harmful or unwanted plants; this type of evidence is considered under Impact Potential.

Notes

- If a taxon has been introduced elsewhere, but you do not know when it was introduced, assume that it was recently introduced (choice "b") but state in "Evidence and Notes" that you are making this assumption. When available, provide dates of introduction.
- Although we use the term "invasive" to describe the class of plants under choice "f," minimize or avoid the use of this term when presenting and describing the evidence for any given country. In the scientific and popular literature, the term "invasive" can refer partially or entirely to plants that are harmful and unwanted. Statements in the evidence that a taxon is "invasive" in a given country are generally too ambiguous for this question. However, evidence that a taxon is "invading" an area may be appropriate as it implies an ecological process rather than a perceived status. To avoid confusion, we recommend that you describe the evidence for a taxon meeting the criteria for choice "f" in terms of its ability to spread.

Full examples

- *Gladiolus undulatus* is native to South Africa (Goldblatt and Manning, 1998). It is naturalized in Portugal (Domingues de Almeida and Freitas, 2006). It "is increasing very rapidly on road verges, creek banks, wetlands and estuarine sites in bushland in Australia" (Hussey et al., 2007). It invades grassland, forest edges, riparian habitats, seasonal freshwater wetlands (Weber, 2003). The alternate answers for the stochastic simulation were both “e.” Answer: “f” with low uncertainty.

References

- Caley, P., and P. M. Kuhnert. 2006. Application and evaluation of classification trees for screening unwanted plants. Austral Ecology 31(5):647-655.
- Gressel, J. (ed.). 2005. Crop Ferality and Volunteerism. CRC Press, Boca Raton, FL. 422 pp.
- 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.
- Richardson, D. M., P. Pyšek, M. Rejmánek, 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.

ES-2 Is the species highly domesticated? (y = -3, n = 0, or ? = 0)?

Criteria. This question will rarely receive a positive answer. Answer yes if the taxon has been intentionally selected over several to many generations for a particular trait or suite of traits that likely reduces the ability of the plant to escape, establish, and spread (e.g., much reduced flower or seed production, reduced vigor, loss of vegetative growth, conversion of stamens to petals). An answer of yes should be accompanied by evidence that people substantially modified one or more traits through domestication (traditional breeding, biotechnology, etc.) and that the modification applies to all lower level taxa including cultivars. Evidence to the contrary [no domestication, or selection that increases invasive traits (e.g., Kitajima et al., 2006)] or no information results in a no response. Breeding that has changed neutral traits (i.e., those not affecting plant invasive potential) results in a no response.

Notes

- We recommend, for all taxa and scenarios, that you describe whether or not the taxon is cultivated, because by definition non-cultivated species cannot be domesticated. If a taxon is not cultivated, use negligible uncertainty.

Full examples

- *Cordia curassavica* is cultivated as a medicinal plant in Brazil (Albuquerque et al., 2012; Mussi-Dias et al., 2012). It is used in traditional Mexican medicine (Hernandez et al., 2007). However, we found no evidence that it has been bred for any particular traits resulting in reduced weed potential. Answer: no with low uncertainty.
- *Fortunella japonica* (kumquat) is cultivated for its fruit. This taxon is “known only from cultivation” (Ziegler and Wolfe, 2008). Some varieties are seedless (Morton, 1987). “Kumquats are rarely grown from seed as they do not do well on their own roots” (Morton, 1987). Seedlings do poorly on their own (Verheij and Coronel, 1991). Based on this suite of traits and the fact this species is only known from cultivation, domestication appears to have reduced the overall ability of the species to survive on its own. Answer: yes with low uncertainty.

References

- Kitajima, K., A. M. Fox, T. Sato, and D. Nagamatsu. 2006. Cultivar selection prior to introduction may increase invasiveness: evidence from *Ardisia crenata*. Biological Invasions 8:1471-1482.

ES-3 Are there any congeners that are considered significant weeds? (y = 1, n = 0, or ? = 0)

Criteria. Review major works and databases to determine if any congeners (taxa within the same genus) are considered significant weeds, meaning those taxa that cause significant direct or indirect damage to production, natural, or anthropogenic systems, or that result in high economic costs due to control efforts. Significant weeds are often subject to some form of control or management to limit their impacts. Taxa classified as serious or principal in Holm et al. (1979) or troublesome in Bridges (1992) should be considered significant weeds. Similarly, plants considered invasive or highly invasive (as defined under ES-1) in the literature may also be significant weeds [e.g., plants listed under category #5 in Randall (2007), or plants listed in other works on major world invaders such as Weber (2003)]. Taxa that are regulated by national plant protection organizations may also qualify as significant weeds. If no weedy congeners are found, answer no. Remember that only congeners that are significant weeds merit a yes.

Notes

- Searching: Genus name + "weed," "invas*," "invad*," "pest." Evidence is usually obtained from internet, primary literature, and weed handbooks [e.g., Weber (2003)].
- Be cautious about relying on a single source when evaluating if a taxon is a significant weed because some sources exaggerate impacts or claim a taxon is a significant weed without provide clear evidence. Remember, you are looking to see if the genus has any significant weeds as an indication that the taxon being assessed may also be weedy/invasive.
- For perspective, we recommend stating the approximate number of taxa contained in the genus. Mabberley (2008) reports taxa numbers for each plant genus.
- Usually, congeners all have a similar life form (e.g., herbs, shrubs, trees, vines, aquatics, etc.). For genera with a diverse set of life forms or very divergent life histories, we recommend you limit the comparison to those taxa with similar life form and biology.
- In some cases, the genus may contain only one taxon. In these cases, if the taxon being assessed is closely related to members of another genus, or was recently classified in that genus, expanding the scope of this question to that genus may be appropriate. However, state why this is being done, and limit the comparison to similar taxa.
- Use the current information on taxonomy and nomenclature [e.g., the GRIN database (NGRP)] to determine which taxa are within the same genus. Some consideration may be given to taxa that were previously considered to be in the same genus since they will likely represent similar species (see full example below); but use this approach only when no other information is available.

Full examples

- *Delairea odorata* is the only species in the genus *Delairea* (Mabberley, 2008), but if we include species in the genus *Senecio*, in which *D. odorata* was once placed, several significant congeneric weeds exist (Holm et al., 1979; Randall, 2007; Weber, 2003). For example, *S. jacobaea* is highly toxic to livestock (Bossard et al., 2000), and *S. vulgaris* is a serious and principal weed in many countries (Holm et al., 1979). *Senecio angulatus* changes community structure, alters species composition (Newton, 1996; Weber, 2003; WMC, 2013), and reduces regeneration of native species (Williams and Hayes, 2007). Because these taxa are not truly congeners of *D. odorata*, we answered yes but with moderate uncertainty. Answer: yes with moderate uncertainty.

References

- Bridges, D. C. (ed.). 1992. Crop Losses Due to Weeds in Canada and The United States - 1992. Weed Science Society of America, Champaign, IL, U.S.A. 403 pp.
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- Mabberley, D. J. 2008. Mabberley's Plant-Book: A Portable Dictionary of Plants, their Classification and Uses (3rd edition). Cambridge University Press, New York. 1021 pp.
- NGRP. Germplasm Resources Information Network (GRIN). United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program (NGRP). http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl?language=en.
- Randall, J. M. 2007. The Introduced Flora of Australia and its Weed Status. CRC for Australian Weed Management, Department of Agriculture and Food, Western Australia, Australia. 528 pp.
- Weber, E. 2003. Invasive Plant Species of the World: A Reference Guide to Environmental Weeds. CABI Publishing, Wallingford, UK. 548 pp.

ES-4 Is it shade tolerant at some stage of its life cycle? (y = 1, n = 0, or ? = 0)

Criteria. Answer yes if you find evidence that the taxon can grow in full shade (low light levels and no direct light) at any stage in the life cycle. Also answer yes for submerged aquatic taxa unless contrary information is available. Answer no if the taxon requires full sun or partial sun/partial shade at all stages of its life cycle; otherwise, answer unknown. If quantitative data are available, choose the shade tolerance status supported by the data; otherwise, consider the weight of the evidence. Consideration of the taxon's ecological niche may also help address this question (e.g., taxa that require canopy disturbance are often intolerant of shade, whereas forest understory taxa are often shade tolerant).

Notes

- With respect to percentage of full light availability, there is no strict criterion for shade. However, for the purpose of this question we will consider 20 percent of full sunlight or less to represent shaded conditions. For reference, we note that in some tropical forests only 2 percent of available sunlight reaches the forest floor.
- A study of light intensity in natural lakes in Wisconsin showed that plants at a depth of 5 meters receive anywhere between 17 percent to less than 1 percent of incident light due to light attenuation in the water column (Riemer, 1993). Plants that grow to these depths should receive a yes with higher uncertainty if more direct evidence is not available.
- Information about a taxon's behavior or traits can also be used to answer this question (e.g., light saturation curves, phototropism, leaf movements, etc.).

- Gardening guides (e.g., http://davesgarden.com/) usually provide some indication of a taxon's light preferences; however, these guides may not always indicate light tolerances under *natural* conditions.
- The CABI Forestry Compendium (http://www.cabi.org/fc/) also gives shade tolerance information for a number of woody taxa.

Full examples

- *Impatiens parviflora* prefers shade and half-shade (Valkenburg and Duistermaat, 2012). It occurs in shady places (Groom, 2012; Perglová et al., 2009; Salisbury, 1961; Valkenburg and Duistermaat, 2012). In its introduced range, "[m]ostly it is found in damp shady places" (Williamson, 1996). "Its ability to grow and reproduce in low light levels is considered the main factor enabling its spread into forests" (Tabak and Von Wettberg, 2008). In Canada, it grows "in even the deepest forest shade" (DAF, 2011). Answer: yes with negligible uncertainty.
- *Gladiolus undulatus* is "not shade tolerant" (Auckland Council, 2007). It requires full sun to partial shade (Dave's Garden, 2011). Answer: no with low uncertainty.

References

- Riemer, D. N. 1993. Introduction to Freshwater Vegetation. Krieger, Malabar, Florida. 205 pp.

ES-5 Is the plant a vine or scrambling plant, or does it form tightly appressed basal rosettes? (y = 1, n = 0, or ? = 0)

Rationale. Taxa with these life forms typically readily grow over and smother existing vegetation, possibly suppressing their growth or eventually killing them.

Criteria. Vines and other plants with a scrambling/clambering life form receive a yes. Plants with basal rosettes that are flat, tightly appressed and with overlapping leaves receive a yes as well. Answer no for taxa that do not physically overgrow other vegetation in this manner. Plants such as trees that simply grow taller and shade out underlying vegetation fall outside of the scope of this question. Information on a taxon's growth form is usually readily available, particularly in floras; however, if it is not, answer unknown. This question may overlap with question ES-6, which relates to plants forming dense populations. Question ES-6 focuses on population density and how that impacts other organisms, whereas this question focuses on the growth form/habit of an individual plant. Certain aquatics or terrestrial herbs may receive a yes if individual plants form mats, although this may be covered under ES-6 because mat-forming plants often root at nodes resulting in a "population" of plants that are interconnected.

Notes

- The evidence should describe the taxon's life form. Usually this will be sufficient to answer the question, but in some cases further discussion and interpretation may be necessary.
- Scrambling plants (also known as scandent, sprawling, or clambering) are taxa that often use stiff branches or hooks to climb and clamber over other vegetation. They differ from

other plants that use more active mechanisms of climbing such twining, adventitious roots, or tendrils.

Full examples

- *Impatiens parviflora* is neither a vine nor an herb with a basal rosette. It is an erect annual herb, 20-150 cm tall (Coombe, 1956). It is a tall herb (Wallentinus, 2002), the stem being erect and simple or branched, and the height of the plant being 0.3 to 1.5 meters (Valkenburg and Duistermaat, 2012). Answer: no with negligible uncertainty.
- *Persicaria chinensis* is a vine (Biosecurity New Zealand, 2011c). Its stems are "often very long and climbing" (PROSEA Foundation, 2011; van Valkenburg and Bunyapraphatsara, 2001). It is a "hardy creeper" (Barbora, 1972). It "can grow rapidly to varying heights depending on what it is scrambling over" (Galloway and Lepper, 2010). It "can scramble up trees to about 10 m" (Goodland and Healey, 1996). It climbs over tea bushes (Haridas and Sharma, 1974). It is a "vigorous climber with the ability to smother native plants, forest areas and horticulture operations" (Biosecurity New Zealand, 2011c). Answer: yes with negligible uncertainty.

ES-6 Does the taxon form dense thickets, patches, or populations? (y = 2, n = 0, or ? = 0)

Rationale. Taxa capable of dense growth may be good invaders because they may suffer less from intraspecific competition than other taxa and may exclude other taxa or obstruct access as they dominate an area. Such taxa may better establish in undisturbed habitats where competition is high.

Criteria. To answer this question with a yes response, look for evidence that the taxon forms dense thickets, patches, or populations. Densely growing woody perennials and tall grasses are most likely to receive yes answers, but other life forms, including aquatics, may receive a yes. Taxa that merely have a dense growth form (i.e., stems and leaves arranged thickly on an individual plant) do not merit a yes on that basis alone. Instead, groups of individuals must be growing together in dense patches or populations. Answer no if there is no evidence that it forms dense thickets, patches, or populations; otherwise, answer unknown as appropriate. Evidence for this question could conceivably also apply to Imp-N3, which concerns a plant changing community composition or reducing biodiversity because it forms monospecific populations, which are often dense. To ensure proper use, a "yes" response for this question should be based on finding positive evidence that a plant forms dense thickets, patches, or populations, and *not* that it reduces biodiversity or smothers others vegetation.

Notes

- Check descriptions of growth and images of plant populations. You can use images as evidence when they are of natural or wild populations (as opposed to domestic plantings).

Full examples

- *Arundo donax* produces many-stemmed tussocks (Weber 2003). It forms "large, continuous, clonal root masses, sometimes covering several acres" (GISD 2011). The Global Invasive Species Database (2011) also refers to "dense populations." "In Hawaii,

it has ‘naturalised in coastal areas, often in thickets’ (Wagner et al. 1999)” (in Csurhes 2009). Answer: yes with negligible uncertainty.
- *Chrysopogon aciculatus* forms “dense green mats...It spreads and forms a firm mat over the ground” (Galinato et al., 1999). “An extensively creeping perennial with many rather brittle, leafy stolons rooting at the joints and forming a close, thick mat” (Whitney et al., 1939). “Creeping perennial grass forming mats by means of leafy stolons...leaves [of culms] mostly crowded near the base” (Whistler, 1995). Mat-forming grass (ABRS, 2012; Whistler, 1995). Answer: yes with negligible uncertainty.

ES-7 Is the taxon an aquatic plant? (y = 1, n = 0, or ? = 0)

Rationale. Aquatic weeds are a major concern because they often choke waterways, hinder recreation and navigation, and alter light, oxygen, and nutrient levels.

Criteria. Determining if a particular taxon is an aquatic species is sometimes difficult because there is a continuum of plant adaptations between terrestrial and aquatic environments. Answer yes to any obligate aquatic taxa that are floating, emergent, or submerged plants in fresh or saltwater systems. Wetland taxa and those that only grow on stream banks do not qualify. In difficult cases, consider the overall distribution of the taxon (e.g., where does it reproduce?), or note specific adaptations it may have for an aquatic habitat. A lack of positive evidence for this question results in a no answer.

Notes
- Most responses will be accompanied by either negligible or low uncertainty, but for some ambiguous taxa, uncertainty may be high.

Full examples
- *Limnobium laevigatum* is a free-floating or rooted aquatic with interconnected rosettes (Acevedo-Rodríguez and Strong, 2005). *Limnobium* seeds germinate underwater (Cook and Urmi-König, 1983). Answer: yes with negligible uncertainty.
- “*Iris pseudacorus* usually grows in sites with a continuously high soil-water content but the soil does not need to be submerged and the plant is capable of growth in dry sandy soil” (Sutherland, 1990). *Iris pseudacorus* occurs at higher positions along the shore of riparian zones and seeds germinate on exposed soil (Coops and Van Der Velde, 1995). It is “usually found near streams” (James, 1956). The rhizomes can grow when submerged in water 25 cm deep (Sutherland and Walton, 1990). Rhizomes continue to grow even after three months without water (Ramey and Peichel, 2001; Sutherland, 1990). “[C]onsidered as [an] emergent aquatic [weed]” (Gedebo and Froud-Williams, 1998). Because this plant is able to grow in dry soil and is not an obligate aquatic species, we answered no. Answer: no with moderate uncertainty.

References

- Pieterse, A. H., and K. J. Murphy. 1990. Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation. Oxford University Press, New York. 593 pp.

ES-8 Is the taxon a grass (Poaceae)? (y = 1, n = 0, or ? = 0)

Criteria. Answer yes for all taxa in the Poaceae, including bamboos. Otherwise, answer no.

Notes

- Sedges and rushes are technically not grasses and should not receive a yes.
- Unless taxonomic issues make it difficult to determine if the taxon is in the Poaceae, uncertainty should always be negligible.

Full examples

- *Cordia curassavica* is not a grass; rather it is a shrub in Boraginaceae family (NGRP, 2013). Answer: no with negligible uncertainty.

ES-9 Is the taxon a nitrogen-fixing woody plant? (y = 1, n = 0, or ? = 0)

Rationale. A large proportion of woody legumes are weeds, particularly in conservation areas, because they alter soil nitrogen levels, which in turn affects other species. In some cases, such plants may alter the successional dynamics of plant communities (e.g., *Myrica faya* in Hawaii; Vitousek et al., 1987). This question focuses on woody nitrogen-fixing taxa because they appear to have a potentially stronger impact on soil nitrogen (e.g., Yelenik et al, 2007).

