Guidance for addressing the Australian Weed Risk Assessment questions

Doria R. Gordon[A], **Belinda Mitterdorfer**[B], **Paul C. Pheloung**[C], **Shahin Ansari**[D], **Chris Buddenhagen**[D], **Chuck Chimera**[E], **Curt C. Daehler**[F], **Wayne Dawson**[G], **Julie S. Denslow**[H], **AnneMarie LaRosa**[H], **Tomoko Nishida**[I], **Daphne A. Onderdonk**[J], **F. Dane Panetta**[K], **Petr Pyšek**[L], **Roderick P. Randall**[M], **David M. Richardson**[N], **Ntakadzeni J. Tshidada**[O], **John G. Virtue**[P] and **Peter A. Williams**[Q]

[A] The Nature Conservancy and Department of Biology, PO Box 118526, University of Florida, Gainesville, FL 32611, USA.
[B] Biosecurity Australia, Department of Agriculture, Fisheries and Forestry, GPO Box 858, Canberra, ACT 2601, Australia.
[C] Department of Agriculture, Fisheries and Forestry, GPO Box 858 Canberra ACT 2601 Australia.
[D] SWCA Environmental Consultants, 201 Merchant St., Suite 1638, Honolulu, HI 96813, USA.
[E] Hawaii Invasive Species Council – Maui Office, P.O. Box 983, Makawao, HI 96768, USA.
[F] Department of Botany, 3190 Maile Way, University of Hawaii, Honolulu, HI 96822. USA.
[G] Institute of Plant Sciences, University of Bern, Altenbergrain 21, 3013 Bern, Switzerland.
[H] Institute of Pacific Island Forestry, USDA Forest Service, 60 Nowelo St, Hilo, HI 96720, USA.
[I] Biodiversity Division, National Institute for Agro-Environmental Sciences, 3-1-3 Kannondai Tsukuba Ibaraki 305-8604, Japan.
[J] Department of Biology, PO Box 118526, University of Florida, Gainesville, FL 32611, USA.
[K] Biosecurity Queensland, Department of Employment, Economic Development and Innovation, Alan Fletcher Research Station, PO Box 36, Sherwood, Q 4075, Australia.
[L] Institute of Botany, Academy of Sciences of the Czech Republic, CZ 25243 Průhonice, Czech Republic, and Department of Ecology, Faculty of Science, Charles University Prague, Viničná 7, CZ 12801 Praha 2, Czech Republic.
[M] Department of Agriculture and Food, Locked Bag 4, Bentley Delivery Centre, WA 6983 Australia.
[N] Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa.
[O] Department of Agriculture, Directorate: Plant Health, Private Bag x14, Gezina 0031 South Africa.
[P] Department of Water, Land and Biodiversity Conservation, GPO Box 2834, Adelaide, SA 5001, Australia.
[Q] Landcare Research, Private Bag 6, Nelson, New Zealand.

Summary

This paper provides guidance on how to address the 49 questions of the Australian Weed Risk Assessment (WRA) system. The WRA was developed in Australia in 1999, and has since been widely adapted for different regions. As interest in implementation and results comparison has increased, the issue of consistency in answering and scoring the questions has become important. As a result, this guidance was developed during the 2007 International WRA Workshop. Suggestions on search methods, data sources and examples are also provided.

Keywords: Invasive, prevention, weed risk assessment.

Introduction

The Australian Weed Risk Assessment system (hereafter 'WRA') was originally developed as a tool for use by the government of Western Australia to assess the weed potential of plants proposed for introduction into that state. Subsequently, the system was modified, tested, and adopted by the Australian Government Department of Agriculture, Fisheries and Forestry following public consultation. The outcomes of assessments are used for ongoing updates of a permitted seeds list contained within a proclamation of the Australian *Quarantine Act 1908*. The WRA system determines quarantine risks associated with plant imports and is considered to be consistent with Australia's international rights and obligations as a member of the International Plant Protection Convention. The WRA system has also been adopted for use within the New Zealand Biosecurity Act of 1993.

A report on the WRA and a manual for its implementation using an Excel spreadsheet are available (http://www.daffa.gov.au/ba/reviews/weeds/system). However, any modifications, particularly where the scoring system is changed, would mean that the performance assessment contained in the report (Pheloung *et al*. 1999) is no longer valid. Clarified and slightly modified guidance on how to address the WRA questions (http://www.botany.hawaii.edu/faculty/daehler/wra/screening_criteria.pdf) was developed for a test of the WRA in Hawaii (Daehler and Carino 2000) and Hawaii and the Pacific Islands (Daehler *et al.* 2004). Some combination of the original and modified guidance was likely used in later tests of the WRA in the Czech Republic (Křivánek and Pyšek 2006), Bonin (Ogasawara) Islands of Japan (Kato *et al.* 2006), Florida, US (Gordon *et al.* 2008b), Japan (Nishida *et al*. 2008), and central Italy (Crosti *et al*. 2009). Although comparison of the results of tests across geographies revealed similar accuracy (Gordon *et al.* 2008a), differences in interpretation of the questions reduces consistency of application (Onderdonk *et al*. 2010). Our objective in this paper is to provide more complete guidance on addressing the WRA questions, and sources of information to ease implementation of this tool as it is applied to new geographies. We hope that this effort will facilitate more consistent application of the WRA and reduce unintended variation in that implementation.

These clarified guidelines (Table 1) were developed during the second International WRA Workshop (14–15 Sept. 2007) and ninth annual conference on the Ecology and Management of Alien Plant Invasions held in Perth, Australia (17–21 Sept. 2007), both held in Perth, Australia. The guidance is consistent with the original intent of the WRA, and build on the information found on the Australian WRA website (http://www.daffa.gov.au/ba/reviews/weeds/system). Scoring for the WRA remains as posted on that website and here in Appendix 1. The clarified guidelines are largely consistent with the interpretation used by the Australian Government in its operation of the system as a quarantine screening tool.

General guidance

Answer the WRA questions for the taxon that has been proposed for introduction (e.g. species, cultivar, variety), despite the use of 'species' in the questions. This approach is consistent with international standards for pest risk analysis established by the International Plant Protection Convention, which state that the taxonomic level for organisms considered in the analysis is usually the species, and that use of higher or lower taxonomic levels should be supported by a scientifically sound rationale (FAO 2004, 2007). Consistent with the IPPC standards (FAO 2007), the risk assessor may conclude that a lower level taxon is not sufficiently distinct from the higher level in characters that influence phytosanitary status, and determine that the species should be the entity evaluated. The identity of the taxon and any synonyms should be determined using accepted, internationally recognized sources (e.g. Germplasm Resources Information Network [GRIN], http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl).

The area for which the potential invasiveness of the taxon is addressed should encompass its full potential range within the political region, country, or other area to which the WRA is applied, regardless of the landscape or geographic extent of the intended introduction. For example, even if the proposed cultivation of the taxon is for only one ownership or land use within a larger region (state, province, country, etc.), assessment is for the entire region of interest.

For the purposes of the WRA, define 'weed' as a plant taxon (not necessarily non-native) that grows in sites where it is not wanted and has detectable economic or environmental impact or both. Define 'naturalized' as a non-native taxon that can sustain self-replacing populations for several years without direct intervention by people (or in spite of human intervention) by recruitment from seed or ramets (tillers, tubers, bulbs, fragments, etc.) capable of independent growth (Pyšek *et al.* 2004). 'Naturalized' species are differentiated from 'casual' species, which are non-native taxa that grow and may reproduce occasionally outside cultivation in an area, but do not form self-replacing populations. These taxa rely on repeated introductions for their persistence (Pyšek *et al*. 2004). Note, however, that the qualification of 'several generations' used by these authors is considered by some to be too restrictive for long-lived trees. Potential for several generations based on evidence of more than one generation may be used in this case. All questions and guidance that discuss seeds also apply to vascular plant spores.

Ideally, any evidence used to answer WRA questions should have independent corroboration; where a single reference is used, statements should be supported with data. Where there is no evidence for a given question, or conflicting evidence with little substantiation, leave it blank as a response of 'unknown'. For some questions, the absence of evidence may warrant a 'no' response and this is indicated in the question-specific guidance that follows. However, it is important in these cases to distinguish between well known or studied species for which there is no evidence of the issue in question (resulting in a 'no' response) and species that are very poorly known or studied (resulting in an 'unknown' response). An example of the latter would be a recently described species that has no documentation beyond a taxonomic description. Where substantiated but conflicting evidence is found, use the evidence from the more reliable or specific source. If conflicting sources are equally reliable, select the 'unknown' response.

Documentation of evidence regarding the 'weed elsewhere' questions (3.02 – 3.05), merits special attention because the terms 'weed' and 'invasive' are used loosely and variably by different sources, and also because the 'weed elsewhere' questions can contribute significantly to the WRA score. Simply checking if a species is included on any compiled list is insufficient: original sources should be checked. Various 'weed handbooks' may include species that do not qualify as weeds for WRA purposes because impacts have not been described or documented. Within the well known volume, A Geographic Atlas of the World's Worst Weeds (Holm *et al.* 1979), species with ratings of 'serious weed' and 'principal weed' are generally supported by documented impacts, but species rated as 'common' or 'present' have less well defined criteria and their status needs to be confirmed using additional sources (C. Daehler personal observation). Always compare the context in which a species is being described as a 'weed' or an 'invader' to the impact criterion (see further elaboration next to each question below) before answering 'yes' to these questions.

Document the original source(s) for the supporting evidence and references used for responses to each question. Ideally, taxon identity, score, and documentation would all be electronically available (see protocol 2, below) so that relevant information could be used by others as they implement or evaluate the WRA. For greatest clarity, include the date that the resource was accessed when providing the URL.

Data search protocol

This protocol has been adapted from that developed for the WRA implementation in Hawaii (http://www.botany.hawaii.edu/faculty/daehler/WRA/General_Instruct.pdf).

1. Confirm the plant's scientific name, synonyms and common names using the following databases: (1) http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl; (2) http://www.itis.gov/; (3) http://www.kew.org/data/index.html, (4) http://www.tropicos.org/; (5) http://www.ipni.org/ipni/plantnamesearchpage.do; and (6) www.ipni.org.
2. Check whether the taxon has already been screened in the area of interest or in the biogeographical region (i.e. screening may have been completed for a neighbouring region that would be applicable to the area of interest). Data for Western Australia, Pacific Island Ecosystems at Risk, and Florida are at: http://www.hear.org/pier/wra.htm; see also: http://www.botany.hawaii.edu/faculty/daehler/wra/default2.htm and sites for supplemental data cited in papers (e.g. Kato *et al*. 2006, Křivánek and Pyšek 2006, Barney and DiTomaso 2008).
3. Check whether the taxon has been screened elsewhere. If so, use the existing screening data as a base for re-screening in the area of interest (see sources cited in (2) above). Review decisions made for applicability to the area of interest and use up-dated information if it is available.
4. Using the criteria and suggested keywords (see Table 1. Examples and Data Sources), do the assessment using the following tools: (1) Floras and other books/reports/published materials relevant to the taxa being screened. Horticultural books can be useful for the questions relating to cultivation (e.g. Bailey and Bailey (1976), Huxley and Griffiths (1992), and Walters (1984–2000)); (2) Internet searches using the taxon name (e.g. http://www.google.ca/ or http://scholar.google.com); (3) Primary literature searches using the following databases: Biological Abstracts (http://scientific.thomson.com/products/ba/), CAB Abstracts (http://www.cabi.org/datapage.asp?iDocID=165), and AGRICOLA (http://agricola.nal.usda.gov/); (4) CABI Forestry compendium (http://www.cabi.org/compendia/fc/); and (5) CD-ROM databases of Horticopia A to Z, Plants, Trees and Shrubs, Southern Trees and Plant Master.

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Table 1. Original Australian Weed Risk Assessment guidance (Walton *et al*. 1999), refined guidance from this working group, and examples and data sources for addressing the 49 questions. Points and look-up tables associated with the questions are in Appendix 1.

WRA Question	Australian WRA System Guidance used by the Australian Government Department of Agriculture, Fisheries and Forestry	International Working Group Guidance	Suggested Examples and Data Sources
1.01 Is the species highly domesticated? If answer is 'no' go to Question 2.01	The taxon must have been cultivated and subjected to substantial human selection for at least 20 generations. Domestication generally reduces the weediness of a species by breeding out noxious characteristics.	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 weediness. The 'yes' answer should be accompanied by evidence that one or more traits have been substantially modified by people through domestication efforts. Evidence to the contrary (no domestication, or selection that increases invasive traits) or no information results in a 'no' response.	• Examples of 'yes' data: *Mangifera indica* (mango) – see www.botany.hawaii.edu/faculty/daehler/wra/full/Mangifera%20indica.xls; *Litchi chinensis* (lychee) – see www.botany.hawaii.edu/faculty/daehler/wra/full/Litchi%20chinensis%20SA.xls. • Domestication of *Ardisia crenata* has resulted in increased seed production (Kitajima *et al*. 2006), which likely confers greater, rather than reduced weediness. In this case, the answer would be 'no'.
1.02 Has the species become naturalized where grown?	Is a domesticated plant, which has been introduced from another region, and is growing, reproducing and maintaining itself in the introduced range. A 'yes' answer to question 1.01 will be modified by the response to this question.	Skip this question if the answer to 1.01 is 'no'. Answer 'yes' if the taxon has been documented to be regularly producing new generations of reproductive individuals in the environment without human assistance. A 'yes' answer to question 1.01 will be modified by the response to this question. Answer 'unknown' if the taxon is reported to 'sparingly naturalize' or 'occasionally escape from cultivation'. 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 (see General Guidelines section). 'No' responses should be supported by data demonstrating that the taxon is not self-perpetuating.	• Search on taxon name + 'weed' 'naturalized,' 'naturalized' or 'invasive'. • Look into floras of the region to which the taxon is not native. Some useful floras are (1) New Zealand: Webb *et al*. (1988); (2) Florida: Wunderlin and Hansen (2003); (3) Jamaica: Adams (1972); (4) Puerto Rico and Virgin Islands: Little and Wadsworth (1964); (5) British Isles: Stace (1991); (6) South Africa: Glen (2002); (7) Europe: Walters *et al*. (1984–2000) and Tutin e*t al*. 1964–1993). • Some online floras are: (1) multiple – www.efloras.org/; (2) Taiwan – http://tai2.ntu.edu.tw/fotdv/fotmain. htm; (3) Hawaii – www2.bishopmuseum.org/HBS/checklist/query.asp?grp=Plant; (4) South Africa – posa.sanbi.org, www.plantzafrica.com and www.agis.agric.za; (5) New Zealand – http://floraseries.landcareresearch.co.nz/pages/Index.aspx; (6) Australia – www.anbg. gov.au/abrs/online-resources/flora/main-query-styles.html; (7) US – http://plants.usda.gov/. • Print or on-line weed lists: e.g., (1) Global Compendium of Weeds – www.hear.org/gcw/; (2) Europe – www.europe-aliens.org; (3) (5) Japan – www.rib.okayama-.ac.jp/wild/okayama_kika_v2/Seed-image-database.html (Note that not all of the plants listed are 'invasive' according to the definition by Pyšek *et al*. [2004]).
1.03 Does the species have weedy races?	Only answer this question if the species you are assessing is a sub-species, cultivar or registered variety of a domesticated species. If the taxon is a less weedy subspecies, variety or cultivar, then there must be good evidence that it does not retain the capacity to revert to a weedy form. A 'yes' answer to question 1.01 will be modified by the response to this question.	Skip this question if the answer to 1.01 is 'no' or if the taxon is not a sub-species, cultivar or registered variety of a domesticated species. A 'yes' answer to question 1.01 will be modified by the response to this question. 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 (see General Guidelines section).	• Evidence usually obtained from online horticultural databases by doing a general Google search on the taxon name. Also try species name + ('varieties' and 'cultivars') + 'weed'. • Walters *et al*. (1984–2000) is a good source for Europe, Bailey and Bailey (1976) for North America.