Criteria. Assume that all woody taxa of the family Fabaceae fix nitrogen (i.e., answer yes) unless you find evidence that a particular taxon does not. Answer no for all herbaceous or semi-woody taxa of the Fabaceae family, regardless of whether or not they fix nitrogen. Based on the resources listed below, ten angiosperm families are known to contain nitrogen-fixing taxa. If the taxon being assessed occurs in one of these families, look for specific evidence of nitrogen fixation and answer accordingly. If the taxon does *not* occur in one of these families, then answer no with negligible uncertainty.

Notes

- Search taxon name + “fix” and “nitrogen.”
- In addition to the Fabaceae, the following families contain nitrogen-fixing woody plants: Betulaceae, Cannabaceae (*Parasponia* spp.), Casuarinaceae, Coriariaceae, Datiscaceae, Elaeagnaceae, Myricaceae, Rhamnaceae, Rosaceae, and Ulmaceae (Martin and Dowd, 1990; Santi et al., 2013). Note that species in other plant families may rarely fix nitrogen; those should become apparent during a routine search of the literature.
- The following website lists some angiosperm taxa that form symbiotic relationships with the nitrogen-fixing bacteria *Frankia*: http://web.uconn.edu/mcbstaff/benson/Frankia/FrankiaHome.htm
- Specific evidence that a given taxon fixes nitrogen results in lower uncertainty. If it is not clear whether the taxon is woody or not, raise uncertainty as appropriate.

Full examples

- We found no evidence that *Cordia curassavica* fixes nitrogen. Furthermore, it is in the Boraginaceae (NGRP, 2013), which is not one of the families known to contain nitrogen-

fixing species (Martin and Dowd, 1990; Santi et al., 2013). Answer: no with negligible uncertainty.
- *Colophospermum mopane* is a woody plant in the Fabaceae family (NGRP, 2013; Royal Botanic Gardens Kew, 2013), but evidence indicates that it does not fix nitrogen. In a study evaluating multiple tree species, *C. mopane* was one of the non-nitrogen fixing species (Pokhriyal et al., 1990). Nitrogen-fixing nodules have not been found (Melusi and Mojeremane, 2012). It "does not have symbiotic nitrogen-fixing rhizobium within its roots, i.e. it does not fix nitrogen" (cited in Mutakela, 2009). Because this woody plant is in the family Fabaceae and we found only one study that specifically looked at whether *C. mopane* fixes nitrogen, we used low instead of negligible uncertainty. Answer: no with low uncertainty.

References

- Martin, P. G., and J. M. Dowd. 1990. A protein sequence study of the dicotyledons and its relevance to the evolution of the legumes and nitrogen fixation. Australian Systematic Botany 3:91-100.
- Santi, C., D. Bogusz, and C. Franche. 2013. Biological nitrogen fixation in non-legume plants. Annals of Botany 111(5):743-767.
- Vitousek, P. M., L. R. Walker, L. D. Whiteaker, D. Mueller-Dombois, and P. A. Matson. 1987. Biological invasion by *Myrica faya* alters ecosystem development in Hawaii. Science 238(4828):802-804.
- Yelenik, S. G., W. D. Stock, and D. M. Richardson. 2007. Functional group identity does not predict invader impacts: Differential effects of nitrogen-fixing exotic plants on ecosystem function. Biological Invasions 9:117-125.

ES-10 Does the taxon produce viable seed or spores? (y = 1, n = -1, or ? = 0)

Criteria. Evidence that the taxon produces viable seed or spores naturally, either in the wild or in a garden (native or naturalized range), results in a yes answer. Information from gardening sources indicating that the plant is propagated by seed may be used to support a yes answer, but use higher uncertainty if you do not find evidence that it produces seed naturally. Taxa that can only be propagated through hand-pollination do not warrant a yes answer. If the taxon is a subspecies, variety, or cultivar, it must be indisputably sterile, not just self-incompatible, to receive a no answer (c.f. Culley and Hardiman, 2009, where 'Bradford' pear is self-sterile but in fact will cross with other cultivars to produce viable seed). Any taxon receiving a no answer for this question will also score no for question ES-14 (prolific seed production). Answer unknown if you find no information on seed or spore viability.

Notes
- Search taxon name + "seedling," "seed," "spore," "germination," and "germinate."
- Data on seed viability for >10,000 taxa exist at the Kew Gardens Seed Information Database (http://data.kew.org/sid/), but the source literature should be checked.
- If seed or spore production is rare or occurs at very low rates, answer yes, but document that it is rare. Taxa with rare seed or spore production will be distinguished from taxa with prolific reproduction by question ES-14.

References

- Culley, T., and N. Hardiman. 2009. The role of intraspecific hybridization in the evolution of invasiveness: a case study of the ornamental pear tree, *Pyrus calleryana*. Biological Invasions 11(5):1107-1119.

Full examples

- *Ardisia crenata* produces viable seeds (Chimera and Drake, 2010; Csurhes and Edwards, 1998; Langeland and Burkes, 1998). Reproduces from seeds in the wild (Kitajima et al., 2006). Answer: yes with negligible uncertainty.

ES-11 Is the taxon self-compatible or apomictic? (y = 1, n = -1, or ? = 0)

Definitions (from Holmes, 1979):

- Allogamy – Cross-fertilization.
- Apomixis – A reproductive process without fertilization in plants, (i.e., asexual reproduction through seeds).
- Autogamy – Self-fertilization.
- Chasmogamy – Opening of a mature flower in the normal way to ensure fertilization.
- Cleistogamy – The condition of having flowers which never open and are self-pollinated, and are often small and inconspicuous.
- Dioecious – Having male and female flowers on different plants.
- Geitonogamy – Fertilization of a flower by another from the same plant.
- Monoecious – Having unisexual male and female flowers on the same plant.

Rationale. Taxa that can produce seed without out-crossing can spread from seed produced by isolated plants.

Criteria. Answer yes if a single individual of the taxon is capable of sexual reproduction, even if the self-fertilization produces fewer viable seeds than cross-pollination does. Self-compatible (including cleistogamous) or apomictic taxa would receive a yes answer to this question. Dioecious taxa should receive a no answer, unless there is specific evidence they are capable of apomixy. Direct evidence on whether or not the taxon is self-compatible is necessary; answer unknown where direct evidence is lacking.

Notes

- Search taxon name + “self*,” “crossing,” “apomi*,” “reproduction,” “fertile,” “fertility,” “geiton*,” “cleistogam*,” “dioecious,” “allogamy,” “autogam.”
- The horticultural literature may refer to plants as “self-seeding.” This generally means that plants produce seeds that drop and germinate in subsequent years (i.e., self-sow). Describing plants as “self-seeding” or “self-sowing” does not address how the seeds (and their embryos) were produced, and therefore does not necessarily mean they are self-compatible. A self-incompatible plant may have gotten pollen from another plant and then “self-seeded.”

Full examples

- *Nassella neesiana* is autogamous and exhibits a selfing rate of close to 100 percent (Vidal et al., 2011). It produces cleistogenes (seeds produced through cleistogamy) in flowering stem joints where they are often concealed by leaf sheaths (Richardson et al., 2006). Answer: yes with negligible uncertainty.

References

- Bicknell, R. A., and A. M. Koltunow. 2004. Understanding apomixis: Recent advances and remaining conundrums. The Plant Cell Online 16(suppl 1):S228-S245.
- Holmes, S. 1979. Henderson's Dictionary of Biological Terms (9th ed.). Van Nostrand Reinhold Company, New York. 510 pp.
- Schön, I., K. Martens, and P. van Dijk (eds.). 2009. Lost Sex: The Evolutionary Biology of Parthenogenesis. Springer, Dordrecht. 615 pp.

ES-12 Does the taxon require specialist pollinators that are not present in the WRA area? (y = -1, n = 0, or ? = 0)

Rationale. Specialist pollinators are organisms that pollinate only a limited number of plant taxa (Johnson and Steiner, 2000) and have usually coevolved with the plants they pollinate (e.g., *Ficus* plants and fig wasps). Plant taxa that depend on specialist pollinators for sexual reproduction are less likely to become invasive when introduced to a new area without their pollinators.

Criteria. Answer yes if the taxon is obligately dependent on a particular pollinator taxon for sexual reproduction, and that pollinator is not present in the area of introduction. Plant taxa that are likely to be pollinated by a different pollinator or set of pollinators in the WRA area should not receive a yes, even if such pollination may be uncommon. In these cases, document your reasoning and evidence and describe your uncertainty. Answer no for taxa that require specialist pollinators that *are* present in the WRA area, for taxa with documented generalist pollinators, or for taxa that reproduce without pollinator assistance (e.g., taxa that are wind pollinated, cleistogamous, etc.). Because the great majority of grasses (Poaceae), sedges (Cyperaceae), and rushes (Juncaceae) are wind-pollinated (Faegri and Van der Pijl, 1979), assume no with low uncertainty for these taxa if direct evidence is lacking. Also assume no with low uncertainty for all ferns and fern allies. Otherwise, answer unknown.

Notes

- Search taxon name + “pollinat*.”
- Although pollinators can be categorized as specialists or generalists, pollinators cover the entire spectrum between those extremes (Johnson and Steiner, 2000), and it may be difficult to classify them either way. In these cases, describe your evidence and reasoning and increase uncertainty as necessary.
- Floral visitors are not the same as pollinators. Many insects visit flowers or take nectar and pollen resources that plants provide without actually transferring pollen to the stigma of the flowers. Use higher levels of uncertainty when it is not clear that a floral visitor is an effective pollinator.

Full examples

- In its native habit in South Africa, *Gladiolus undulatus* is pollinated by long-proboscid flies with specialized elongated mouthparts (Goldblatt and Manning, 1999). *Gladiolus undulatus* does not set seed in Australia where the long-proboscid flies are not present (Western Australian Herbarium, 2011). Answer: yes with low uncertainty.
- *Penstemon barbatus* is primarily adapted for hummingbird pollination. In a study by Lange et al. (2000), large reductions in seed set resulted from hummingbird exclusion. Two of the hummingbird species known to pollinate it (rufous and calliope) are present in Canada, but found only in the west (NAPPC, 2007). It is not known if Canada's most wide-ranging hummingbird (ruby-throated) would pollinate this species. Some areas of Canada have no hummingbirds. To a much lesser extent, *P. barbatus* is pollinated by insects (e.g., halictid bees) (Lange et al., 2000), which are present in Canada. We answered no because hummingbirds and halictid bees represent two large guilds of pollinators and are not "specialized enough" for the scope of this question. However, because hummingbirds are not widely distributed in Canada and because halictid bees are not as effective as hummingbirds, we used high uncertainty. Answer: no with high uncertainty.

References

- Johnson, S. D., and K. E. Steiner. 2000. Generalization versus specialization in plant pollination systems. Trends in Ecology and Evolution 15(4):140-143.
- Faegri, K., and L. Van der Pijl. 1979. The Principles of Pollination Ecology. Pergamon Press, Oxford. 244 pp.

ES-13 What is the taxon's minimum generation time? Choose one: (a) less than a year with multiple generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) Unknown. (a = 2, b = 1, c = 0, d = -1, ? = 0).

Rationale. Generation time is the length of time between one plant generation and the next at the same life-cycle stage or point in the life cycle (e.g., germinating seed to germinating seed, corm to corm, vegetative offshoot to an offshoot of the same size; *sensu* Ricklefs and Miller, 2000). This applies to both sexually and vegetatively reproducing plants. For vegetatively produced plants consider generation time as the time taken for a plant to produce a clone (e.g., ramet) that is capable of independent growth. However, some plants remain attached to their parents for some time.

Criteria. Use specific generation time data on the taxon, to answer this question, unless a taxon's life form (e.g., a woody tree) can help eliminate one or more answer choices. Otherwise, answer unknown.

- Plants typically completing their life cycle in a year (i.e., annuals) should usually get an answer of "b." Many plants are annuals that germinate, grow, and reproduce in a few months, but produce seeds that remain dormant for the rest of the year; answer "b" for these plants. For example, an annual may germinate in March and produce seed by the end of May, but seed dormancy is a part of a plant's life cycle and the resulting progeny will not germinate until next spring. Therefore, concluding that the generation time is less than a year would be incorrect. Many seeds are dormant at maturity due to a variety of morphological and physiological mechanisms (Baskin and Baskin, 2004).

- Answer “a” for taxa that produce more than one generation per year under natural conditions, i.e., multiple generations per year are possible. This may be uncommon for plants reproducing by seed but some vegetatively reproducing plants can produce multiple generations in a year.
- Answer “c” for taxa that require two or three years to complete their generation time. In other words, these taxa will not produce a seed or vegetative propagules until their second or third year. Most biennials should receive a “c” response. If the answer is based on vegetative reproduction, then the life cycle starts and ends with vegetative propagules of the same size.
- Answer “d” for taxa that require four or more years to complete their generation time. Most shrubs and trees will receive a “d.”

You will not often find enough information to definitively answer this question. However, based on a taxon’s life form, you should be able to easily exclude one or two answer choices every time. For example, a tree that does not reproduce vegetatively is not going to have a minimum generation time of one year or less, and probably not even less than four years. Thus, an answer of “d,” with an alternate choice of “c” and moderate uncertainty may be the best answer. We recommended you select the best answer, alternate choices, and uncertainty level commensurate with the evidence available.

Notes

- Search taxon name + “years” + “flower” + “age.”
- Information from horticultural or forestry sources may be helpful.
- Do not assume that just because a plant is a biennial or perennial that it cannot reproduce in its first year.
- Because ferns experience an alternation of generation where the sporophyte is the noticeable generation and the independent gametophyte is much more inconspicuous, consider the minimum generation time as the time to go from reproductive sporophyte to reproductive sporophyte.
- For terrestrial vines that root along their nodes, determining generation time is very difficult because often each rooted segment is capable of independent growth. Furthermore, such taxa could simply continue to grow indefinitely. In these cases, it may be better to rely on information about sexual reproduction. If the vine taxa do not reproduce sexually, then consider how many years may go by before older portions of the vine die, leaving several independent segments. Whatever evidence and approach you use, clearly describe it in the notes column.

Full examples

- We found no information about this species’ generation time. *Limnobium laevigatum* is ecologically similar to water hyacinth, only smaller. Both are free-floating, herbaceous aquatics, have similar morphology, and reproduce vegetatively. Water hyacinth (*Eichhornia crassipes*) can double in population size in five days due to vegetative reproduction; furthermore, plants can begin blooming at three to four weeks of age (Parsons and Cuthbertson, 2001). We are conservatively answering “b” for *L. laevigatum*, as it seems very likely that new offshoots will be produced within a year. In fact, we suspect that there may be several generations of vegetative offshoots in a year, potentially supporting an “a” response. Using high uncertainty because of a lack of information for this species and because we had to rely on information for a similar species. Alternate answers for the stochastic simulation were “a” and “c.” Answer: “b” with high uncertainty.

<u>References</u>

- Baskin, J. M., and C. C. Baskin. 2004. A classification system for seed dormancy. Seed Science Research 14(1):1-16.
- Ricklefs, R. E., and G. L. Miller. 2000. Ecology (4th ed.). W. H. Freeman and Company, New York. 822 pp.

ES-14 Is the taxon a prolific seed producer? (y = 1, n = -1, or ? = 0)

<u>Criteria</u>. The level of seed production must be met under natural conditions and applies only to viable seeds. For herbaceous taxa, this rate should be >5,000/m^2 crown area per year to receive a yes answer; for woody taxa, a rate of >1,000/m^2 crown area per year would receive a yes answer. Assume yes for ferns unless contradictory evidence exists. For this question, specific evidence is needed to support both yes and no answers. Ideally, use quantitative information when available. If specific data on this attribute are unavailable, extrapolate seed production from data on numbers of seeds per flower or fruit, and number of flowers or fruit per individual of average size, per unit area. Qualitative statements may be used to support no answers but should only be used to answer yes if it is confirmed by several references and consistent with other aspects of the species’ biology. If you cannot find sufficient information, answer unknown.

<u>Notes</u>

- Search taxon name + “seed.”
- Botanical sketches or pictures of the plant, flowers, and/or fruit can be used to estimate the seed/fruit output, but increase uncertainty accordingly.
- If answers are based on qualitative statements, use higher levels of uncertainty

<u>Full examples</u>

- The maximum productivity of *Falcaria vulgaris* (an herbaceous species) is up to 900 achenes per plant (AgroAtlas, 2012), but this reference does not indicate the number of plants per square meter. Note that achenes are fruit that contain only one seed each. *Falcaria vulgaris* produces several thousand seeds (Korman, 2011). Germination rates of 70-90 percent in the lab and 24-54 percent in the greenhouse are reported (Korman, 2011). Based on stem densities of 24 to 40, to possibly 645 per square meter (Korman, 2011), production of hundreds of achenes, and pictures of plant populations in South Dakota, it very likely this herbaceous species produces more than 5000 seeds per square meter. A researcher and manager who has studied *Falcaria* believes it produces more than 5000 seeds per square meter (Korman, 2012). Answer: yes with low uncertainty.

ES-15 Are propagules likely to be dispersed unintentionally by human activity? (y = 1, n = -1, or ? = 0)

Criteria. Answer yes if human activity has resulted or is likely to result in unintentional dispersal of propagules (any structure, sexual or asexual, which serves as a means of reproduction) of the taxon. Taxa found in disturbed habitats or habitats frequented by people, and having morphological dispersal adaptations such as burrs, sticky seeds, or small seeds that might be carried on vehicle tires or on shoes should receive a yes answer. Also consider propagules dispersed in yard waste, soil, or other debris, and as contaminants of machinery or other human dispersal vectors (see below for more examples). Answer no if you find no evidence of previous dispersal through human activity and absence of adaptations for such dispersal. If no information exists, answer unknown.