WRA Question	Australian WRA System Guidance used by the Australian Government Department of Agriculture, Fisheries and Forestry	International Working Group Guidance	Suggested Examples and Data Sources
2.01 Species suited to *Australian climates*	This question applies to any one Australian climate type, or more than one. Ideally, base the climate matching on an approved computer prediction system such as CLIMEX , BIOCLIM or CLIMATE. If no computer analysis is carried out then assign the maximum score (2).	The intent of this question is to predict whether the taxon might become naturalized (definition above) in the assessed area. The italicized portion of this question should be modified to address the predominant climate of the area of interest. Species suited to the climates of the defined region (0–low; 1–intermediate; 2–high). This question applies to any one climate type within the region, or more than one. Ideally, base the climate matching on a computer prediction system such as CLIMEX , BIOCLIM or CLIMATE. The guidance from Australia states that if no computer analysis is conducted, assign the maximum score of 2. Other implementation efforts have used descriptions of climate tolerance or native range environmental conditions to qualitatively score climate suitability (e.g., Species suited to the climates of the defined region: 0–low; 1–intermediate; 2–high). The approach used should be clarified in documentation accompanying any WRA effort. The score is used to weight questions in Section 3 as described in the look-up table.	• Information on the plant species can be obtained by reference to its native or naturalized distribution, or from horticultural records of where it has been successfully grown. • Use published objective climate classification systems like the US Department of Agriculture hardiness zones (www.usna.usda.gov/Hardzone/ushzmap.html) or global hardiness zones (www.nappfast.org/Plant_hardiness/ph_index.htm). • Use CLIMEX, CLIMATE, or GARP models to generate taxon-specific or geography based climate match predictions. • Use published maps that include the area of interest (e.g., Richardson and Thuiller (2007) maps of global locations that match South African climates). • Check GRIN (www.ars-grin.gov/cgi-bin/npgs/html/tax_search.pl, the Integrated Taxonomic Information System (ITIS) www.itis.usda.gov/advanced_search.html, and the Global Biodiversity Information Facility http://secretariat.mirror.gbif.org/welcome.htm for information on species ranges. • Walters *et al.* (1984–2000) gives values for hardiness of 16 000+ taxa in Europe; see Bailey and Bailey (1976) for North American data. • See Gordon and Gantz (2008) for an example of how this and other questions have been modified for the US.
2.02 Quality of climate match data	The score for this question is an indication of the quality of the data used to generate the climate analysis. Reliable specific data scores 2, general climate references scores 1, broad climate or distribution data scores 0. If a computer analysis was not carried out assign the maximum score of 2.	This question indicates the quality of the data used to generate the climate analysis in question 2.01. The score is used to weight questions in Section 3 as described in the look-up table. The guidance from Australia states that if no computer analysis is carried out, default to the maximum score of 2. Other implementation efforts that have not used computer analysis have used a range of scores for the quality of climate match data as follows: High: score = 2; native range is well known. If there are regions outside the native range where the plant has naturalized, climate in these regions is also well known. Intermediate: score = 1; boundaries of the native and naturalized range are not well known with respect to whether they lie within the climate of interest. Or, the plant is grown in the climate of interest outside its native range, or the plant has a range that only marginally overlaps with the climate of interest. Low: score = 0; the native/naturalized range is poorly known and/or climate in the native and naturalized range is poorly understood.	• Greater quality in climate matching will be achieved using point location data rather than simply countries or states (where there may be a wide variation in climate, including altitudinal effects). • Example of intermediate score = 1: *Thespesia populnea* (milo) – www.botany.hawaii.edu/faculty/daehler/wra/full/Thespesia%20populnea.xls.

WRA Question	Australian WRA System Guidance used by the Australian Government Department of Agriculture, Fisheries and Forestry	International Working Group Guidance	Suggested Examples and Data Sources
2.03 Broad climate suitability (environmental versatility)	Score 'yes' for this question if the species is found to grow in a broad range of climate types. Output from the climate matching program may be used for this question. Otherwise base the response on the natural occurrence of the species in 3 or more distinct climate categories. Use the map of climatic regions provided or one available in a comprehensive atlas (e.g., Trewartha or Koppen climatic maps).	Score 'yes' for this question if the taxon is found to grow naturally in a broad range of climate types. Output from a climate matching program may be used for this question. Otherwise base the response on the natural or naturalized range of the species in 3 or more distinct climate categories as defined by the minor climate regions in the Köppen-Geiger system (Aw, Af, BS, BW, etc,) or similar scale. Answer 'yes' to this question if a species occurs in 3 or more climatic regions. Answer 'no' if the species clearly grows in fewer than 3 climatic regions. Otherwise, answer 'unknown'.	• Use Goodes World Atlas (Espenshade 1990) climatic regions. • Peel *et al.* (2007) have updated the Köppen-Geiger climate maps: www.hydrol-earth-syst-sci.net/11/1633/2007/hess-11-1633-2007.pdf. • The Comprehensive Times Atlas of the World (Times Books Group 2005) has a map of climate zones in the front. • Global plant hardiness zones developed by the North Carolina State University APHIS Plant Pest Forecasting System (NAPPFAST) can be found at: www.nappfast.org • The altitude and latitude range of the taxon can usually be found on the internet and/or in the flora. Check the online herbarium databases such as Missouri Botanical Garden: www.mobot.org for data on the taxon's elevational range. Note: the taxon needs to be growing naturally at that elevation.
2.04 Native or naturalized in *habitats with extended dry periods*	Score 'yes' if the species is able to grow in areas with rainfall in the driest quarter less than 25 mm. Plants from this group may potentially grow and survive in arid Australian conditions.	The italicized portion of this question may be modified to address climate influences within extensive habitats in the area of interest (e.g., precipitation or frost-based) *separate from those specified in 2.01*. For Australia, use the original specified criterion. Generally, the climate variable included will address extreme events experienced in some or all of the area of interest. Naturalized is defined as described above. Answer 'no' if the taxon cannot naturalize under the described climate condition or if only marginal occurrences (casual invaders, see General Guidance) exist in that condition. Answer 'unknown' if no information on tolerance to these conditions can be found.	• Check GRIN www.ars-grin.gov/cgi-bin/npgs/html/tax_search.pl and ITIS www.itis.gov/advanced_ search.html for information on geographic distribution and useful links. • The Global Biodiversity Information Facility has information on species ranges: http://secretariat.mirror.gbif.org/welcome.htm. • See Gordon and Gantz (2008) for an example of how this and other questions have been modified for the US.
2.05 Does the species have a history of repeated introductions outside its natural range?	This history should be well documented, but may also be inferred from occurrence in multiple regions outside of the native range. A potential weed must have opportunities to show its potential. Species with repeated introductions but no establishment outside their native range are a lower risk. A score for this question will modify the score for a 'no' answer to Question 3.01.	A potential weed must have had opportunities to demonstrate its invasive potential. The history of planting outside glasshouse/indoor conditions should be well documented for a 'yes' answer to this question. Taxa with repeated introductions that have not naturalized are a lower risk. If several separate introductions (intentional or unintentional) have been documented, or there is documentation of outdoor horticultural use, answer 'yes'. A lack of positive evidence for this question results in an 'unknown' answer unless a 'no' answer is indicated because the taxon is newly described, documented as a novel introduction, or discovered from a remote location. The answer to Question 2.05 will modify the score for a 'no' answer to Question 3.01.	• Evidence usually obtained from internet, floras and primary literature. • Plants sold in nurseries outside of the native range can be used as evidence for introduction in that region (e.g. nursery and seed websites, landscaping websites and discussion groups – http://davesgarden.com/).

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3.01 Naturalized beyond native range	Naturalized (plants growing and reproducing in non-native range) species will be cited in floras of localities which are clearly outside of the native range. If the native range is uncertain and the known extent of the naturally growing plants is within the area of uncertainty then the answer is 'don't know'.	A naturalized taxon, as defined above, should be documented to produce new generations of reproductive individuals in the environment without or despite human assistance in areas that are clearly outside of the native range. If the native range is uncertain and the known extent of the naturally growing plants is within the area of uncertainty then the answer is 'unknown.' If the taxon under evaluation is a hybrid with a native range, naturalization beyond that range should be documented for a 'yes' response. If the taxon is a horticulturally produced entity with no native range, naturalization anywhere is sufficient for a 'yes' response. 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 (see General Guidelines section).	• Many reference sources (e.g., floras) do not give clear definitions of naturalization, or they use different definitions (e.g. inclusion of casuals). If naturalization status is unclear, or vague terms such as 'escape' or 'rare' are used, answer 'don't know'. • Use same sources as for question 1.02. • See also Weber (2003).
3.02 Garden / amenity / disturbance weed	The plant is generally an intrusive weed of gardens, parklands, roadsides, quarries, etc. This question carries less weight than 3.03 or 3.04. If a plant is listed as a weed in relevant references but the type of weed is uncertain or it is a minor weed – score 'yes' for 3.02.	The taxon is generally identified as a weed (see above definition) of gardens, parklands, golf courses, roadsides, quarries, etc. Taxa may be considered disturbance weeds both within and beyond their native range. Evidence that a taxon occurs in disturbed areas is not sufficient for a 'yes' response; there should be documentation that the species has negative impacts or is subject to control. 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. This question carries less weight than 3.03 or 3.04.	• Taxon name + 'weed', 'invas*', 'invad*', 'pest'. Evidence usually obtained from internet and primary literature. • For example, the CRC Australia (www.weeds.crc.org.au/weed_management/indiv_species_a.html) rated naturalized plants according to their weediness (Groves *et al.* 2003). Ratings <3, score positively here and not in questions 3.03 or 3.04. • See discussion under General Guidance on addressing this question.
3.03 Weed of agriculture / horticulture / forestry	The plant is generally a weed of agriculture/horticulture/forestry and causes productivity losses and/or costs due to control. This question carries more weight than 3.02. If a plant is listed as a weed in relevant references but the type of weed is uncertain or it is a minor weed – score 'yes' for 3.02.	The taxon is generally a weed (see above definition) of agriculture / horticulture / forestry, causing productivity losses and/or costs due to control. If a plant is listed as a weed in relevant references but the type of weed is uncertain or it is a minor weed - score 'yes' for 3.02 but not here. Taxa may be considered agricultural weeds both within and beyond their native range. 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. This question carries more weight than 3.02.	• Taxon name + 'weed', 'invas*', 'invad*', 'pest'. Evidence usually obtained from internet, and primary literature. • For example, *Pithecellobium dulce* (monkeypod) is a documented weed in Hawaiian pastures: www.ctahr.hawaii.edu/forestry/Data/WeedsHI/W_Pithecellobium_dulce.pdf. • Check Holm *et al.* (1979) and look for species rated as serious or principal weeds. If rated as a common weed or is present as a weed, additional evidence from other source(s) is necessary to support a 'yes' response (see General Guidelines section).

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3.04 Environmental weed	The plant is documented to alter the structure or normal activity of a natural ecosystem. This question carries more weight than 3.02. If a plant is listed as a weed in relevant references but the type of weed is uncertain or it is a minor weed – score 'yes' for 3.02.	The taxon is documented to alter the composition, structure, or normal processes or function of a natural ecosystem. Impact or management of the taxon in an area with conservation goals that include protection of native vegetation should be well documented. If a taxon is listed as a weed in relevant references but the type of weed is uncertain or it is a minor weed – score 'yes' for 3.02 rather than this question. Alternately, if the taxon is managed on disturbed edges of conservation areas to protect those areas from invasion, answer 'yes' here, but not for question 3.02. Taxa may be considered environmental weeds only outside their native range. 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. This question carries more weight than 3.02.	• Taxon name + 'weed', 'invas*', 'invad*', 'pest'. Evidence usually obtained from internet and primary literature. • See taxon listing in Weber (2003). • See Global Invasive Species Programme (GISP) database (www.issg.org/data base/welcome/). • See discussion under General Guidance on addressing this question.
3.05 Congeneric weed	Documented evidence of weediness of one or more species, with similar biology, within the genus of the species being evaluated. Weedy relatives may indicate weedy characteristics which are not catalogued from less well known species in the genus.	Documented evidence that one or more taxa, with similar biology, within the genus of the taxon being evaluated are serious or principal (*sensu* Holm *et al.* 1979) weeds anywhere would warrant a 'yes' response. If no weedy congener is documented, answer 'no'.	• Genus name + 'weed', 'invas*', 'invad*', 'pest'. Evidence usually obtained from internet, and primary literature and weed handbooks. • See taxon listings in Weber (2003) and Holm *et al.* (1979). • See discussion under General Guidance on addressing this question.
4.01 Produces spines, thorns or burrs	The plant possesses a structure known to cause fouling, discomfort or pain to animals or man. If the taxon is a thornless subspecies, variety or cultivar, then there must be good evidence that it does not retain the capacity to revert to a thorny form.	The plant possesses a structure known or highly likely to cause fouling (interfering with product processing or quality), discomfort, or pain to animals or people. A lack of positive evidence for this question results in a 'no' answer. If the taxon is a thornless subspecies, variety or cultivar, then there must be good evidence that it does not retain the capacity to revert to a thorny form.	• Evidence obtained from morphological description of the taxon in any flora or from internet. • An example of fouling is the affect on processing wool (carding, etc.) caused by entanglement with burrs. • For example, many species in the rose (*Rosa* spp.), gorse (*Ulex* spp.), and black-berry or raspberry (*Rubus* spp.) genera have thorns.
4.02 Allelopathic	The plant is well documented as a potential suppressor of the growth of other species by chemical (e.g., hormonal) means. Such evidence is rare throughout the whole plant kingdom.	The taxon is documented to be a potential suppressor of the growth of other taxa by chemical means. Such evidence is rare throughout the whole plant kingdom. For example, answer 'yes' if experimental evidence involving the use of non-concentrated leaf or root leachates (or other natural plant parts or products) exists. Where data rely on concentrated extracts or little is known about the taxon, answer 'unknown'. Answer 'no' where the taxon has been documented not to be allelopathic. A lack of reported or suggested allelopathy for very well known and studied taxa should generally result in a 'no' response.	• Taxon name + 'allelopath*'. Evidence 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.
4.03 Parasitic	The parasite must have a detrimental effect on the host. Only score 'yes' if the potential host is present in Australia. This question includes wholly and semi-parasitic plants. Such plants are rare.	Answer 'yes' for any parasitic taxon with potential hosts present in the assessed area. This question includes wholly and semi-parasitic plants. Such plants are rare. A lack of positive evidence for this question results in a 'no' answer.	• Evidence usually obtained from internet and primary literature. Online parasitic plant database – www.omnisterra. com/bot/pp_home.cgi. • Includes species in the *Loranthaceae*, *Cuscutaceae*, *Orobanchaceae* and *Santalaceae.*