Notes

- Search taxon name + "seed dispersal."
- Greater weight should be placed on evidence of unintentional dispersal by humans than on seed size alone.
- The next question (ES-16) focuses on propagules dispersing on or in agricultural, forestry, or horticultural products. Do not count that evidence here if it better applies there. Some examples could qualify as evidence under *either* ES-15 or ES-16. In these difficult cases, use the evidence where most appropriate, but in only one answer.
- Some examples of human dispersal vectors include the following: boats, vehicles, trains, hiking and other outdoor equipment, agricultural machinery, personal equipment, and yard waste.

Full examples

- *Dittrichia graveolens* is spreading along roadways in California from the San Francisco area into the Central Valley (Hrusa et al., 2002). Seeds attach to clothing and bags, and move in sand and gravel for road construction (Parsons and Cuthbertson, 2001). Contaminates vehicles and equipment (Moerkerk, 2006), and likely spreading that way in California (Brownsey et al., 2013). Answer: yes with negligible uncertainty

ES-16 Are propagules likely to be dispersed as contaminants or hitchhikers of any agricultural, forestry, or horticultural products? (y = 2, n = -1, or ? = 0)

Rationale. In this question agricultural, forestry, or horticultural products are any of the raw or unprocessed, or partially processed plant or animal products of these industries that may be capable of carrying viable plant propagules (see examples below).

Criteria. A lack of positive evidence for this question and a growth form, biology, ecology, or habitat that makes contamination unlikely results in a no answer, since contaminants and hitchhikers are likely to be reported in the literature or by quarantine authorities. Otherwise, answer unknown.

Notes

- Search taxon name + "contaminant," "pathway."

- Search CAB Abstracts and Agricola, or any other relevant databases. Search national pest interception databases if available.
- Examples of contaminants include:
    1. Seeds of taxa included as contaminants in shipments of grain or imported seeds or fruit
    2. Propagules contaminating hay, wood, mulch, etc.
    3. Seeds likely to be included in potpourri mixtures
    4. Seeds with cut flowers or decorative branches
    5. Seeds stuck or caught on shipping containers, ventilation grills, pallets, or other transportation conveyances.
- References to "potential seed contaminant" in lists such as the GRIN database are insufficient without direct evidence. However, such statements can be used to support higher uncertainty levels.

<u>Full examples</u>

- Unknown. Vegetative fragments of *Nymphoides cristata* could be present in materials distributed within the aquarium trade (Maki and Galatowitsch, 2004). Answer: unknown with maximum uncertainty.
- *Nassella neesiana* has barbed seeds. It was introduced to the Waipawa area of New Zealand in contaminated pasture seed (Slay et al., 1999). It moves in hay bales (Weller et al., 2012). Because it is similar in appearance to desirable hay species in the vegetative state, it may be overlooked by managers (Weller et al., 2012). It is present in Genoa, Italy, near leather tanning facilities that processed hides from Argentina (Haywood and Druce, 1919). Several taxa of *Nassella* are wool adventives in Europe (Verloove, 2005). Answer: yes with negligible uncertainty.

ES-17 What is the number of natural dispersal vectors as described by ES-17a through ES-17e? (none = -4, one = -2, two = 0, three = 2, four or five = 4)

<u>Criteria</u>. This question is automatically answered by the spreadsheet based on the answers to questions ES-17a through ES-17e. The answer should be a number from 0 to 5. A single uncertainty value for the five sub-questions is not produced; instead, the five uncertainties are directly incorporated into the index of uncertainty for this risk element. For this row in the spreadsheet, enter a general description of the properties of the fruit, seeds, and/or other propagules in the notes column that will help support determinations for the five sub-questions.

<u>Notes</u>

- You can use congeneric information to answer questions ES-17a through ES-17e if the propagule traits of the congener are similar to the taxon being assessed. In these cases, use a higher level of uncertainty and note that the answer is based on congeneric information.

<u>References</u>

- van der Pijl, L. 1982. Principles of Dispersal in Higher Plants (3 ed.). Springer-Verlag, Berlin. 214 pp.

Full examples

- Fruit and seed description for questions ES-17a through ES-17e: *Cordia curassavica* has red-colored, fleshy fruit with thin testas (Opler et al., 1975). Seeds are 4.5-5 x 3.5 mm (Reed, 1977). Red-colored fruit (5 mm across) have one seed each (Swarbrick, 1997).

ES-17a Are propagules wind dispersed? (y, n, ?)

Criteria. Answer yes if evidence demonstrates that wind contributes significantly to the dispersal of propagules. Even without such documentation, taxa with morphological features that facilitate propagule movement by wind (achenes with a pappus, samaras, etc.) should receive a yes response. This group includes tumbling plants and fern spores. If fruit or seed do not have traits indicating wind dispersal, answer no, except answer unknown when the evidence is ambiguous or there is no information leading one answer or the other. Some references may claim a species is wind dispersed when seeds possess no obvious adaptation for wind dispersal, or when a breeze just helps knock seeds off swaying parent plants. Answer no or unknown in these cases, as appropriate, and use higher uncertainty.

Notes

- Search taxon name + "seed dispers*," "wind."
- Online databases that include information on the means of dispersal include BIOLFLOR for Germany (www.biolflor.de), and the Kew Gardens database (http://data.kew.org/sid/dispersal.html), but the source literature should also be checked.

Full examples

- *Hakea sericea* seeds are winged (Gordon, 1993b; Gunn and Ritchie, 1988; Weber, 2003). Wind disperses seeds over several kilometers (Richardson et al., 1997). Seeds are dispersed long distances by wind, forming the nucleus of new invasions (CABI, 2012). Seeds are dispersed well by wind (Richardson et al., 1987). *Hakea* are wind-dispersed (Groom, 2010). Answer: yes with negligible uncertainty.

References

- Sheldon, J. C., and F. M. Burrows. 1973. Dispersal effectiveness of achene-pappus units of selected Compositae in steady winds with convection. New Phytologist 72(3):665-675.

ES-17b Are propagules water dispersed? (y, n, ?)

Criteria. Evidence that the propagule is carried by and survives in water, or is buoyant, results in a yes response. Answer no with low or negligible uncertainty where there is evidence that propagules are not buoyant or dispersed by water. If fruit or seed characters or other biogeographical evidence suggest that the taxon is not dispersed by water, answer no. Otherwise, answer unknown. Just about any seed or other dispersal propagules can be dispersed by water if the water flow is strong enough (e.g., floods, tidal surges, etc.), and some sources may claim a taxon is water dispersed based on these rare events. In these circumstances, answer no but with higher uncertainty. Only answer yes if the taxon routinely disperses by water under normal (i.e., average) environmental conditions. If multiple, independent sources claim a taxon is dispersed by water when there is no other type of supporting evidence available, answer yes with higher uncertainty as appropriate. In difficult cases, consider where the species naturally occurs and other aspects of its biology. For example, aquatic and wetland taxa are likely to be dispersed by water. Species that grow only along streams, rivers, or other water bodies may also be routinely dispersed by water.

Notes

- Search taxon name + "buoyant," "floats" + "water dispers*."
- See online databases listed under ES-17a.
- Examples of fruit or seed adaptations that may facilitate water dispersal include unwettable seed coats, seeds or fruit that contain air spaces, cork or oil, and hairs or slime on the seed coat, which provide resistance to sinking (Howe and Smallwood, 1982).
- Documented distribution along waterways and other relevant ecological information provides supporting evidence for a yes response, but use higher uncertainty without other supporting evidence.

Full example

- The propagules of *Colophospermum mopane* are dispersed by water (Melusi and Mojeremane, 2012; Sharma et al., 1989). In a field study, the authors concluded that "the most likely agents of dispersal of mopane diaspores to be water and wind," and flotation was an important means of dispersal (Styles and Skinner, 1997). Furthermore, "[a] characteristic of the summer rainfall period is the subsequent sheetflow of water along the surface of the ground"; this run-off collects masses of mopane diaspores and deposits them in piles along the drainage lines. We answered yes with low uncertainty because multiple references mention dispersal by water, it has broad pods that could likely float easily, and flooding occurs yearly in its native habitat. Answer: yes with low uncertainty.

References

- Howe, H. F. and J. Smallwood. 1982. Ecology of Seed Dispersal. Annual Review of Ecology and Systematics 13: 201-228.

ES-17c Are propagules dispersed by birds? (y, n, ?)

Criteria. Dispersal of propagules by birds includes transport in a viable form externally on birds (on feet or feathers) or through their digestive tracts (excluding flightless birds). Evidence of bird dispersal is sufficient for a yes response. Where you find no information, assume yes for fleshy fruits that are less than 3–4 cm in diameter. Taxa known not to be dispersed by birds, that have seeds/spores known to always be digested, or with propagules too large for such dispersal should receive a no answer. Otherwise, answer unknown.

Notes

- Search taxon name + "seed dispers*," "birds."
- See online databases listed under ES-17a.
- Taxa with small red fruits and indigestible seeds, e.g., *Schinus terebinthifolius* (Panetta, 1997) would receive yes answers. Taxa with cones that are opened by birds to release the seeds would also receive a yes response.

- When there is evidence of bird dispersal but no information about seed viability or the effectiveness of bird dispersal, answer yes, but use higher uncertainty. When an answer of yes is based on fleshy fruit morphology alone, use high uncertainty.

Full examples

- The fruits of *Persicaria chinensis* "…are berries, globose in shape. Enclosed in the enlarged and fleshy calyx at maturity...Seeds small, black, fruits edible, sour tasting" (Tabish and Girija, 2011). The seeds of *Persicaria chinensis* are dispersed by birds intentionally eating the seed (Royal Botanic Gardens Kew, 2008). "Its fruits are bird dispersed" (Goodland and Healey, 1996). Additionally, the related species, *Persicaria perfoliata* (mile-a-minute weed) has seed that is spread by birds (Swearingen et al., 2010). Answer: yes with negligible uncertainty.

References

- Panetta, F. D., and J. McKee. 1997. Recruitment of the invasive ornamental, *Schinus terebinthifolius*, is dependent upon frugivores. Australian Journal of Ecology 22:432-438.

ES-17d Are propagules dispersed by other animals (externally)? (y, n, ?)

Criteria. This dispersal type includes seeds likely to be dispersed by (non-avian) animals, in hooves/feet or on fur. It also includes, some plant taxa that have seeds with an oily or fat-rich organ (an elaiosome) that aids in dispersal by ants. Taxa that dispersed by animals in this fashion will have adaptations (e.g., burrs), and/or grow in situations that make it likely that propagules become temporarily attached to the animal (non-avian). When a propagule clearly has adaptations for external dispersal, but you find no evidence that it is dispersed by animals externally, answer yes, but use high uncertainty. Where direct evidence is lacking, assume no for propagules that clearly have no mechanisms of attachment.

Notes

- Search taxon name + "seed dispers*."
- See online databases listed under ES-17a.

Full examples

- We found no evidence, and the species is well studied. Answer: no, with low uncertainty.
- The seeds of *Nassella neesiana* readily bore into the skins of animals (Haywood and Druce, 1919), and seeds often disperse on wool, hides, and animal carcasses (Bourdôt et al., 2012). The backward-pointing hairs on the apex of the seed help anchor seeds on animal fur (Storrie and Lowien, 2003). Seeds can fall from fleece several months later; after five months, unshorn sheep still had 10 percent of seeds remaining (Gardener et al., 2003a). Answer: yes with negligible uncertainty.

ES-17e Are propagules dispersed by other animals (internally)? (y, n, ?)

Criteria. Answer yes if propagules of the taxon pass through the digestive tract of animals (including bats and flightless birds but excluding flying birds) and maintain viability. If fruit are consumed (along with seeds) but you find no evidence that seeds pass remain intact and viable, answer yes with higher uncertainty if the animals are known to effectively disperse seeds of other, similar species. Answer no if the taxon is unlikely to be eaten by animals or if seeds do not remain viable after passage through the gut. Answer unknown if neither data nor morphological traits clarify whether this means of dispersal is likely.

Notes
- Search taxon name + "seed dispers*," "animal," "gut," "droppings."
- See online databases listed under ES-17a.

Full examples
- Fruits of *Vitex rotundifolia* are eaten by birds and squirrels, which may disperse the seeds (Suiter, 2005). "Could be dispersed by animals but I do not think they care for the odor or other chemicals. The primary dispersal is by water or people" (Whitwell, 2010). A naturalist has not seen deer or any other animal (other than birds) eat the fruit (Dewire, 2010). Collared peccaries consume and disperse the seed of *Vitex mollis* (Martinez-Romero and Mandujano, 1995). Answer: unknown with maximum uncertainty.
- *Phyllanthus maderaspatensis* seeds were able to germinate after being found in tortoise feces (Hnatiuk, 1978). Answer: yes with low uncertainty.

References

- Willson, M. F. 1993. Mammals as seed-dispersal mutualists in North America. Oikos 67(1):159-176.

ES-18 Is there evidence that a persistent (>1 year) seed bank (or other propagules) is formed? (y = 1, n = -1, or ? = 0)

Rationale. Long-term seed viability increases the invasive potential of a taxon by enabling them to escape unfavorable conditions in time rather than space.

Criteria. For a yes response, greater than 1 percent of the seeds in the soil should remain viable for more than 12 months. Consider both soil and canopy seed banks. If seeds of the taxon require scarification or other dormancy-breaking treatments for germination, answer yes with high uncertainty unless that treatment naturally and uniformly occurs within 12 months of seed production. Documented lack of any type of seed dormancy (including dormancy induced and/or enforced by burial) supports a no answer. Otherwise, answer unknown.

Although this question generally applies to seeds, in some cases plants may form other types of persistent propagules, such as rhizomes, that can escape unfavorable conditions (beyond yearly seasonal changes). For example, *Epipactis helloborine*, a temperate terrestrial orchid, forms rhizomes that can remain dormant for 7-18 years, thereby escaping drought conditions (Light and MacConaill, 2004). If you find such evidence, then answer yes, but only for extreme examples. We do not intend this question to result in yes answers for the type of seasonal "dormancy" found in many plant structures (e.g., bulbs, corms, rhizomes, etc.).

Notes

- Search taxon name + “seed storage,” “seed bank,” “recalcitrant,” “seed” + “germination,” “viability” + “years,” “seed” + “dorman*.”
- Data on seed viability for more than 10,000 taxa exist at the Kew Gardens Seed Information Database (http://data.kew.org/sid/), but the source literature should be checked.
- Do not use data on seed viability from controlled laboratory storage conditions to answer this question. For example, seed stored in liquid nitrogen can remain viable indefinitely and seeds stored under cool, dry, and dark conditions can remain dormant far longer than under field conditions.
- Thompson et al. (1997) details seed banks in northern temperate floras. Baskin and Baskin’s (1998) book on seeds includes information on dormancy and seed banks.
- Sometimes a source may refer to a soil seed bank but is simply discussing seeds in the soil irrespective of how long they have been or will be there. Remember that a yes response requires evidence of persistence for more than a year.

Full examples

- Freshly matured seeds of *Geranium lucidum* have water impermeable seed coats (Van Assche and Vandelook, 2006). Seed burial experiments showed that seeds remain viable for more than one year and need a period of desiccation to break dormancy (Van Assche and Vandelook, 2006). Experience from managers controlling populations suggests it has a long-term seed bank (Taylor, 2006). Answer: yes with negligible uncertainty.

References

- Baskin, C. C., and J. M. Baskin. 1998. Seeds, Ecology, Biogeography and Evolution of Dormancy and Germination. Academic Press, San Diego, CA, U.S.A. 666 pp.
- Light, M. H. S., and M. MacConaill. 2004. Appearance and disappearance of a weedy orchid, *Epipactis helleborine*. Pages 77-93 in International Orchid Workshop. Acad Sci Czech Republic Inst Botany, Haapsalu, ESTONIA.
- Levin, D. A. 1990. The seed bank as a source of genetic novelty in plants. The American Naturalist 135(4):563-572.
- Thompson, K., J. P. Bakker, and R. M. Bekker. 1997. The Soil Seed Bank of NorthWest Europe: Methodology, Density and Longevity. Cambridge University Press, Cambridge. 276 pp.

ES-19 Does the taxon tolerate or benefit from mutilation, cultivation, or fire? (y = 1, n = -1, or ? = 0)

Rationale. Mutilation, cultivation, and fire are artificial treatments or natural disturbances that can remove or kill most of the biomass of a plant. Taxa that tolerate or benefit from such disturbances may out-compete other taxa.

Criteria. Answer yes if the taxon tolerates or benefits from any physical biomass removal, including those intended for control purposes. Taxa adapted to fire or grazing pressure are likely to have yes responses. Taxa that over-compensate to tissue loss by herbivory should also receive a yes answer. Use explicit evidence of response/non-response to biomass loss for yes or no answers. Answer unknown if direct evidence is lacking.

Notes
- Search taxon name + "coppice," "resprout." Many species are capable of resprouting after being cut. In these cases, look for evidence that the species resprouts more vigorously than most other species, or that resprouts occur along the root system, not just from the base of the stem/trunk.
- This question does **not** apply to seed banks or how seeds respond to disturbance.

Full examples
- *Falcaria vulgaris* produces a deep taproot (at least 35 cm; Gress, 1923). Experiments where the taproot was cut into 4 cm long portions and buried at 5 cm soil depth showed that the root pieces had high shoot regeneration rates (62-82 percent) (Korman, 2011). This species has survived near a greenhouse at South Dakota State University since the 1970s despite repeated mowing (Korman, 2011). In South Dakota, plant densities are higher in areas with pocket gopher tunnels, possibly due to their foraging activity breaking roots and creating new vegetatively produced plants (Korman, 2011). Answer: yes with low uncertainty.