WRA Question	Australian WRA System Guidance used by the Australian Government Department of Agriculture, Fisheries and Forestry	International Working Group Guidance	Suggested Examples and Data Sources
4.04 Unpalatable to grazing animals	Consider the plant with respect to where the plant has the potential to grow and if the herbivores present could keep it under control. This trait may be found at any stage during the lifecycle of the plant and/or over periods of the growing season.	Consider areas where the taxon has the potential to naturalize and if it is likely to be avoided by the vertebrate grazers and browsers present (domesticated and wild). Answer 'yes' if the taxon is not consumed by grazers/browsers when they have a choice of species. While herbivores may consume fruit or reproductive parts (e.g., flowers), answer 'no' only if herbivory would remove significant aboveground biomass of individual or multiple plants. Herbivory may be at any stage of the plant lifecycle or growing season. Evidence that the plant is readily eaten, preferred, or used as a fodder is sufficient to answer 'no'. Evidence that the taxon is abundant in overgrazed pastures should result in a 'yes' answer.	• Taxon name + ('graz*, brows* 'cattle', 'fodder', 'livestock', 'deer', 'palatable', 'unpalatable', 'palatability'). • Evidence usually obtained from internet and primary literature.
4.05 Toxic to animals	There must be a reasonable likelihood that the toxic agent will reach the animal, by grazing or contact. Some species are mildly toxic but very palatable and could cause problems if heavily grazed.	There must be a reasonable likelihood that the animal will be exposed to the toxic agent in the taxon by grazing or other physical contact. Some taxa are mildly toxic but very palatable and could cause problems if heavily grazed. Consider all grazing and browsing by wild and domestic vertebrates. Answer 'yes' if toxic compounds are uniformly characteristic of the genus or family even if data on the particular taxon are not available. 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 (see General Guidelines section).	• Evidence usually obtained from internet. Also conduct a primary literature search on the taxon name in 'Toxnet' and 'Pubmed'. • Consult Cooper and Johnson (1998) and websites like the Cornell University Poisonous Plants Informational Database: www.ansci.cornell.edu/plants/. • Some taxa become toxic when they are associated with micro-organisms (e.g., fungi, endophytes). • While *Heracleum mantegazzianum* contains toxic substances that can cause blistering in animal mouths (Pyšek *et al*. 2007), in general it does not cause harm to grazers and would receive a 'no' response.
4.06 Host for recognized pests and pathogens	The main concerns are plants that are hosts of toxic pathogens and alternate or alternative hosts of crop pests and diseases. Where suitable alternative or alternate hosts are already widespread in cropping or natural systems the answer should be 'no' unless the species will affect the current control strategies for the pathogen or pest. Apply a reasonable level of specificity; a pathogen of an entire family, such as take-all, should not be the basis for answering 'yes' for an individual species.	This question is intended to identify whether the taxon might be a significant primary or alternate host of crop pests or pathogens. Where suitable alternative or alternate hosts are already widespread in cropping or natural systems the answer should be 'no' unless the taxon will increase pathogen or pest damage or affect the current control strategies for the pathogen or pest. The pest or pathogen should have recognized economic or health impacts. Apply a reasonable level of specificity; a pathogen of an entire family, such as take-all (*Gaeumannomyces graminis* var. *tritici*), a fungus infecting roots of many graminoids, should not be the basis for answering 'yes' for an individual taxon. Answer 'no' where literature states that the assessed taxon is not a host for recognized pests or pathogens. Answer 'unknown' where there is no evidence regarding pests or pathogens.	• Evidence can be obtained from the internet and a primary literature search. Some useful online databases: (1) http://nt.ars-grin.gov/fungaldatabases/index.cfm; (2) http://pnwfungi.wsu.edu/programs/aboutDatabase.asp; (3) www.aphis.usda.gov/plant_health/permits/organism/wpp/virus/index.shtml; and 4) http://image.fs.uidaho.edu/vide/famindex.htm. • Once the pathogen associated with the taxon has been identified use the sources to determine if the associated pests or pathogens are of economic or environmental importance and whether hosts are already present in the introduced range. Consultation with a pathologist or entomologist may help determine whether the species or genus is likely to be a significant host. • For example, *Carica papaya* is host to numerous pathogens that infest other species as well (www.hear.org/pph/hosts/639.htm) and would receive a 'yes' answer.

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4.07 Causes allergies or is otherwise toxic to humans	This condition must be well documented and likely to occur under normal circumstances. For example by physical contact or inhalation of pollen from the species.	These conditions must be well documented and likely to occur under normal circumstances, for example by physical contact or inhalation of pollen from the taxon. General allergic reaction, such as to graminoid or pine pollen is not evidence for a 'yes' answer. If the taxon is generally well documented, a lack of positive evidence for this question should result in a 'no' answer. If few data exist for the taxon, a lack of evidence should result in an 'unknown' answer (see General Guidance section).	• Evidence usually obtained from internet and primary literature. Also check the primary literature databases of 'Toxnet' and 'Pubmed'. • For example, *Heracleum mantegazzianum* causes photodermatitis, resulting in blisters on human skin and soft tissues of animals when the juice is exposed to sunlight (Pyšek *et al.* 2007). • For example, *Plumeria rubra* (Watt and Breyer-Brandwijk 1962) • Documentation from the medicinal plant literature (e.g., side effects or allergic reactions to medicinal compounds) does not generally apply here, as this does not represent exposure under normal circumstances.
4.08 Creates a fire hazard in natural ecosystems	This question applies to species that have a documented growth habit that leads to the rapid accumulation of fuel for fires when growing in natural or unmanaged ecosystems.	This question applies to taxa that have a documented growth habit that leads to the rapid accumulation of fuel for fires when growing in natural or unmanaged ecosystems. Also answer 'yes' if the taxon contains volatile oils or similarly flammable compounds or accumulates a large amount of dry plant material. Answer 'no' if the taxon is unlikely to carry fire. Flammability ratings from horticultural data sheets should not be used to answer this question unless they specify flammability under natural conditions. Answer 'unknown' if no information on flammability exists or fire hazard is not a relevant ecological factor in the area being considered.	• Search taxon name + 'fire' or 'flamm*'. Evidence usually obtained from internet and primary literature. • In the US, check the Fire Effects Information System database: www.fs.fed.us/database/feis/index.html. • An example of flammability ratings of species in their natural habitats is at: www.ces.ncsu.edu/forestry/pdf/ag/firewise_landscaping.pdf.
4.09 Is a shade tolerant plant at some stage of its life cycle	Shade tolerance can enhance the invasive potential of a species.	Answer 'yes' where there is 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; otherwise, answer 'unknown' (including for partial sun).	• Search taxon name + 'shade' / 'sun' / 'light' • For parts of Europe, Ellenberg indicator values (Ellenberg *et al*. 1991) can be used for assessment of response to ecological factors – the system includes a semi-quantitative scale (from 1 to 9–12) for moisture, nitrogen, temperature, and soil reaction. • CABI Forestry Compendium (www.cabi.org/compendia/fc/index.asp) also gives shade tolerance information for a number of woody taxa.
4.10 Grows on *infertile* soils	Australian soils are generally very infertile. Species that tolerate low nutrient levels could potentially grow well here. Legumes, tolerant of low soil phosphorus, are a particular concern since they would also modify the soil environment.	The italicized portion of this question may be modified to address edaphic influences in the area of interest. As such, the criteria for the 'yes' response will vary by region. For Australia, use the originally specified criterion and always answer 'no' for submerged or floating aquatic plants or air plants. Answer 'unknown' if no information about soil tolerance or soil types in the native or invaded range is available.	• Search taxon name + 'soil' / '*soil character identified*' • For Hawaii, this question was modified to reflect their broader edaphic conditions: 'Tolerates a wide range of soil conditions (or limestone conditions if not a volcanic island)' (Daehler and Carino 2000). • The Florida test retained the original criterion as soils are typically oligotrophic, limerock, or excessively draining soils (Gordon *et al*. 2008b).

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4.11 Climbing or smothering growth habit	This trait includes fast growing vines and ivies that cover and kill or suppress the growth of the supporting vegetation. Plants that rapidly produce large rosettes could also score for this question.	This trait describes plants that grow over, suppress the growth of, and may eventually kill existing vegetation. Many environmental weeds are documented to grow in dense patches and exclude native species. However, this would not merit a 'yes' answer to this question. It must be clear that the mechanism is aboveground climbing or smothering. Assume a vine or vining shrub has the potential to smother unless negative evidence from the naturalized range supports a 'no' answer. Answer 'no' for taxa that do not physically overgrow other vegetation. If growth habit data are not available, answer 'unknown'. Note: The general guidance that plants with rosettes would receive a 'yes' answer has been removed here. However, evidence that a rosette or other growth form is documented to kill or suppress surrounding vegetation (see example) may be used to support a 'yes' response.	• While not all vines smother existing vegetation (shading out of competitors due to self-supported vertical growth is not considered smothering), many have significantly more aggressive growth habits in invaded than in native regions (e.g., *Lygodium microphyllum* (Hutchinson *et al.* 2006)). • For example, *Carduus pycnocephalus*: 'rosettes of slender thistle spread over the soil surface, covering other species' (Parsons and Cuthbertson 2001), resulting in a 'yes' answer for this species. • Check Ellenberg *et al.* 1991 for European species.
4.12 Forms dense thickets	The thickets produced should obstruct passage or access, or exclude other species. Woody perennials are the most likely candidates, but this question may include densely growing grasses.	Thickets of dense stem and branch tissue should obstruct passage or access, or exclude other taxa. Densely growing woody perennials and tall grasses are most likely to receive 'yes' answers. Answer 'no' if natural growth does not impede movement (e.g., low groundcover species); otherwise, answer 'unknown'.	• Check descriptions of growth; pictures may be used as evidence when they come from the field. • This trait should not be evaluated based on domestic plantings.
5.01 Aquatic	The question includes any plants normally found growing on rivers, lakes and ponds. These species have the potential to choke waterways and starve the system of light, oxygen and nutrients. Aquatic weeds are a major concern and consequently the score is high (5).	The question includes any floating, emergent, or submerged vascular plant taxon in fresh or saltwater systems. These taxa have the potential to choke waterways and alter light, oxygen and nutrient levels. Aquatic weeds are a major concern and consequently, the score is high (5). A lack of positive evidence for this question results in a 'no' answer.	• Applies to obligate aquatic taxa. Wetland taxa and those that grow on stream banks do not qualify.
5.02 Grass	A large proportion of the grass family (Poaceae/Gramineae) are weeds in some context. As with congeneric weed species, there is a high probability that a species from this family will be a weed.	Answer 'yes' for all taxa in the Poaceae, including bamboos. Otherwise, answer 'no'.	
5.03 Nitrogen fixing woody plant	A large proportion of woody legumes (Family Leguminosae / Fabaceae) are weeds, particularly of conservation areas. As with congeneric weed species, there is a high probability that a species from this family will be a weed.	A large proportion of woody legumes are weeds, particularly of conservation areas. Assume that all woody taxa of the family Fabaceae fix nitrogen unless there is evidence that a particular taxon does not. Also answer 'yes' for any other woody taxon documented to fix nitrogen. Answer 'no' for all herbaceous or semi-woody taxa, and for all other taxa.	• Search taxon name + 'fix' 'nitrogen' • Common in Fabaceae: >30% of species of the Caesalpinoideae and >90% of the species in the other subfamilies within Fabaceae form nodules (Brewbaker *et al.* 1982, Dart 1988) • *Casuarina* spp. are examples of woody non-legume nitrogen-fixing taxa.

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5.04 Geophyte	This question relates to perennial plants with tubers, corms or bulbs. This question is specifically to deal with plants that have specialized organs and should not include plants merely with rhizomes/ stolons (see 6.06). Plants from this group can be particularly difficult to eradicate from a site.	This question addresses taxa that have specialized organs and should not include plants with just rhizomes/ stolons (see 6.06). Answer 'yes' only for perennial taxa with tubers, corms, or bulbs. Answer 'no' for non-geophytes, including those with rhizomes or stolons only (see 6.06). Answer 'unknown' in the rare case where growth form is unknown and cannot be determined from characteristics of related taxa.	• A geophyte is defined as a perennial plant that bears its perennating buds below the surface of the soil. By definition, annuals and most trees (some woody geophytes exist; Alexandre 1992) are not geophytes. See Raunkiaer (1934) for a full definition of geophyte. • Gingers (Zingiberaceae) are non-geophytes with rhizomes and receive a 'no' answer.
6.01 Evidence of substantial reproductive failure in native habitat	Predators and other factors present (e.g., disease) in the native habitat can cause substantial reductions in reproductive capacity. The reproductive output of a species may greatly increase when the plant grows in areas without these factors.	This question will rarely get a 'yes' answer, which requires evidence that predators or other factors (e.g., disease) present in the native habitat consistently cause substantial reductions in reproductive capacity. The reproductive output of a taxon may greatly increase when the plant grows in areas free of such constraints. Answer 'no' if no data exist on controlling factors (the most frequent case). The 'unknown' answer will, therefore, rarely be used.	• Though of limited application, the IUCN Red List of Threatened Species (www.iucnredlist.org/search/search-basic) provides data on taxa that are critically threatened in their native range, suggesting controlling factors. • Evidence that a taxon has a widespread distribution or is common or weedy, without any evidence of reproductive failure is sufficient for a 'no' answer.
6.02 Produces viable seed	If the taxon is a subspecies, variety or cultivar, it must be indisputably sterile. The male plants of a dioecious species are regarded as seed producers.	Evidence that the taxon produces viable seed in the wild (native or naturalized range) results in a 'yes' answer. If the taxon is a subspecies, variety, or cultivar, it must be indisputably sterile to receive a 'no' answer, not just self-incompatible. Any taxon receiving a 'no' answer for this question will also score 'no' for question 8.01 (prolific seed production). Taxa available as male clones only would get an 'unknown' here but a 'no' for question 6.04. Answer 'unknown' if no information on seed or spore viability exists.	• Search taxon name + 'seedling', 'seed', 'germination', '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.
6.03 Hybridizes naturally	A 'yes' answer for this question requires documented evidence of interspecific hybrids occurring, without assistance, under natural conditions.	This question will generally receive an answer of 'unknown'. A 'yes' answer for this question requires documented evidence of interspecific hybrids occurring, without assistance, under natural conditions. A 'no' answer requires specific documentation that hybridization does not occur (e.g., hybrids absent where congeners are sympatric). Evidence that the taxon requires a specific pollinator that will not switch to other related taxa would support a 'no' answer. If the entire genus is well-studied and no instances of hybridization have been reported, answer 'no' (this information is usually available only for small genera). Also answer 'no' if the taxon cannot reproduce sexually. If there is mention only of horticultural hybrids, the answer is 'unknown'.	• Search taxon name + 'hybrid*' 'crossing'. Genus name + 'hybrid*' • Check floras from the native range.

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6.04 Self-fertilization	Species capable of self seeding, can spread from seed produced by an isolated plant.	Taxa capable of producing seed without out-crossing, can spread from seed produced by an isolated plant. Answer 'yes' if a single individual of the taxon is capable of sexual reproduction, even if the self-fertilization produces fewer viable seed than does cross-pollination. Self-compatible (including cleistogamous) or apomictic taxa would receive a 'yes' answer to this question. Dioecious species should receive a 'no' answer. Direct evidence on whether or not the taxon is self-compatible is necessary; answer 'unknown' where direct evidence is lacking.	• Search taxon name + 'self*', 'crossing', 'apomict', 'reproduction', 'fertile', 'fertility'. • Check in Halevy (1989). • Use judgment with regard to experimental data (e.g., seeds resulting from pollination methods not likely under natural conditions should not be accepted as evidence of self-fertilization).
6.05 Requires specialist pollinators	The invasive potential of the plant is reduced if the species requires specialist pollinating agents that are not present or rare in Australia. The answer is 'yes' only if a specific pollinator is known.	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 importation. Answer 'no' for taxa with documented generalist pollinators or that reproduce sexually without pollinator assistance (e.g., taxa that are wind pollinated, cleistogamous, etc.). Also assume 'no' for fern, grass, and sedge taxa even if direct evidence is lacking. Otherwise, answer 'unknown'.	• Search taxon name + ('pollinator' 'pollination'). • Check in Halevy (1989).
6.06 Reproduction by vegetative propagation	The plant must be capable of increasing its numbers by vegetative means. This may include reproduction by: rhizomes, stolons, suckers or stem/root fragments.	Answer 'yes' if the taxon is capable of naturally increasing its numbers by vegetative means. This may include reproduction by: rhizomes, stolons, bulbils, root fragments, suckers, plantlets, or division. An indication that a taxon can be propagated vegetatively by horticultural methods is insufficient evidence to answer 'yes' to this question. Evidence that a taxon roots at nodes is sufficient for a 'yes' response. Specific information that vegetative reproduction does not occur in the taxon or genus supports a 'no' answer. Where there is no evidence regarding vegetative reproduction, answer 'unknown'.	• Most annuals will receive a 'no' response.
6.07 Minimum generative time (years)	This is the time from germination to production of viable seed, or the time taken for a vegetatively reproduced plant to duplicate itself. The shorter the timespan, the more weedy a plant is likely to be. The score for this trait uses the correlation factor (1 year score 1, 2–3 years score 0, greater than or equal to 4 years score −1).	Generation time is the time from germination to production of viable seed, or the time taken for a vegetatively reproduced plant to produce a clone that is capable of independent growth. Use specific generative time data on the taxon, including data from horticultural or forestry sources, to answer this question. The score for this trait uses the following rules: 1 year – score = 1 (this includes any species that produces propagules within 12 months of germination); 2–3 years – score = 0; ≥4 years – score = −1. When there is no specific evidence on time to reproduction, answer 'unknown'.	• Search taxon name + 'years' + 'flower' + 'age' • Information from horticulturalists may be helpful.