ES-20. Does the taxon have resistance to some herbicides or demonstrate potential to acquire herbicide resistance? (y = 1, n = 0, or ? = 0)

Definitions [from WSSA, 1998]
- Herbicide resistance: "The inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. In a plant, resistance may be naturally occurring or induced by such techniques as genetic engineering or selection of variants produced by tissue culture or mutagenesis."
- Herbicide tolerance: "The inherent ability of a species to survive and reproduce after herbicide treatment. This implies that there was no selection or genetic manipulation to make the plant tolerant; it is naturally tolerant."

Rationale. Herbicide resistance is likely to promote invasiveness or weediness of taxa in environments subject to frequent herbicide applications.

Criteria. Very few plants will score a yes as less than 250 species are officially recognized to be resistant to herbicides (Heap, 2013). Determine if the taxon is one of the few plants to have developed herbicide resistance, but be careful to distinguish between herbicide tolerance and herbicide resistance (see the official definitions from the Weed Science Society of America above). If the taxon has resistance, answer yes and use low or negligible uncertainty as appropriate. If the taxon has a congener or other close relative with herbicide resistance, then it may be able to acquire this trait through gene flow, or it may carry the gene for the underlying trait but not yet have undergone selection. In such cases, answer yes if you find supporting evidence for interspecific gene flow or if the plant occurs in places where it is likely to be regularly subjected to herbicide applications, which would provide a selective force for herbicide resistance. If you find no positive evidence, then answer no. Otherwise, answer unknown.

Notes

- http://www.weedscience.com has a list of plants with known herbicide resistance.
- Search taxon genus + "herbicide" + "resist*."
- If the answer is based on congeneric information, use higher levels of uncertainty (moderate or high).

Full examples

- We found no evidence that *Xanthoceras sorbifolium* is resistant to herbicides. Furthermore, it is not listed by Heap (2013). Given that this species is not a weed and does not occur in environments where herbicides are heavily used (e.g., row crops), it is unlikely to have developed herbicide resistance. Answer: no with low uncertainty.

References

- Heap, I. 2013. The International Survey of Herbicide Resistant Weeds. Online. Available: http://www.weedscience.com/summary/home.aspx.
- WSSA. 1998. Technology Notes. Weed Technology 12(4):789-790.

ES-21 Adaptive potential: Number of plant hardiness zones (out of 13) suitable for survival. (zero to three = -1, four to nine = 0, ten to thirteen = 1)

Rationale. The latitudinal range of a species is associated with invasiveness (Goodwin et al., 1999; Reichard, 2001). Species with broad latitudinal ranges are more likely to be invasive. Although many abiotic factors change with latitude, temperature is one of the most important. This question evaluates one possible measure of adaptive potential by measuring the number of Plant Hardiness Zones suitable for the species. The PPQ WRA was validated with the global Plant Hardiness Zones established by Magarey et al. (2008).

Criteria. This question is automatically answered in the spreadsheet based on the answers to questions Geo Z1-Z13. The answer should be a number from 1 to 13. An uncertainty value for this question is not generated.

References

- Goodwin, B. J., A. J. McAllister, and L. Fahrig. 1999. Predicting invasiveness of plant species based on biological information. Conservation Biology 13(2):422-426.
- Magarey, R. D., D. M. Borchert, and J. Schlegel. 2008. Global plant hardiness zones for phytosanitary risk analysis. Scientia Agricola 65 (Special Issue):54-59.
- 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.

ES-22 Adaptive potential: Number of Köppen-Geiger climate classes (out of 12) suitable for survival. (zero to two = -2, three = 0, four to twelve = 2)

Rationale. This question evaluates another measure of adaptive potential by measuring the number of different climate types suitable for the species. The PPQ WRA model was validated with the Köppen-Geiger system presented by Peel et al. (2007).

Criteria. This question is automatically answered in the spreadsheet based on the answers to questions Geo-C1 through Geo-C12. The answer should be a number from 1 to 12. An uncertainty value for this question is not generated.

References

- Peel, M. C., B. L. Finlayson, and T. A. McMahon. 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth Systems Sciences 11:1633-1644.

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

Rationale. This question evaluates another measure of adaptive potential by measuring the range of precipitation suitable for species survival. Species adapted to a wide range of conditions are expected to establish and spread more readily than those with narrow niches. The PPQ WRA model was validated with 11 ten-inch global precipitation bands generated from climate data and the procedure followed in Magarey et al. (2008).

Criteria. This question is automatically answered in the spreadsheet based on the answers to questions Geo-R1 through Geo-R11. The answer should be a number from 1 to 11. An uncertainty value for this question is not generated.

References

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- Magarey, R. D., D. M. Borchert, and J. Schlegel. 2008. Global plant hardiness zones for phytosanitary risk analysis. Scientia Agricola 65 (Special Issue):54-59.

Appendix F. Question-specific guidance and examples for the risk element Impact Potential

This risk element categorizes a species' capacity for direct and indirect impacts in production (P), natural (N), and anthropogenic (A) systems based on existing evidence. Production systems include, but are not limited to, croplands, container and field nurseries, orchards, pastures, rangelands, and forest plantations. Natural systems refer to wild or conservation lands that are set aside or managed for their natural biological diversity (e.g., national/state parks, preserves, conservation areas, wildlands, forested areas). Anthropogenic systems refer to human landscapes such as cities and suburbs or other non-agricultural areas frequently associated with or managed and disturbed by people (e.g., gardens, lawns, recreational areas, roadways, railroad corridors, construction sites). Two general impacts (G) are also assessed. Because terms used in the invasive plant literature confound spread and impact, pay careful attention to how sources use this terminology when you answer the questions.

For each question in the guidelines below, we provide the full question, answer choices, and scoring in bold type. Following that is the question-specific guidance. When necessary, additional suggestions, definitions, search criteria, and references are provided in bullets. For each question, one or more examples for weed risk assessment are provided.

Imp-G1 Is the taxon allelopathic? (y = 0.1, n = 0, or ? = 0)

Rationale. Plants that suppress the growth of other species through chemical means are allelopathic. Evidence of allelopathy is rare throughout the plant kingdom.

Criteria. Often the only available evidence is from laboratory studies that used artificial concentrations of plant tissue extracts on a few test species. For the purpose of this question, we consider such evidence to be insufficient to merit a yes as this evidence is likely based on unnatural concentrations and artificial conditions. Answer yes if the evidence is derived from field studies or if the experimental evidence involved the use of non-concentrated plant tissues. Although rare, field-derived studies usually involve planting an indicator species in association with the plant believed to be allelopathic, or in soil obtained from the allelopathic plant, and then comparing to a control. Where data rely on concentrated extracts or little is known about the taxon being evaluated, answer unknown. Answer no with negligible uncertainty if the taxon has been documented not to be allelopathic. A lack of reported or suggested allelopathy for well-known and studied taxa should generally result in a no response with low uncertainty.

Notes

- Search taxon name + "allelopath*." Evidence is usually obtained from primary literature, which must be examined to evaluate the experimental evidence.
- See Qasem and Foy (2001) for a review of allelopathic effects of multiple agricultural weeds.
- See Radosevich et al. (2007, p. 239) for a list of some plants with allelopathic compounds.
- Congeneric information may be used here, but use higher uncertainty.

Full examples

- Several studies and data sheets have reported that *Mikania micrantha* produces allelopathic chemicals that inhibit the growth of other plants (ISSG, 2010; Tiwari et al., 2005; Wu et al., 2010; Zhao and Peng, 2009), and that this has helped its invasion in China (Xie et al., 2010). Chen et al. (2009) examined allelopathy under field conditions and using soil from directly underneath *M. micrantha* plants. They showed that soil and plant extracts of *M. micrantha* inhibited radish seed germination, radicle length, and shoot length, and concluded that "allelopathic chemicals from *M. micrantha* not only affect other plants, but also soil nutrient properties." Based on the anecdotal evidence from numerous other studies and the outcomes from the Chen et al. (2009) field study, we have little doubt this species is allelopathic. Answer: yes with negligible uncertainty.
- We found no evidence of allelopathy for *Sideritis montana*. One study using plant extracts found evidence of allelopathy for the congener *S. italic* (Basile et al., 2011). We answered "no" because this evidence was derived from artificial extracts in a laboratory study, and it was based on a congener. Answer: no with moderate uncertainty.

References

- Qasem, J. R., and C. L. Foy. 2001. Weed allelopathy, its ecological impacts and future prospects: a review. Journal of Crop Production 4:43-120.
- Radosevich, S. R., J. S. Holt, and C. M. Ghersa. 2007. Ecology of Weeds and Invasive Plants: Relationship to Agriculture and Natural Resource Management. Wiley, Hoboken, NJ., U.S.A. 454 pp.

Imp-G2 Is the taxon parasitic, and does it have potential hosts in the WRA area? (y = 0.1, n = 0, or ? = 0)

Rationale. A parasitic plant is a vascular plant that obtains nutrients and water from another plant through an attachment called a haustorium. Two main types of parasitic plants exist: stem parasites and root parasites (Nickrent et al. 2004).

Criteria. Answer yes for any parasitic taxon with potential hosts present in the assessed area. This question includes holoparasitic (no chlorophyll) and hemiparasitic (chlorophyll present) plants. Parasitic plants are rare; a lack of positive evidence for this question results in a "no" answer. If your taxon is not in one of the plant families known to contain parasitic plants, then negligible uncertainty is appropriate. However, if your taxon is in one of these plant families, and you find no direct evidence of parasitism for your taxon, then use no with higher uncertainty or answer unknown, as appropriate.

Based on information from the references below, the following families are known to contain parasitic plants: Amphorogynaceae, Apodanthaceae, Aptandraceae, Balanophoraceae, Cervantesiaceae, Comandraceae, Convolvulaceae, Coulaceae, Cynomoriaceae, Cytinaceae, Eremolepidaceae, Erythropalaceae, Hydnoraceae, Krameriaceae, Lauraceae, Lennoaceae, Loranthaceae, Misodendraceae, Mitrastemonaceae, Nanodeaceae, Octoknemaceae, Olacaceae, Opiliaceae, Orobanchaceae, Rafflesiaceae, Santalaceae, Schoepfiaceae, Scrophulariaceae, Strombosiaceae, Thesiaceae, Viscaceae, and Ximeniaceae.

Full examples

- We found no evidence that *Colophospermum mopane* is parasitic. It does not belong to a family known to contain parasitic plants (Heide-Jorgensen, 2008; Nickrent, 2009; Walker, 2010). Answer: no with negligible uncertainty.

References

- Heide-Jorgensen, H. S. 2008. Parasitic Flowering Plants. Brill, Leiden, The Netherlands. 438 pp.
- Nickrent, D. L. and L. J. Musselman, L. J. 2004. Introduction to parasitic flowering plants. The Plant Health Instructor 13: 300-315.
- Nickrent, D. 2009. Parasitic plant classification. Southern Illinois University Carbondale, Carbondale, IL, U.S.A. Last accessed June 12, 2009, http://www.parasiticplants.siu.edu/ListParasites.html.
- Walker, R. 2014. Parasitic Plants Database. Rick Walker. http://www.omnisterra.com/bot/pp_home.cgi.

Sub-element: Natural Systems

This sub-element evaluates impacts the taxon may have in natural systems. Natural systems are areas (public or private) set aside for the conservation of nature and biotic diversity, including national or local parks, wildlife refuges, and habitat preserves.

Imp-N1 Does the taxon change ecosystem processes and parameters? (y = 0.4, n = 0, or ? = 0)

Rationale. This question focuses on species that significantly impact ecosystem processes and parameters that affect other organisms (e.g., changes fire regime, nutrient cycling, water availability). These kinds of species are sometimes called transformers. From Richardson et al. (2000): "Transformers are those taxa that have clear ecosystem impacts." Several categories of transformers may be distinguished: (a) excessive users of resources (e.g., water, light, oxygen), (b) donors of limiting resources (e.g., nitrogen), (c) fire promoters/suppressors, (d) sand stabilizers, (e) erosion promoters, (f) colonizers of intertidal mudflats/sediment stabilizers, (g) litter accumulators, and (h) salt accumulators/redistributors. For examples of species causing each of these impacts, see Richardson et al. (2000).

Criteria. A yes response to this question requires direct evidence of changes to ecosystem processes, or statements from more than one source that the taxon is changing or has changed ecosystem processes. Changes in community light levels must involve documented changes to one or more vegetation strata. If no evidence is available and the taxon is relatively well known or studied, then answer no; if the taxon is poorly known or you suspect it may be changing one of the listed processes, then answer unknown and provide your rationale.

Full examples

- *Nymphoides peltata* is a free-floating aquatic plant species whose growth decreases water oxygen levels, causing stagnant areas under the floating mats; additionally, it excludes light availability to the aquatic ecosystem and increases sedimentation (DCR, 2011; ISSG, 2012; Kelly and Maguire, 2009; van der Velde, 1976). Answer: yes with negligible uncertainty.

References

- Richardson, D. M., P. Pyšek, M. Rejmánek, 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.
- Gordon, D. R. 1998. Effects of invasive, non-indigenous plant species on ecosystem processes: Lessons from Florida. Ecological Applications 8(4):975-989.

Imp-N2 Does the taxon change habitat structure? (y = 0.2, n = 0, or ? = 0)

Definitions

- Habitat is the "place where an animal or plant normally lives, often characterized by a dominant plant form or physical characteristic (that is, the stream habitat, the forest habitat)" (Ricklefs and Miller, 2000).
- Vegetation layer refers to the physical layers of plant communities, such as the herbaceous (understory), shrub, and canopy layers of forests and other habitats.

Rationale. This question strictly addresses changes to the overall structure of habitats, including the number and density of vegetation layers. The most obvious changes to habitat structure occur when an invading taxon converts a habitat from one type into another (e.g., a prairie into a forest, a shrubland into a grassland, or a mudflat into a grassy sward). Less obvious changes include effects on the number or density of layers of a given habitat. "Community structure" is commonly used synonymously with "habitat structure."

Criteria. If a taxon modifies the overall structure of the habitat, creates a new layer, eliminates or covers a layer, or significantly modifies the density of a layer, then answer yes. Aquatic taxa that form mats on the surface of otherwise open water bodies may also receive a yes for this question. Taxa that form dense monotypic stands may also receive a yes if they reduce the structural diversity of the habitat. To answer yes for taxa reported to form monotypic stands, we require evidence of what the previous habitat structure was like to conclusively determine if it changed. If not, evidence of monotypic stands would support an answer of unknown. If no evidence is available and the taxon is relatively well known or studied, then answer no. If the taxon is poorly known or you suspect it may be having this impact, then answer unknown and provide your rationale.

Full examples

- *Ligustrum sinense* alters habitat structure (Smith, 2008); it displaces the native shrub layer (Weber, 2003) and often forms monotypic stands (Hanula et al., 2009). Answer: yes with negligible uncertainty.
- *Cestrum laevigatum* forms dense stands that prevent the regeneration of native shrubs and trees (Fourie, 2011; Weber, 2003), but we found no information about this plant changing forest structure. Thus, we answered unknown with maximum uncertainty.

References

- Ricklefs, R. E., and G. L. Miller. 2000. Ecology (4th ed.). W. H. Freeman and Company, New York. 822 pp.

Imp-N3 Does the taxon change species diversity? (y = 0.2, n = 0, or ? = 0)

Rationale. Species diversity refers to the numbers of species in a community (species richness) and the relative abundances of those species (Ricklefs and Miller, 2000). Thus this question addresses changes to the composition of species in natural communities. Invasive plant species can dominate communities and alter species composition through any number of mechanisms, including direct competition, propagule pressure, and responsiveness to disturbance events. Some invasive plant taxa may slowly change the environment to the detriment of natives. Although the majority of the available evidence on the impacts of invasive plant species relates to impacts on native taxa, this question also considers impacts to animal communities as well.

Criteria. Answer yes if the taxon changes species diversity or suppresses seedlings of recruiting native species, leading to altered species diversity over time. Although it would be preferable to understand the exact mechanism(s) by which species composition is altered, that evidence is not necessary for a positive answer to this question. If no evidence is available and the taxon is relatively well known or studied, then answer no; if the taxon is poorly known or you suspect it may be having this impact, then answer unknown and provide your rationale.

Full examples

- *Delairea odorata* reduces biodiversity in state parks in California (Elliott, 1994). In areas that have not become monospecific, *D. odorata* impacts non-native species, and reduces native species richness by 50 percent, seedling diversity by about 90 percent, with greater impacts on annual than woody species (Alvarez and Cushman, 2002). This taxon smothers vegetation in the low scrub and grass/forb level (Csurhes and Edwards, 1998). In a study ranking species for their potential to impact biodiversity in New South Wales, *D. odorata* ranked 16th out of 340 species (Downey et al., 2010). Answer: yes with negligible uncertainty.

Imp-N4 Is the taxon likely to affect Federal Threatened & Endangered species? (y = 0.1, n = 0, or ? = 0)

Rationale. In this question, we are evaluating the *likelihood* a weed or invasive species *may* impact Federal Threatened and Endangered (T&E) species. Often we will not find direct evidence for this impact, particularly if the taxon has not been introduced into or is not widely distributed in the United States. Thus, this answer relies on expert judgment. It is beyond the scope of a routine WRA to do a detailed and specific evaluation for the taxon being evaluated to determine which Federal T&E species it may affect. We approach this question at a very broad and general level, and assume that most U.S. natural systems contain one or more T&E species that may be impacted by an invading taxon.