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7.01 Propagules likely to be dispersed unintentionally	Propagules (any structure, sexual or asexual, which serves as a means of reproduction), unintentionally dispersed resulting from human activity. An example is plants growing in heavily trafficked areas such as farm paddocks or roadsides.	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 on disturbed edges and having morphological dispersal adaptations such as burrs or small seeds that might be carried on vehicle tires or shoes should be included here. Answer 'no' if there is no evidence of previous dispersal through human activity and absence of such adaptations. If no information exists, answer 'unknown'.	• Search taxon name + 'seed dispersal' • Taxa in heavily trafficked areas such as farm paddocks, agricultural lands, railways or roadsides are unintentionally dispersed, as are taxa moved as contaminants (but not with produce, since scored in question 7.03) and taxa spread through yard waste disposal. • Greater weight should be placed on evidence of unintentional dispersal by people than on seed size alone.
7.02 Propagules dispersed intentionally by people	The plant has properties that make it attractive or desirable, such as an edible fruit, an ornamental or curiosity. These species are readily spread as a: whole plant, fragment, seed or other vegetative structure. This group includes most horticultural plants.	Any taxon proposed for import should be scored 'yes' for this question. Intentional dispersal is generally of taxa with attractive or desirable traits, such as an edible fruit, an ornamental, or curiosity. The taxon may be readily spread as a whole plant, fragment, seed or other vegetative structure. This group includes all non-native horticultural plants and taxa used for forestry, agricultural, and restoration purposes. A lack of positive evidence for this question results in a 'no' answer, since intentional dispersal is likely to be reported.	• If the taxon is sold online then this could be used as evidence to answer 'yes'. • Taxa moved only through contamination would receive a 'no' answer.
7.03 Propagules likely to disperse as contaminants of produce	Produce is the economic output from any agricultural, forestry or horticultural activity. An example is grain shipments that contain seeds of weed species.	Produce is the economic output from any agricultural, forestry or horticultural activity. A lack of positive evidence for this question, and a growth form, biology, ecology, or habitat that makes produce contamination unlikely, results in a 'no' answer, since produce contaminants are likely to be reported in the literature or by quarantine authorities. Otherwise, answer 'unknown'.	• Search taxon name + 'contaminant' • Search CAB Abstracts (www.cabi.org/datapage.asp?iDocID=165) • For example, seeds of taxa included as contaminants in shipments of grain or imported seeds. • Seeds introduced on cut flowers would be included here. • Note that references to 'potential seed contaminant' in lists such as the GRIN database are insufficient without supporting evidence.
7.04 Propagules adapted to wind dispersal	Documented evidence that wind significantly increases the dispersal range of the propagule. An example is an achene with a pappus. This group includes tumbling plants.	Answer 'yes' where documented evidence shows that wind contributes significantly to the dispersal range of the propagule. 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. Where fruit or seed do not have traits indicating wind dispersal, answer 'no', except where information is ambiguous or not documented. In this latter case, answer 'unknown'.	• Search taxon name + 'seed dispersal', 'wind' • Online databases that include information on the means of dispersal, include: BIOLFLOR for Germany (www.biolflor.de), DAWIS for woody taxa in Czech Republic (www.ibot.cas.cz/invasions/projects.htm#dawis), and the Kew Gardens database (http://data.kew.org/sid/dispersal.html), but the source literature should be checked.
7.05 Propagules buoyant	This question includes any structure containing the propagule that typically becomes detached from the plant and is buoyant. An example is a pod of a legume. This is a limited method of distribution of land plants.	This question includes any structure containing the propagule that typically becomes detached from the plant and is buoyant. This is a limited method of distribution of land plants. Evidence that the propagule is carried by and survives in water, or is buoyant, results in a 'yes' response to this question. Answer 'no' where there is documentation that propagules are not buoyant or dispersed by water. Otherwise, answer 'unknown'.	• Search taxon name + 'buoyant', 'floats' + 'water dispers' • See online databases listed under 7.04. • Documented distribution along waterways is supporting evidence for the 'yes' response. • Legume pods are often buoyant.

WRA Question	Australian WRA System Guidance used by the Australian Government Department of Agriculture, Fisheries and Forestry	International Working Group Guidance	Suggested Examples and Data Sources
7.06 Propagules bird dispersed	Any propagule that may be transported and/or consumed by birds, and will grow after defecation. An example is small red berries with indigestible seeds.	Any propagule that may be transported on the surface (feet or feathers) or through the digestive tract of birds (excluding flightless birds) in a viable form. Evidence of bird dispersal is sufficient for a 'yes' response. Where there is no information on dispersal, assume 'yes' for fleshy fruits that are <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'.	• Search taxon name + 'seed dispersal', 'birds' • See online databases listed under 7.04. • Taxa with small red fruits with indigestible seeds, e.g., *Schinus terebinthifolius* (Panetta and McKee 1997) would receive 'yes' answers. • Taxa with bird-dispersed cones would also receive a 'yes' response.
7.07 Propagules dispersed by other animals (externally)	The plant has adaptations, such as burrs, and/or grows in situations that make it likely that propagules become temporarily attached to the animal. This can include the spread of plants parts on clothing. This dispersal group includes seeds with an oily or fat-rich outgrowth that aids in ant seed dispersal.	The taxon has adaptations, such as burrs, and/or grows in situations that make it likely that propagules become temporarily attached to the animal (non-avian). This dispersal group includes seeds with an oily or fat-rich organ that aids in ant seed dispersal and seeds likely to be dispersed in animal hooves as well as on fur. Where direct evidence is lacking, assume 'no' for fruits that clearly have no mechanism of attachment.	• Search taxon name + 'seed dispers' • See online databases listed under 7.04.
7.08 Propagules dispersed by other animals (internally) Note: Some versions of the WRA have changed this question to: 'Propagules survive passage through the gut' (Williams 1996), to include birds and other animals and allow some overlap with question 7.06.	The propagules are eaten by animals, dispersed and will grow after defecation.	Answer 'yes' if propagules of the taxon pass through the digestive tract of animals (other than birds except flightless birds and including bats) in a viable form. Answer 'no' where the taxon is unlikely to be eaten by animals or if seeds are not viable following passage through the gut. Answer 'unknown' if no data clarify whether this means of dispersal is likely.	• Search taxon name + 'seed dispers', 'animal', 'gut', 'droppings' • See online databases listed under 7.04.
8.01 Prolific seed production	The level of seed production must be met under natural conditions and applies only to viable seed. For grasses and annual species a rate of (>5000–10,000 $m^{-2}y^{-1}$) would be considered high, for woody annual a rate of (>1000 $m^{-2}y^{-1}$) would be considered high. Specific data on this attribute may be unavailable; however, an estimate can be made from the seed/plant and the average size of the plant.	The level of seed production must be met under natural conditions and applies only to viable seeds. For herbaceous taxa, this rate should be (>5000 m^{-2} crown area y^{-1}); for woody taxa a rate of (>1000 m^{-2} crown area y^{-1}) would be considered high. Ideally use quantitative information. 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. Qualitative statements on seed production should be used to answer 'yes' only if confirmed by several references. Qualitative responses may be used to support 'no' answers. Assume 'yes' for fern taxa unless contradictory evidence exists.	• Search taxon name + 'seed'. • Botanical sketches of the plant, flowers, fruit and seeds that are drawn to scale can be used to estimate the seed/fruit output.