Criteria. To answer the question, consider the types of habitats and systems invaded by the taxon, and whether it causes any of the impacts described under questions Imp-N1 through Imp-N3. Taxa that invade natural systems and cause any of the impacts described in those three questions are likely to affect T&E species; in these cases, answer yes, unless specific evidence suggests otherwise. Because T&E species are likely to be restricted to undisturbed systems, weeds that only grow in highly disturbed systems (e.g., croplands, cities) are unlikely to affect them, but exceptions may exist. This question, unlike most others in this risk element, allows for reasonable and defensible speculation on the part of the analyst (hence the term "likely"). If a particular species is unlikely to impact T&E species, then answer no or unknown as appropriate.

Notes

- In the PLANTS database advanced search engine you can search for T&E species in particular states or counties: http://plants.usda.gov/adv_search.html
- The U.S. Fish and Wildlife Service's Threatened and Endangered Species System (TESS) database lists current information on T&E species: http://ecos.fws.gov/tess_public/
- Direct evidence for impacts on T&E species in the United States or elsewhere in the world reduces uncertainty to negligible.

Full examples

- In a model prioritizing 340 invasive weeds, *Rumex sagittatus* was identified as posing a very high threat to biodiversity, ranking 22nd in the list (Downey et al., 2010). It impacts the New South Wales Threatened taxon *Allocasuarine portuensis* (Coutts-Smith and Downey, 2006; The University of Queensland, 2013). Answer: yes with negligible uncertainty.
- At least one Federally listed Threatened plant, sea-beach amaranth (*Amaranthus pumilus*) (USFWS, 2005) would be in greater peril if beach vitex (*Vitex rotundifolia*) invades its habitat. The fibrous root system of beach vitex traps endangered sea turtles and impedes their nesting (SCBVTF, 2005). Invasion by beach vitex would also disrupt the habitat of several Federal Threatened and Endangered birds (Suiter, 2005). Finally, this species outcompetes endangered species in the United States (Kaufman and Kaufman, 2007). Answer: yes with negligible uncertainty.
- *Solanum sisymbriifolium* mainly grows in disturbed areas such as "waste areas, roadsides, fence rows, and dykes" (Karaer and Kutbay, 2007), so it seems unlikely that *S. sisymbriifolium* would affect Threatened and Endangered species in natural areas. Answer: no with moderate uncertainty.

Imp-N5 Is the taxon likely to affect any U.S. globally outstanding ecoregion? (y = 0.1, n = 0, or ? = 0)

Rationale. Globally outstanding ecoregions are ecologically unique because of higher levels of biodiversity, endemism, unique evolutionary phenomena, etc. Ricketts et al. (1999) identified these regions in the United States and Canada.

Criteria. To answer this question, consider the potential distribution of the taxon in the United States and the potential habitats it may invade. Determine if the taxon is likely to impact any of the globally outstanding ecoregions as defined by Ricketts et al. (1999, p. 34, Fig. 3.1). Taxa that are likely to have significant and widespread impacts in these regions receive a yes. Then consider the types of impacts the taxon is causing as categorized by Imp-N1 and Imp-N2. If the species invades natural systems, can establish in globally outstanding ecoregions, and has demonstrated an ability to change habitat structure or ecosystem processes, then answer yes.

Although invasive plant species can have significant impacts on species diversity at a local level, that type of impact (Imp-N3) is not sufficient to merit a yes because this question's scope is much broader. This question, unlike most others in this risk element, allows for reasonable and defensible speculation on the part of the analyst (hence the term "likely"). If a taxon is unlikely to impact globally outstanding ecoregions in the United States, then answer no or unknown as appropriate. For example, answer no for species that are clearly associated only with disturbed environments.

Full examples

- *Iris pseudacorus* is a "potential threat to Louisiana wetlands" (Pathikonda et al., 2009). It grows in freshwater wetlands, salt marshes, and riparian habitats (Coops and Van Der Velde, 1995; Ramey and Peichel, 2001; Weber, 2003). Based on the impacts listed in Imp-N1 through Imp-N3, this plant could alter globally outstanding wetland and riparian habitats in the United States where it does not yet occur, such as the Florida Everglades (Ricketts et al., 1999). Answer: yes with low uncertainty.

References

- Olson, D. M., and E. Dinerstein. 2002. The global 200: Priority ecoregions for global conservation. Annals of the Missouri Botanical Garden 89:199-224.
- Olson, D. M., E. Dinerstein, E. D. Wikramanayake, N. D. Burgess, G. V. N. Powell, E. C. Underwood, J. A. D'Amico, I. Itoua, H. E. Strand, J. C. Morrison, C. J. Loucks, T. F. Allnutt, T. H. Ricketts, Y. Kura, J. F. Lamoreux, W. W. Wettengel, P. Hedao, and K. R. Kassem. 2001. Terrestrial ecoregions of the world: A new map of life on earth. BioScience 51(11):933-938.
- Ricketts, T. H., E. Dinerstein, D. M. Olson, C. J. Loucks, W. Elchbaum, D. DellaSala, K. Kavanagh, P. Hedao, P. T. Hurley, K. M. Carney, R. Abell, and S. Walters. 1999. Terrestrial Ecoregions of North America: A Conservation Assessment. Island Press, Washington D.C. 485 pp.

Imp-N6 What is the taxon's weed status in natural systems? Choose one: (a) Taxon not a weed; (b) taxon a weed but no evidence of control; (c) taxon a weed and evidence of control efforts. (a = 0, b = 0.2, c = 0.6, ? = 0).

Rationale. Loosely defined, a weed is simply a plant viewed to be undesirable due to some type of negative impact. As such, the term weed relates to how people perceive a plant. In this question, we are using perception as an index of impact.

Criteria. Choose the best answer for the taxon being assessed and describe your reasoning or your uncertainty as appropriate. Choose your alternate answers for the uncertainty analysis and report them as either "The alternate answers for the uncertainty analysis were X and Z" or "The alternate answers for the uncertainty analysis were both X." Answering "unknown" is permissible for this question, but that implies that you believe that the three choices, a, b, and c are *equally likely*. That scenario is unlikely because one answer can almost always be ruled out or considered to be much less likely than the others. For example, taxon is clearly described as a weed, which precludes "a," or you find no evidence of control, which precludes "c." One reasonable scenario for an answer of "unknown" is if the taxon being evaluated is new (i.e., recently developed cultivar or hybrid), with no prior history of behavior.

- If a taxon is not considered a weed, then it may not have any specific or appreciable impacts in natural areas. Answer "a" if you find no evidence the taxon is considered a weed.
- Answer "b" if the species is listed or considered a weed of natural systems in any relevant reference. Our most sensitive measure for impact is how people perceive a plant. If a plant is regarded as a weed, then it likely has some type of impact. We consider this a sensitive measure of impact because perceptions will usually change before published studies and factsheets become available. This measure of impact is particularly useful when relatively little published information is found. Species that have naturalized in areas set aside for conservation may also be considered weeds, because a general goal of conservation efforts is to maintain native species diversity. In those cases, use higher uncertainty.
- We consider any species that is being managed, controlled, or regulated to be causing significant harm. Evidence of control efforts is not only an indirect measure of impact, but also captures the indirect economic costs associated with weed management. A variety of evidence may be used to support an answer of "c," including: 1) direct evidence of management, 2) information linking management strategies to the taxon, 3) studies evaluating efficacy of different management strategies or herbicide formulations on the taxon, and 4) regulatory lists from foreign governments/entities. If a plant is regulated by a foreign entity, the evidence must be clear that the taxon is being regulated because of impacts in natural systems. Otherwise the same evidence could be used to answer questions Imp-N6, Imp-A4, and Imp-P6, which would overinflate the risk score for Impact Potential. If it is not clear why the taxon is regulated, then state this in the notes field for all three questions without using this to support an answer of "c." Also, weeds are often managed collectively in natural, anthropogenic, or production systems. Therefore, answering "c" because a weed is present in an area with ongoing weed management for multiple weeds is not sufficient. To answer "c," you must provide evidence that the taxon is specifically targeted or prioritized beyond a general weed management program.

<u>Notes</u>

- Search taxon name + "control," "manage," or "herbicide." Search regulatory lists. In both cases verify that the plant is being controlled in natural systems.
- A plant in its native range may be considered a weed. This type of information is valuable, particularly for plants that have not been taken out of their native range.

<u>Full example</u>

- *Pistacia chinensis* is regarded as an environmental weed in New South Wales and the Australian Capital Territory and as a potential environmental weed or 'sleeper weed' in other parts of southern Australia (University of Queensland, 2011). It is considered a weed of the natural environment in Australia by others as well (Randall, 2011; Csurhes and Edwards, 1998) but we found no specific evidence of management. Alternate answers for the uncertainty analysis are both "c." Answer: "b" with moderate uncertainty.

- *Geranium lucidum* is a major weed of natural systems (Dennehy et al., 2011). It can invade and overwhelm high quality native habitat, including woodlands and prairies (Anonymous, 2013). The Nature Conservancy in Oregon has been trying to eradicate it from some of their preserves (Alverson, 2007). It is a specific management target in Washington and Oregon in oak woodland, prairie, and savanna habitats within the Willamette Valley, Puget Trough, and Georgia Basin ecoregions (Dennehy et al., 2011). Hand pulling is effective for small populations, but for larger infestations, herbicide application at the seedling stage is best (Dennehy et al., 2011). Similar tips for management can be found on the King County government website (Anonymous, 2013). Alternate answers for the uncertainty analysis are both "b." Answer: "c" with negligible uncertainty.

Sub-element: Anthropogenic Systems

This sub-element evaluates impacts the taxon has in anthropogenic systems, which are areas that are highly disturbed and populated by people, including cities, suburbs, and transportation and utility corridors. Anthropogenic systems categorically exclude all natural and agricultural production systems.

Imp-A1 Does the taxon negatively impact personal property, human safety, or public infrastructure? (y = 0.1, n = 0, or ? = 0)

Rationale. Beyond direct impacts to human health and cultivated plants, some weeds and invasive plant species affect human property, processes, civilization, and safety. For example, weeds and invasive plant species may affect personal property by staining cars and uplifting sidewalks (e.g., *Bucida burcera*, *Morus rubra*). They may endanger human safety by destabilizing coastal dunes or reducing visibility along roadways (e.g., *Vitex rotundifolia*, *Phragmites australis*). They may also damage public infrastructure such as canals, sewers, bridges, roads, and electrical grids (e.g., *Arundo donax*, *Pueraria lobata*).

Criteria. To answer "yes," direct evidence is necessary. If the taxon is well studied and you find no evidence of these types of impacts, then answer "no." If the taxon is not well known and you suspect it may have these kinds of impacts based on its biology or similarity to other taxa that have these impacts, then answer "unknown" and provide your reasoning.

Notes

- This question does not apply to plants that may be toxic or allergenic to people. During the development and validation of the PPQ WRA, that question was not predictively useful in discriminating between invaders and non-invaders in the broad sense). However, because impacts to human health are still important in the definition of a Federal Noxious Weed, record and convey such impacts elsewhere in the final WRA document, either under the summary for the impact risk element, or in the discussion section.

Full examples

- Coastal ecologists and beach volunteers have noted that *Vitex rotundifolia* (beach vitex) does not retain the sand as well as native vegetation; specifically, they noticed that dune profiles were lower where beach vitex was established (BVTF, 2010). The U.S. Army Corp of Engineers, which recently completed a $2 million beach restoration project in South Carolina, is concerned about the potential impact of this plant on the stability of coastal dunes (Socha and Roecher, 2004). We used moderate uncertainty as this appears to be based on casual observation. Answer: yes, with moderate uncertainty.

- "Planted but soon regretted. Wide-creeping rootstocks (of the timber bamboo *Phyllostachys aurea*) form impenetrable solid stands. 'Roots of steel' can buckle sidewalks and driveways" (J.R. Allison, Invasive.org 2012). Answer: yes with low uncertainty.

References

- Invasive.org. 2012. Invasive.org: Center for Invasive Species and Ecosystem Health, The University of Georgia - Warnell School of Forestry and Natural Resources and College of Agricultural and Environmental Sciences - Department of Entomology. Available at: http://www.invasive.org.

Imp-A2 Does the taxon change or limit recreational use of an area? (y = 0.1, n = 0, or ? = 0)

Rationale. In addition to the impacts described above under natural systems, plant taxa may change or limit the way people use and/or interact with the environment, and usually in a negative way. This includes hunting, fishing, sightseeing, navigation, hiking, skiing, and other ecotourism-related activities (USFWS, 2006). Invasive plants may change vistas [e.g., *Melaleuca quinquenervia* (Serbesoff-King, 2003)], limit access [e.g., *Ligustrum sinense* (Hanula et al. 2009)], or otherwise make an area undesirable. With respect to sightseeing, remember that millions of domestic and international visitors travel to national parks to experience natural heritage areas and observe unique vistas (USFWS, 2006). Unfortunately, the types of impacts captured by this question are often not well studied or reported.

Criteria. Only direct evidence from the published literature or documented public concerns about these types of impacts support yes answers. Personal communications with field experts familiar with the taxon could be an important source of information. If the taxon is well studied and you find no evidence of these types of impacts, then answer no, otherwise answer unknown as appropriate.

Notes

- Consider contacting park and recreational area managers.
- An area may become undesirable if the invading taxon poses a health risk to people or pets.
- Uncertainty is likely to be greater because these types of impacts are not well reported or even studied.

Full examples

- *Arundo donax* hampers navigability: "…quite troublesome in many river systems, preventing the usual recreation and angling activities" (Moreira et al., 1998). Answer: yes with low uncertainty.

- *Hakea sericea* obstructs access and vision (van Wilgen and Richardson, 1985; Wells et al., 1986). Has prickly, needle-like, 1 mm-thick leaves that restrict access to mountains (CABI, 2012). "Reduces the aesthetic, recreational and scientific value of the indigenous plant communities" (cited in Kluge and Neser, 1991). Answer: yes with negligible uncertainty.

References

- Hanula, J. L., S. Horn, and J. W. Taylor. 2009. Chinese privet (*Ligustrum sinense*) removal and its effect on native plant communities of riparian forests. Invasive Plant Science and Management 2(4):292-300.
- Serbesoff-King, K. 2003. Melaleuca in Florida: A literature review on the taxonomy, distribution, biology, ecology, economic importance and control measures. Journal of Aquatic Plant Management 41(2):98-112.
- USFWS. 2006. National survey of fishing, hunting, and wildlife-associated recreation. United States Department of the Interior (DOI), U.S. Fish and Wildlife Service (USFWS), and U.S. Department of Commerce, U.S. Census Bureau. 168 pp.

Imp-A3 Does the taxon affect desirable and ornamental plants and vegetation? (y = 0.1, n = 0, or ? = 0)

Rationale. This question addresses taxa that are in essence nuisance weeds to humans; they may not have any impacts in production or natural systems.

Criteria. Direct evidence that the taxon displaces, outcompetes, or otherwise affects ornamental or other desirable plants in gardens, lawns, hedges, cities, aquaria, ponds, etc., is necessary for a "yes" response. Usually the best source for information for this question and the other questions relating to anthropogenic impacts are gardening forums and blogs. However, because the concept of weediness is a perception and often subjective, you should not rely on any single observation or comment to support a "yes" response; instead look for multiple independent observations to support a "yes" answer. If the taxon is well studied and you find no evidence of these types of impacts, then answer "no," otherwise answer "unknown" as appropriate.

Notes

- Impacts to commercially cultivated plants (e.g., farms, nurseries, forests) are considered under production system impacts.

Full examples

- One gardener on Dave's Garden forum says *Delairea odorata* is twining into her plantings (Dave's Garden, 2013b), but does not explicitly state if it is having any impacts. We answered unknown because this was the only evidence we found and because it is not clear if there are any actual impacts. Answer: unknown with maximum uncertainty.
- Of *Iris pseudacorus,* one gardener wrote, "When it is in its prime habitat of shallow water it becomes a thug. It can seed over an immense area crowding out nearly every other plant" (Murrain, 2011). Another gardener says, "[this plant] was planted by the previous owner around our fish pond....it's dominating and crowding out or hiding other plants I'd like to show off" (Dave's Garden, 2013c). Yet another gardener writes, "I, like an idiot,

put this in a small pond in our deck without checking it out first. It has a root mass from Hell and literally took up every square inch of pond space....I am surprised there are any bodies of water in existence with this monster around" (Dave's Garden, 2013c). Answer: yes with low uncertainty.

Imp-A4 What is the taxon's weed status in anthropogenic systems? Choose one: (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts. (a = 0, b = 0.1, c = 0.4, ? = 0)

Criteria. Follow the guidance provided under Imp-N6, except that the scope here is anthropogenic systems. Additional information regarding each answer choice follows. Evidence used to support this question is more likely to represent anecdotal comments (e.g., from gardeners, homeowners, or city officials). Because those sources of information are not peer-reviewed and because anyone can easily claim that a plant is a weed or is being controlled in their yard, a greater number of sources or higher quality evidence is required to support "b" or "c" responses.

- For this question, unlike for Imp-N6, simple plant establishment on roadsides or in city neighborhoods does not automatically represent weedy behavior. Look for evidence it is actually considered a weed in anthropogenic areas to answer "b."
- Finding specific evidence for weed control in anthropogenic areas is challenging, because such activities are not often well documented. A "c" answer requires direct evidence the species is targeted or controlled in anthropogenic areas. Gardening websites are good sources to determine if homeowners are taking any actions. Also consider extension offices when evaluating lawn weeds, or departments of transportation when evaluating roadside weeds.

Full examples

- *Hakea sericea* is a ruderal, and industrial (tourist) weed (Wells et al., 1986). It is one of the weeds targeted for removal under the working for water program in South Africa (CABI, 2012). While this species is clearly considered an anthropogenic weed and is controlled because it affects water availability, the importance of these impacts relative to those in natural systems in motivating control is not clear. For this reason we used high uncertainty. Both alternate answers for the stochastic simulation were "b." Answer: "c" with high uncertainty.
- *Dittrichia graveolens* is present along roadsides, in empty lots, and in disturbed areas in California (Univ. of California, 2013), and in similar habitats in Australia (Parsons and Cuthbertson, 2001). It is being controlled along roadsides in Australia (Kay, 1981). In California, it is primarily a weed of roadsides and highly disturbed areas, and different control strategies are being tested (Brownsey et al., 2013). It is treated by the California Department of Transportation along roadsides (Ortiz, 2013). Alternate answers for the stochastic simulation were both "b." Answer: "c" with negligible uncertainty.

Sub-element: Production Systems

This sub-element evaluates impacts the taxon has in production systems, which are areas of agricultural or forestry production including row crops, orchards, plantations, pastures, rangelands, aquaculture, nurseries, etc. Some production systems, such as rangelands (but not pastures) and national forests, may also be considered natural systems because they are maintained or managed in a near pristine or wild state. In those cases, consider and distribute the evidence as appropriate across each system, by type of impact. For example, a taxon that invades rangelands may change habitat structure (natural system impact), but may also reduce the carrying capacity of the land to support cattle (production system impact).

Imp-P1 Does the taxon reduce crop or commodity yield? (y = 0.4, n = 0, or ? = 0)

<u>Rationale.</u> Weeds reduce yield by competing with crops for space, nutrients, light, and water resources. Some weeds directly damage crops through parasitism or other mechanisms. They may also indirectly increase pest loads on cultivated species if the weed is a host or alternate host for a pest. All of these mechanisms may result in reduced crop and commodity yield, particularly if the weeds are abundant enough.

<u>Criteria.</u> Direct evidence of yield reduction (quantitative or qualitative) is necessary for a yes response. Evidence for yield reduction in pasture productivity may be more difficult to obtain, but direct evidence is nevertheless required. In these cases, evidence that the carrying capacity of pastures is reduced, or that animal stock avoid the plants and therefore promote weed abundance indirectly is sufficient for a yes response. If the taxon is well studied and you find no evidence of these types of impacts, then answer no, otherwise answer unknown as appropriate. If yield loss is suspected, but no evidence is available, answer "unknown" and provide your reasoning. Quantitative data on yield loss should reduce uncertainty.

<u>Notes</u>

- Search in CAB Abstracts, the CABI Crop Protection Compendium, or the CABI Forestry Compendium for information on weed impacts in production systems.

<u>Full examples</u>

- *Nassella neesiana* can account for up to 60 percent of canopy cover in infested pastures (Gardener et al., 2003). Because flowering stems are not palatable (Bourdôt et al., 2012), plant populations greatly reduce stock-carrying capacity during the summer (Gardener et al., 2003; Snell and Grech, 2008), but they are a good source of forage during the winter. Flowering stalks are actively avoided by stock (Grech et al., 2006). Answer: yes, with negligible uncertainty.
- In cut-over coastal redwood forests in northern California, *Cortaderia jubata* suppresses establishment of seedling conifers (Bossard et al., 2000). In forestry operations, it is very competitive and can retard the establishment and growth of seedling trees (ODA, 2013). Answer: yes, with moderate uncertainty.

Imp-P2 Does the taxon lower commodity value? (y = 0.2, n = 0, or ? = 0)

<u>Rationale.</u> A plant taxon may lower commodity value by deforming/damaging plant or animal commodities, contaminating seed lots, or otherwise altering commodity quality. For example, some pasture weeds when consumed by cattle produce an off-flavor to the milk. Weed seed contaminants of commercial seed usually necessitate cleaning procedures, or reduce sale price because of lowered quality. Weed taxa may also lower commodity value by increasing the costs

of production due to weed management or other costs to machinery. For example vines that form tangles could interfere with harvesting equipment in row crops and orchards, and slow down harvest.

Criteria. Direct evidence is required for a yes response. If the plant is well known and you find no direct evidence, then answer no. Otherwise answer unknown, as appropriate.

Notes
- Search in CAB Abstracts, the CABI Crop Protection Compendium, or the CABI Forestry Compendium.

Full examples
- Seeds of *Nassella neesiana* have a very sharp point (Richardson et al., 2006). The sharp seeds bore into animal skins, causing painful wounds (Haywood and Druce, 1919). Sometimes seed will pierce the skin of sheep, irritating the animal, damaging the hide, and reducing its value (Gardener et al., 2003; Storrie and Lowien, 2003). "Its invasion of these grasslands also leads to the downgrading of wool, skins (hides) and carcasses as a result of the sharp callus and hygroscopic geniculate awn that together facilitate penetration of the mature fruit into the wool, skin and underlying muscle of grazing animals" (Bourdôt, 2010; Bourdôt et al., 2012). Answer: yes with negligible uncertainty.

Imp-P3 Does the taxon impact or is it likely to impact trade? (y = 0.2, n = 0, or ? = 0)

Definitions (from IPPC 2013):
- Definition of "quarantine pest": A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (IPPC, 2013).
- Definition of "regulated, non-quarantine pest": A non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party (IPPC, 2013).

Rationale. A weedy taxon is likely to impact trade if it is a quarantine pest or a regulated non-quarantine pest (see definitions below) that can follow the pathway of a traded commodity. In these cases importing countries or administrative regions within those countries may destroy or reject contaminated shipments, or they may impose phytosanitary treatments to reduce the risk associated with the contaminant.

Criteria. Answer yes if you find direct evidence that a plant is a regulated pest and it can follow a pathway of a traded commodity. This question allows for reasonable speculation by the analyst. You need not establish both criteria—i.e., that the pest is regulated and a pathway exists—for any given country or region (e.g., state or province) because that is usually not available. If the taxon is regulated anywhere in the world, and if it can follow a pathway on any traded commodity, answer yes. Answer "no" if the taxon is unlikely to follow a trade pathway (e.g., coconut seeds). The answer to the pathway component of this question should be consistent with the answer given under ES-16. If the plant is well known, and you find no direct evidence then answer no; otherwise answer unknown, as appropriate.

Notes

- Search the internet: taxon name + "quarantine" + "regulat*" + contaminant + treatment. Some countries refer to regulated weeds as "noxious weeds" (e.g., Australia; Parson and Cuthbertson, 2001) or "declared weeds" (South Africa; Henderson, 2001).
- If accessible, search for governmental lists of regulated pests (e.g., APHIS, 2014.). For U.S. regulated weeds, consider not only the Federal Noxious Weed (7 CFR §361) and Federal Noxious Seed lists (7 CFR §361), but also State noxious weed and noxious seed lists (USDA-AMS, 2013).
- When the weed taxon *is* the commodity and is intentionally introduced (e.g., plants for planting) answer no, unless you have evidence the taxon is a contaminant in some other pathway where it is not being intentionally introduced.
- If the commodity being introduced contains its own viable propagules (e.g., seeds in dried flower arrangements or in pine cone decorations) then answer yes.

Full examples

- *Praxelis clematidea* is a declared noxious weed in Western Australia; consequently, it is not permitted entry and must be eradicated when found in the state (DAFWA, 2012). Because it is a contaminant of seeds moving in trade (Waterhouse, 2012; Scott, 1998) and of other commodities and conveyances (AQAS, 2014), it may impact trade to areas restricting its movement. This species spreads in sugar cane mulch (English, 2014), which is restricted entry into Western Australia because of weed contaminants (DAFWA, 2013). Answer: yes with negligible uncertainty.

References

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Imp-P4 Does the taxon affect the quality or availability of irrigation, or strongly compete with plants for water? (y = 0.1, n = 0, or ? = 0)

Rationale. Although all plants compete with each other for water and other resources, the scope of this question is limited to taxa that are exceptionally competitive for water or that affect the quality or availability of water (e.g., by clogging irrigation canals). Adequate water resources are critical in production systems.

Criteria. Direct evidence is required for a yes, and it must demonstrate why the taxon is exceptional in this regard. Also answer yes if the taxon being evaluated contributes to flooding or hinders drainage in production systems. If the plant is well known, and you find no direct evidence then answer no, otherwise answer unknown, as appropriate.

Notes

- This question applies only to production systems. Impacts on water quality or availability that affect natural resources or humans are considered above under natural and anthropogenic systems.
- Taxa that affect navigation in anthropogenic systems or water resources in natural systems will not necessarily affect water resources in production systems. Specific evidence of impact in production systems is required to support a yes.

Full examples

- *Luziola subintegra* impedes the flow of water to irrigated rice fields and increases the evapotranspiration of water, which is valuable for rice production (Fischer, 1997). It is associated with irrigation canals (and/or rice fields) in Costa Rica (Rojas and Agüero, 1996), but those authors did not state whether or not it had a significant effect on rice irrigation. Answer: yes with low uncertainty.
- In tea production, *Persicaria chinensis* is a common weed often found in field drainage channels (Barbora, 1972). This is one of a group of weed species described as restricting the free flow of surplus water that reduces the efficiency of an otherwise adequate drainage system (Barbora, 1972). Because we are uncertain if *P. chinensis* or the other weed taxa affect water in tea production, we used high uncertainty. Answer: yes with high uncertainty.

Imp-P5 Is the taxon toxic to animals? (y = 0.1, n = 0, or ? = 0)

Rationale. Consumption of toxic plants can sicken rangeland and farm animals, cause or increase their susceptibility to disease, and, in some cases, cause mortality. Many toxic plants are not normally eaten by animals (e.g., *Heracleum mantegazzianum*).

Criteria. To answer yes, the animal must reasonably be likely to be exposed to the toxic agent by consumption or other physical contact. Toxic plants may grow naturally in pastures and rangelands or be contaminants in hay or other feed. Some mildly toxic but palatable plant taxa could cause problems if heavily grazed. Consider grazing by both wild and domestic vertebrates. If you find direct evidence that consumption of the taxon affects animal health, answer yes. Also answer yes if toxic compounds are uniformly characteristic of the plant genus or family, even if data on the particular taxon are not available (but increase uncertainty as this represents congeneric information). A lack of positive evidence for this question results in a no or unknown answer depending on the amount of information available on the taxon and how well studied it may be.

Notes

- Some plant taxa cause physical injury to animals (e.g., lacerations, eye punctures). These kinds of impacts are beyond the scope of this question which focuses on toxicity *per se*. Evidence of physical injury should be recorded in either the summary paragraph of the impact or discussion sections of the weed risk assessment.
- Some taxa become toxic when they are associated with micro-organisms (e.g., fungal endophytes). Note that in these cases, the taxon itself is not toxic, it or its product becomes toxic due to improper cultivation, handling, or processing. Generally, in these cases, answer no, but use higher uncertainty if you deem necessary.
- This question focuses on plant toxicity to animals. Although you might include evidence of human toxicity to help support your answer, the answer should not be based solely on human toxicity evidence.
- We identify several useful references and databases below.

Full examples

- *Rumex sagittatus* is a health concern for sheep and goats in South Africa (Wells et al., 1986). *Rumex sagittatus* is toxic (Randall, 2012). No known risk of toxicity to goats in Australia but highly palatable to them (Simmonds et al., 2000). We did not find any other information on *R. sagittatus*. Some species of *Rumex* are known to be toxic to animals and humans, and yet some are consumed with no adverse effects (Burrows and Tyrl, 2001). Answer: yes with high uncertainty.
- We found no evidence that *Falcaria vulgaris* is toxic. Cattle will consume it and humans eat it as a vegetable in the Middle East (Korman, 2012). Answer: no with low uncertainty.

References

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Imp-P6 What is the taxon's weed status in production systems? Choose one: (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts. (a = 0, b = 0.2, c = 0.6, ? = 0)

Criteria. Follow the same guidance provided under Imp-N6, except the scope here is production systems. For an answer of "b," the taxon must be recognized as a weed and not merely be present in production systems. Studies that evaluate the efficacy of particular herbicide formulations against the plant taxon can be used to support an answer of "c."

Notes

- Agricultural databases such as CAB Abstracts and Agricola may be useful in finding specific evidence. Likewise, searching Google Scholar for the taxon and "competition," "yield loss" or "control" may provide useful information.

Full examples

- *Echinochloa pyramidalis* is a weed in rice fields in Australia, India, the Philippines, and Tropical America (López Rosas et al., 2006). It has been introduced to India and tropical America, but apparently is not a significant weed outside Africa (Michael, 1983). It is controlled in rice in Madagascar (Bruyere and Rakotomanana, 1964). This species is considered a troublesome weed in irrigation canals of the Guyana Sugar Corporation and is controlled with herbicides (Bishundial et al., 1997). Along with other weeds, herbicides are used to control it in rice (Jauffret, 1954). It is recommended that *E. pyramidalis* be replaced with another grass species along sugarcane irrigation canals in Madagascar (Rochecouste, 1965). Alternate answers for the stochastic simulation were both "b." Answer: "c" with low uncertainty.

Appendix G. Question-specific guidance and examples for the risk element Geographic Potential

This risk element evaluates the ability of the taxon to survive at different levels of three climatic variables: 1) plant hardiness, 2) climate class, and 3) mean annual precipitation. The PPQ WRA uses this information two different ways. First, we use it to evaluate the regions of the United States where the taxon is likely to survive without human intervention using a simple climate matching algorithm developed specifically for the PPQ WRA (see Process 4). Although the information is used to predict suitable regions in the United States, the same algorithm can be used for other regions of the world. Second, we also use the information to estimate the adaptive potential of the taxon as the number of hardiness zones, climate types, or mean annual precipitation bands suitable for survival. It has been shown that species with greater climatic tolerances are more likely to become invasive than those with narrower tolerances (Sexon et al., 2002). During the development and validation of the PPQ WRA model, we determined that our estimates of the adaptive potential of a species are predictive of weed risk (Koop et al., 2012). These three estimates are incorporated into the predictive WRA model in questions ES- 21 through ES-23.

This risk element contains 36 questions about the different levels (i.e., sub-classes) of the following three variables: Plant Hardiness Zones (13 questions), Köppen-Geiger climate classes (12 questions), and mean annual precipitation bands (11 questions). Each question asks if the given climatic level is suitable for species survival. All questions require either a yes or no answer. Answers of unknown are not acceptable because the process requires each climate level to be classified as either suitable or not.

Unlike in the previous risk elements, where the answers generated scores, we use the geographic potential evaluation to produce a map showing the predicted areas for a taxon.

General guidance for recording evidence
Most of the evidence we consider for this risk element consists of georeferenced data and reports about establishment of a taxon in a particular area (without specific geographic coordinates). As described in Process 4, we download these data from the GBIF database and create datasets or layers representing global distribution in ArcGIS. Other types of evidence come from literature reviews and may include descriptions of climatic tolerances (e.g., evidence that a taxon cannot survive temperatures below freezing). Any data relating to the location of established populations or climatic tolerance of the taxon is important to record, and may help you answer the questions with lower uncertainty.

As you answer each question, provide your evidence and cite your sources in the Evidence column of the "Screening Tool" worksheet. List the countries (states, provinces, etc.) where the taxon occurs that support a yes answer. Because most data will be based on GBIF entries, you do not need to cite GBIF each time; there is a general comment at the beginning of this section stating that uncited information was derived from GBIF[6]. All other data sources should be

[6] "Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2014)."

referenced, along with the location of the taxon in the Evidence column. When you use non-GBIF evidence, note whether it is georeferenced or not.

General guidance for answering the questions

When evaluating the evidence to answer each question, consider the total number of georeferenced points and reports of occurrence, as well as the overall distribution of the taxon and in which particular climates/habitats it can survive. If a taxon has many georeferenced points for a given climatic level, answer yes with negligible uncertainty. If a taxon has very few points in a level, and you found no other supporting information, then a yes answer is reasonable if it is consistent with the biology and native range of the taxon (but raise the uncertainty). Otherwise, a yes answer is unlikely. If the taxon has one point in a distinct climate type (e.g., desert), with no other evidence to support its establishment there, answer no and raise the uncertainty. For example, most broadleaved species are unlikely to survive in very dry habitats. In difficult cases, provide an explanation for your answer choice.

Occurrences in a given climate level do not always mean a taxon can survive in that climate or even occur there. For example, although infrequent, some data may represent misidentifications. Also, georeferenced data may have been entered incorrectly or points may represent herbaria or living collections. Some data might be real occurrences, but in highly protected, modified or rare microhabitats. For suspect points, the locality column of the original GBIF data may describe the area from which the specimen was taken. Ignore any points that cannot be reconciled with what you know about your taxon. We can often remove erroneous georeferenced points (e.g., reversed latitudes and longitudes, mismatches between reported country and latitude/longitude) through our data cleaning process, described in the Geographic Potential Instruction Manual.

Consider other factors that may introduce error into your analyses and maps. For example, some areas reflect highly variable climates, such as mountainous regions where elevation changes over short spatial scales cause significant climatic differences. Georeferenced points in such regions may be difficult to interpret. Also the broad scale of our datasets (grid cell size = 10 square km) limits our precision. If a point of occurrence falls on a line between two levels (e.g., hardiness zones), consider the other points representing your taxon. If six points occur in one level and only one (or half of a point) occurs in a new level, include the new level only if other points occur in that level elsewhere in the world.