WRA Question	Australian WRA System Guidance used by the Australian Government Department of Agriculture, Fisheries and Forestry	International Working Group Guidance	Suggested Examples and Data Sources
8.02 Evidence that a persistent propagule bank is formed (>1 y)	Greater than 1% of the seed should remain viable after more than one year in the soil. This bank may include both canopy and soil seed banks. Long seed viability increases a plant's invasive potential.	Greater than 1% of the seed should remain viable in the soil for >12 months after its production. Both canopy and soil seed banks are included. Long seed viability increases a plant's invasive potential. If seeds of the taxon are documented to require scarification or other dormancy-breaking treatments for germination, answer 'yes' 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.	• Search taxon name + 'seed storage', 'seed bank', 'recalcitrant', 'seed' + 'germination', 'viability' + 'years' • 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. • Thompson *et al*. (1997) details seed banks in northern temperate floras. • Baskin and Baskin (1998) book on seeds includes information on dormancy and seed banks. • Data on seed viability from highly controlled lab conditions should not be used to answer this question (e.g., seed stored in liquid nitrogen can remain viable indefinitely).
8.03 Well controlled by herbicides	Documented evidence is required for good chemical control of the plant. This control must be acceptable in the situations in which it is likely to be found. The chemical management should be safe for other desirable plants that are likely to be present. This information will be poorly documented for most non-agricultural plants.	Documented evidence is required for effective chemical control of the plant. This control must be acceptable in the situations in which it is likely to be found. This information may be poorly documented for most non-agricultural plants and in this case answer 'unknown'. Answer 'no' if herbicides are documented to be an unsuccessful control approach.	• Search taxon name + 'control', 'herbicide'. Evidence usually obtained from internet and primary literature, weed control handbooks. • Effective control by herbicides may be in conjunction with other control mechanisms.
8.04 Tolerates or benefits from mutilation, cultivation, or fire	Plants that tolerate or benefit from such disturbance may out-compete other species. This question does not apply to seed banks.	Plants that tolerate or benefit from such disturbance may out-compete other taxa. The treatments referenced by 'mutilation' cause mortality of the majority of the biomass of the taxon. Answer 'yes' if the taxon tolerates or benefits from any physical biomass removal intended for control purposes. This question does not apply to seed banks. Use explicit evidence of response to biomass loss for 'yes' or 'no' answers; answer 'unknown' where direct evidence is lacking.	• Search taxon name + 'coppice', 'resprout' • Taxa adapted to full above-ground biomass loss through fire, grazing, or browsing pressure are likely to have 'yes' responses.
8.05 Effective natural enemies present in *Australia*	A known, effective, natural enemy of the plant may or may not be present in Australia. The answer is 'don't know' unless a specific enemy/enemies are known.	The italicized portion of this question should be modified to address the area of interest. This question will rarely be answered. Such enemies are predators, parasites and pathogens that are known to substantially reduce growth and reproduction. The answer is 'don't know' unless a specific effective enemy or enemies are known.	• The CABI Forestry Compendium lists pests/pathogens for many tree taxa (www.cabi.org/compendia/fc/index.asp). • See Gordon and Gantz (2008) for an example of how this and other questions have been modified for the US.

Appendix 1. Scoring for the Australian Weed Risk Assessment

The scoring system depicted in Figure A1 (Form B) is reproduced from the original report on the system (Pheloung 1995). Implementation of the WRA by Biosecurity Australia is based on these scores. The report and the Excel-based spreadsheet are available on request.

The lookup table for scores for questions 3.01–3.05 are in Tables A1 and A2. Whole numbers (Table 1A) were originally intended for use (Pheloung 1995) in the WRA. However, the Excel spreadsheet that was developed generates fractional scores for some combinations of climate match and quality (Table A2), and has been used by some researchers (e.g., Daehler *et al.* 2004, Kato *et al*. 2006). The fractional values (which round up to the whole numbers) will occasionally result in a decision outcome that is different from the outcome using rounded scores, as the latter can raise the final score. Implementers of the WRA should consider the implications when determining which lookup table to use. Biosecurity Australia uses Table A1, having concluded that whole numbers better reflect the overall precision of the WRA.

Tables A1 and A2 correct an error in the original lookup table published in Pheloung (1995) and on-line (http://www.daff.gov.au/__data/assets/image/0008/11222/wraman2.gif). The weighted scores depicted in Figure A1 for questions 3.03 and 3.04 should be 4 when both climate match and quality of match are low (questions 2.01 and 2.02 are 0) rather than the value of 3 depicted elsewhere. The Excel spreadsheet correctly sets these scores.

Procedure

1. Record appropriate responses in column b.
2. Look up score in columns d and e and record result in column c.
3. Calculate total score.
4. Look up and record recommendation.
5. Verify that minimum number of questions from each section are answered.
6. Compute Agricultural (A and C) and Environmental (E and C) scores. If either score is less than 1, the outcome pertains to the other sector.

Score	Outcome
<1	Accept
1–6	Evaluate
>6	Reject

Section	Minimum # questions
A	2
B	2
C	6
Total	10

Figure A1. Weed Risk Assessment Scoring Sheet (Form B) (http://www.daff.gov.au/__data/assets/image/0008/11222/wraman2.gif).

		a	b	c	d	e
Section		Question	Response[1]	Score[2]	*N* score	*Y* score
A	C	1.01			0	−3
	C	1.02			−1	1
	C	1.03			−1	1
		2.01		The response to questions 2.01 and 2.02 is 2 unless a climate analysis is done		
		2.02				
	C	2.03			0	1
	C	2.04			0	1
		2.05		?, Y or N response only (see Table A1)		
	C	3.01			Refer to lookup Table A1	
	E	3.02				
	A	3.03				
	E	3.04				
	C	3.05				
B	C	4.01			0	1
	C	4.02			0	1
	C	4.03			0	1
	A	4.04			−1	1
	C	4.05			0	1
	C	4.06			0	1
	C	4.07			0	1
	E	4.08			0	1
	E	4.09			0	1
	E	4.10			0	1
	E	4.11			0	1
	C	4.12			0	1
C	E	5.01			0	5
	C	5.02			0	1
	E	5.03			0	1
	C	5.04			0	1
	C	6.01			0	1
	C	6.02			−1	1
	A	6.03			−1	1
	C	6.04			−1	1
	C	6.05			0	−1
	A	6.06			−1	1
	C	6.07		Refer to lookup Table A3		
	A	7.01			−1	1
	C	7.02			−1	1
	A	7.03			−1	1
	C	7.04			−1	1
	E	7.05			−1	1
	E	7.06			−1	1
	C	7.07			−1	1
	C	7.08			−1	1
	C	8.01			−1	1
	C	8.02			−1	1
	A	8.03			1	−1
	A	8.04			−1	1
	C	8.05			1	−1
		Total score[3]				
		Outcome[4]				
		Agricultural score[5]				
		Environmental score[6]				

Table A1. Lookup table for Section 3 of Figure A1.

Locate value of inputs and lookup output for each question										
	Yes to questions 3.01 – 3.05									**default**
Inputs	2.01	0	0	0	1	1	1	2	2	**2**
	2.02	0	1	2	0	1	2	0	1	**2**
Results	3.01	2	1	1	2	2	1	2	2	**2**
	3.02	2	1	1	2	2	1	2	2	**2**
	3.03	4	2	1	4	3	2	4	4	**4**
	3.04	4	2	1	4	3	2	4	4	**4**
	3.05	2	1	1	2	2	1	2	2	**2**
	No to questions 3.01 – 3.05									
Input	2.05	?	N	Y						
Results	3.01	−1	0	−2						
	3.02–3.05	0	0	0						

Table A2. Alternative lookup table for Section 3 of Figure A1 with fractional scores.

Locate value of inputs and lookup output for each question										
	Yes to questions 3.01 – 3.05									**default**
Inputs	2.01	0	0	0	1	1	1	2	2	**2**
	2.02	0	1	2	0	1	2	0	1	**2**
Results	3.01	2	1	0.5	2	1.5	1	2	2	**2**
	3.02	2	1	0.5	2	1.5	1	2	2	**2**
	3.03	4	2	1	4	3	2	4	4	**4**
	3.04	4	2	1	4	3	2	4	4	**4**
	3.05	2	1	0.5	2	1.5	1	2	2	**2**
	No to questions 3.01 – 3.05									
Input	2.05	?	N	Y						
Results	3.01	−1	0	−2						
	3.02–3.05	0	0	0						

Table A3. Lookup table for 6.07.

Years	1	2	4
Score	1	0	−1

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