General guidance for addressing uncertainty

Use the standard ratings for uncertainty for each yes or no answer. In general, if you found sufficient georeferenced data points for a given level and the biology of your taxon matches the climate of that area, use negligible uncertainty. If your answer was based only on occurrence information in a country, state or province, and multiple climate levels occur in that area, raise uncertainty to moderate or high. As mentioned above, in the evidence column of the spreadsheet, distinguish between evidence based on georeferenced points and reported occurrences.

Specific guidance for each climatic variable

The following is general and specific guidance for answering the geographic questions and addressing specific issues that may arise. For each of these three climatic variables, our datasets were created on a 10-km scale (each pixel represents 10 square kilometers).

Plant Hardiness Zones
Rationale. Plant Hardiness Zones are based on average yearly minimum temperatures (USDA-ARS, 2012) and are widely used by horticulturalists to broadly identify regions of the United States suitable for plant establishment. The global Plant Hardiness Zone maps we use here are based on extreme minimum temperatures in each pixel of our datasets with the values converted to plant hardiness zones using USDA definitions (USDA-ARS, 2012). There are 13 global Plant Hardiness Zones; the United States and its territories include all 13 (Saha et al. 2010; Magarey et al. 2008). The Zones are defined as follows:

Zone 1 (below -50 °F or below -46.6 °C)
Zone 2 (-50 to -40 °F or -45.6 to -40.0 °C)
Zone 3 (-40 to -30 °F, or -40.0 to -34.4 °C)
Zone 4 (-30 to -20 °F, or -34.4 to -28.9 °C)
Zone 5 (-20 to -10 °F, or -28.9 to -23.3 °C)
Zone 6 (-10 to 0 °F, or -23.3 to -17.8 °C)
Zone 7 (0 to 10 °F, or -17.8 to -12.2 °C)
Zone 8 (10 to 20 °F, or -12.2 to -6.7 °C)
Zone 9 (20 to 30 °F, or -6.7 to -1.1°C)
Zone 10 (30 to 40 °F, or -1.1 to 4.4 °C)
Zone 11 (40 to 50 °F, or 4.4 to 10 °C)
Zone 12 (50 to 60 °F, or 10 to 15.6 °C)
Zone 13 (above 60 °F, or above 15.6 °C)

Criteria. Answer yes if you find good evidence for the presence of the taxon in that zone. Otherwise answer no. If you have evidence for a series of zones, e.g., 5, 6 and 7, and evidence for Zones 9 and 10, but not for Zone 8, answer "yes" for Zone 8, based on the evidence above and below it.

Full examples
- For Zone 6, numerous georeferenced data points in the United States (Kansas, Missouri, and Ohio). Answer: yes with negligible uncertainty.
- A few dozen georeferenced data points exist for *Ardisia crenata* in Zone 7 clustered in or southwest of Tokyo Japan; but given this plant's cold sensitivity and the heat island effect of major cities, we are assuming that it cannot generally live in this hardiness zone. The coldest zone this species is reported suitable for is Zone 8 (DavesGarden, 2012; Page and Olds, 2001). Answer: no with high uncertainty.

Köppen-Geiger climate classes
Rationale. The Köppen-Geiger climate classification scheme has been in use for over 100 years. A new global map was produced recently using the Köppen-Geiger system based on a large global data set of long-term monthly precipitation and temperature station time series (Peel et al., 2007), with the global map made available online. We aggregated the third-tier classifications in the Peel et al. (2007) dataset (shown in parentheses), to produce the following 12 climate classes:

Tropical rainforest (Af, Am)

Tropical savanna (Aw)
Steppe (Bsh, Bsk)
Desert (Bwh, Bwk)
Mediterranean (Csa, Csb)
Humid subtropical (Cwa, Cfa)
Marine west coast (Cwb, Cwc, Cfb, Cfc)
Humid continental warm summers (Dsa, Dwa, Dfa)
Humid continental cool summers (Dsb, Dwb, Dfb)
Subarctic (Dsc, Dsd, Dwc, Dwd, Dfc, Dfd)
Tundra (ET)
Icecap (EF)

Criteria. For each particular climate class, answer yes if you find good evidence for the presence of the taxon in that class. Unlike for the plant hardiness and precipitation variables, do not automatically answer yes for a climate class that falls between two other climate classes for which you have evidence. Answer no if you find no evidence for occurrence within a particular class.

Typically, the most problematic climate class to answer is "Humid continental warm summers" (HCWS). Globally, this climate class is present in patchy areas in Europe and Asia, but in the United States, it comprises a large portion of many central states (Kansas, Illinois, Indiana, Iowa, Missouri, Nebraska, New Jersey, Ohio, Pennsylvania, and South Dakota). Answering yes for Humid subtropical (HS) and Humid continental cool summers (HCCS), but no for HCWS, results in a predictive map without the above-listed states but with states both north and south. If you answer yes for the HS and HCCS climates, we recommend carefully examining the literature to find evidence for HCWS in Europe and Asia. Often, searching for the taxon and a particular European or Asian country (Slovakia or Japan) will provide the evidence needed.

Full examples

- For Mediterranean habitats, numerous georeferenced points exist for *Rumex sagittatus* in Australia and South Africa. Answer: yes with negligible uncertainty.
- *Leptochilus pteropus* is broadly distributed in southern India (Singh et al., 2012), which includes steppe climates. However, it is unclear if it can occur in steppe climates, as it is well adapted to wet habitats. Answer: no with high uncertainty.

Mean annual precipitation bands

Rationale. The mean annual precipitation maps are based on mean annual precipitation values in each pixel across 10 or 30 years (see Process 4). Mean values are expressed as 10-inch (or 25-cm) precipitation bands, and there are 11 bands as follows:

- 0-10 inches (0-25 cm)
- 10-20 inches (21-51 cm)
- 20-30 inches (51-76 cm)
- 30-40 inches (76-102 cm)
- 40-50 inches (102-127 cm)
- 50-60 inches (127-178 cm)

- 60-70 inches (152-178 cm)
- 70-80 inches (178-203 cm)
- 80-90 inches (203-229 cm)
- 90-100 inches (229-254 cm)
- 100+ inches (254+ cm)

Criteria. As before, answer yes if you find good evidence for the presence of the taxon in that precipitation band, and otherwise answer no. As with plant hardiness zones, if you find strong evidence that a species occurs across a range of bands, except for one band in the middle of the range (e.g., 40-50, 50-60 and 70-80, but not 60-70), answer yes for that middle band with the same uncertainty level used in the adjacent bands. However, in this example, if the evidence for band 70-80 were very weak, consider answering no for bands 60-70 and 70-80. In some regions, many bands fall within a given area. In those cases, before answering yes for all of the bands, consider the overall distribution of the taxon including other regions of the world. For example, if most points are located in areas with 40 to 70 inches of precipitation, but one point occurs between 10 and 20 inches, answer "no" for the 10-20 inch band.

If your taxon is a submerged aquatic species, consider answering "yes" to all or most precipitation questions as the distribution for that taxon will not be determined by precipitation *per se*, but rather the availability of aquatic bodies such as ponds, lakes, streams, etc.

Full examples

- For the 30-40 inch band, *Xanthoceras sorbifolium* is reported to occur in areas of China (e.g., Gansu, Shanxi, Shandong; NGRP, 2013; Zhengyi et al., 2013) that include this precipitation band. Answer: yes with low uncertainty.
- Multiple points for *Falcaria vulgaris* occur in Armenia, Azerbaijan, Turkey, Israel, and the United States (South Dakota) for the 10-20 inch band. It also occurs in a steppe region of Russia receiving an average of 334 mm per year (Yunusbaev et al., 2003). Answer: yes with negligible uncertainty.

References for Geographic Potential

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.

Peel, M. C., B. L. Finlayson, and T. A. McMahon. 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth Systems Sciences 11:1633-1644.

Sexon, J. P., J. K. McKay, and A. Sala. 2002. Plasticity and genetic diversity may allow saltcedar to invade cold climates in North America. Ecological Applications 12(6):1652-1660.

USDA-ARS. 2012. Plant Hardiness Zone Map, 2012. U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS). http://planthardiness.ars.usda.gov.

Appendix H. Question-specific guidance and examples for the risk element Entry Potential

This risk element evaluates the potential that a plant taxon will be introduced into the United States intentionally for cultivation, accidentally as a contaminant, or through natural dispersal. The entry potential risk element consists of 14 questions that evaluate the number of pathways with which a taxon is or may be associated. Taxa that are cultivated elsewhere or are positively valued by society are more likely to enter than other less valued taxa. The risk score for this element ranges from zero to one, with higher scores indicating a higher likelihood of entry. If a taxon is already present in the United States, or if a permit for its entry has been requested, assessment of this risk factor is not necessary. Otherwise, the question scores for the various pathways are summed to produce a risk element score that can range from 0 to 1. Because intentional introduction automatically results in the entry of an organism, this question is weighted much more highly than the other pathways. Potential score values for each question is indicated below in parentheses.

For each question in the guidelines below, we provide the full question, answer choices, and scoring in bold type. Following that is the question-specific guidance. When appropriate, additional suggestions, search criteria, and references are provided in bullets. For each question, one or more examples for weed risk assessment are provided.

Ent-1 Is the plant taxon already in the United States? (y=1, n=0)

Criteria. If the plant taxon is already cultivated or naturalized in the United States, answer yes for Ent-1, and stop further assessment in this risk element. Many plant collectors specialize in growing rare or uncommon plants, so many taxa may be present in the United States but not widely cultivated. If you find no indication a species is present in the United States after a reasonable internet search, answer no, but use moderate uncertainty. If a plant is present but only under quarantine or some other restrictive permit, answer no, because permit restrictions provide safeguards that equate to non-presence.

Notes

- An answer of yes to either Ent-1 or Ent-2 causes the workbook to automatically set all other answers to not applicable, preventing analysts from evaluating the remainder of the risk element. If the taxon is present in the United States but evaluating its entry potential is still prudent or necessary for some reason, answer no to this question but explain both that the taxon is present and why evaluating its entry potential is nevertheless important.
- Refer to Section 3, Process 2, Section 2-4 of these WRA Guidelines for recommended sources for determining whether a taxon is cultivated, naturalized, or under regulations in the United States.
- Check BONAP (http://www.bonap.org/), the USDA Plants database (http://plants.usda.gov/java/), EDDMapS (http://www.eddmaps.org/species/), and GBIF (http://data.gbif.org/welcome.htm) for U.S. distribution information.
- Search gardening compendia such as Hortus Third (Bailey and Bailey, 1976).

- Search gardening websites such as Dave's Garden (http://davesgarden.com/), GardenWeb (http://forums.gardenweb.com/forums/), Plant Information Online (http://www.plantinfo.umn.edu/), and the Plant Finder (http://www.backyardgardener.com/Plant-Index/).
- Search online and print nursery catalogues.
- Try an internet search for "buy + taxon name."

<u>Full examples</u>

- *Toona sinensis* has been cultivated and traded in the United States for a long time, e.g., 100 years in California (Grotkopp and Rejmánek, 2007). It is for sale in California (smgrowers.com, 2011), Oregon (greergardens.com, 2011), growing in Maryland (Tasker, 2011), and escaped in Pennsylvania (Soloman and Dijois, 2011). It is also reported to be growing in arboretums in Massachusetts, Pennsylvania, New Jersey, Illinois, Washington DC, New York, and Ohio (Koller, 1978), as well as growing (in gardens) in Iowa, Kentucky, Mississippi, New York, Pennsylvania, and Texas (DavesGarden, 2011). This taxon was acquired by the J. C. Ralston Arboretum in North Carolina (JCRA, 1992). Answer: yes with negligible uncertainty.

<u>References</u>

- Bailey, L. H., and E. Z. Bailey. 1976. Hortus Third: A Concise Dictionary of Plants Cultivated in The United States and Canada (revised and expanded by The Staff of the Liberty Hyde Bailey Hortorium). Macmillan, New York, U.S.A. 1290 pp.

Ent-2 Is the plant taxon proposed for import or is its entry imminent? (y=1, n=0)

<u>Criteria.</u> Answer yes for taxa that have been proposed for entry or cultivation in the United States and cite relevant supporting documentation, and STOP further analysis in this risk element. If you answer no, continue with questions Ent-3 through Ent-5.

<u>Full example</u>

- *Echinodorus uruguayensis* is proposed for import into the United States from Denmark (MFAF, 2009). Answer: yes with negligible uncertainty.

Ent-3 What is the cultivation status of this plant taxon? Choose the best answer: (a) Neither cultivated nor positively valued; (b) Not cultivated, but positively valued or potentially beneficial; (c) Cultivated, but no evidence of trade or resale; (d) Commercially cultivated or other evidence of trade or resale. (a = 0, b = 0.05, c = 0.25, d = 0.5)

<u>Rationale.</u> Most plants introduced to new areas are intentionally introduced for cultivation. Choices "a" through "d" represent increasing levels of entry potential because of potential cultivation. You should consider both legal and illegal pathways in this question.

- Taxa that receive an answer of "a" are the least likely to be intentionally introduced for cultivation because they are not used by humans or even considered to be beneficial.
- Choice "b" represents taxa that are not cultivated, but may be harvested in the wild by some people. They may have useful traits or beneficial biochemical properties, and may be imported for research purposes.

- Choice “c” represents taxa that are cultivated either locally or by a small group of specialists, and demand is not large enough for these plants to be traded at any appreciable level.
- Choice “d” represents plants that are easily available for order over the internet or through seed or other nursery catalogues.

Criteria. Answer “a” if you find no evidence of cultivation or potential benefit. Answer “b” if you find good evidence for potential benefit, but no evidence of cultivation. Answer “c” if you find good evidence for limited cultivation (e.g., research, early breeding trials). Answer “d” if you find good evidence for wide cultivation by many different people, including being for sale.

Using congeneric information is generally not acceptable for this question but it may sometimes be prudent. For example, evidence that the *entire* genus/family/etc. is medicinally important or beneficial can be used as evidence for a “b” answer. In these cases, however, raise your uncertainty level.

Notes

- Review the same sources listed in Ent-1.
- Try an internet search for “buy + taxon name.”
- While Ent-1 covers only cultivation in the United States, in this question you should consider if the taxon is cultivated anywhere in the world.

Full examples

- *Phyllanthus maderaspatensis* is valued as a medicinal plant in several African countries (Schmelzer, 2008). “Generally grown from seed, but vegetative propagation by budding, grafting, cutting and root sprouting is possible…it is rarely cultivated…all plant parts are probably only collected from the wild. Mature plants…require little or no management once established” (Schmelzer, 2008). We are answering “c” with moderate uncertainty because we have evidence that this plant is being propagated, even if it is rarely done. Answer: “c” with moderate uncertainty.

Ent-4 Entry as a contaminant

Plants may also be introduced to new areas accidentally as contaminants during trade activities. Questions Ent-4a through Ent-4i evaluate the potential for a taxon to be introduced as a contaminant or hitchhiker of different pathways.

Notes

- Search published and online literature, as well available port interception records.
- Positive evidence is required for a yes response to these questions. Answer no based on a lack of evidence.
- Congeneric information is appropriate for questions Ent-4b through Ent-4i provided that the taxon being assessed is similar to the congeners and that the factors allowing the congener(s) to contaminate the pathway are expected to be similar for the taxon being assessed. Use higher uncertainty or answer unknown as appropriate.

Ent-4a Is the taxon present in Canada, Mexico, Central America, the Caribbean, or China? (y or n)

Rationale. The likelihood of a plant being introduced into the United States as a contaminant is expected to be greater if the plant occurs in nearby regions and/or countries with which there is more trade or travel. If the taxon is present in these regions or countries, the scores from all of the contaminant-related questions are doubled.

Criteria. Answer yes if a taxon is present and reasonably abundant in any of these countries or regions. Answer no if you find no evidence that the taxon occurs in those areas.

Notes

- Check VASCAN (http://data.canadensys.net/vascan/search/)
- Although incomplete, the Flora of North America is a good source for determining presence in Canada: http://www.efloras.org/flora_page.aspx?flora_id=1
- Catalago de Malezas de Mexico (Villaseñor Rios and Espinosa Garcia, 1998) is good for weeds of Mexico but will not have cultivated plants.
- The book series Flora Neotropica is useful for native and naturalized plants of the Caribbean and Central America (as well as tropical South America).
- E-floras also feature an electronic flora of China: http://www.efloras.org/index.aspx. Also see Zhirong, 1990.

Full examples

- We found no evidence of *Phyllanthus maderaspatensis* being present in the United States, Canada, Central America, or the Caribbean. A single sample was collected from Hong Kong in the 19th century but otherwise this plant is not known to occur in China (eFlora, 2009). Answer: no with low uncertainty.

References

- Zhirong, W. (ed.). 1990. Farmland Weeds in China: A Collection of Coloured Illustrative Plates. Agricultural Publishing House. 506 pp.

Ent-4b Is the plant taxon a contaminant of propagative plant material (except seed)? (y = 0.4, n = 0, ? = 0)

Rationale. Propagative plant material is any material that is intended for reproducing and multiplying plants. Seeds are considered separately in the next question, so in this question evaluate nursery stock, roots, bulbs, corms, stems, or any other vegetative plant material. Weed propagules can be introduced to new areas as contaminants of propagative plant material. For example, roots of the weed *Inula britannica* grow intertwined with *Hosta* roots, which are imported into the United States.

Criteria. Answer yes if you find evidence that the taxon may be in this pathway, otherwise answer no.

Full examples

- Vegetative propagules of *Crassula helmsii* can contaminate aquatic plants in trade (OEPP/EPPO, 2007). Answer: yes with low uncertainty.

Ent-4c Is the plant taxon a contaminant of seeds for planting? (y = 0.4, n = 0, ? = 0)

Rationale. Seeds for planting is limited to any type of seed imported for planting, including (but not limited to) grain, grass, vegetable, and flower seeds.

Criteria. Answer yes if you find evidence that the taxon may be in this pathway; otherwise, answer no.

Notes

- Search lists of noxious seeds, including USDA's Germplasm Resource Information Network (GRIN) database (http://www.ars-grin.gov/) and the USDA manual of State Noxious Weed Seed Requirements (https://www.ams.usda.gov/sites/default/files/media/NWS%20List%202016.PDF). If the taxon appears on a noxious weed seed list, it is reasonable to assume the taxon is a contaminant of seed. When answering using this evidence alone, use high uncertainty.
- Also review the information collected for ES-16.

Full examples

- *Nassella neesiana* is thought to have been introduced to the Waipawa area of New Zealand in contaminated pasture seed (Slay et al., 1999). Answer: yes with low uncertainty.

Ent-4d Is the plant taxon a contaminant of ballast? (y = 0.3, n = 0, ? = 0)

Rationale. Ballast is a known pathway for many organisms, including aquatic plants, algae, and terrestrial plants that occur in coastal habitats (Drake and Lodge, 2007). Ballast includes material carried in the ballast tanks of ships or other vehicles to provide balance and stability. This may include water taken on at one port and released at new ports as cargo is offloaded, as well as dry ballast, such as rocks and sand. Dry ballast was very common prior to the twentieth century, but is probably less commonly used today.

Criteria. Answer yes if you find evidence that the taxon may be in this pathway, otherwise answer no.

Full examples

- We found no evidence that *Austroderia richardii* propagules spread in ballast water, but noted this species occurs in riparian and coastal habitats (GBIF, 2013; Landcare Research, 2014; Linder et al., 2010; Parsons and Cuthbertson, 2001). Thus, its seeds may be taken up in ballast water. Answer: no with high uncertainty.

References

- Drake, J. M., and D. M. Lodge. 2007. Rate of species introductions in the Great Lakes via ships' ballast water and sediments. Canadian Journal of Fisheries and Aquatic Sciences 64(3):530-538.

Imp-4e Is the plant taxon a contaminant of aquarium plants or other aquarium products? (y = 0.2, n = 0, ? = 0)

Rationale. Contaminants of aquarium plants, live rock, or water used to transport them can be a pathway for certain plants and algae, such as *Caulerpa* spp. Contaminants may be introduced by people dumping aquarium contents into local environments.

Criteria. Answer yes if you find evidence that the taxon may be in this pathway; otherwise, answer no.

Full examples

- *Crassula helmsii* is a contaminant of water plants (OEPP/EPPO, 2007) and can be spread to new areas via emptied aquaria (Dawson, 1994). Answer: yes with low uncertainty.

Ent-4f Is the plant taxon a contaminant of imported landscape products? (y = 0.2, n = 0, ? = 0)

Rationale. Imported landscape products include any materials used to improve the design of a landscape (e.g., pine straw, wood mulch, hydro mulch, gravel, top soil). These materials are an important weed contaminant pathway because landscape materials are often used in disturbed, open habitats that are favorable for plant establishment.

Criteria. Answer yes if you find evidence that the taxon may be in the pathway; otherwise, answer no.

Notes

- Only consider materials that are incorporated into landscapes. Weeds that contaminate shipping pallets, tile, or other products that may be stored or set on the ground are considered in the next question, Ent-4g.

Full examples

- Unknown for *Cestrum laevigatum*. The related species *C. parqui* can be moved to new areas in roadside gravel when root pieces are relocated during cultivation or roadside grading (DAFF, 2013). Answer: unknown with maximum uncertainty.

Ent-4g Is the plant taxon a contaminant of containers, packing materials, equipment, conveyances, or other non-agricultural products? (y = 0.2, n = 0, ? = 0)

Rationale. This category is very broad and is meant to include a variety of pathways. “Containers” refers to any kind of shipping container or materials used in shipping (e.g., refrigerated container units). “Equipment” includes engines, generators, boots and shoes, or other tools. “Conveyances” refer to anything that serves as a means of transporting commodities including planes, railway cars, ships, trucks, and other vehicles. “Non-agricultural products” includes any non-plant material that is imported or traded, including tile, engines, etc.

<u>Criteria.</u> Answer yes if you find evidence that the taxon may be in this pathway; otherwise, answer no.

<u>Full examples</u>

- A large population of *Nassella neesiana* in southern France may have been introduced through railway traffic (Verloove, 2005). Answer: yes with high uncertainty.

Ent-4h Is the plant taxon a contaminant of highly processed commodities or fruits, vegetables, grains or other products for consumption? (y = 0.1, n = 0, ? = 0)

<u>Rationale.</u> Examples of products for consumption or processing that can be contaminated with propagules include grain for milling (e.g., wheat), seed for processing (e.g., spices), wool, and coconut coir. Relative to the previous pathways, this pathway poses less risk, because these products are either consumed or destroyed during processing. However, contaminants can still rarely escape during transport (e.g., grain spillage), or be removed and disposed of improperly (e.g., Nesom, 2004).

<u>Criteria.</u> Answer yes if you find evidence that the taxon may be in this pathway; otherwise, answer no.

<u>Notes</u>

- Do not consider consumption commodities here if the intended use will place it directly into the environment where exotic taxa can readily escape and establish (e.g., hay, birdseed). In some of these cases, this information may be appropriate for Ent-4i.

<u>Full examples</u>

- Some French infestations of *Nassella neesiana* may have been introduced in imported cereals for consumption from Argentina (Verloove, 2005) Answer: yes with low uncertainty.

Ent-4i Is the plant taxon a contaminant of some other pathway(s) not covered above? Choose the letter for the risk score that best represents the relative risk for the pathway(s): (a) 0; (b) 0.01; (c) 0.02; (d) 0.03; (e) 0.04.

<u>Rationale.</u> This is a catchall question designed for any pathways not covered above and/or for evidence that did not readily fit the previous questions.

<u>Criteria.</u> Clearly describe the pathway(s) in the notes column and provide supporting documentation. Choose the letter for the risk score that you think is appropriate for the pathway(s). If no other pathways are known, answer “a.” Consider the possible scores for other pathways described under Ent-4. The highest scores are reserved for contaminants in pathways that end in environments highly conducive for establishment (e.g., flower gardens, landscapes).

Scores are lower for pathways that are less likely to end in favorable environments, or in which propagules must overcome additional barriers to establishment. For example, aquarium plants must be dumped in an outdoor aquatic environment to establish. Answer unknown as appropriate.

<u>Notes</u>

- Recall that if the weed is present in any of the countries or regions indicated in Ent-4a this score value will be doubled.

<u>Full examples</u>

- Inflorescences of *Austroderia richardii* are used in dried floral arrangements (Anonymous, 2014b). Dried plumes of pampas grass (exact species is unknown) are available for sale on the internet (e.g., Anonymous, 2013b). Because *A. richardii* is also known as New Zealand pampas grass (Richardson et al., 2006), its flowers and associated seeds are likely to move in trade. Answer: "c" with low uncertainty.
- *Nassella neesiana* is a contaminant of hay (Weller et al., 2012). We answered e for 0.4 points because hay is used in agricultural environments where it could easily establish. Answer: "e" with negligible uncertainty.
- We found no evidence that *Phyllanthus maderaspatensis* is a contaminant of other pathways. Answer: "a" with moderate uncertainty.

Ent-5 Is the plant taxon likely to enter the United States through natural dispersal? (y = 0.6, n = 0, ? = 0)

<u>Rationale.</u> As a pathway for entry, natural dispersal is most likely to occur for plants that occur in neighboring regions. For the lower 48 states, natural dispersal is likely for plants that grow along the Canadian and Mexican border, as well as for plants present in the upper Caribbean.

<u>Criteria.</u> This question requires the risk analyst to use their best judgment. To answer yes, evidence must indicate that a taxon is present in a nearby region AND that it has a means of natural dispersal that enables long-distance colonization. Answer no if the taxon is either not present in a nearby country or if it has no relevant means of natural dispersal. Answer unknown if you find very little information about the taxon.

<u>Full examples</u>

- *Austroderia richardii* is wind-dispersed (Parsons and Cuthbertson, 2001) and the botanical garden where it is grown in British Colombia is relatively close to the U.S. border (GBIF, 2013). "The seed-bearing florets of the female plant [of the related species *Cortaderia selloana*] are particularly hairy and readily dispersed by wind, often being carried for up to 25 km" (Parsons and Cuthbertson, 2001). Because the inflorescences of both species are similar (plumose, silky, and hairy; Landcare Research, 2014), we believe *A. richardii* is just as likely to enter the United States from Canada through wind dispersal. Answer: yes with high uncertainty.
- *Nassella neesiana* does not seem likely to enter the United States through natural dispersal because it is not present in a bordering country. Answer: no with low uncertainty.

Appendix I. Conceptual process for the uncertainty analysis in the PPQ WRA

The uncertainty analysis in the PPQ WRA uses a stochastic simulation to evaluate the sensitivity of the model-derived risk score to uncertainty in the assessment. The process described and shown below summarizes how the simulation works, using answers and uncertainties from the "Screening Tool" worksheet. The simulation is performed by @Risk within Microsoft Excel. After the full simulation is complete, the analyst will create the graph of the simulated risk scores around the observed score. The risk analysts and managers will interpret the results to make appropriate decisions.

Step	Process performed in the model
1	For a given question, based on the uncertainty rating, randomly determine the probability that some other answer is correct. Probabilities are selected from triangular distributions, as defined by minimum, maximum, and most likely values (see Table 4, in Process 3).
2	Using the probability from Step 1, determine in a binomial process if a given answer changes. For example, if the probability is 0.13, then the answer has a 13 percent chance of changing.
3	If the answer changed, select a different answer. For yes/no questions this is a simple switch, while for multiple-choice questions another random determination may be necessary.
4	Based on the answer, determine the risk score for that question.
5	Repeat steps 1-4 for every question.
6	Calculate the new risk scores for ES and Imp, determine the outcome of the WRA (low risk, evaluate further, or high risk), and run the secondary screening if necessary.
7	Store and track the results. This represents one simulated WRA.
8	Repeat Steps 1-7 4,999 more times to generate 5,000 simulated WRAs.

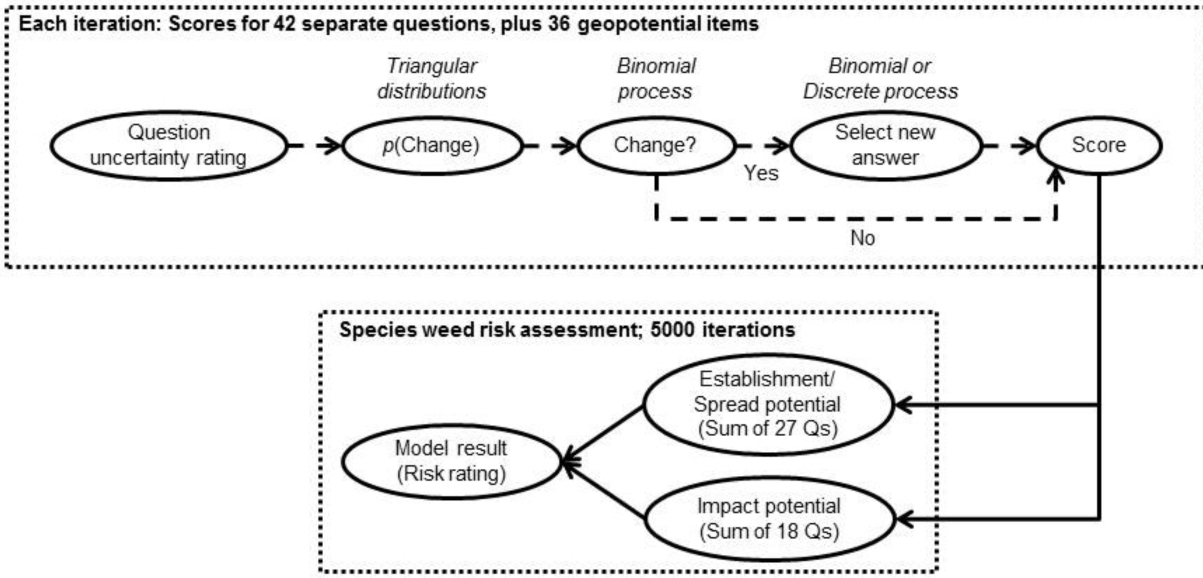

Figure I-1. Conceptual process of the stochastic simulation that is conducted as part of the PPQ WRA uncertainty process.

Appendix J. Work instructions for performing an uncertainty analysis (a stochastic simulation) using @Risk.

1. After opening Microsoft Excel and the WRA workbook, open the @Risk program from Window's Start button to load it into Excel.
2. Go to the @Risk tab in the top menu tool bar. If this is the first time running @Risk or if the simulation settings have changed since the last WRA uncertainty analysis, do the following; otherwise go to Step 3.
    a. Click on the Simulation Settings icon. A new window will appear with several tabs. Change the indicated settings to the values described. Other settings are not relevant to a standard uncertainty analysis.
    b. General Tab
        i. Number of iterations: 5,000
        ii. Number of simulations: 1
        iii. Multiple CPU support: Enabled
    c. Sampling Tab
        i. Sampling type: Latin hypercube
        ii. Generator: Mersenne Twister
        iii. Initial seed: Fixed 101
        iv. Collect distribution samples: Inputs marked with collected
    d. View Tab
        i. Automatic results display: Show output graph
        ii. Update windows during simulation Automatic
3. Close all other Excel workbooks containing @Risk models, including WRA workbooks for other taxa. This ensures that only one stochastic model is run at a time.
4. Click on Start simulation. The simulation will only take a few moments to complete.
5. In the @Risk menu tab, click on the "Simulation Detailed Statistics" icon under Results. Select and copy the means for the following columns.
    a. Proportion High Risk Output
    b. Proportion EF-High Risk Output
    c. Proportion EF-EF Risk Output
    d. Proportion EF-Low Risk Output
    e. Proportion Low Risk Output
6. Go to the "Risk Score Plot" worksheet in the workbook. Paste the means in a blank space in the worksheet, and then enter the values as percentages (e.g., 23.2%) in the inset of the uncertainty graph (bottom graph). Ensure that the means are entered in the appropriate row corresponding to: High Risk, EF→High, EF→EF, EF→Low, or Low. To avoid possible confusion, delete the values that you initially pasted.
7. In the @Risk menu tab, click on the "Simulation Data" icon under Results. Select and copy columns 2 and 3 which correspond to "Establishment/Spread Output" and "Impact Potential Output." Temporarily paste these two columns into two blank columns in the workbook.
8. From the output just pasted into the spreadsheet, select the two cells in the first row containing simulated risk scores, and click on CTRL + SHIFT + Down Arrow. This selects all of the simulated risk scores. Copy the data. Click on the Home button on your keyboard, to quickly take you back to the top. Select cell E3, and paste the copied data.

9. Ensure that the uncertainty graph is properly displaying the data. To avoid possible confusion, delete the two columns of data that were temporarily pasted into the spreadsheet in Step 7.
10. If the @Risk program loads from a shared network, select the Utilities button from the menu tab, and select "Unload @Risk Add-in" so that others may access it if there are a limited number of licenses in your organization.
11. When saving or closing the Excel workbook, it is not necessary to save the @Risk results as they can be easily reproduced.

Acknowledgements

The PPQ WRA Guidelines was completed through the dedicated efforts of the PERAL Weed Team and other PPQ employees who reviewed the document. We could not have completed these guidelines or developed the PPQ WRA process without the support of our supervisors and PPQ leaders. Much of the question-specific guidance used in this document is based on guidance developed by an international committee of participants at the 2nd International Weed Risk Assessment workshop in Perth, Australia, for the Australian WRA (Gordon et al., 2010; Pheloung et al., 1999)[7]. In many cases the guidance developed at this workshop was adapted, clarified, or augmented for the PPQ WRA process. We would like to thank Paul Pheloung and the editors of Plant Protection Quarterly for allowing us to use portions of those guidelines (Pheloung, 2009)[8].

Special thanks to members of the Canadian Food Inspection Agency's weed risk analyst team, who not only reviewed this document as it was being created, but also inspired or created certain features of the guidelines. We also want to thank all past and future participants of our Weed Risk Assessment training workshops for their comments, which have helped to create and improve our guidelines.

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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.

[8] Pheloung, P. 2009. Request to use question-specific guidance. Personal communication to A. Koop on December 13, 2009, from Paul Pheloung, Department of Agriculture, Fisheries and Forestry, Australian Government.

Version Change Log

This file is a controlled document under the PERAL Weed Team's quality control system. Although the document is called "The PPQ WRA Guidelines", it is filed as Technical Procedure E-300 (TP E-300). Version 2.2 of the PPQ WRA Guidelines was approved by Tony Koop. Below is a log of the changes made to the document since the original version.

Date	Description
2/11/2019	Version 2.3 • Removed the term ISO from one of the pages.
9/29/2016	Version 2.2 • Minor changes and updates to some of the citations related to plant hardiness zones.
8/23/2016	Version 2.1 • Formatted the Question specific guidance headings so that they show up in the Navigation pane (for ease of finding this guidance). • Re-inserted missing text from Section 1 (Instroduction to the PPQ Weed Risk Assessment) (We are not sure how this text got deleted from Version 2).
6-3-2016	Version 2 • Incorporated minor comments from weed risk analysts and WRA training workshop attendees. • Incorporated recommended minor changes from the PERAL Weed Team. • Improved consistency in the use of some terminology and formatting throughout the document.
1-24-2015	Version 1 (Original)